International Outsourcing, Carbon Leakage and Employment Leakage

Kurt Kratena

Austrian Institute of Economic Research (WIFO), Vienna

kurt.kratena@wifo.ac.at

Abstract:

This paper attempts to bring together two lines of research in one consistent approach, namely the impact of international outsourcing on labour and the impact of carbon pricing on the dislocation of industries. The common framework is a model of production and factor demand for 23 EU countries, based on the WIOD database. The model incorporates substitution effects between labour and energy on the one hand, and imported intermediates on the other hand.

It can be shown that while in many industries labour and imported intermediates are substitutes and some fear of a negative labour impact of outsourcing might therefore be justified, this is not the case for energy. Imported intermediates and energy are complements in many industries, so that carbon pricing will not lead to a direct negative impact on domestic output. However, the indirect effects might be much more important in both cases. In the case of labour, this is the cost savings effect which increases real income and competitiveness and thereby counteracts the direct negative effect on labour. In the case of carbon pricing this is the loss in competitiveness brought about by higher production costs, leading to higher imports and lower output in a second stage. As the cost share of imported intermediates is much higher than the energy cost share in Europe - even in the most energy intensive industries - the indirect cost effect is much larger in relation to the direct effect for the case of labour and outsourcing than for the case of energy prices (carbon pricing) and imports.

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1. Introduction

The impact of international outsourcing on labour, in terms of employment shifts or changes in the wage distribution, has been the subject of numerous studies during the last decade starting with the seminal studies of Feenstra and Hanson (1996 and 1999). Berman, et al. (1994) introduced a research line, where demand shifts between different skills are attributed to technical change bias and international outsourcing in a factor demand function framework. A large body of empirical literature has emerged from this research (Feenstra and Hanson 2001, Morrison-Paul and Siegel 2001, Strauss-Kahn, 2004, Hijzen, Goerg and Hine 2005, Eckholm and Hakkala, 2006 and Geishecker 2006, among others). All these studies have focused on the impact of outsourcing on labour in a partial framework of production. After Berman, et al. (1994), the main methodology has been the estimation of factor demand functions for labour or for different skill groups within the labour aggregate. These studies therefore have neglected the *cost savings effect* of outsourcing that has been put forward in theoretical models by Kohler (2004). This cost savings effect creates a macroeconomic surplus with a positive feedback on labour demand, so that the total net effect can only be quantified in a macroeconomic or general equilibrium model. This holds true, especially in the case of a non-competitive labour market regime (Egger and Kreickemeier, 2008). Another relatively new line of research deals with potentially positive macroeconomic effects of international outsourcing via a general equilibrium feedback (Baldwin and Robert-Nicoud, 2007, as well as Grossman and Rossi-Hansberg, 2008).

The literature on carbon leakage in the case of a unilateral climate policy of the ‘Kyoto countries’ identifies different potential channels for or carbon leakage. One mechanism is working via international energy markets and has led to the formulation of the ‘green paradox'. Unilateral climate policy in a significant part of the world economy leads to lower world energy demand and that might in turn lead to lower world energy prices and therefore stimulate energy demand in those regions that are not constrained by climate policy.

The most important channel that will also be dealt with here is the relocation of industries to other countries that do not face carbon constraints due to the higher costs and output prices in the climate policy regions. Large part of the literature consists of CGE model simulations on this channel (for example: Burniaux, Oliveira Martin, 2000, Paltsev, 2000). The mechanism for leakage is that domestic output of energy intensive activities is crowded out by imports according to the Armington elasticities traditionally used in these models.

The research presented here will present a comprehensive methodology to address both questions of outsourcing and labour, as well as of carbon pricing and leakage in a production (cost) function framework of the Translog type. As is well known, the Translog model allows for substitution as well as complementarity of factors. The study is based on the full accounts of the WIOD database, especially on the International Supply and Use Tables (SUTs) in current and previous year's prices. Therefore, international outsourcing can be described as a direct substitution between imported intermediate inputs, labour, as well as other inputs. The WIOD data have further been complemented by detailed energy price data from other sources, so that energy demand effects can be dealt with in a consistent way.

Outsourcing measured in this way is driven both by substitution effects, as well as technological change, and both effects can be analytically separated. A focus of this paper is on the indirect effects of both outsourcing and carbon pricing via the price system. The first round of these indirect effects, namely the cost and out price effects can still be quantified in this approach. Farther reaching price system impacts on domestic and imported intermediates via international spillovers can only be dealt with in a full price system of a macroeconomic or CGE model.

For outsourcing the indirect effect represents the cost savings effect and for carbon pricing it is the cost push of higher effective energy prices. It is shown that outsourcing, caused by lower effective prices for imported intermediates, has considerable output price decreasing impacts. Carbon pricing, on the other hand neither has direct positive impacts on imports in all energy intensive industries, nor are the indirect cost push effects large in relation to the direct effect.

Section 2 of this deliverable contains the econometric model of a Translog unit cost function, and the corresponding factor demand functions. In section 3, data construction, estimation results, including own and cross price elasticities of factor demand are shown. In section 4, the cost savings impact of outsourcing and in section 5 the cost push impact of carbon pricing are calculated. Finally, section 6, sums up and draws some conclusions.

2. Econometric model of factor demand with outsourcing

The impact of international outsourcing on labour and of carbon prices on imports is analysed here within the cost and factor demand function framework. The representative producers in each industry all face a unit cost function with constant returns to scale

$$\log p_Q = \alpha_0 + \sum_i \alpha_i \log(p_i) + \frac{1}{2}\sum_i \gamma_{ii}\left(\log(p_i)\right)^2 + \sum_{i,j}\gamma_{ij}\log(p_i)\log(p_j) + \alpha_t t + \frac{1}{2}\alpha_{tt}t^2 + \sum_i \rho_{ti} t \log(p_i) \quad (1)$$

, where p_Q is the output price (unit cost), p_i, p_j are the input prices for input quantities x_i, x_j, and t is the deterministic time trend. Note that equation (1) comprises different components of technological change. Autonomous technical change can be found for all input factors (i.e. the factor biases, ρ_{ti}). Another source of autonomous technical change that only influences unit costs is TFP, measured by α_t, and α_{tt}.

The Translog model is set up with inputs of capital (K), labor (L), energy (E), imported (M^m) and domestic non-energy materials (M^d), and their corresponding input prices p_K, p_L, p_E, p_{Mm} and p_{Md}. As is well known, Shepard's Lemma yields the cost share equations in the Translog case, which in this case of five inputs can be written as:

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\begin{aligned}
v_K &= \left[\alpha_K + \gamma_{KK} \log(p_K / p_{Md}) + \gamma_{KL} \log(p_L / p_{Md}) + \gamma_{KE} \log(p_E / p_{Md}) + \gamma_{KM} \log(p_{Mm} / p_{Md}) + \rho_{tK} t\right] \\
v_L &= \left[\alpha_L + \gamma_{LL} \log(p_L / p_{Md}) + \gamma_{KL} \log(p_K / p_{Md}) + \gamma_{LE} \log(p_E / p_{Md}) + \gamma_{LM} \log(p_{Mm} / p_{Md}) + \rho_{tL} t\right] \\
v_E &= \left[\alpha_E + \gamma_{EE} \log(p_E / p_{Md}) + \gamma_{KE} \log(p_K / p_{Md}) + \gamma_{LE} \log(p_L / p_{Md}) + \gamma_{EM} \log(p_{Mm} / p_{Md}) + \rho_{tE} t\right] \\
v_M &= \left[\alpha_M + \gamma_{MM} \log(p_{Mm} / p_{Md}) + \gamma_{KM} \log(p_K / p_{Md}) + \gamma_{LM} \log(p_L / p_{Md}) + \gamma_{EM} \log(p_E / p_{Md}) + \rho_{tM} t\right]
\end{aligned}
\tag{2}
$$

The homogeneity restriction for the price parameters $\sum_i \gamma_{ij} = 0$, $\sum_j \gamma_{ij} = 0$ has already been imposed in (2), so that the terms for the price of domestic intermediates p_{Md} have been omitted. In this model, labour and import demand react to changes in the prices of all inputs and changes in time due to the factor biases that can be labour saving or labour using, as well as import saving or import using. The immediate reaction to price changes is given by the own and cross price elasticities. These own- and cross- price elasticities for changes in input quantity x_i can be derived directly, or via the Allen elasticities of substitution (AES), and are given as:

$$\varepsilon_{ii} = \frac{\partial \log x_i}{\partial \log p_i} = \frac{v_i^2 - v_i + \gamma_{ii}}{v_i} \tag{3}$$

$$\varepsilon_{ij} = \frac{\partial \log x_i}{\partial \log p_j} = \frac{v_i v_j + \gamma_{ij}}{v_i} \qquad (4)$$

Here, the v_i represent the factor shares in equation (2), and the γ_{ij} the cross-price parameters. It must be emphasized that these price elasticities are *compensated* elasticities, i.e. they measure the impact of factor price changes on factor demand without a change in the aggregate.

For the analysis here we focus on the cross price elasticity of L with respect to M^m and the on the cross price elasticity of M^m with respect to E:

$$\varepsilon_{LM} = \frac{\partial \log L}{\partial \log p_{Mm}} = \frac{v_M v_L + \gamma_{LM}}{v_L} \qquad (5)$$

$$\varepsilon_{ME} = \frac{\partial \log M^m}{\partial \log p_E} = \frac{v_M v_E + \gamma_{EM}}{v_M} \qquad (6)$$

The elasticity ε_{LM} measures the direct ceteris paribus impact of outsourcing, driven by lower effective import prices (decrease in trade barriers, transport/communication costs, etc.) on labour demand. The elasticity ε_{ME} measures the direct ceteris paribus impact of effective energy prices (including carbon pricing) on intermediate import demand.

Implementing the cost savings effect of international outsourcing from the theoretical literature (e.g. Kohler, 2004), as well as the cost push effect of carbon pricing described in CGE models in this model leads to a change in the output price (unit cost), p_Q. The logarithmic derivation of the output price to the factor input prices corresponds exactly to the equation for the factor share, v_i:

$$\frac{\partial \log p_Q}{\partial \log p_i} = \alpha_i + \sum_{i,j=1}^{k-1} \gamma_{ij} \log(p_i / p_k) + \rho_{ti} t \qquad (7)$$

Therefore the cost savings impact equals the cost share of the corresponding factor. In our case these effects are given with:

$$\frac{\partial \log p_Q}{\partial \log p_{Mm}} = \alpha_M + \sum_{j=K,L,E} \gamma_{Mj} \log(p_j / p_{Md}) + \rho_{tM} t \tag{8}$$

$$\frac{\partial \log p_Q}{\partial \log p_E} = \alpha_E + \sum_{j=K,L,Mm} \gamma_{Ej} \log(p_j / p_{Md}) + \rho_{tE} t \tag{9}$$

When the unit cost function is estimated together with the factor share equations, the effects in (8) and (9) can be directly derived from the parameter valus and the historical variables. That corresponds to an *ex post* simulation with the factor share equations.

2.2 Factor prices and indirect costs

Factor prices are exogenous for the derivation of factor demand in (2), but are endogenous in the system of supply and demand. This holds true for all factor prices, also for the price of labour, p_L, which is determined together with mechanisms in the labour market. Furthermore, some factor prices are directly linked to the output prices p_Q which are determined in the same system. That refers to the price of capital, p_K, the price of domestic, p_{Md} and imported intermediates, p_{Mm}.

The price of domestic intermediates, p_{Md} for an industry is directly linked to the output prices p_Q via the market shares matrix and the structure of domestic intermediate demand. Both matrices can be derived from the supply and use tables in the WIOD database:

$$p^d = p_Q C \tag{10}$$

,with **C** as the market shares matrix (industries * commodities) with column sum equal to one.

The same holds true for the price of imported intermediates, p_{Mm}, which is the weighted sum of the commodity prices of the r sending countries ($p^{d,r}$) in the international supply and use tables in the WIOD database (including international transport costs). In a first step, the total import price of commodity i in country s can be determined as:

$$p_{i,s}^{m} = \sum_{r=1}^{s-1} w_{m,rs} p^{d,r} \tag{11}$$

The weights ($w_{m,rs}$) are given by the structure of the international supply and use tables. In a second step, the total import matrix is split up into an energy (*E*) and a non-energy (*NE*) part. The domesic as well as the import matrix are converted into 'use structure matrices' (S_{NE}^{m} and S_{NE}^{d}) by dividing by the column sum of total intermediates, domestic and imported non-energy, respectively. That in turn allows for deriving the prices p_{Mm} and p_{Md}:

$$p_{Mm} = p^{m} S_{NE}^{m} \qquad\qquad p_{Md} = p^{d} S_{NE}^{d} \tag{12}$$

The price of capital is based on the user cost of capital: $u_K = p_I(r+\delta)$ with p_I as the price of investment goods an industry is buying, r as the deflated benchmark interest rate and δ as the aggregate depreciation rate of the capital stock K. The investment goods price p_I can be defined as a function of the domestic commodity prices and import prices, given the input structures for investment, derived from a capital formation matrix (investment by industry * investment by commodity) for domestic and imported investment demand:

$$p_I = p^{m} B_K^{m} + p^{d} B_K^{d} \tag{13}$$

It is important to note that by these input-output loops in the model, indirect effects or feedback effects of prices occur. Policies that introduce carbon pricing with the impact of changing the effective price of energy also change prices of domestic and imported intermediates in all regions, which has important feedbacks on the production structures and on factor demand.

3. Data, estimation method and estimation results

The empirical application of the K,L,E,M^m,M^d model outlined above is based on a detailed data set comprising all nominal values of inputs as well as their corresponding prices.

In general, the Socio Economic Accounts (SEA) of the WIOD database have been used, which contain aggregate nominal values as well as prices for the following variables from 1995 to 2009 for the EU 27:

$p_Q Q$ Nominal gross output (in millios of local currency)

M Intermediate material and service inputs at current purchasers' prices (in millions of local currency)

$p_L L$ Labour compensation (in millions of local currency)

$p_K K$ Capital compensation (in millions of local currency)

The Environmental Accounts of the WIOD database contain detailed data on energy consumption in energy units (TJ) by energy carrier (E) that have been combined with data from the OECD "Energy Prices and Taxes" to derive energy inputs in values from 1995 to 2009:

$P_E E$ Energy input in values (in millions of local currency)

By subtracting $P_E E$ from M, the total non-energy intermediates have been derived. These had to be split up into domestic and imported intermediates in a next step with the use of the

International Supply and Use Tables (SUT) of the WIOD database. The column sum of all intermediate deliveries less the deliveries from domestic sources yields total imported intermediates and the column sum of the domestic deliveries yields total domestic intermediates by industry:

$p_M M^m$ Imported intermediate material and service inputs at current purchasers' prices (in US $, converted to millions of local currency)

$p_D M^d$ Domestic intermediate material and service inputs at current purchasers' prices (in US $, converted to millions of local currency)

Prices are either directly taken from the WIOD database or calculated from nominal values and quantity data. Directly from the SEA we take:

p_Q Deflator of gross output, 1995 = 1

p_I Deflator of gross fixed capital formation by industry, 1995 = 1

The prices p_L and p_E have been calculated by combining the nominal values with the quantity data (employment, energy in TJ). The prices of domestic intermediates, $p_{D,}$ have been taken from nominal and previous years prices from International SUT of the WIOD database. For prices of imported intermediates, p_M we do not use the previous years prices from International SUT of the WIOD database, but take a different deflation procedure carried out by IPTS (Iñaki Arto) and based on the regional input-output structure of the International SUT. The basic idea consists in using the domestic deflators of each country together with the regional input-output structure to calculate the price of inputs by receiving country.

The price of capital is based on the user price of capital, $u_K = p_I(r + \delta)$, where the following sources have been used:

δ Rate of depreciation of total capital stock, calculated from the structure of *K* and depreciation rate by asset

r Real rate of return, calculated by deflating the benchmark interest rate (treasury bills on the secondary market) with the deflator of GDP

p_K Index of $u_K = p_I(r+\delta)$, with 1995 = 1

Major data gaps and problems have been encountered in Bulgaria, Cyprus, Estonia and Malta, so that a full time series could not have been constructed for these countries without the wide application of interpolation techniques. Minor data gaps, for example for depreciation rates, and energy price data, have been either bridged by interpolation techniques or by applying aggregate variables development or the development of the same variable in a similar country to the development of the same variable in another industry in another country, where this data point is missing.

The econometric estimation is carried out for the system comprising the unit cost function (1) and the factor demand functions (2). The systems have been estimated applying the Seemingly Unrelated Regression (SUR) estimator for balanced panels under cross section fixed effects in EViews 6.0 for each of the 35 industries in the WIOD database. The full dataset contains a balanced panel for 23 EU countries for the time series 1995 to 2009, which gives a total of 345 observations.

As a first result, we derive all parameter estimates of the model, which have been estimated under the restrictions of homogeneity and symmetry of the Translog model. We did not in general enforce concavity of the cost function, but only forced parameters to certain values, when in a first step concavity was violated and some positive mean values of own price elasticities appeared.

Table 1 shows selected parameter values for the factor bias, modelled as a deterministic trend. In total, 62 out of the 128 parameters for technological change turn out to be insignificant (not even significant at the 10% level). Technological change assumed as a deterministic trend is in general labour saving (negative value of ρ_{Lt}) and imported intermediates using (positive value of ρ_{Mt}), though not always based on a significant parameter value. The approach followed here makes a clear distinction between substitution effects between factors within a given technology and autonomous technological change, i.e. the factor bias. The econometric results show that although all different cross substitution effects are allowed for, there is still a component of technological change that can be clearly identified. This technological change in our case enforces the threat of outsourcing for labour, as it is simultaneously labour saving and imported intermediates using.

A more comprehensive picture of the different impacts and channels of prices and technical change on factor demand can be concluded from the calculation of the elasticities. In Table 2 the mean values and corresponding standard errors for own and cross price elasticities of capital are shown. The own price elasticity of capital is below one in almost all industries and not very different across the manufacturing sectors. The cross price elasticity between capital and imported intermediates is positive in all but three industries, indicating that international outsourcing has a negative impact on capital.

Table 3, 4 and 5 contain the price elasticities for labour, energy, and imported intermediates respectively. The own price elasticity of labour is on average about -0.5, with relatively high values in some manufacturing industries. Concerning the cross price elasticity of labour wrt imported intermediates, Table 3 also shows that in most industries, including the service sector, labour and imported intermediates are substitutes (positive value of the cross price elasticity). In manufacturing, this holds true in the following industries: Leather and footwear, Wood and cork, Rubber and plastics, Non-metallic minerals, Basic metals and fabricated metal, Machinery, Electrical and optical equipment, Transport equipment, and Other manufacturing,nec. These sectors are therefore at the risk of loosing employment due to outsourcing. In those industries, where labour and imported intermediates are complements (negative value of the cross price elasticity), labour can due to the technology applied in the sector not be substituted by imported intermediates. In manufacturing, this is the case for Food, beverages and tobacco, Textiles, Pulp, paper, printing, and Chemicals. The discussion in the literature about outsourcing in service sectors is based on the concept of 'trading tasks', where different tasks or occupations can b substituted by imported services (Ahmed, Hertel, and Walmsley, 2011). The main implication is that services that are not local and do not need personal contact to costumers are more at risk to outsourcing than others. For the US several studies have been carried out about the total potential of service sector jobs that might be sourced out (Blinder, 2007). The estimation results shown in Table 3 indicate that most service sectors are characterized by labour and imported intermediates being substitutes, though the cross price elasticities in some cases are rather low. Relatively high cross price elasticities can be found in the transport activities. Service sectors that according to our estimation results cannot be substituted by imported intermediates are: Retail trade, Hotels and restaurants, Post and telecommunications, Real estate activities, Education and Social and personal services. These results seem to be in line with the starting hypothesis that services that are local and need personal contact are less at risk to outsourcing.

Table 5 shows the own and cross price elasticities for M^m (the imported intermediates) and reveals the symmetric picture of Table 3 for the substitution between labour and imported intermediates. Note, that the elasticities are not identical in magnitude to those in Table 3 as they are defined as different linear combinations of identical parameters (γ_{LM}) and the involved factor cost shares (v_L, v_M). The own price elasticity for imported intermediate demand is very close to unity or even larger in some industries, including the service sector.

The cross price elasticity of imported intermediates with respect to energy is positive (substitutes) in half of the manufacturing industries and negative in the other half. In those sectors with negative values for the cross price elasticity of imported intermediates with respect to energy, carbon pricing will not lead to a dislocation of part of the production. It is worth noting, that this is the case in two energy intensive industries (Non-metallic minerals and Basic metals) that are seen as most exposed to the risk of carbon leakage in the policy debate. Obviously, the production process in these energy intensive industries is not fragmented in order to outsource parts of the production, but less energy demand due to higher prices also leads to less demand for imported intermediates. This does not exclude carbon leakage at a second round due to a loss in price competitiveness of these industries vis a vis other countries without carbon constraints.

As Ahmed, Hertel, and Walmsley (2011) have also shown, the total labour market impact of outsourcing depends on direct substitution effects, as well as expansionary effects on labour and outsourcing at different nests of the production structure. These indirect, expansionary effects mainly depend on the interaction of different substitution elasticities and the relative magnitude of cost shares. In the approach presented here, the expansionary effect on output and thereby on employment will be mainly driven by the cost savings effect. The CGE model simulations on the magnitude of carbon leakage also demonstrate that the main channel for leakage is the indirect effects via changes in relative prices of trading partner. This is especially important to note in the analysis presented here, because no partial positive impact of energy/carbon prices on import demand could be found in some energy intensive industries. Though, there might be a stimulus for higher imports, if cost and output price effects deteriorate the competitiveness of these industries compared to other countries.

4. Outsourcing and labour

Based on the development of import prices relative to domestic prices in the sample of the WIOD database for the 23 EU countries included in this study, a single 10% decrease in the price of imported intermediates is assumed. This might be due to opening up of markets outside the EU 27, the reduction of trade barriers in those countries or a lowering of transport and communication costs. That leads to higher demand for imported inputs and therefore to international outsourcing. Simultaneously, cross substitution effects are triggered by this price shock. The direct *ceteris paribus* impact on labour is given by multiplying the cross price elasticity between labour and imported intermediates with the import price decrease of 10%. Table 6 shows that in most industries labour demand would decrease by some percentage points by this shock. In some industries, where labour and imported intermediates are complements, labour would even benefit directly from international outsourcing.

However, the cost savings effect of outsourcing indirectly also affects labour in a positive way. This cost savings effect can be measured here by the impact of the import price decrease on the output deflator. This impact equals the cost share as defined in equation (5). For this exercise we do not use the historical cost share data, but we use the mean value of the *ex post* forecasts for the cost shares simulated by the model that has been estimated.

In Table 6 we see that the cost savings effect (in %) is sometimes even larger than the direct negative impact on labour. How this cost savings effect influences labour demand could only be shown in a macroeconomic setting, for example in a general equilibrium model. One important mechanism works via the whole domestic and international input-output price system: lower domestic output prices depress the price of domestic intermediates as well as of imported intermediates via international trade spillovers. That, in turn, would change the matrix of trade flows and production structures throughout all countries.

5. Carbon pricing and carbon leakage

Based on calculations with the WIOD Energy Accounts and different values for a price of CO_2, in the following a single 10% increase in the price of energy is assumed. This assumption represents a unilateral climate policy in the EU and no similar action in the rest of the world. That leads to lower demand for energy inputs and to other substitution effects. The direct *ceteris paribus* impact on imported intermediates is given by multiplying the cross price elasticity between imported intermediates and energy with the energy price increase of 10%. Table 7 shows that in some industries the impact is negative, so that no carbon leakage based on relocation of the energy intensive parts of the production is taking place. The only energy intensive industry where a large direct positive impact on imports can be observed is the Chemicals sector. Besides that, also the energy intensive Pulp and paper industry shows a small direct positive impact on imports. Additionally, other non-energy intensive industries like the Leather and footwear also show a direct positive impact of carbon prices on imports.

As no uniform direct positive impact of carbon prices on imports can be found, especially in some energy intensive industries, the cost push effect might be an important channel for carbon leakage in this model. This cost push effect is measured here by the impact of the energy price increase on the output deflator. This impact equals the cost share as defined in equation (9). Again, we do not use the historical cost share data, but we use the mean value of the *ex post* forecasts for the cost shares simulated by the model that has been estimated.

In Table 7 we see that the cost push-effect (in %) is in general rather small and only in Chemicals amounts to 1% of price increase. Therefore, the Chemicals sector is affected by carbon leakage both from the direct substitution effect as well as from the competitiveness impact. For the two energy intensive industries that face a negative direct impact on imports, the cost push-effect is also rather small (about 0.7%). The import effect triggered by this small change in relative prices will therefore cause relatively small changes in imports in the second nest of international trade by countries. Like in the case of outsourcing, the impact on domestic and import prices will bring about changes in the whole domestic and international input-output price system.

6. Conclusions

In this study, the impact of international outsourcing on the demand for labour, as well as the impact of carbon pricing on carbon leakage have been analysed empirically for 23 selected EU countries (EU 27 without Bulgaria, Cyprus, Estonia, and Malta) in one comprehensive framework. Different accounts within the WIOD database have been used and combined with other international price statistics.

A Translog model with a unit cost function and factor demand for the factors K,L,E,M^m,M^d is set up. This full system has been estimated for the full sample of the WIOD database (1995 – 2009), applying system estimation techniques for panels. One main contribution of this research is that due to the simultaneous system estimation including the unit cost (output price) equation, the cost savings impact of outsourcing and the cost push effect of carbon pricing can be directly derived from the parameters. The Translog model also allows for the differentiation of pure substitution effects and effects of technological change on all input factors. The estimation results reveal that technological change is in general labour saving, partly energy saving, and imported intermediates using.

In terms of cross price elasticities, labour and imported intermediates are substitutes in most industries, including the service sector. Only in some manufacturing industries and in those service sectors where local contact to the consumer dominates, labour and imported intermediates are complements. Imported intermediates and energy are substitutes only in few industries and there is no uniform picture for energy intensive industries.

A decrease in transport and communication costs that leads to price decrease for imported intermediates, and therefore induces international outsourcing, has a clear direct *partial* negative impact on labour. A similar increase in the effective price of energy due to carbon pricing only in some industries has a clear direct *partial* positive impact on imports. The picture for energy intensive industries is divided, some industries even face a negative direct *partial* impact on imports.

The indirect effect, measured by the impact on output prices is much more significant and important in the case of outsourcing and labour, than in the case of carbon pricing and imported intermediates. Therefore, the price depressing effect of outsourcing contribute much more to further macroeconomic effects than the price increasing effects will contribute to carbon leakage. A better accounting of all indirect effects can only be shown in an extended model, where the price system and macroeconomic (general equilibrium) effects are included.

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Table 1: Parameter estimation results for factor bias of technological change, 1995 – 2009, 23 EU countries

	ρ_{tK}		S.E	ρ_{tL}		S.E	ρ_{tE}		S.E	ρ_{tM}		S.E
AtB	-0.0115	***	0.0034	0.0024		0.0034	0.0022	***	0.0006	0.0049	***	0.0010
C	0.0125	***	0.0024	-0.0109	***	0.0016	-0.0034	***	0.0008	0.0033	***	0.0010
15t16	0.0010		0.0008	-0.0009		0.0007	-0.0008		0.0005	0.0036	***	0.0008
17t18	0.0005		0.0009	-0.0046	***	0.0010	-0.0014	*	0.0007	0.0044	***	0.0011
19	0.0030	***	0.0012	-0.0009		0.0012	0.0000		0.0012	0.0014		0.0011
20	0.0022	**	0.0009	-0.0035	***	0.0009	-0.0012	**	0.0006	0.0053	***	0.0011
21t22	-0.0014		0.0009	-0.0024	**	0.0012	0.0005		0.0007	0.0050	***	0.0013
24	0.0008		0.0014	-0.0066	***	0.0011	0.0004		0.0014	0.0045	***	0.0015
25	-0.0003		0.0009	-0.0016	*	0.0010	-0.0003		0.0007	0.0022	**	0.0011
26	-0.0001		0.0008	-0.0022	***	0.0008	-0.0013	*	0.0007	0.0028	***	0.0010
27t28	-0.0010		0.0007	-0.0026	***	0.0007	-0.0005		0.0008	0.0052	***	0.0012
29	-0.0035	***	0.0010	-0.0016		0.0010	0.0045	***	0.0012	0.0045	***	0.0012
30t33	0.0012		0.0013	-0.0041	***	0.0010	-0.0018	**	0.0008	0.0061	***	0.0015
34t35	0.0014		0.0012	-0.0018		0.0013	-0.0007		0.0007	0.0063	***	0.0017
36t37	0.0008		0.0009	-0.0002		0.0012	0.0005		0.0006	0.0003		0.0010
E	-0.0020		0.0016	-0.0021	**	0.0010	0.0016		0.0013	0.0036	***	0.0008
F	0.0018		0.0011	-0.0021	***	0.0007	0.0000		0.0003	-0.0007		0.0007
50	0.0073	***	0.0020	-0.0103	***	0.0022	-0.0005		0.0005	0.0016	**	0.0007
51	0.0001		0.0015	-0.0018		0.0012	-0.0004		0.0009	0.0035	***	0.0006
52	-0.0006		0.0012	0.0007		0.0016	-0.0004		0.0007	0.0014	***	0.0007
H	0.0005		0.0013	-0.0002		0.0010	-0.0019	***	0.0007	0.0003	***	0.0006
60	-0.0014		0.0016	-0.0030	**	0.0015	0.0009		0.0009	0.0005	***	0.0010
62	-0.0035	**	0.0016	-0.0036	***	0.0013	0.0041	***	0.0010	0.0046	***	0.0013
63	-0.0053	***	0.0017	0.0028	**	0.0013	0.0005		0.0004	0.0005		0.0009
64	-0.0011		0.0014	-0.0083	***	0.0008	-0.0016	**	0.0007	0.0033	***	0.0008
J	0.0032	**	0.0015	-0.0082	***	0.0012	-0.0009		0.0007	0.0004		0.0016
70	-0.0019		0.0015	0.0007		0.0005	-0.0003		0.0009	0.0014	*	0.0008
71t74	-0.0013		0.0016	-0.0006		0.0013	-0.0030	***	0.0010	0.0016		0.0011
L	0.0011		0.0008	0.0011		0.0011	0.0002		0.0006	0.0003		0.0004
M	0.0031	***	0.0009	-0.0031	**	0.0013	0.0011	*	0.0007	0.0007		0.0005
N	0.0036	***	0.0009	-0.0040	***	0.0010	-0.0004		0.0005	0.0009		0.0008
O	0.0019		0.0013	-0.0028	***	0.0011	-0.0041	***	0.0016	0.0005		0.0010

S.E. is the standard error, *, **, and *** denote significance level of 10%, 5%, and 1% respectively

Table 2: Own and cross price elasticities of K (sample means and standard errors)

K	K	S.E.	L	S.E.	E	S.E.	M^{m}	S.E.
Agriculture,	-0.066	11.34	0.015	5.54	-0.062	1.37	-0.099	2.41
Mining, quarrying	-0.667	0.13	0.220	0.05	0.052	0.04	0.104	0.01
Food, beverages	-0.584	0.00	0.039	0.00	-0.041	0.00	0.084	0.00
Textiles	-0.519	0.01	-0.331	0.01	-0.195	0.00	0.584	0.01
Leather, footwear	-0.393	0.04	0.036	0.01	0.078	0.00	0.371	0.01
Wood and cork	-0.582	0.01	-0.412	0.03	-0.151	0.01	0.930	0.03
Pulp,paper	-1.058	0.00	0.163	0.00	-0.046	0.00	0.602	0.01
Coke, refinery	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Chemicals	-0.903	0.00	0.002	0.00	-0.116	0.00	0.620	0.01
Rubber and plastics	-1.029	0.00	0.270	0.00	-0.080	0.00	0.459	0.00
Non-metallic minerals	-0.634	0.00	0.163	0.00	0.022	0.00	0.215	0.00
Basic metals	-0.923	0.00	0.124	0.00	0.326	0.00	0.119	0.00
Machinery	-0.203	0.01	-0.078	0.00	-0.256	0.00	0.350	0.00
Electrical equipment	-0.786	0.00	0.083	0.00	-0.190	0.00	0.310	0.00
Transport equipment	-0.595	0.01	-0.126	0.01	-0.073	0.00	0.866	0.02
Other manufacturing	-0.524	0.01	0.061	0.00	0.010	0.00	0.166	0.00
Electricity, gas, water	-0.850	0.01	0.170	0.00	0.249	0.00	0.094	0.00
Construction	-0.206	0.02	-0.463	0.02	-0.159	0.00	-0.224	0.01
Sale of motor vehicles	-0.184	0.02	-0.495	0.03	-0.044	0.00	0.146	0.00
Wholesale trade	-0.892	0.00	0.237	0.00	0.026	0.00	0.170	0.00
Retail trade	-0.392	0.02	0.897	0.03	-0.098	0.01	0.019	0.00
Hotels, restaurants	-0.643	0.14	0.184	0.10	-0.164	0.11	-0.009	0.05
Other Inland transport	-1.006	0.01	0.383	0.01	0.137	0.00	-0.441	0.02
Other Water transport	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Other Air transport	-1.091	0.83	0.187	0.08	0.176	0.23	0.311	0.65
Other transport activities	-1.318	0.01	0.531	0.01	0.045	0.00	0.010	0.00
Post, telecommunications	-0.677	0.00	0.226	0.00	-0.012	0.00	0.085	0.00
Financial Intermediation	-0.494	0.00	0.133	0.00	0.018	0.00	0.008	0.00
Real estate activities	-0.317	0.00	0.083	0.00	-0.012	0.00	0.056	0.00
Other business activities	-0.463	0.04	0.026	0.04	-0.292	0.04	0.050	0.00
Public Administration	-0.717	0.03	0.546	0.01	0.057	0.01	0.026	0.01
Education	-1.180	0.53	0.924	0.42	-0.049	0.15	0.009	0.04
Health	-0.178	0.04	0.096	0.02	0.039	0.00	0.113	0.00
Social,personal services	-0.623	0.00	0.171	0.00	-0.035	0.00	-0.081	0.00

S.E. is the standard error

Table 3: Own and cross price elasticities of L (sample means and standard errors)

L	K	S.E.	L	S.E.	E	S.E.	M^m	S.E.
Agriculture,	0.311	0.01	-0.655	0.01	-0.022	0.00	-0.018	0.00
Mining, quarrying	0.058	0.10	-0.443	0.15	0.028	0.02	-0.171	0.13
Food, beverages	0.032	0.00	-0.807	0.00	0.043	0.00	-0.155	0.00
Textiles	-0.079	0.00	-0.288	0.00	0.068	0.00	-0.068	0.00
Leather, footwear	0.019	0.00	-0.628	0.00	-0.021	0.00	0.163	0.00
Wood and cork	-0.087	0.00	-0.668	0.00	0.170	0.00	0.033	0.00
Pulp,paper	0.101	0.00	-0.752	0.00	0.169	0.00	-0.198	0.00
Coke, refinery	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Chemicals	0.015	0.00	-0.707	0.00	0.531	0.01	-0.254	0.01
Rubber and plastics	0.152	0.00	-0.895	0.00	0.071	0.00	0.249	0.00
Non-metallic minerals	0.106	0.00	-0.818	0.00	0.130	0.00	0.169	0.00
Basic metals	0.058	0.00	-0.549	0.00	-0.096	0.00	0.255	0.00
Machinery	-0.020	0.00	-0.661	0.00	0.001	0.00	0.135	0.00
Electrical equipment	0.031	0.00	-0.739	0.00	0.126	0.00	0.270	0.00
Transport equipment	-0.075	0.00	-1.095	0.01	-0.016	0.00	0.352	0.00
Other manufacturing	0.030	0.00	-0.981	0.00	-0.065	0.00	0.427	0.00
Electricity, gas, water	0.346	0.00	-0.720	0.00	-0.058	0.01	0.070	0.00
Construction	-0.098	0.00	-0.253	0.00	0.087	0.00	0.120	0.00
Sale of motor vehicles	-0.234	0.00	-0.221	0.00	-0.024	0.00	0.062	0.00
Wholesale trade	0.168	0.00	-0.711	0.00	-0.013	0.00	0.013	0.00
Retail trade	0.216	0.00	-0.538	0.00	0.007	0.00	-0.034	0.00
Hotels, restaurants	0.074	0.00	-0.422	0.00	0.006	0.00	-0.061	0.00
Other Inland transport	0.122	0.01	-0.748	0.01	0.181	0.00	0.225	0.00
Other Water transport	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Other Air transport	0.052	0.00	-0.723	0.00	0.075	0.00	0.105	0.00
Other transport activities	0.395	0.01	-0.421	0.01	0.046	0.00	0.266	0.01
Post, telecommunications	0.269	0.00	-0.737	0.00	0.088	0.00	-0.025	0.00
Financial Intermediation	0.122	0.00	-0.344	0.00	0.081	0.00	0.029	0.00
Real estate activities	1.029	0.12	-0.667	0.09	-0.304	0.10	-0.729	0.25
Other business activities	0.050	0.00	-0.386	0.00	0.149	0.00	0.014	0.00
Public Administration	0.173	0.00	-0.613	0.00	0.002	0.00	0.040	0.00
Education	0.002	0.00	-0.240	0.00	-0.017	0.00	-0.002	0.00
Health	0.015	0.00	-0.277	0.00	0.085	0.00	0.029	0.00
Social,personal services	0.065	0.00	-0.501	0.00	0.103	0.00	-0.020	0.00

S.E. is the standard error

Table 4: Own and cross price elasticities of E (sample means and standard errors)

E	K	S.E.	L	S.E.	E	S.E.	M^m	S.E.
Agriculture,	0.662	0.04	-0.154	0.02	-0.528	0.03	-0.222	0.02
Mining, quarrying	-0.203	0.02	0.116	0.01	-0.131	0.02	-0.378	0.02
Food, beverages	-0.206	0.02	0.317	0.02	-0.136	0.03	-1.161	0.08
Textiles	-0.537	0.03	0.656	0.04	-0.130	0.02	-0.542	0.03
Leather, footwear	0.334	0.02	-0.428	0.02	-0.651	0.04	0.597	0.03
Wood and cork	-0.365	0.17	1.543	0.48	-0.235	0.27	-1.494	0.61
Pulp,paper	-0.224	0.03	1.435	0.12	-1.201	0.06	0.023	0.01
Coke, refinery	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Chemicals	-0.399	0.02	1.263	0.06	-1.644	0.08	0.684	0.03
Rubber and plastics	-0.421	0.02	0.590	0.03	-0.854	0.05	0.476	0.02
Non-metallic minerals	0.042	0.00	0.428	0.02	-0.670	0.04	-0.233	0.01
Basic metals	0.566	0.03	-0.446	0.03	-0.209	0.03	-0.219	0.02
Machinery	-1.984	12.58	-0.059	1.87	-0.084	5.45	0.498	1.54
Electrical equipment	-2.386	0.66	2.786	0.69	-0.365	0.16	-1.095	0.37
Transport equipment	-0.516	0.07	-0.245	0.20	-0.069	0.37	-1.712	0.67
Other manufacturing	0.038	0.00	-1.085	0.06	-0.455	0.03	1.102	0.06
Electricity, gas, water	0.442	0.02	-0.071	0.01	-0.491	0.03	-0.235	0.01
Construction	-1.226	0.55	2.811	0.96	-2.487	0.57	0.967	0.32
Sale of motor vehicles	-0.526	0.07	-0.598	0.09	-0.357	0.05	-0.200	0.03
Wholesale trade	0.412	0.24	-0.367	0.82	-0.081	1.09	-0.082	0.20
Retail trade	-0.259	0.02	0.111	0.01	-0.953	0.05	-0.705	0.04
Hotels, restaurants	-1.061	0.11	0.044	0.02	-0.162	0.06	-1.282	0.13
Other Inland transport	0.120	0.01	0.502	0.03	-0.677	0.04	-0.154	0.01
Other Water transport	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Other Air transport	0.251	0.01	0.114	0.01	-0.534	0.03	0.002	0.01
Other transport activities	0.332	0.02	0.458	0.02	-1.541	0.08	-0.063	0.01
Post, telecommunications	-1.549	0.33	1.807	0.29	-0.116	0.15	-0.706	0.14
Financial Intermediation	0.746	0.29	4.084	2.28	-0.138	0.51	-3.552	2.18
Real estate activities	-9.436	1.98	-6.192	1.23	-0.252	0.15	9.237	1.81
Other business activities	-3.944	2.23	5.682	2.89	-1.602	0.34	-1.423	0.82
Public Administration	0.975	0.06	0.006	0.01	-0.090	0.03	-0.744	0.05
Education	1.251	0.09	-1.070	0.10	-2.153	0.13	0.145	0.01
Health	0.251	0.02	2.828	0.32	-2.421	0.22	-0.699	0.10
Social,personal services	-0.321	2.47	1.974	8.45	-0.082	4.72	-1.376	7.66

S.E. is the standard error

Table 5: Own and cross price elasticities of M^m (sample means and standard errors)

M^m	K	S.E.	L	S.E.	E	S.E.	M^m	S.E.
Agriculture,	0.616	0.04	-0.064	0.01	-0.119	0.01	-0.996	0.05
Mining, quarrying	0.374	0.02	-0.366	0.03	-0.323	0.02	-0.170	0.04
Food, beverages	0.067	0.00	-0.224	0.01	-0.203	0.01	-0.894	0.05
Textiles	0.192	0.01	-0.099	0.01	-0.062	0.00	-0.722	0.04
Leather, footwear	0.896	0.04	-0.338	0.02	0.597	0.03	-1.356	0.07
Wood and cork	0.411	0.02	0.011	0.00	-0.249	0.01	-0.108	0.02
Pulp,paper	0.389	0.02	-0.277	0.02	0.013	0.00	-0.930	0.05
Coke, refinery	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Chemicals	0.447	0.02	-0.199	0.01	0.231	0.01	-0.673	0.04
Rubber and plastics	0.218	0.01	0.205	0.01	0.049	0.00	-0.871	0.05
Non-metallic minerals	0.219	0.01	0.272	0.01	-0.122	0.01	-0.707	0.04
Basic metals	0.044	0.00	0.205	0.01	-0.039	0.00	-0.737	0.04
Machinery	0.140	0.01	0.126	0.01	0.029	0.00	-0.790	0.04
Electrical equipment	0.103	0.01	0.187	0.01	-0.031	0.00	-0.615	0.03
Transport equipment	0.204	0.01	0.203	0.01	-0.059	0.00	-0.658	0.04
Other manufacturing	0.070	0.00	0.614	0.03	0.106	0.01	-1.109	0.06
Electricity, gas, water	0.630	0.10	0.220	0.02	-0.919	0.30	-0.278	0.19
Construction	-0.108	0.01	0.255	0.01	0.072	0.00	-0.868	0.05
Sale of motor vehicles	0.258	0.01	0.179	0.01	-0.030	0.00	-0.794	0.04
Wholesale trade	0.427	0.02	-0.001	0.01	-0.015	0.00	-0.088	0.03
Retail trade	0.088	0.01	-0.338	0.02	-0.274	0.02	-0.914	0.05
Hotels, restaurants	-0.036	0.01	-0.434	0.04	-0.424	0.03	-0.893	0.05
Other Inland transport	-0.567	0.03	1.169	0.06	-0.306	0.02	-0.683	0.04
Other Water transport	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
Other Air transport	0.423	0.02	0.117	0.01	0.001	0.00	-0.725	0.04
Other transport activities	0.011	0.01	0.623	0.03	-0.011	0.00	-0.959	0.05
Post, telecommunications	0.325	0.02	-0.123	0.01	-0.109	0.01	-0.647	0.04
Financial Intermediation	-0.077	0.01	0.023	0.01	-0.423	0.02	-0.828	0.05
Real estate activities	1.617	4.48	-1.198	5.84	0.782	3.56	-1.848	4.05
Other business activities	0.105	0.01	-0.015	0.01	-0.198	0.01	-0.492	0.03
Public Administration	-0.067	0.00	0.311	0.02	-0.224	0.01	-0.886	0.05
Education	0.318	0.02	-0.376	0.03	0.133	0.01	-0.760	0.04
Health	0.161	0.01	0.121	0.01	-0.149	0.01	-1.021	0.05
Social,personal services	-0.235	0.01	-0.185	0.01	-0.381	0.02	-0.455	0.03

S.E. is the standard error

Table 6: Impact of outsourcing (10% price decrease for imported intermediates) on labour demand (substitution effect) and on output prices (cost savings effect)

	substitution effect ΔL	cost savings effect Δp_Q
Agriculture	0.18	-1.00
Mining, quarrying	1.71	-0.98
Food, beverages	1.55	-1.30
Textiles	0.68	-2.44
Leather, footwear	-1.63	-2.06
Wood and cork	-0.33	-1.72
Pulp,paper	1.98	-1.86
Coke, refinery	0.00	0.00
Chemicals	2.54	-2.32
Rubber and plastics	-2.49	-2.60
Non-metallic minerals	-1.69	-1.46
Basic metals	-2.55	-2.69
Machinery	-1.35	-2.43
Electrical equipment	-2.70	-3.05
Transport equipment	-3.52	-3.24
Other manufacturing	-4.27	-1.91
Electricity, gas, water	-0.70	-0.66
Construction	-1.20	-1.27
Sale of motor vehicles	-0.62	-1.10
Wholesale trade	-0.13	-0.85
Retail trade	0.34	-0.62
Hotels, restaurants	0.61	-0.70
Other Inland transport	-2.25	-0.80
Other Water transport	0.00	0.00
Other Air transport	-1.05	-1.73
Other transport activities	-2.66	-1.10
Post, telecommunications	0.25	-0.84
Financial Intermediation	-0.29	-0.77
Real estate activities	7.29	-0.31
Other business activities	-0.14	-0.86
Public Administration	-0.40	-0.60
Education	0.02	-0.26
Health	-0.29	-0.83
Social,personal services	0.20	-0.83

Table 7: Impact of carbon pricing (10% price increase for energy) on imported intermediates demand (substitution effect) and on output prices (cost push effect)

	substitution effect ΔM^m	cost push effect Δp_Q
Agriculture	-1.19	0.51
Mining, quarrying	-3.23	0.75
Food, beverages	-2.03	0.21
Textiles	-0.62	0.26
Leather, footwear	5.97	0.25
Wood and cork	-2.49	0.27
Pulp,paper	0.13	0.36
Coke, refinery	0.00	0.00
Chemicals	2.31	1.03
Rubber and plastics	0.49	0.28
Non-metallic minerals	-1.22	0.73
Basic metals	-0.39	0.60
Machinery	0.29	0.13
Electrical equipment	-0.31	0.11
Transport equipment	-0.59	0.14
Other manufacturing	1.06	0.21
Electricity, gas, water	-9.19	1.98
Construction	0.72	0.10
Sale of motor vehicles	-0.30	0.16
Wholesale trade	-0.15	0.11
Retail trade	-2.74	0.23
Hotels, restaurants	-4.24	0.22
Other Inland transport	-3.06	1.34
Other Water transport	0.00	0.00
Other Air transport	0.01	1.27
Other transport activities	-0.11	0.27
Post, telecommunications	-1.09	0.14
Financial Intermediation	-4.23	0.07
Real estate activities	7.82	0.10
Other business activities	-1.98	0.11
Public Administration	-2.24	0.17
Education	1.33	0.25
Health	-1.49	0.21
Social,personal services	-3.81	0.17