Journal of Applied Economics. Vol IX, No. 2 (Nov 2006), 255-273

FOREIGN OUTSOURCING, LABOUR DEMAND AND THE CHOICE OF FUNCTIONAL FORM

MICHEL DUMONT*

University of Antwerp

Submitted August 2004; accepted May 2006

Elasticity of the demand for low-skilled and high-skilled labour in the European Union with respect to foreign outsourcing is estimated, using alternative flexible cost functions. The choice of functional form is apparently not immaterial, as different forms can lead to conflicting conclusions. Tests that can help to discriminate between different forms of functional specification show that a traditional generalized Leontief cost function is often rejected in favour of a minflex Laurent generalized Leontief cost function. Overall, the estimation results show that foreign outsourcing had a significant impact on the demand for low-skilled and high-skilled workers in the sample period. The pattern is however industry-specific and suggests, in line with some recent theoretical models, an ambiguous relationship between outsourcing and labour demand. There is some evidence that high-skilled labour and capital are (relative) complements.

JEL classification: F16, C52

Key words: foreign outsourcing, labour demand, flexible cost function specification

I. Introduction

Recently, some trade economists have argued that the academic consensus, prompted by early empirical work, on the limited impact of international trade with low-wage countries on the position of low-skilled workers in high-skill abundant countries, may have been overhasty (Deardorff 1998a, Slaughter 2000, Feenstra and Hanson 2001).

According to Feenstra and Hanson (2001), the fact that in almost all empirical

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* Department of International Economics, International Management and Diplomacy, Kipdorp 61, 2000 Antwerp, Belgium. The author would like to thank two anonymous referees and the co-editor Mariana Conte Grand for useful comments and suggestions. The usual disclaimer holds. E-mail: michel.dumont@ua.ac.be.

work the phenomenon of foreign outsourcing (i.e., international trade in intermediate inputs) is ignored, could explain why relatively little evidence has been found on the potential role of international trade in rising wage inequality or the increased unemployment of low-skilled workers. Krugman (1995), in pointing out that the overall volume of international trade did not change as dramatically as is sometimes assumed, noticed a potentially new aspect of international trade: the slicing up of the value added chain, with multinational firms being increasingly able to break up their production process in geographically separated steps, although he subjoined that this was more a general belief than that it could be substantiated by hard statistical evidence. Feenstra and Hanson (1996) point out that Krugman (1995) only considers foreign direct investment flows by multinationals, which are in his view too modest to explain observed changes in wages and employment in the United States. Using a more general definition of foreign outsourcing, i.e., all imports of intermediate goods or final goods used in domestic production or sold domestically, Feenstra and Hanson (1996, 1999) find a significant and substantial impact of foreign outsourcing on wage inequality for the United States.[1]

Feenstra and Hanson (1996) proposed a theoretical model of foreign outsourcing with a country that is relatively abundant with high-skilled labour (e.g., the United States) and a country that is relatively abundant with low-skilled workers (e.g., Mexico). An interesting feature of the proposed model is that if capital would flow from the US to Mexico in response to differences in the rate of return to capital and the liberalization of investment in Mexico (or alternatively if neutral technological change occurs in Mexico), the demand for high-skilled labour will rise and, given flexible labour markets, the relative wages of high-skilled workers will increase in both countries, which apparently conciliates well with stylized facts.

Whereas the Feenstra and Hanson (1996) framework explains both the decrease in relative wages of low-skilled workers and increased skill-intensity of production in both high-skill and low-skill abundant countries, other models lead to more ambiguous conclusions as to the impact on low-skilled workers (e.g., Arndt 1997, Deardorff 1998b, Venables 1999, Jones and Kierzkowski 2001).

Later on, Kohler (2002) tries to link up the different theoretical principles that

[1] Apparently there is some competition among scholars to coin the most original term for the phenomenon of firms breaking up their production process and moving (or outsourcing) separable stages to the most optimal location (country), with some of the contestants being: (foreign) outsourcing (Katz and Murphy 1992, Feenstra and Hanson 1996); slicing up the value added chain (Krugman 1995); (international) fragmentation (Deardorf 1998b); intra-product specialization (Arndt 1997) and global production sharing (Feenstra and Hanson 2001). Without designating a winner I will stick to the term foreign outsourcing throughout this text.

have been put forward to model outsourcing by proposing a general equilibrium framework where both Ricardian and Heckscher-Ohlin aspects play a role in determining the impact on factor rewards. International factor price differences and differences in technology are the driving forces of foreign outsourcing. The impact on factor rewards depends on the factor intensity of the production stages that remain in the outsourcing country and not on the factor intensity of the stages that are outsourced. In addition, Strauss-Kahn (2002) proposes a model of foreign outsourcing in which, reflecting the situation in continental Europe, foreign outsourcing will cause unemployment of low-skilled workers in high-skilled abundant countries, due to assumed wage rigidity.

From the foregoing it is clear that the relatively scarce theoretical models of foreign outsourcing do not provide an unambiguous prior assumption about the impact of outsourcing on income distribution. Empirical work can provide some useful insights.

In this paper, data on international trade in intermediate inputs and wages of low-skilled and high-skilled workers are combined to assess the impact of foreign outsourcing, by high-skilled abundant EU countries, on the domestic demand for low-skilled and high-skilled workers in the period 1985-1996.[2] The impact of international trade on labour demand is estimated within a flexible cost function framework. In contrast with most other empirical methodologies, such a framework permits to derive the demand for production factors without assuming perfect competition. If the demand for a specific factor, such as low-skilled labour, is reduced due to a given external factor like foreign outsourcing, a number of low-skilled workers will be unemployed if their wages are sticky. The assumption of perfect (labour) market competition is very heroic for most EU countries and a flexible cost function framework therefore seem more appropriate for the EU than a framework based on for example the Stolper-Samuelson theorem.

This is one of the first studies to estimate the impact of foreign outsourcing on the demand for low-skilled and high-skilled labour for a panel of EU countries. Most of the previous flexible function estimates focus on the United States or on single EU countries. Moreover, most of these studies consider trade in final goods rather than in intermediate goods. Another contribution of this paper is that it considers a number of alternative forms of the cost function, whereas in other

[2] For most of the countries considered in this analysis data on wages of non-manual workers (proxy for high-skilled workers) and manual workers (proxy for low-skilled workers) are no longer provided by EUROSTAT after 1997 or 1998. Therefore the estimations reported in this paper could not be performed for more recent years.

studies only one specific form is considered. The choice of the functional form is however not immaterial, as estimates are apparently sensitive to the form of the cost function, with occasionally conflicting results. Tests can be used to discriminate between alternative cost functions, which permits to rely upon the results of the estimates of the most favoured flexible cost function.

In the next section, different flexible cost functions and the tests to discriminate between them, as well as the data and the methodology are described. In Section III, the resulting estimates are compared to results of previous empirical studies. And, finally, Section IV provides some conclusions and suggestions for future research.

II. Empirical section

A. Labour demand and the choice of functional form

One of the fundamental assumptions in the Heckscher-Ohlin-Samuelson theory is that wages are fully flexible. If this assumption holds, wages will adjust to market-clearing levels, which guarantees full employment of all production factors. However, if wages are sticky, full employment of the relatively scarce production factor is no longer ascertained (e.g., Krugman 1995). If wages in EU countries are indeed sticky, as is often argued, lack of evidence on the impact of international trade on the relative wages of low-skilled workers in the European Union does not necessarily imply that the position of low-skilled workers may not be affected in terms of employment.

The demand for production factors like high-skilled and low-skilled labour can rather straightforwardly be derived from a cost function, which reflects the cost-minimising behaviour of firms. Flexible function specifications impose as little restrictions as possible. The most popular flexible cost functions are the duals of the transcedental logarithmic production function (translog- TL) and the generalized Leontief production function (GL) proposed respectively by Christensen, Jorgensen and Lau (1971) and Diewert (1971). The translog cost function (TL) is given by

$$\ln C = \alpha_0 + \sum_{i=1}^{I} \alpha_i \ln p_i + \beta \ln X + \tfrac{1}{2} \sum_{i=1}^{I} \sum_{j=1}^{J} \alpha_{ij} \ln p_i \ln p_j + \sum_{i=1}^{I} \chi_{iX} \ln p_i \ln X, \quad (1)$$

and the generalized Leontief cost function (GL) by

$$C = \alpha_0 + \sum_{i=1}^{I} \alpha_i p_i^{1/2} + \beta X^{1/2} + \tfrac{1}{2} \sum_{i=1}^{I} \sum_{j=1}^{J} \alpha_{ij} p_i^{1/2} p_j^{1/2} + \sum_{i=1}^{I} \chi_{iX} p_i^{1/2} X^{1/2}, \quad (2)$$

where C denotes costs, p_i the price of the i-th input factor and X output.

Using the well-known KLEM database of US manufacturing in the period 1947-1971, Berndt and Khaled (1979) reject models that are close to the translog specification as they fail concavity conditions. Berndt and Wood (1982) and Diewert and Wales (1987) find that imposing concavity on a translog form substantially reduces the goodness of fit and that both a translog and GL specification rather often violate concavity conditions. Barnett (1985) and Barnett, Lee and Wolfe (1985) have shown that both the GL function and the TL function tend to violate regularity conditions within the data region.[3] The GL function has good regional properties when substitutability is low and the TL function has good regional properties when elasticity of substitution is close to one. This is not entirely surprising given that the GL function is derived from a second-order Taylor series expansion of a Leontief function for which elasticity of substitution equals zero and the TL function from a second-order Taylor series expansion of a Cobb-Douglas function for which elasticity of substitution equals one (Barnett, Lee and Wolfe 1985: p. 4).

In addition to the finding by Caves and Christensen (1980) that the performance of both functional forms deteriorates rapidly as elasticity moves away from their respective specific values of global well-behaviour, this leads Barnett, Lee and Wolfe (1985: pp. 4-5) to argue: "As a result, neither model is attractive when little prior knowledge exists about the relevant elasticities, and the selection between models requires very strong prior knowledge about elasticities." They propose to use second-order Laurent expansions of the TL and GL functions and find that these functional forms perform better, especially for time series. A Laurent expansion results in the following expressions, a Laurent translog cost function (LTL):

$$\ln C = \alpha_0 + \sum_{i=1}^{I} \alpha_i \ln p_i + \beta \ln X + \tfrac{1}{2} \sum_{i=1}^{I} \sum_{j=1}^{J} \alpha_{ij} \ln p_i \ln p_j + \sum_{i=1}^{I} \chi_{iX} \ln p_i \ln X - \tfrac{1}{2} \sum_{i=1}^{I} \sum_{j \neq i}^{J} \zeta_{ij} \frac{1}{\ln p_i} \frac{1}{\ln p_j} - \sum_{i=1}^{I} \psi_{iX} \frac{1}{\ln p_i} \frac{1}{\ln X}, \qquad (3)$$

and a Laurent generalized Leontief cost function (LGL):

$$C = \alpha_0 + \sum_{i=1}^{I} \alpha_i p_i^{1/2} + \beta X^{1/2} + \tfrac{1}{2} \sum_{i=1}^{I} \sum_{j=1}^{J} \alpha_{ij} p_i^{1/2} p_j^{1/2} + \sum_{i=1}^{I} \chi_{iX} p_i^{1/2} X^{1/2} - \tfrac{1}{2} \sum_{i=1}^{I} \sum_{j \neq i}^{J} \zeta_{ij} \frac{1}{p_i^{1/2}} \frac{1}{p_j^{1/2}} - \sum_{i=1}^{I} \psi_{iX} \frac{1}{p_i^{1/2}} \frac{1}{X^{1/2}} \qquad (4)$$

[3] Barnett (1985) and Barnett, Lee and Wolfe (1985) actually consider indirect utility functional forms rather than production or cost functions.

The remainder term of a Laurent expansion is the sum of two terms which by definition always move in opposite directions and therefore varies more smoothly than the remainder term of a Taylor series expansion, which is close to zero at the centre of approximation but rapidly increases outside the radius of convergence (Barnett, Lee and Wolfe 1985: p. 9). A minflex Laurent function is obtained by imposing on a full second-order Laurent expansion the minimality property, which states that functions should have just enough parametric freedom to satisfy the definition of a flexible functional form. Minimality is obtained by imposing the restriction $\alpha_{ij}.\zeta_{ij} = \chi_{iX}.\Psi_{iX} = 0$ for all *i-j* combinations (Barnett 1985: pp. 35-38).

Laurent flexible functional forms have not been applied frequently in empirical work. Recently Giannakas, Tran and Tzouvelekas (2003) compared a number of production function forms, nested within a generalized quadratic Box-Cox model (e.g. GL and TL), with a minflex LTL and a minflex LGL production function specification in an estimation of technical efficiency in 125 Greek olive growing farms. The functional forms nested within the generalized quadratic Box-Cox model can be tested against the Box-Cox specification with likelihood ratio tests and against one another with the likelihood dominance criterion proposed by Pollak and Wales (1991). As the minflex Laurent functional forms are not nested within the generalized quadratic Box-Cox, Giannakas, Tran and Tzouvelekas (2003) use the non-nested hypothesis tests developed by MacKinnon et al. (1983) to discriminate pair-wise between the different non-nested functional forms. The non-nested hypothesis test shows that the minflex LTL and LGL functional forms are strongly favoured over the generalized quadratic Box-Cox function, which in turn is favoured over any of its considered nested functional forms (e.g. the traditional TL and GL forms). The minflex Laurent functional forms are superior to the Box-Cox functional forms but both Laurent functions fit the data comparably and it is therefore not possible to favour one over the other.

Berman, Bound and Griliches (1994), used a TL cost function to estimate the impact of computer investment and R&D activities on the wage bill share of non-production workers in the US in the period 1979-1987. Feenstra and Hanson (1996) used the import share as an explanatory variable in a TL specification to estimate its impact on the wage bill share of non-production workers in the US in the period 1959-1987. Strauss-Kahn (2003) and Egger and Egger (2003) also use a TL specification but consider the employment share rather than the wage bill share as the dependent variable to account for wage rigidity in respectively France and Austria.

Morrison and Siegel (1997) show how the generalized Leontief function can be extended to consider external effects. External determinants are exogenous factors that may affect the cost function and thereby shift the demand for production factors. Morrison Paul and Siegel (2001) consider high-tech capital, R&D investment and (domestic) outsourcing as potential external determinants. The interest of the external factors lies in their overall impact on industries, which as Morrison Paul and Siegel (2001) point out joins with endogenous growth theories in stressing the importance of spillovers and other sources of increasing returns.

The extended GL cost function can be written as (e.g. Morrison Paul and Siegel 2001):

$$C = X\left[\sum_{i=1}^{I}\sum_{j=1}^{J}\alpha_{ij}\,p_i^{1/2}\,p_j^{1/2} + \sum_{i=1}^{I}\sum_{m=1}^{M}\delta_{im}\,p_i\,s_m^{1/2} + \sum_{i=1}^{I} p_i\sum_{m=1}^{M}\sum_{n=1}^{N}\gamma_{mn}s_m^{1/2}s_n^{1/2}\right]. \tag{5}$$

The variables s denote output (X) and the external determinants. Applying Shephard's lemma, the demand for the j-th input factor can be obtained by differentiating (5) with regard to its own price:

$$D_i = \partial C/\partial p_i\,. \tag{6}$$

Log-differentiating the demand for an input factor given in equation (6) with respect to the n-th element of vector S gives the elasticity of demand for that factor with respect to the considered external factor:

$$\varepsilon_{D_i S n} = \partial \ln D_i / \partial \ln S_n\,. \tag{7}$$

The J-test proposed by Davidson and MacKinnon (1981) permits to discriminate between two non-nested functional forms. Consider two non-nested model specifications:

$$H_1 : y = x\,(\alpha) + \varepsilon_1\,, \tag{8}$$

$$H_2 : y = z\,(\beta) + \varepsilon_2, \tag{9}$$

with α and β the respective parameter vectors. The two models are artificially nested within a compound model:

$$H_C : y = (1\text{-}\delta)\,x\,(a) + \delta\,z\,(\beta) + \varepsilon \tag{10}$$

As δ, α, β are generally not identifiable Davidson and MacKinnon (1981) proposed a J-test in which β (i.e., the parameter vector of the hypothesis specification that is not tested) is replaced by its least squares estimate $\hat{\beta}$. They showed that if hypothesis H_1 holds the t-statistic of $\hat{\delta}$ will be asymptotically standard normally distributed.

To test hypothesis H_2, α is replaced by its least squares estimate $\hat{\alpha}$ in (10). The pair of non-nested hypotheses tests can have four outcomes (Davidson and MacKinnon 1993: p. 383):

- H_1 is rejected but H_2 not ➔ H_2 preferred model
- H_2 is rejected but H_1 not ➔ H_1 preferred model
- H_1 and H_2 both rejected ➔ neither H_1 nor H_2 satisfactory specification
- Neither H_1 nor H_2 rejected ➔ both specifications are similar (or data set is not very informative)

B. Data and methodology for estimation

Data on wages and employment of low-skilled and high-skilled workers, foreign outsourcing and R&D expenditures are at the two-digit ISIC industry level, except for ISIC 38 for which data are at the three-digit level. Sufficient data are available for Belgium, Demark, France, Germany and the United Kingdom, for the period 1985-1996. With regard to foreign outsourcing, three country groups are distinguished: High-skilled abundant countries (HSC), relatively low-skilled abundant EU countries (EULS) and the group of Newly Industrialized Countries (NIC).[4]

Both TL and GL specifications and the alternative LTL and LGL specifications have been considered. However, the translog cost functions performs very bad. For many sectors the estimation procedure fails to converge or results in significant own price elasticity estimates with a wrong sign. Given these poor results the discussion focuses on the results of the GL specifications. Berndt and Wood (1982) found, for US manufacturing industries in the period 1948-1971, that imposing global concavity conditions on a TL cost function ensured that the cost function was well-behaved but resulted in poor goodness of fit, for their data set, and suggested that the trade-off between conditions of well-behavior and goodness of fit may be less severe for other functional forms like the generalized Leontief (Berndt and Wood 1982: p. 219). Overall, the GL cost functions appear to be well-behaved, even without imposing restrictions.

[4] See Appendix for details on data sources, definitions and country groups.

For each individual ISIC industry an extended GL specification (Morrison and Siegel 1997) and an extended minflex LGL specification are considered. The system of demand equations was estimated with iterative three-stage least squares, using lagged variables as instruments (cf. Morrison Paul and Siegel 2001). Three input factors are considered: high-skilled labour (HS); low-skilled labour (LS) and capital (K).

III. Results

Table 1 shows the results of elasticity measures derived from the GL and LGL specification for each individual ISIC industry, estimated for the panel of five EU countries. Elasticity has been evaluated at the means and the ANALYZ procedure in TSP has been used to compute standard errors.[5,6]

For all industries, except for high-skilled labour in ISIC 35 (*chemicals*) and ISIC 385 (*precision instruments*), own price elasticity of input factors (i.e. $\varepsilon_{LS,wls}$ for low-skilled workers and $\varepsilon_{HS,whs}$ for high-skilled workers) has the expected (negative) sign and is mostly highly significant.

The results of the J-tests show that in eight out of the twelve industries considered the traditional GL specification is rejected whereas a Laurent GL specification is not, albeit in five industries GL is only rejected at the 10 % level. Only in two industries (ISIC 34- *paper, printing and publishing* and ISIC 37- *basic metal industries*) GL is clearly preferred to LGL. For ISIC 35 both a GL and a LGL specification are rejected and for ISIC 383 (*electrical equipment*) the J-test is inconclusive. Given the rather substantial differences in estimated elasticity, in some cases even with contradictory conclusions, the choice of functional form seems to matter. Moreover, the appropriate functional form appears to be industry specific. Actually, the eight LGL specifications that are preferred to a GL specification differ in which parameters are restricted to be zero and can therefore also be considered as different functional forms.

Trusting in the results of the preferred specification, the positive estimates of $\varepsilon_{LS,whs}$ suggest that low-skilled and high-skilled labour are substitutes in nine

[5] Anderson and Thursby (1986) show that for a translog demand model, only elasticities evaluated on the means of actual cost shares are likely to satisfy a normal or ratio-of-normals distribution.

[6] As pointed out by Morrison Paul and Siegel (2001) the elasticity measures are complex combinations of parameter estimates for which the "delta method" has to be used (which the ANALYZ procedure performs).

Table 1. Elasticities from generalized Leontief (GL) and minflex Laurent generalized Leontief (LGL) cost function specifications (1985-1996)

	ISIC 31 Food, beverages and tobacco		ISIC 32 Textiles, footwear and leather		ISIC 33 Wood, cork and furniture		ISIC 34 Paper, printing and publishing	
	GL	LGL	GL	LGL	GL	LGL	GL	LGL
$\varepsilon_{LS,wls}$	-0.89 (-5.88)***	-0.58 (-4.13)***	-1.00 (-5.69)***	-1.01 (-5.58)***	-0.43 (-4.30)***	-0.43 (-4.46)***	-1.27 (-15.1)***	-0.44 (-5.57)***
$\varepsilon_{HS,whs}$	-0.61 (-6.89)***	-0.45 (-4.72)***	-1.11 (-5.36)***	-1.25 (-4.30)***	-0.41 (-5.92)***	-0.27 (-4.15)***	-1.04 (-8.05)***	-0.78 (-7.83)***
$\varepsilon_{K,wk}$	-0.16 (-5.58)***	-0.11 (-6.89)***	-0.24 (-6.22)***	-0.08 (-3.48)***	-0.08 (-3.48)***	-0.03 (-1.29)	-0.44 (-7.93)***	-0.22 (-7.44)***
$\varepsilon_{LS,whs}$	0.17 (1.86)*	0.11 (1.36)	0.19 (1.06)	0.15 (0.82)	0.21 (2.79)***	0.27 (4.07)***	-0.22 (-2.44)**	-0.03 (-0.35)
$\varepsilon_{LS,wk}$	0.72 (5.71)***	0.47 (5.40)***	0.81 (9.17)***	0.86 (8.71)***	0.22 (3.10)***	0.15 (2.13)**	1.49 (9.63)***	-0.16 (-3.34)***
$\varepsilon_{HS,wk}$	0.47 (4.08)***	-0.12 (-4.40)***	0.90 (4.39)***	0.77 (3.67)***	0.21 (2.35)**	0.00 (.02)	1.19 (6.59)***	0.80 (9.17)***
$\varepsilon_{LS,hsc}$	0.69 (2.41)**	1.06 (4.51)***	0.08 (0.45)	0.21 (1.04)	0.45 (6.63)***	0.48 (7.80)***	0.24 (1.34)	0.24 (1.83)*
$\varepsilon_{HS,hsc}$	-0.58 (-1.86)*	-0.14 (-0.58)	-1.30 (-5.24)***	-1.12 (-4.09)***	-0.23 (-2.90)***	-0.23 (-2.69)***	-0.67 (-4.00)***	-0.41 (-2.68)***
$\varepsilon_{LS,eulw}$	-1.93 (-7.73)***	-1.34 (-5.91)***	0.01 (0.04)	-0.12 (-0.45)	-0.42 (-5.20)***	-0.36 (-4.24)***	-0.77 (-3.04)***	-0.18 (-1.05)
$\varepsilon_{HS,eulw}$	-1.12 (-4.81)***	-0.38 (-1.51)	0.28 (0.75)	0.12 (0.32)	-0.31 (-2.76)***	-0.15 (-1.19)	0.07 (0.29)	-0.05 (-0.19)
$\varepsilon_{LS,nic}$	0.92 (3.64)***	0.60 (2.97)***	-0.30 (-2.00)**	-0.13 (-0.92)	0.69 (5.85)***	0.68 (5.88)***	0.92 (4.74)***	-0.12 (-0.96)
$\varepsilon_{HS,nic}$	0.87 (4.20)***	0.71 (3.80)***	0.48 (2.02)**	0.85 (3.91)***	0.92 (4.97)***	0.92 (4.18)***	1.22 (6.30)***	0.39 (1.94)*
$\varepsilon_{LS,rds}$	0.63 (3.13)***	0.57 (3.45)***	-0.43 (-2.69)***	-0.33 (-2.15)**	0.09 (1.30)	0.14 (2.27)**	-0.02 (-0.09)	-1.67 (-1.12)
$\varepsilon_{HS,rds}$	0.36 (1.69)*	0.23 (1.38)	-0.72 (-3.11)***	-0.61 (-2.56)***	0.44 (6.21)***	0.48 (6.36)***	-0.44 (-2.70)***	-0.10 (-0.54)
P-test	GL vs. LGL 1.82*	LGL vs. GL 0.89	GL vs. LGL 1.91*	LGL vs. GL 0.85	GL vs. LGL 2.87***	LGL vs. GL 1.21	GL vs. LGL -1.49	LGL vs. GL 4.79***

Table 1. (continued) Elasticities from generalized Leontief (GL) and minflex Laurent generalized Leontief (LGL) cost function specifications (1985-1996)

	ISIC 35 Chemicals		ISIC 36 Non-metallic mineral products		ISIC 37 Basic metal industries		ISIC 381 Fabricated metal products	
	GL	LGL	GL	LGL	GL	LGL	GL	LGL
$\varepsilon_{LS,wls}$	-0.36 (-1.44)	-0.20 (-0.99)	-0.30 (-3.10)***	0.03 (0.28)	-0.45 (-3.54)***	-0.54 (-5.93)***	-0.26 (-2.54)**	-0.22 (-2.05)**
$\varepsilon_{HS,whs}$	.08 (0.59)	0.38 (3.96)***	-0.58 (-4.78)***	-0.51 (-5.65)***	-0.36 (-4.39)***	-0.41 (-6.01)***	-0.24 (-2.50)**	-0.23 (-1.68)*
$\varepsilon_{K,wk}$	-0.01 (-0.25)	0.07 (3.13)***	-0.06 (-4.69)***	0.01 (0.76)	-0.04 (-3.87)***	0.04 (1.58)	-0.04 (-0.82)	-0.07 (-1.36)
$\varepsilon_{LS,whs}$	0.01 (0.07)	0.22 (1.17)	-0.01 (-0.14)	0.29 (3.86)***	0.14 (1.04)	-0.30 (-4.51)***	0.16 (1.36)	0.12 (0.99)
$\varepsilon_{LS,wk}$	0.35 (3.43)***	0.01 (0.25)	0.32 (3.30)***	0.11 (2.81)***	0.31 (4.10)***	-0.36 (-1.91)***	0.10 (0.95)	0.10 (0.89)
$\varepsilon_{HS,wk}$	-0.08 (-0.58)	-0.46 (-3.54)***	0.59 (4.74)***	0.21 (2.95)***	0.10 (1.04)	-0.21 (-1.29)	0.09 (0.65)	0.22 (1.23)
$\varepsilon_{LS,hsc}$	1.09 (6.68)***	1.30 (6.42)***	0.35 (2.37)**	0.48 (1.75)*	0.60 (3.07)***	0.43 (1.41)	0.68 (8.09)***	0.78 (7.95)***
$\varepsilon_{HS,hsc}$	0.56 (2.03)**	0.71 (2.28)**	-0.46 (-3.29)***	-0.17 (-0.56)	-0.31 (-2.29)**	-0.50 (-2.67)***	0.11 (0.86)	0.30 (2.32)
$\varepsilon_{HS,eulw}$	-0.82 (-1.88)*	-0.84 (-1.71)*	-1.94 (-6.04)***	-4.14 (-7.06)***	-0.53 (-1.66)*	0.24 (0.58)	-0.39 (-2.12)**	-0.57 (-3.26)***
$\varepsilon_{LS,nic}$	0.33 (1.83)*	0.03 (0.13)	1.64 (7.01)***	2.75 (6.87)***	0.08 (0.29)	0.52 (0.78)	-0.06 (-0.40)	0.02 (014)
$\varepsilon_{HS,nic}$	0.01 (0.02)	-0.20 (-0.64)	2.44 (12.00)***	4.15 (9.55)***	-0.09 (-0.39)	0.30 (1.04)	0.06 (0.32)	0.15 (0.62)
$\varepsilon_{LS,rds}$	0.39 (1.60)	0.80 (2.41)**	1.66 (6.95)***	3.10 (9.02)***	-0.30 (-1.62)	-1.71 (-2.95)***	0.20 (2.51)**	0.35 (3.49)***
$\varepsilon_{HS,rds}$	1.08 (2.41)**	1.38 (2.93)***	1.52 (4.62)***	3.21 (6.80)***	0.22 (1.21)	-0.94 (-3.71)***	0.89 (6.91)***	1.16 (5.45)***
P-test	GL vs. LGL	LGL vs. GL	GL vs. LGL	LGL vs. GL	GL vs. LGL	LGL vs. GL	GL vs. LGL	LGL vs. GL
	-2.03**	2.56***	2.49**	0.78	-1.45	4.57***	2.75***	0.44

Table 1. (continued) Elasticities from generalized Leontief (GL) and minflex Laurent generalized Leontief (LGL) cost function specifications (1985-1996)

	ISIC 382 Non-electrical machinery		ISIC 383 Electrical equipment		ISIC 384 Transport equipment		ISIC 385 Precision instruments	
	GL	LGL	GL	LGL	GL	LGL	GL	LGL
$\varepsilon_{LS,wls}$	-0.61(-3.77)***	-0.02 (-0.23)	-0.05 (-1.03)	0.01 (0.02)	-1.16 (-4.70)***	-1.25 (-4.97)***	0.40 (2.27)**	0.19 (1.11)
$\varepsilon_{HS,whs}$	-0.66 (-7.63)***	-0.46 (-7.05)***	-0.40 (-6.91)***	-0.27 (-4.29)***	-0.72 (-4.99)***	-0.81 (-5.41)***	0.26 (2.55)**	0.39 (2.34)**
$\varepsilon_{K,wk}$	-0.08 (-4.82)***	-0.08 (-3.51)***	-0.19 (-9.50)***	-0.27 (-8.37)***	-0.14 (-6.88)***	-0.15 (-5.43)***	-.09 (-2.89)***	-0.05 (-1.85)*
$\varepsilon_{LS,whs}$	0.39 (2.93)***	0.01 (0.15)	-0.21 (-6.18)***	-0.28 (-6.27)***	0.51 (2.81)***	0.55 (2.94)***	-1.07 (-6.36)***	0.29 (4.77)***
$\varepsilon_{LS,wk}$	0.22 (2.49)*	0.04 (0.30)	0.26 (8.88)***	0.28 (6.18)***	0.65 (6.80)***	0.70 (7.38)***	0.66 (6.11)***	0.69 (5.36)***
$\varepsilon_{HS,wk}$	0.35 (7.07)***	0.47 (8.17)***	0.51 (8.27)***	0.77 (6.88)***	0.26 (2.78)***	0.25 (2.26)**	0.15 (1.28)	0.01 (0.33)
$\varepsilon_{LS,hsc}$	0.36 (3.31)***	0.23 (2.22)**	0.52 (5.43)***	0.48 (5.30)***	1.11 (2.67)***	0.76 (2.29)**	-0.29 (-1.22)	-0.99 (-3.48)***
$\varepsilon_{HS,hsc}$	-0.27 (-2.36)**	-0.19 (-1.61)	0.39 (3.26)***	0.44 (4.65)***	-0.20 (-0.41)	-0.62 (-1.64)	-0.40 (-2.30)**	-0.87 (-4.38)***
$\varepsilon_{LS,eulw}$	-0.74 (-6.05)***	-0.58 (-4.82)***	-0.38 (-3.89)***	-0.32 (-3.30)***	-0.84 (-1.99)**	-0.53 (-1.51)	0.04 (0.29)	-0.09 (-0.63)
$\varepsilon_{HS,eulw}$	-0.23 (-2.17)**	-0.30 (-2.62)**	-0.88 (-5.51)***	-0.94 (-6.96)***	0.38 (0.68)	0.76 (1.66)	-0.26 (-1.89)*	-0.14 (-0.83)
$\varepsilon_{LS,nic}$	0.58 (6.12)***	0.68 (5.61)***	-0.46 (-3.67)***	-0.19 (-1.94)*	0.45 (1.67)*	0.24 (1.21)	0.76 (2.80)***	-0.20 (-0.68)
$\varepsilon_{HS,nic}$	0.79 (11.30)***	0.83 (9.30)***	-0.03 (-0.20)	0.08 (0.61)	-0.00 (-0.00)	-0.24 (-0.98)	0.38 (1.95)*	-0.13 (-0.51)
$\varepsilon_{LS,rds}$	0.09 (1.09)	-0.01 (-0.09)	0.19 (1.72)	0.04 (0.39)	-0.04 (-0.18)	-0.20 (-1.08)	0.15 (0.54)	1.23 (3.85)***
$\varepsilon_{HS,rds}$	-0.02 (-0.21)	0.08 (0.52)	0.38 (2.93)***	0.38 (3.16)***	0.16 (0.68)	-0.01 (-0.06)	0.14 (0.63)	0.61 (2.45)**
P-test	GL vs. LGL	LGL vs. GL	GL vs. LGL	LGL vs. GL	GL vs. LGL	LGL vs. GL	GL vs. LGL	GL vs. GL
	1.64*	1.17	1.30	0.27	-1.83*	1.15	2.19*	0.55

Note: Elasticity is computed at the means of the respective variables and is derived from the demand equations, which result from differentiating the cost function. Standard errors have been computed with the ANALYZ procedure in TSP. The system of demand equations has been estimated with an iterative three-stage least squares procedure with lagged RHS variables as instruments. Country dummies have been included in all specifications. J-tests are pair-wise non-nested hypothesis tests (Davidson and MacKinnon 1981) of a traditional GL specification with LGL specifications based on the high-skilled labour demand equation. *, **, *** denotes significance at respectively 10%, 5% and 1%.

industries and statistically significantly so in five industries. Low-skilled labour also appears to be a substitute for capital in eleven industries with a significant positive elasticity ($\varepsilon_{LS,wk}$) in nine industries. The elasticity of demand for high-skilled labour with regard to capital ($\varepsilon_{HS,wk}$) is only (significantly) negative in ISIC 31 (*food, beverages and tobacco*), so there is little evidence for absolute skill-complementarity. Frondel and Schmidt (2003) pointed out that high-skilled labour and capital can be relative complements, even if elasticity is positive, if the elasticity of the demand for high-skilled labour is smaller than the elasticity of low-skilled labour. According to this criterion high-skilled labour and capital are relative complements in seven industries. The results suggest that in the group of countries considered technological change, when accompanied with capital investment, has increased the demand for high-skilled labour with both capital and high-skilled labour substituting for low-skilled labour, i.e., technological change (or capital deepening) was biased in favour of high-skilled labour, at the expense of low-skilled workers.

With regard to the relationship between high-skilled labour and capital, the GL and LGL specifications have a substantially different outcome, even contradictory conclusions in a number of industries (e.g., significant absolute complementarity between capital and high-skilled labour following a LGL specification but significant substitution following a (rejected) GL specification in ISIC 31).

Foreign outsourcing towards high-skill abundant countries increased both the relative and absolute demand for low-skilled workers (see $\varepsilon_{LS,hsc}$) and decreased the demand for high-skilled workers ($\varepsilon_{HS,hsc}$) in most industries. In some industries, outsourcing towards relatively low-skilled abundant EU countries decreased the absolute demand for low-skilled as well as high-skilled workers ($\varepsilon_{LS,eulw}$ and $\varepsilon_{HS,eulw}$ respectively). In the group of relatively low-skill abundant EU countries three countries joined the European Union (Portugal and Spain), or had only been a member for a short time (Greece), at the beginning of the period considered (1985-1996). The estimation results suggest that the increased foreign outsourcing that resulted from the integration of these relatively low-skill abundant countries in the EU had a negative impact on the demand for low-skilled workers in the five EU countries considered.

The results show that foreign outsourcing does not unambiguously harm low-skilled workers and that the impact may depend on the difference in factor intensity in both the outsourcing country and the country whereto production fragments are outsourced, as suggested by some theoretical models (e.g., Deardorff 1998b and Venables 1999). The estimates seem to be in line with previous empirical studies in which the impact of foreign outsourcing on the labour market in industrialized countries is estimated within a flexible cost function framework. Feenstra and Hanson (2001), for example, found that for US manufacturing sectors in the period 1979-1990, foreign outsourcing can explain 15 to 24 per cent of the increase in the wage bill share of non-production workers. Using import shares as a proxy for foreign outsourcing Anderton and Brenton (1999) and Anderton, Brenton and Oscarsson (2002) also found that imports from low-wage countries significantly increased the demand for non-manual workers, for the UK and Sweden respectively. For France, the estimates by Strauss-Kahn (2003) suggest that foreign outsourcing explains 25 per cent of the decrease in the employment share of low-skilled workers in the period 1985-1993 and for Austria Egger and Egger (2003) estimated that 25 per cent of the increase in relative employment of high-skilled workers can be explained by outsourcing towards East European Countries for the period 1990-1998.

In contrast with some of the early empirical studies, most flexible cost function estimates suggest a significant impact of international trade (in final or intermediate goods) with Newly Industrialized Countries on the wages or employment of low-skilled workers in high-skill abundant countries. However, the results in this study, as well as most previous flexible cost function estimates, also indicate that other determinants (e.g. technological change) have to be considered, as the share of changes in the wage bill or employment that can be explained by international trade is relatively modest (generally close to 25 per cent).

IV. Conclusions

In previous empirical work the demand for low-skilled and high-skilled workers with regard to international trade and technological change has been estimated with demand equations that can be derived from flexible cost functions. The two most popular flexible functional forms are the translog (TL) and the generalized Leontief (GL) and these have been used in previous studies. However, Barnett (1985) and Barnett, Lee and Wolfe (1985) have shown that these functional forms are only appropriate under strict assumptions on substitution elasticity. They proposed minflex Laurent functional forms, which have better global properties. In this paper a traditional GL cost function is compared with a minflex Laurent GL (LGL) cost function to estimate the impact of foreign outsourcing from five EU countries towards three different country groups in the period 1985-1996. Non-nested hypotheses tests show that in eight out of twelve industries the latter is clearly the preferred specification, whereas only in two industries traditional GL is preferred. The fact that the traditional translog and generalized Leontief have often been rejected in favour of other functional forms and the sensitivity of results to the choice of function specification should warn against the conclusions that are based on these popular functional forms. Other functional specifications may outperform the Laurent generalized Leontief specification. It may be interesting to compare Laurent specifications to other functional forms (Barnett and Binner 2004 provide a recent overview of flexible function specifications).

Foreign outsourcing seems to have had a significant impact on labour demand in the five EU countries considered. Overall, in most industries, outsourcing towards high-skill abundant countries decreased relative demand for high-skilled workers and outsourcing towards Newly Industrialized Countries increased the demand for high-skilled workers, but the results suggest a complex rather than a straightforward relationship between foreign outsourcing and labour demand. This finding seems in line with some of the complex relationships proposed in a number of recent theoretical models on international outsourcing, although these models clearly adopt a broad view that is beyond the scope of this paper. More empirical work needs to be carried out to test the different mechanisms and hypotheses proposed in the theoretical models.

Although the impact of foreign outsourcing on the demand for labour, in the EU countries considered, is relatively modest and technological change possibly can explain a more substantial part of changes in labour demand, future research needs to account for the interaction between two determinants, trade-induced technological change and the impact of technological change on trade competitiveness.

Appendix

Table A1 below has a description of data sources, definition of variables and country groups used.

Table A1. Description of variables and data sources

Employment
Number of operatives and non-operatives is taken from the the UNIDO General Industrial Statistics database for the period 1985-1991. From 1992 onwards data for manual and non-manual workers from the Labour Force Surveys (LFS) data (Eurostat). For Belgium data on the number of manual and non-manual workers are provided by the National Office for Social Security (RSZ) for the entire period 1985-96.
Wages
Monthly wages of non-manual workers from NewCronos (Eurostat). For manual workers this data source gives gross hourly wages. For the period 1985-1991 UNIDO provides the wage sum of operatives and the number of operatives, which allows for a straightforward way of computing monthly wages of operatives. From 1992 onwards, monthly wages of manuals are computed with the wage sum of manual workers (total wage sum-wage sum non-manual workers (LFS + NewCronos)) and the rescaled number of manual workers (LFS).
Price of capital
The price of capital is calculated as: $P_{Ki,t} = q_{i,t}*(r_t + d_i)$, with $q_{i,t}$: investment deflator of *i*-th type capital (e.g. capital in sector i) in year t ; r_t: long-term government bond yield and d_i: depreciation rate of *i*th type capital (e.g., Berndt and Hesse 1986). Data on long-term government bond yields were taken from the IMF International Financial Statistics. The same source contains data on fixed capital consumption from which depreciation rates can be computed. Unfortunately this information is given for few countries, sectors and years. Rather than using the sector depreciation rate for just a couple of observations, and disregarding it for most observations, only r_t is used. For $q_{i,t}$ sector-specific deflators are computed from the value added data given in the OECD Structural Analysis industrial (STAN) database.
R&D
R&D stocks are computed with data from ANBERD, completed with BERD data (both from OECD). The 1973 stock was taken as the initial stock and computed with the formula given by Coe and Helpman (1995).

Foreign outsourcing

Foreign outsourcing is measured using data from the OECD Input-Output database. At present the OECD data cover the period 1973-1990. The database contains separate matrices of flows of imported intermediate inputs. For Belgium, the input-output data from the Federal Planning Bureau are used. Bilateral import shares (OECD International Trade by Commodities Statistics) are considered to decompose flows of imported intermediate inputs into flows imported from three country groups:

- NIC (Newly Industrialized Countries): Czech Republic, Hungary, Poland, Hong Kong, Indonesia, Republic of Korea, Malaysia, Philippines, Singapore, Thailand, Argentina, Brazil, Chile and Mexico.
- EULS (Relatively low-skill abundant EU countries): Greece, Ireland, Portugal, Spain.
- HSC (High-skill abundant countries): Austria, Belgium-Luxembourg, Denmark, France, Finland, Germany, Italy, the Netherlands, Sweden, UK, Australia, Japan, New Zealand, Norway and the US.

There are sufficient data to construct all necessary variables for Belgium, Denmark, France, Germany and the United Kingdom for the period 1985-1996.

The flow matrices of imported intermediate inputs of 1990 are used as no more recent data were available. Foreign outsourcing (narrow sense) is given by:

FO_{ik} = [(imported intermediate inputs from industry i abroad by domestic industry i)/(gross production of domestic industry i)]/[(imports from country (group) k's industry i)/(total imports from industry i abroad)]

References

Anderson, Gene R., and Jerry G. Thursby (1986), "Confidence intervals for elasticity estimators in translog models", *Review of Economics and Statistics* **68:** 647-656.

Anderton, R. and P. Brenton (1999), "Outsourcing and low-skilled workers in the UK", *Bulletin of Economic Research* **51**: 267-285.

Anderton, R., Brenton, P. and E. Oscarsson (2002), "What's trade got to do with it? relative demand for skills within Swedish manufacturing", *Review of World Economics* **138**: 628-651.

Arndt, Sven W. (1997), "Globalization and the open economy", *North American Journal of Economics and Finance* **8**: 71-79.

Barnett, William A. (1985), "The minflex-Laurent translog flexible functional form", *Journal of Econometrics* **30**: 33-44.

Barnett, William A., and Jane M. Binner, eds., (2004), *Functional Structure and Approximation in Econometrics*, Amsterdam, North Holland- Elsevier Science.

Barnett, William A., Lee, Yul W., and Michael D. Wolfe (1985), "The three-dimensional global properties of the minflex Laurent, generalized Leontief, and translog flexible functional forms", *Journal of Econometrics* **30**: 3-31.

Berman, Eli, Bound, John, and Zvi Griliches (1994), "Changes in the demand for skilled labor within US manufacturing industries: Evidence from the annual survey of manufacturing", *Quarterly Journal of Economics* **109**: 367-397.

Berndt, Ernst R., and Dieter Hesse (1986), "Measuring and assessing capacity utilisation in the manufacturing sector of nine OECD countries", *European Economic Review* **30**: 961-989.

Berndt, Ernst R., and Mohammed S. Khaled (1979), "Parametric productivity measurement and choice among flexible functional forms", *Journal of Political Economy* **87**: 1220-1245.

Berndt, Ernst R., and David O. Wood (1982), "The specification and measurement of technical change in U.S. manufacturing", *Advances in the Economics of Energy and Resources* **4**: 199-221.

Caves, Douglas W., and Laurits R. Christensen (1980), "Global properties of flexible functional forms", *American Economic Review* **70**: 422-432.

Christensen, Laurits R., Jorgensen, Dale W., and Laurence J. Lau (1971), "Conjugate duality and the transcedental logarithmic production function", *Econometrica* **39**: 255-256.

Coe, David T., and Elhanan Helpman (1995), "International R&D spillovers", *European Economic Review* **39**: 859-87.

Davidson, Russell, and James G. MacKinnon (1981), "Several tests for model specification in the presence of alternative hypotheses", *Econometrica* **49**: 781-793.

Davidson, Russell, and James G. MacKinnon (1993), *Estimation and Inference in Econometrics*, New York, NY, Oxford University Press.

Deardorff, Alan V. (1998a), "Technology, trade, and increasing inequality: Does the cause matter for the cure?", RSIE Discussion Paper 428, School of Public Policy, University of Michigan.

Deardorff, Alan V. (1998b), "Fragmentation across cones", RSIE Discussion Paper 427, School of Public Policy, University of Michigan.

Diewert, Walter E. (1971), "An application of the Shepard duality theorem: A generalized Leontief production function", *Journal of Political Economy* **79**: 481-507.

Diewert, Walter E., and Terence J. Wales (1987), "Flexible functional forms and global curvature conditions", *Econometrica* **55**: 43-68.

Egger, Hartmut, and Peter Egger (2003), "Outsourcing and skill-specific employment in a small economy: Austria and the fall of the Iron Curtain", *Oxford Economic Papers* **55**: 625-643

Federal Planning Bureau (2000), *Relocation, Innovation and Employment*, Brussels.

Feenstra, Robert C., and Gordon Hanson (1996), "Foreign investment, outsourcing, and relative wages", in R.C. Feenstra , G.M. Grossman and D.A. Irwin, eds., *Political Economy of Trade Policy*, Cambridge, MA, MIT Press.

Feenstra, Robert C., and Gordon Hanson (1999), "The impact of outsourcing and high-technology capital on wages: Estimates for the United States", *Quarterly Journal of Economics* **114**: 907-940.

Feenstra, Robert C., and Gordon Hanson (2001), "Global production sharing and rising inequality: A survey of trade and wages", Working Paper 8372, Cambridge, MA, NBER.

Frondel, Manuel, and Christoph M. Schmidt (2003), "Rejecting capital-skill complementarity at all costs", *Economics Letters* **80**: 15-21.

Giannakas, Konstantinos, Tran, Kien C., and Vangelis Tzouvelekas (2003), "On the choice of functional form in stochastic frontier modelling", *Empirical Economics* **28**: 75-100.

Jones, Ronald W., and Henryk Kierzkowski (2001), "A Framework for fragmentation", in S.

W. Arndt and H. Kierzkowski, eds., *Fragmentation: New Production Patterns in the World Economy*, Oxford, Oxford University Press.

Katz, Lawrence, and Kevin Murphy (1992), "Changes in relative wages, 1963-1987: Supply and demand factors", *Quarterly Journal of Economics* **107**: 36-78.

Kohler, Wilhelm (2002), "The distributional effects of international fragmentation", Working Paper 0201, Department of Economics, Johannes Kepler University of Linz.

Krugman, Paul (1995), "Growing world trade: Causes and consequences", *Brookings Papers on Economic Activity* (Macroeconomics) **1**: 327- 377.

Krugman, Paul (2000), "Technology, trade and factor prices", *Journal of International - Economics* **50**: 51-71.

MacKinnon, James G., White, Halbert, and Russell Davidson (1983), "Tests for model specification in the presence of alternative hypotheses", *Journal of Econometrics* **21**: 53-70.

Morrison, Catherine J., and Donald Siegel (1997), "External capital factors and increasing returns in U.S. manufacturing", *Review of Economics and Statistics* **79**: 647-654.

Morrison Paul, Catherine, and Donald Siegel (2001), "The impacts of technology, trade and outsourcing on employment and labour compensation", *Scandinavian Journal of Economics* **103**: 241-264.

OECD (1998), "OECD data on skills: Employment by industry and occupation", STI Working paper 1998/4, Paris, OECD.

Pollak, Robert A., and Terence J. Wales (1991), "The likelihood dominance criterion: A new approach to model selection", *Journal of Econometrics* **47**: 227-242.

Slaughter, Matthew J. (2000), "What are the results of product-price studies?", in R.C. Feenstra, ed., *The Impact of International Trade on Wa*ges, Chicago, University of Chicago Press.

Strauss-Kahn, Vanessa (2002), "Firms' location decision across asymmetric countries and employment inequality", Working Paper, Fontainebleau, INSEAD.

Strauss-Kahn, Vanessa (2003), "The role of globalization in the within-industry shift away from unskilled workers in France", Working Paper 9716, Cambridge, MA, NBER.

Tyers, Rod, and Yongzheng Yang (2000), "Capital-skill complementarity and wage outcomes following technical change in a global model", *Oxford Review of Economic Policy* **16**: 23-41.

Venables, Anthony K.J. (1999), "Fragmentation and multinational production", *European Economic Review* **43**: 935-945.