

# Foreign Outsourcing, the Demand for Labour and the Choice of Functional Form

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## Abstract

The elasticity of demand for low-skilled and high-skilled labour with regard to foreign outsourcing by five EU countries, in the period 1985-1996, is derived from two alternative flexible cost functions. Non-nested hypotheses tests favour a Laurent generalized Leontief cost function over a traditional generalized Leontief in the majority of considered industries. Given the substantial differences and even contradictory conclusions of both functional forms the choice of functional form is not trivial. Foreign outsourcing appears to have had a significant impact on the demand for low-skilled and high-skilled workers. The pattern is however industry specific and suggests a complex rather than a straightforward relationship between outsourcing and labour demand. There is little evidence of capital-skill complementarity and some evidence of R&D investment being biased in favour of high-skilled workers.

JEL: F16; C52

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## 1 Introduction

Recently, some prominent researchers have argued that the academic consensus, prompted by early empirical work, on the limited impact of international trade with low-skill abundant countries on the position of low-skilled workers in high-skill abundant countries, may have been overhasty.

Slaughter (2000) argues that research has still, despite methodological progress, fundamental limitations as to answering how much international trade contributes to wage inequality.

Deardorff (1998 a: p. 24) tentatively characterizes our ignorance: *“It seems likely that both trade and technology have contributed to the increased skill differential, both in substantial amounts, with technology probably contributing a bit more than trade. I am sceptical of other causes having contributed to it at all, but my range of uncertainty around each of these statements is very large”*.

Feenstra and Hanson (2001) counter-argue the three major reasons why economists have come to hold international trade with low-wage countries as an unlikely culprit of increased wage inequality.

The first reason is that import volumes from low-wage countries are still considered too modest to affect wages.

Leaving aside the entertaining debate between Leamer (1998), who argues that trade volumes do not matter as prices are set at the margin, and Krugman (2000) who claims that trade volumes cannot be considered as irrelevant, given one really understands trade theory, Feenstra and Hanson (2001) argue that the ratio of trade to GDP, often used to measure changes in trade volumes, is biased as non-tradable goods and services have become increasingly important in industrialized countries<sup>1</sup>.

A second argument for the limited role of international trade follows from empirical studies (Lawrence and Slaughter, 1993; Neven and Wyplosz, 1996 and Leamer, 1998) in which no evidence is found that the relative prices of low-skill intensive goods in industrialized countries decreased, due to trade competition with countries that are relatively abundantly endowed with low-skilled workers, as would be expected within a Heckscher-Ohlin-Samuelson (HOS) theoretical framework.

Feenstra and Hanson (2001) argue that, given the increased importance of imports of intermediate inputs, prices should not be compared between industries but rather within industries and they show for Germany, Japan and the United States that, within industries, prices of domestic goods did actually increase more than prices of imported goods.

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<sup>1</sup> Maußner (1999) shows, in a sticky wage model, that the non-tradables sector may have a dampening effect on the unemployment of low-skilled workers. Harrigan and Balaban (1999), applying a general equilibrium estimation to the US in the period 1970-1990, find that a large increase in the price of non-traded high-skilled services “caused” a substantial rise in the wages of high-skilled workers. The direction of causality assumed by Harrigan and Balaban is somewhat controversial as Feenstra and Hanson (2001) argue that relative wage changes may have “caused” price changes of non-traded services rather than the other way around.

The third argument à décharge of international trade is that the ratio of low-skilled workers to high-skilled workers seems to change within industries and that workers do not seem to move much between industries. OECD (1998) provides evidence for OECD countries that within-industry movements dominate between-industry movements of relative employment. The evidence of substantial within-industry movements in favour of high-skilled workers is often considered as an indication of pervasive skill-biased technological change (SBTC), which would explain increased wage inequality far more than international trade (e.g. Berman, Bound and Griliches 1994). However, Howell (1997) casts some doubt on the conclusions of Berman, Bound and Griliches (1994). Card and DiNardo (2002) show a number of stylised facts of the U.S. labour market that cannot easily be reconciled with a SBTC explanation and conclude that the SBTC hypothesis is not very helpful in explaining shifts in wages.

Feenstra and Hanson (2001), refer to plant-level evidence by Bernard and Jensen (1997), who show that a large part of within industry movements of relative wages and employment can be explained by between plant movements rather than within plant movements, which may still incriminate international trade.

Technological change may, moreover, be caused by trade liberalisation. This potential indirect effect of trade has been pointed out, by e.g. Martin and Evans (1981) and more recently by Wood (1994).

Morrison Paul and Siegel (2001) find that although technological change had the largest impact on relative wages in the US in the period 1959-1989, trade appears to have stimulated computerisation.

Haskel and Slaughter (2001) find evidence, for the UK, of trade-induced technological change but its effect on wage inequality was not found to be significant.

Cuyvers et al. (2003 a, b) find, for a panel of EU countries, evidence of trade-induced technological change, with a significant impact on relative wages. Especially trade with (South-) East-Asian NIC induced technological change, which however appears to have reduced wage inequality. This somewhat surprising result agrees with the theoretical model by Acemoglu (2002), in which labour market institutions in Europe are assumed to stimulate investment in technologies that increase productivity of low-skilled workers. In this model skill-biased technological change may be less substantial in Europe than in the U.S.

Feenstra and Hanson (1999) argue that international trade in intermediate inputs has been neglected and their estimations show that foreign outsourcing can explain a considerable part of the increase in wage inequality between high-skilled and low-skilled workers, in US industries, during the 1980s.

Haskel and Slaughter (2001) find that changes in prices were more important than technological change (total factor productivity) in explaining increased wage inequality in the UK in the 1980s.

Both Feenstra and Hanson (1999) and Haskel and Slaughter (2001) apply a two-step mandated wage estimation procedure, in which the impact of international trade on wages can be disentangled from the impact of technological change. Anderton and Brenton (1999) conclude that in the period 1970-1983 foreign outsourcing towards low-wage countries accounted for 40 per cent of the increased relative wage and one third of the increase in relative employment of high-skilled workers in the UK textiles industry.

Within a partial equilibrium framework, which focuses on short-run effects and labour market factors, Greenaway, Hine and Wright (2000) find a considerable impact of international trade on wages in the UK. Especially trade competition from (South-) East Asian Newly Industrialized Countries (NIC) appears to have increased wage inequality.

Strauss-Kahn (2003) estimates foreign outsourcing to explain 25% of the decline in the low-skilled employment share in France in the period 1985-1993.

Egger and Egger (2003) find that outsourcing towards Eastern Europe and the former Soviet Union significantly increased relative employment of high-skilled workers in Austria in the period 1990-1998.

In this paper I combine data on international trade in intermediate inputs and wages of low-skilled and high-skilled workers to assess the impact of outsourcing by high-skilled abundant EU countries on the wages and labour demand in the European Union in the period 1985-1996.

In section 2 some stylised facts on income inequality are shown. The relatively recent phenomenon of foreign outsourcing is discussed in section 3.

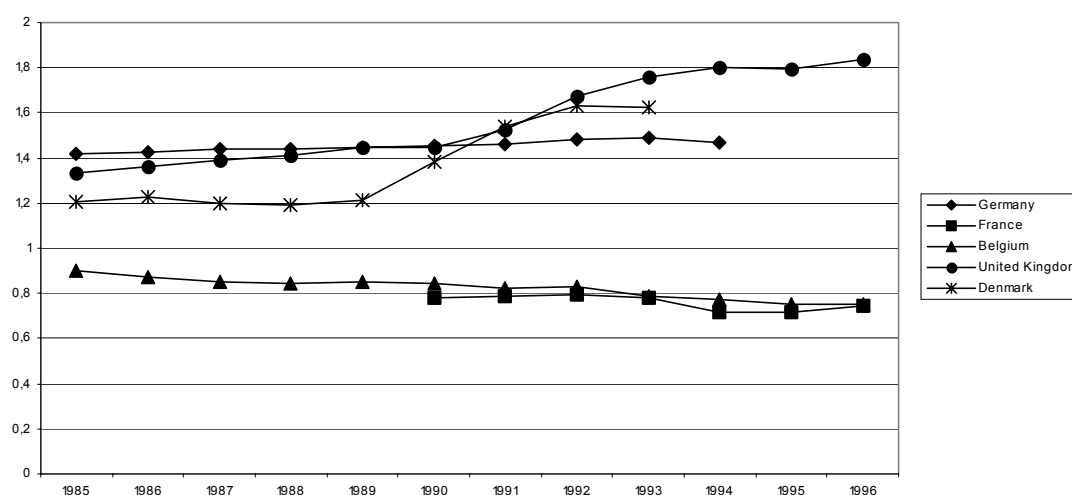
Section 4 deals with the use of flexible cost functions to estimate the impact of international trade on labour demand and the sensitivity of estimation results with regard to the choice of functional form. Morrison and Siegel (1997, 2001) proposed an extended generalized Leontief cost function estimation, by which the interaction among input factors (e.g. high-skilled and low-skilled labour) and external factors like international trade and technological change can be analysed. A generalized Leontief (GL) function is derived from a second-order Taylor expansion of a Leontief function. Barnett (1985) and Barnett, Lee and Wolfe (1985) have shown that both the GL function and the popular translog function (i.e. a second-order Taylor expansion of a Cobb-Douglas function) tend to violate regularity conditions, even within the region of the data. They proposed minflex Laurent generalized Leontief and translog functions that can be derived from second-order Laurent expansions and are shown to be well-behaved and 'truly' flexible functional forms.

Section 5 reports the results of an GL cost function estimation as well as the results of an extended Minflex Laurent GL cost function.

## 2 The Rise and Fall of Wages and Employment

Most of the early studies on the impact of international trade on the position of low-skilled workers the focus on the United States. In the U.S. both the wages and the employment of non-production workers (proxy for high-skilled workers) increased considerably relative to the wages and employment of production workers, since the beginning of the 1980s (e.g. Feenstra, 2000: 2-3). Figure 1 shows the evolution of the wages of non-manual workers (proxy for high-skilled workers<sup>2</sup>) to the wages of manual workers (proxy for low-skilled workers), in the period 1985-1996, for the five EU countries, for which sufficient data is available on all necessary variables to perform estimation<sup>3</sup>. The wages are averaged over manufacturing industries using each industry's share in the total wage bill as a weight.

**Figure 1: The change in average relative wages of non-manual workers in manufacturing in the period 1985-1996**



**Source:** own calculations from the UNIDO General Industrial Statistics database; Labour Force Surveys and Earnings data (EUROSTAT); OECD Structural Analysis industrial (STAN) and International Sector database (ISDB).

The evidence for the five considered EU countries is mixed. Denmark, Germany and the UK, which in 1985 already had the highest wage inequality, witnessed an increase in the relative wages of non-manual workers, which was considerable, especially in Denmark and the United Kingdom. On the contrary, in Belgium and France wage inequality appears to have decreased<sup>4</sup>. However, in the latter two countries the relative employment of non-manual workers slightly increased as can be seen in figure 2. Acemoglu (2002) pointed at the evidence of relative wage stability in most continental

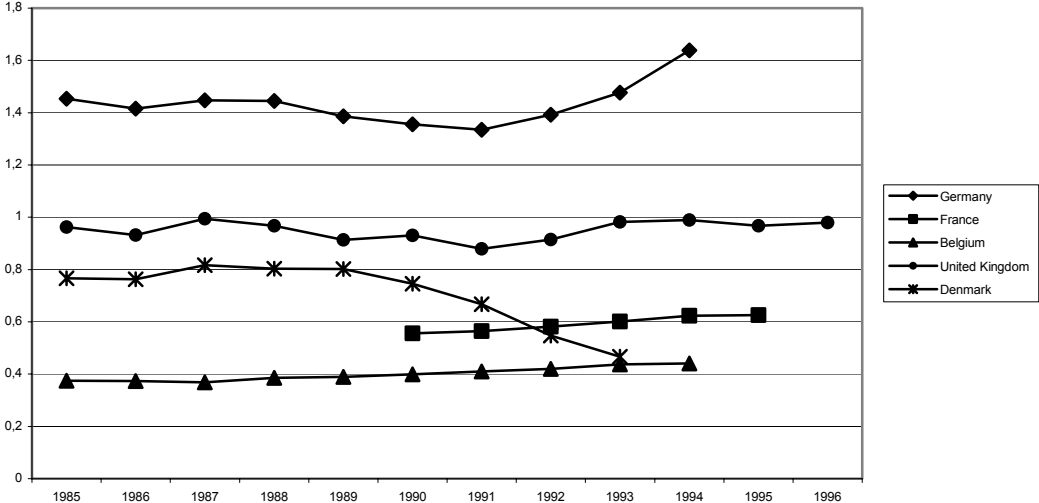
<sup>2</sup> Relatively little data on wages and employment by skill level are available. EUROSTAT provides data on employment (but not on wages) by skill level for most EU countries from 1992 onwards. These data are gathered from surveys and there are indications that they are not entirely reliable. Obviously, if reliable data by skill level would be available these are to be preferred to proxies like non-manual/ manual workers; non-production/ production; white-collar/ blue-collar workers although it seems that proxies result in similar results for skill composition and trends (e.g. OECD, 1998).

<sup>3</sup> See data annex for details on data sources and definitions.

<sup>4</sup> The remarkable finding that wages of non-manual would have been lower than wages of manual workers in Belgium and France may be due to the hours worked by manuals. For non-manual workers monthly wages are given whereas for manual workers only hourly wages are given (see annex for more details on data sources). Assuming the hours worked by manuals did not change substantially during the considered period the evolution of the level of relative wages should be unbiased. I have no knowledge of data to ascertain how reasonable this assumption is.

European countries. Strauss-Kahn (2003) shows that in France, over the past three decades, wage inequality between high-skilled and low-skilled workers did not rise substantially contrary to the high-skilled workers' share in total employment, which increased considerably. Figure 2 shows the change in the average relative employment of non-manual workers, weighted by each sector's share in total employment. In Denmark relative employment of non-manual workers decreased substantially whereas in the UK this ratio hardly changed. Only for Germany is there evidence that both the relative wages and the relative employment of high-skilled workers increased as it did in the U.S.

**Figure 2: The change in relative employment of non-manual workers in manufacturing in the period 1985-1996**



**Source:** own calculations from the UNIDO General Industrial Statistics database, Labour Force Surveys data (Eurostat) and OECD Structural Analysis industrial (STAN) and International Sector database (ISDB).

The fact that despite an increase in the skill premium the demand for high-skilled workers increased in the U.S., has been put forward as an indication of a structural shift (e.g. due to skill-biased technological change) in favour of high-skilled labour (Lawrence and Slaughter, 1993; Berman, Bound and Machin, 1998; Katz and Autor, 1999). For the EU there is apparently little overall evidence of a similar positive correlation between the changes in the relative wages and employment of high-skilled workers. The conclusions of U.S. studies can therefore not simply be extrapolated to the entire European Union. Moreover, the different patterns in figure 1 and 2 show that EU countries do not form an homogenous group and that heterogeneity should be accounted for. The fact that wage inequality actually would have decreased in Belgium and France does not imply that international trade may not have had a negative impact on the wages of low-skilled workers, as this negative impact may well have been counterbalanced by other country-specific determinants (e.g. institutional factors).

Figure A.1 in the annex shows, combining data on wages and employment, the change in the average value added share of non-manual workers relative to the average share of manual workers. In Germany and the UK non-manual workers took home an increasing share of value added relative to manual workers. The same occurred in Denmark but the increase was less substantial. In Belgium and France the relative value added share hardly changed.

### 3 Foreign outsourcing

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.

Srinivasan (1995) argues that Krugman understates the important role of technological progress in decreasing transport and communications costs and thereby facilitating the slicing up of the value added chain. 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 U.S. Using a more general definition of foreign outsourcing<sup>5</sup>, 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 U.S.<sup>6</sup>

Jones and Kierzkowski (2001) consider significant cuts in coordination costs that allow firms to take advantage of international differences in technologies and factor prices to develop global production networks and suggest that, as the price of international services declines, the need to contain the different production stages within the framework of a multinational organization may have reduced in favour of international arms-length transactions.

Figure A.2 shows, for each of the five considered EU countries, the evolution of foreign outsourcing in the narrow sense<sup>7</sup> with regard to four groups of trade partners: relatively low-skill abundant EU countries (Ireland, Greece, Portugal and Spain); (South-) East Asian Newly Industrialized Countries

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<sup>5</sup> 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 the following contestants: (*foreign outsourcing* (Katz and Murphy, 1992; Feenstra and Hanson, 1996; Kohler, 2001a; Grossman and Helpman, 2002; Egger and Egger, 2003); *slicing up the value added chain* (Krugman, 1995); (*international fragmentation* (Deardorf, 1998 b; Jones and Kierzkowski, 2001; Venables, 1999; Arndt and Kierzkowski, 2001; Burda and Dluhosch, 2001; Kohler, 2001b, 2002); *intra-product specialization* (Arndt, 1997); *disintegration of the production process* (Feenstra, 1998); *vertical specialization in international trade* (Hummels, Rapoport and Yi, 1998; Hummels, Ishii and Yi, 2001; Strauss-Kahn, 2002; 2003); *intra-mediate trade* (Antweiler and Trefler, 2000); *global production sharing* (Feenstra and Hanson, 2001). Without designating a winner I will stick to the term *foreign outsourcing* throughout this text.

<sup>6</sup> In a survey of Belgian firms, 35 % of the respondents claim to have outsourced activities to firms abroad in the period 1990-1996 whereas only 27 % of the responding firms invested in a foreign affiliate (Federal Planning Bureau, 2000: p. 242)

<sup>7</sup> Feenstra and Hanson (1997; 1999) distinguish outsourcing in the narrow sense (i.e. within the same industry) from outsourcing in the broad sense (i.e. trade in intermediate inputs originating from all sectors). For a detailed definition of foreign outsourcing used in this paper see data appendix.

(Hong Kong, Indonesia, South-Korea, Malaysia, Philippines, Singapore and Thailand); Central and East European NIC (Czech Republic, Hungary and Poland) and NIC from Central and South America (Argentina, Brazil, Chile and Mexico).

Imports of intermediate inputs from the relatively low-skill abundant EU countries and from (South-) East Asian NIC increased substantially in all five considered EU countries. Foreign outsourcing with regard to Central and East European NIC increased sharply in Germany and to a lesser extent in Denmark. In Germany, at the end of the 1985-1996 period the considered Central and East European countries were the group with the highest foreign outsourcing share of the four groups, whereas the relatively low-skill abundant EU countries and (South-) East Asian NIC hold respectively first and second place in the four other EU countries. Foreign outsourcing with regard to Central and South-American NIC hardly increased. The average percentage of foreign outsourcing in 1996 seems, despite considerable increases during the period 1985-1996, still rather modest but the averages conceal substantial foreign outsourcing in some individual industries.

Feenstra and Hanson (1996) developed a model of foreign outsourcing with a country that is relatively abundant with high-skilled labour (e.g. the U.S.) and a country that is relatively abundant with low-skilled workers (e.g. Mexico). It is assumed that there is only one manufactured good, produced with a continuum of intermediate inputs, the production of which requires high-skilled and low-skilled labour in different proportion. Given the differences in endowment, the U.S. will produce the range of most skill-intensive inputs and Mexico the range of least skill intensive inputs, with the line of fracture depending on the cost advantage (i.e. relative wages of high-skilled workers) of both countries. An interesting feature of the proposed model is that if capital would flow from the U.S. 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 conciliates well with observed facts. The model also implies that one should look at price changes of intermediate inputs and compare the movement of prices and relative wages within rather than across industries (see discussion on the second argument à décharge in the introduction).

Deardorff (1998 b) shows that in a world without factor price equalization (due to countries operating in different diversification cones) outsourcing of a production stage towards a country that requires more resources than in the country of original production may still be worthwhile if there are substantial differences in factor rewards across countries. Deardorff shows that factor prices may actually even be driven apart by fragmentation although outsourcing may also result in factor price equalization. The factor deciding which way the wind will blow is the factor intensity of the different production stages and more precisely the difference between factor intensity of the respective sliced up

stages of the value added chain and the factor intensity of production in each country before outsourcing occurred. A similar point is made by Venables (1999).

Kohler (2001a) shows, in a specific factors model, that if outsourcing of low-skill intensive activities involves foreign direct investment, domestic wages of low-skilled workers will fall, irrespective of factor intensity of the different production stages, whereas if outsourcing does not involve any foreign direct investment, factor intensity does matter.

Kohler (2002) argues that theoretical models describing foreign outsourcing and its driving forces are rather stylised with regard to distribution of income over production factors whereas models focusing on income distribution tend to simplify the forces of foreign outsourcing. He also points at the diverging conclusions of different theoretical models on the impact of outsourcing on the position of low-skilled workers. Whereas the framework by Feenstra and Hanson (1996) explains both the decrease in relative wages of low-skilled workers and the increased skill-intensity of production in both the high-skill and the low-skill abundant countries, other models lead to more ambiguous conclusions as to the impact on low-skilled workers. In Arndt (1997); Venables (1999) and Jones and Kierzkowski (2001) it is shown that under certain conditions, outsourcing may actually favour low-skilled workers in high-skill abundant countries that outsource part of their production to low-skill abundant countries. The main difference between Feenstra and Hanson (1996) and most other models is that Feenstra and Hanson consider an economy with a single good being produced with a continuum of inputs. Outsourcing will involve increasingly more skill-intensive inputs from the high-skill abundant country towards the low-skill abundant country. The ambiguity regarding the impact on factor rewards in models with more than one final good (or industry) follows from the fact that some production stages in a high-skill intensive industry may be low-skill intensive and therefore be eligible for outsourcing.

Kohler (2002) tries to link up the different theoretical principles that 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. The model allows for an arbitrary number of final goods, input factors and production fragments. 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.

Strauss-Kahn (2002) proposes a model of foreign outsourcing in which, to reflect the situation in continental Europe, wages are assumed to be fixed. Outsourcing increases relative employment of high-skilled workers in the high-skilled abundant country whereas agglomeration effects, which are also considered in the model, result in a simultaneous impact on employment inequality in both high-

skilled abundant and low-skilled abundant countries (i.e. similar to the co-movement of wages in Feenstra and Hanson (1996)).

Egger and Egger (2003) consider a model in which foreign outsourcing increases the relative employment of high-skilled workers if the low-skill segment of the labour market is unionised, as unions will set wages of low-skilled workers in response to the wages of high-skilled workers.

From the foregoing it is clear that the theoretical models, elicited by the relatively recent phenomenon of foreign outsourcing, do not provide an unambiguous a priori assumption about the impact of outsourcing on income distribution and that it is rather an empirical issue to assess the specific nature of this relationship, which may moreover be industry specific.

#### **4 Foreign outsourcing and labour demand**

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. Brecher, 1974, Krugman, 1995). Wage flexibility is often put forward to explain the increased wage inequality between high-skilled and low-skilled workers in the United States whereas sticky wages- due to labour market rigidities- are considered as an explanation for the relatively high unemployment (of low-skilled workers) in most EU countries. The difference between the “money-less jobs” US and the “job-less money” EU would suggest that there exists a trade-off between inequality and unemployment (see e.g. Krugman, 2000).

Howell and Huebler (2001) argue that there is actually little evidence to support the view of such a trade-off. They agree that institutional factors (e.g. social protection) may explain part of the difference across OECD countries in income inequality but these do not seem to be the main source of unemployment. An increase in wage inequality is unlikely to decrease unemployment in the EU and decreasing wage inequality in the US need not raise unemployment.

Anyhow, if wages in EU countries are indeed sticky, lack of evidence on the impact of international trade on the relative wages of low-skilled workers in the European Union (e.g. Cuyvers et al. 2003 a, b) does not necessarily imply that the position of low-skilled workers may not be affected in terms of employment.

The demand for production factors (e.g. high-skilled and low-skilled labour) can rather straightforwardly be derived from a cost function, which reflects the cost-minimising behaviour of firms. The most popular flexible cost functions are the duals of the transcendental logarithmic production function (translog) and the generalized Leontief production function (GL) proposed respectively by Christensen, Jorgensen and Lau (1971) and Diewert (1971).

Translog cost function (TL):

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

Generalized Leontief cost function (GL):

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

Where C denotes costs,  $p_i$  the prices of the I input factors and X output.

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<sup>8</sup>. 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:

Laurent translog cost function (LTL):

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

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<sup>8</sup> Barnett (1985) and Barnett, Lee and Wolfe (1985) actually consider indirect utility functional forms rather than production or cost functions.

Laurent generalised Leontief cost function (LGL):

$$\begin{aligned}
C = & \alpha_0 + \sum_{i=1}^I \alpha_i p_i^{1/2} + \beta X^{1/2} + \frac{1}{2} \sum_{i=1}^I \sum_{j=1}^J \alpha_{ij} p_i^{1/2} p_j^{1/2} + \sum_{i=1}^I \chi_{iX} p_i^{1/2} X^{1/2} \\
& - \frac{1}{2} \sum_{i=1}^I \sum_{j \neq i}^J \zeta_{ij} \frac{1}{p_i^{1/2}} \frac{1}{p_j^{1/2}} - \sum_{i=1}^I \psi_{iX} \frac{1}{p_i^{1/2}} \frac{1}{X^{1/2}}
\end{aligned} \tag{4}$$

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  $\alpha_{ij} \cdot \zeta_{ij} = \chi_{iX} \cdot \psi_{iX} = 0$  for all  $i, j$  combinations (Barnett 1985: pp. 35-38).

Laurent flexible functional forms have not been applied frequently in empirical work.

Le Compte and Smith (1990) compared the results of the estimation of a translog cost function to the results of a minflex Laurent translog cost function estimation for the U.S. savings and loans industry. When using the latter functional form the hypothesis of constant returns to scale could not be rejected contrary to when a traditional translog function was used and Hunter, Timme and Yang (1990) used a minflex Laurent translog cost function to examine a sample of large U.S. commercial banks.

More recently Giannakas, Tran and Tzouvelekas (2003) compared a number production functional 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 pairwise between the different non-nested functional forms. The non-nested hypothesis test show that the minflex LTL and LGL functional forms are strongly favoured over the generalized quadratic Box-Cox function, which in its 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. Given the different conclusions of both functional specifications (e.g. technological change appears to be Hicks-neutral in the LGL estimation but not in the LTL estimation) Giannakas, Tran and Tzouvelekas (2003) consider this to be somewhat problematic but rightly argue that this does not imply that the choice of functional form is irrelevant since the testing allowed to favour the Laurent functional forms over the other considered functional forms and the estimates proved to be sensitive to the functional form that is considered.

Pollak, Sickles and Wales (1984) proposed a CES-translog cost function which nests a CES and a translog cost function. Likelihood ratio tests showed that for seven out of eight considered data sets the CES-translog is superior to a translog specification and superior to a CES specification for all eight data sets. The different functional specifications result in substantially different substitution elasticity estimates, which leads the authors to suggest that if their results would hold for other data sets and modeling scenarios the translog form should be replaced by the CES-translog form as the standard flexible form for cost function estimation. However, both the CES-translog and the translog cost functions violate regularity conditions for a large number of sample observations in most data sets. With the translog cost function regularity conditions are violated for more than 50% of observations in five out of eight data sets and for all observations in two data sets (Pollak, Sickles and Wales, 1984: pp. 604-605). Dewan and Min (1997), analyzing the substitution of IT for other production factors by large U.S. corporations, find that a CES-translog production function dominates the nested Cobb-Douglas, CES and translog specifications and that whereas output elasticity is quite robust to the functional specification, substitution elasticity is rather sensitive to the choice of functional form.

Demand share equations can straightforwardly be derived from TL and GL cost functions.

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 U.S. 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 U.S. 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 (e.g. Romer 1986 and Grossman and Helpman 1991) in stressing the importance of spillovers and other sources of increasing returns.

An extended GL cost function can be written as (e.g. Morrison Paul and Siegel, 2001)<sup>9</sup>:

$$C = X \left[ \sum_i \sum_j \alpha_{ij} p_i^{1/2} p_j^{1/2} + \sum_i \sum_m \delta_{im} p_i s_m^{1/2} + \sum_i p_i \sum_m \sum_n \gamma_{mn} s_m^{1/2} s_n^{1/2} \right] \quad (5)$$

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:

$$D_i = \partial C / \partial p_i \quad (6)$$

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:

$$\varepsilon_{D_i S_n} = \partial \ln D_i / \partial \ln S_n \quad (7)$$

## 5 Estimation procedure and results

I used data on wages and employment of low-skilled and high-skilled workers, foreign outsourcing and R&D stocks at the two-digit ISIC industry level, that were available for Belgium; Denmark; France; Germany and the United Kingdom, for the period 1985-1996, to estimate the impact of foreign outsourcing and R&D investment on the demand for low-skilled and high-skilled workers<sup>10</sup>. With regard to foreign outsourcing I distinguish three country groups (see data annex for full details): High-skilled abundant countries (HSC); relatively low-skilled abundant EU countries (EULS) and the group of Newly Industrialized Countries (NIC).

I used both TL and GL specifications and the alternative LTL and LGL specifications. The translog cost functions appear to perform very bad on the data set (e.g. significant wrongly signed own price elasticity) and I will therefore restrain the discussion to the results of the GL specifications. Berndt and

<sup>9</sup> Morrison Paul and Siegel (2001) distinguish short run (when e.g. capital is considered to be fixed) from long run effects. I will only consider long run effects.

<sup>10</sup> See data annex for details on data sources and definitions.

Wood (1982) found, for U.S. manufacturing industries in the period 1948-1971, that imposing global concavity conditions on a translog 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.

For each two-digit ISIC industry I considered both an extended GL specification (Morrison and Siegel, 1997) and an extended minflex LGL specification. I used the P-test proposed by Davidson and MacKinnon (1981, 1993) and MacKinnon et al. (1983) to discriminate between both GL specifications. They consider two non-nested model specifications:

$$H_1: y = x(\alpha) + \varepsilon_1 \quad (8)$$

$$H_2: y = z(\beta) + \varepsilon_2 \quad (9)$$

With  $\alpha$  and  $\beta$  the respective parameter vectors.

The two models are artificially nested within an artificial compound model:

$$H_C: y = (1-\delta)x(\alpha) + \delta z(\beta) \quad (10)$$

For the P-test the following Gauss-Newton regression is derived from the compound model (10):

$$y - \hat{x} = \hat{X}a + d(\hat{z} - \hat{x}) \quad (11)$$

where  $\hat{x} = x(\hat{\alpha})$  and  $\hat{X} = X(\hat{\alpha})$ ,  $X(\alpha)$  being the matrix of derivatives of  $x(\alpha)$  with respect to  $\alpha$  and  $\hat{\alpha}$  the estimate of  $\alpha$  under the  $H_1$  hypothesis. Rejection of the assumption  $d = 0$  in regression (11) can be considered as evidence against the first specification. Switching  $x$  and  $z$  in the Gauss-Newton regression, tests the validity of the second specification. 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  $\rightarrow H_2$  preferred model
- $H_2$  is rejected but  $H_1$  not  $\rightarrow H_1$  preferred model
- $H_1$  and  $H_2$  both rejected  $\rightarrow H_1$  nor  $H_2$  satisfactory specification
- $H_1$  nor  $H_2$  rejected  $\rightarrow$  Both specifications are similar (or data set is not very informative)

I applied an iterative three-stage least squares procedure to estimate the system of demand equations with lagged variables as instruments (cf. Morrison Paul and Siegel, 2001). The unreported results of an

alternative FIML estimation are very similar. Three input factors are considered: High-skilled labour (HS); low-skilled labour (LS) and capital (K).

Table 1 shows the results of elasticity measures derived from the GL and LGL specification for each individual two-digit industry estimated for the panel of five EU countries.

Elasticity has been evaluated at the means<sup>11</sup> and the ANALYZ procedure in TSP has been used to compute standard errors, 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).

For all industries own price elasticity of input factors has the right sign and is mostly highly significant. The P-tests show, considering a significance level of 5 %, that in six cases the Laurent generalized Leontief specification is clearly preferred to the traditional GL specification. Only in two cases (ISIC 35 and ISIC 36) GL is preferred to LGL. For industries ISIC 34 and ISIC 384 both specifications perform similar whereas for industry ISIC 384 the GL nor the LGL appear to be appropriate specifications. Given the rather substantial differences in estimated elasticity, in some cases even with contradictory conclusions, these results show the need to discriminate between functional forms. Moreover, the appropriate functional form appears to be industry specific. Actually, the six 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 specifications the estimated substitution elasticity suggests that both low-skilled and high-skilled labour are complements in five preferred industry specifications and substitutes in three preferred specifications.

There is little evidence in our data set of capital-skill complementarity.

Berman, Bound and Griliches (1994) and Feenstra and Hanson (1996, 2003) find evidence of such a complementarity for US industries. For France, Strauss-Kahn (2003) finds that the coefficients have, in most specifications, the expected negative sign but the coefficients are never significant. For Austria Egger and Egger (2003) even find some evidence of a significant negative correlation between high-skilled labour and capital<sup>12</sup>.

With regard to the relationship between high-skilled labour and capital the GL and LGL specifications have a substantial different outcome, in a number of industries even contradictory conclusions (e.g. significant capital-skill complementarity following a LGL specification but significant substitution following a GL specification in ISIC 31 and ISIC 32).

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<sup>11</sup> 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.

<sup>12</sup> All these results are derived from translog specifications. Frondel and Schmidt (2003) argue that using a static translog specification is rather questionable to address the hypothesis of capital-skill complementarity

**Table 1: Elasticities derived from generalized Leontief (GL) and minflex Laurent generalized Leontief (LGL) cost function specifications for the period 1985-1996**

	ISIC 31		ISIC 32		ISIC 33		ISIC 34	
	GL	LGL	GL	LGL	GL	LGL	GL	LGL
$\epsilon_{LS,whs}$	-0.07 (-1.12)	-0.22 (-3.78) ***	-0.48 (-4.57) ***	-0.52 (-7.09) ***	-0.41 (-5.90) ***	-0.33 (-6.17) ***	-0.92 (-13.0) ***	-0.59 (-16.3) ***
$\epsilon_{HS,whs}$	-0.15 (-1.61)	-0.34 (-2.46) **	-0.93 (-4.57) ***	-0.68 (-6.07) ***	-0.50 (-5.47) ***	-0.80 (-5.20) ***	-1.13 (-11.9) ***	-0.79 (-6.27) ***
$\epsilon_{K,wk}$	-0.13 (-9.88) ***	-0.14 (-9.18) ***	-0.27 (-7.35) ***	-0.21 (-5.42) ***	-0.10 (-5.12) ***	-0.37 (-5.72) ***	-0.40 (-10.2) ***	-0.20 (-6.97) ***
$\epsilon_{LS,whs}$	-0.35 (-5.68) ***	-0.21 (-2.81) ***	-0.20 (-2.03) ***	0.03 (1.00)	0.20 (2.85) ***	0.12 (3.55) ***	-0.07 (-1.01)	0.17 (3.56) ***
$\epsilon_{LS,wk}$	0.42 (9.28) ***	0.43 (10.2) ***	0.68 (8.46) ***	0.61 (5.84) ***	0.22 (4.50) ***	0.70 (5.93) ***	0.99 (8.33) ***	0.42 (7.65) ***
$\epsilon_{HS,wk}$	0.48 (6.44) ***	-0.18 (-5.62) ***	1.19 (5.86) ***	-0.27 (-4.56) ***	0.30 (3.79) ***	1.19 (5.21) ***	1.19 (10.7) ***	0.15 (3.56) ***
$\epsilon_{LS,hsc}$	0.69 (4.22) ***	0.74 (5.31) ***	0.21 (0.97)	0.11 (0.68)	0.37 (6.63) ***	0.24 (5.17) ***	0.08 (0.46)	-0.21 (-5.08) ***
$\epsilon_{HS,hsc}$	-0.77 (-4.49) ***	-0.63 (-4.04) ***	-1.22 (-4.08) ***	-1.44 (-7.42) ***	-0.36 (-5.40) ***	-0.37 (-3.41) ***	-0.69 (-3.73) ***	0.37 (3.51) ***
$\epsilon_{LS,eulw}$	-1.52 (-9.48) ***	-1.12 (-7.77) ***	-0.28 (-0.89)	0.18 (0.76)	-0.30 (-4.03) ***	-0.13 (-1.25)	-0.02 (-0.10)	-0.67 (-5.34) ***
$\epsilon_{HS,eulw}$	-0.35 (-2.42) **	-0.02 (-0.15)	0.13 (0.32)	1.03 (3.57) ***	-0.21 (1.88) *	-0.22 (-1.17)	-0.03 (-0.11)	-0.23 (-1.61)
$\epsilon_{LS,nic}$	0.56 (3.27) ***	0.40 (2.59) ***	-0.34 (-1.53)	-0.54 (-3.19) ***	0.42 (2.99) ***	0.30 (2.25) **	1.67 (7.85) ***	0.42 (1.96) **
$\epsilon_{HS,nic}$	0.48 (3.85) ***	0.64 (4.14) ***	0.20 (0.60)	0.35 (1.52)	0.72 (3.59) ***	0.45 (1.57)	0.37 (2.05) **	-0.21 (-1.52)
$\epsilon_{LS,rds}$	0.46 (3.54) ***	0.28 (2.50) **	-0.26 (-1.30)	-0.39 (-2.33) **	0.02 (0.35)	0.08 (1.09)	-0.36 (-2.43) **	0.90 (6.04) ***
$\epsilon_{HS,rds}$	-0.11 (-0.75)	-0.23 (-1.85) **	-0.84 (-2.88) ***	-0.93 (-5.22) ***	0.36 (5.71) ***	0.54 (3.45) ***	-0.36 (-1.94) *	-0.42 (-2.71) ***
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
	2.37 **	1.84 *	2.69 ***	1.56	3.43 ***	-0.25	0.97	1.75 *

Note: Elasticities are computed at the means of the respective variables and are 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. P-tests are pairwise non-nested hypothesis tests (e.g. Davidson and MacKinnon, 1993) of a traditional GL specification with LGL specifications based on the high-skilled labour demand equation. \*, \*\*, \*\*\* denotes significance at respectively 10%, 5% and 1%.

**Table 1: continued**

	ISIC 35		ISIC 36		ISIC 37		ISIC 381	
	GL	LGL	GL	LGL	GL	LGL	GL	LGL
$\varepsilon_{LS,whs}$	-0.49 (-3.61) ***	-0.78 (-4.06) ***	-0.12 (-2.31) ***	-0.15 (-2.17) ***	-0.20 (-2.70) ***	-0.30 (-4.33) ***	-0.25 (-5.34) ***	-0.27 (-4.22) ***
$\varepsilon_{HS,whs}$	-0.22 (-1.66) *	-1.12 (-9.36) ***	-0.73 (-2.97) ***	-0.73 (-3.04) ***	-0.32 (-3.66) ***	-0.26 (-2.60) ***	-0.54 (-5.99) ***	-0.68 (-6.31) ***
$\varepsilon_{K,wk}$	-0.06 (-3.84) ***	-0.10 (-5.23) ***	-0.07 (-8.16) ***	-0.08 (-7.73) ***	-0.05 (-4.87) ***	-0.05 (-6.92) ***	-0.17 (-5.16) ***	-0.24 (-6.43) ***
$\varepsilon_{LS,whs}$	0.04 (0.21)	0.80 (4.53) ***	-0.20 (-4.42) ***	-0.11 (-1.15)	-0.02 (-0.21)	-0.02 (-0.25)	-0.01 (-0.19)	0.02 (0.78)
$\varepsilon_{LS,wk}$	0.45 (7.54) ***	0.00 (0.13)	0.32 (5.66) ***	0.24 (2.99) ***	0.22 (3.95) ***	-0.11 (-6.04) ***	0.26 (3.66) ***	0.34 (4.76) ***
$\varepsilon_{HS,wk}$	0.20 (1.75) *	0.70 (5.22) ***	0.69 (6.01) ***	-0.28 (-5.16) ***	0.34 (4.99) ***	0.28 (4.87) ***	0.55 (5.73) ***	0.77 (7.17) ***
$\varepsilon_{LS,hsc}$	0.74 (3.17) ***	0.94 (2.78) ***	0.36 (3.07) ***	0.44 (3.30) ***	0.55 (3.07) ***	0.63 (4.06) ***	0.53 (8.73) ***	0.35 (4.70) ***
$\varepsilon_{HS,hsc}$	0.28 (1.14)	0.41 (1.42)	-0.42 (-4.35) ***	-0.22 (-1.51)	-0.38 (-3.23) ***	-0.38 (-4.52) ***	0.01 (0.06)	-0.23 (-1.74) *
$\varepsilon_{LS,eulw}$	0.13 (0.39)	0.29 (0.48)	-1.26 (-5.70) ***	-1.21 (-4.68) ***	-0.27 (-0.75)	0.08 (0.26)	-0.12 (-1.00)	0.06 (0.47)
$\varepsilon_{HS,eulw}$	-0.72 (-1.70) *	-1.44 (-2.86) ***	-1.21 (-5.22) ***	-1.25 (-3.97) ***	-0.40 (-1.76) *	-0.20 (-0.87)	-0.61 (-3.88) ***	-0.47 (-2.90) ***
$\varepsilon_{LS,nic}$	0.23 (1.07)	-0.06 (-0.19)	1.28 (8.12) ***	1.40 (8.25) ***	-0.05 (-0.17)	0.02 (0.06)	0.12 (0.89)	0.16 (1.10)
$\varepsilon_{HS,nic}$	0.24 (0.80)	0.99 (2.93) ***	1.81 (13.0) ***	2.40 (10.7) ***	-0.09 (-0.48)	-0.10 (-0.48)	0.68 (4.65) ***	0.81 (4.44) ***
$\varepsilon_{LS,rds}$	-0.49 (-1.26)	-0.34 (-0.45)	1.11 (5.96) ***	1.15 (5.79) ***	-0.46 (-1.72) *	-0.67 (-2.55) **	-0.18 (-2.17) **	-0.48 (-3.19) ***
$\varepsilon_{HS,rds}$	0.65 (1.46)	1.08 (1.82) *	0.70 (2.61) ***	0.72 (2.11) **	0.08 (0.57)	0.03 (0.22)	0.32 (4.75) ***	0.25 (1.26)
<b>P-test</b>	<b>GL vs. LGL</b>	<b>LGL vs. GL</b>	<b>GL vs. LGL</b>	<b>LGL vs. GL</b>	<b>GL vs. LGL</b>	<b>GL vs. LGL</b>	<b>GL vs. LGL</b>	<b>LGL vs. GL</b>
	-1.74	2.52 **	1.06	2.05 **	-2.37 **	0.00	4.51 ***	-1.56

**Table 1: continued**

	ISIC 382		ISIC 383		ISIC 384	
	GL	LGL	GL	LGL	GL	LGL
$\epsilon_{LS,wls}$	-0.07 (-1.24)	-0.14 (-2.34) **	-0.09 (-3.30) ***	-0.14 (-3.64) ***	-0.45 (-5.67) ***	-0.52 (-5.31) ***
$\epsilon_{HS,whs}$	-0.54 (-5.91) ***	-0.57 (-6.22) ***	-0.36 (-7.32) ***	-0.38 (-6.19) ***	-0.46 (-2.77) ***	-0.61 (-3.08) ***
$\epsilon_{K,wk}$	-0.08 (-6.24) ***	-0.13 (-10.8) ***	-0.20 (-13.2) ***	-0.22 (-6.90) ***	-0.14 (-7.34) ***	-0.13 (-5.58) ***
$\epsilon_{LS,whs}$	0.05 (0.88)	0.01 (0.10)	-0.17 (-6.27) ***	-0.14 (-2.96) ***	0.05 (0.50)	0.08 (0.73)
$\epsilon_{LS,wk}$	0.02 (0.30)	0.13 (2.75) ***	0.25 (12.8) ***	0.27 (9.14) ***	0.40 (6.81) ***	0.45 (7.68) ***
$\epsilon_{HS,wk}$	0.48 (10.2) ***	0.68 (7.88) ***	0.50 (10.5) ***	0.57 (5.00) ***	0.41 (4.19) ***	0.26 (1.83) *
$\epsilon_{LS,hsc}$	0.20 (1.84) *	0.34 (3.85) ***	0.53 (6.36) ***	0.54 (5.06) ***	1.37 (3.72) ***	1.10 (3.79) ***
$\epsilon_{HS,hsc}$	-0.25 (-1.90) *	-0.10 (-0.82)	0.35 (3.42) ***	0.33 (2.78) ***	-0.64 (-1.20)	-1.13 (-2.56) ***
$\epsilon_{LS,eulw}$	-0.55 (-5.37) ***	-0.64 (-8.09) ***	-0.34 (-4.03) ***	-0.29 (-2.43) **	-1.04 (-2.79) ***	-0.79 (-2.55) **
$\epsilon_{HS,eulw}$	-0.29 (-2.53) **	-0.39 (-3.59) ***	-0.73 (-5.12) ***	-0.70 (-4.22) ***	0.57 (0.99)	0.96 (2.03) **
$\epsilon_{LS,nic}$	0.64 (0.63)	0.62 (6.35) ***	-0.28 (-2.65) ***	-0.20 (-1.95) *	0.36 (1.52)	.12 (0.68)
$\epsilon_{HS,nic}$	0.86 (8.58) ***	0.81 (6.53) ***	0.11 (0.62)	0.22 (1.28)	0.07 (0.20)	-0.10 (-0.38)
$\epsilon_{LS,rds}$	-0.07 (-0.70)	-0.02 (-0.16)	0.15 (1.69)*	0.17 (1.72) *	0.11 (0.56)	-0.02 (-0.14)
$\epsilon_{HS,rds}$	0.01 (0.14)	0.11 (0.75)	0.28 (2.44) **	0.35 (2.34) **	-0.11 (-0.46)	-0.31 (-1.62)
P-test	GL vs. LGL	LGL vs. GL	GL vs. LGL	LGL vs. GL	GL vs. LGL	GL vs. GL
	1.97 **	0.97	0.87	-0.43	-2.64 ***	4.58 ***

Foreign outsourcing towards high-skill abundant countries appears to have increased both the relative and absolute demand for low-skilled workers in most industries in the period 1985-1996 in the five considered EU countries. Outsourcing towards the relatively low-skilled abundant EU countries decreased absolute demand for low-skilled as well as high-skilled workers whereas the impact on relative demand is more ambiguous and industry specific.

In all except one industry outsourcing towards the Newly Industrialized Countries increased the absolute demand for high-skilled workers and mostly reduced the relative demand for low-skilled workers. R&D investment decreased the demand for low-skilled workers in five industries and increased the demand for high-skilled workers in six industries, which gives some support to the view that R&D activities are biased in favour of high-skilled workers.

## **6 Conclusions**

Only in Germany did both the relative wages and relative employment of high-skilled workers seem to have increased as they did in the US. In Denmark and the UK relative wages of high-skilled workers increased but relative employment decreased or did not change. In Belgium and France wage inequality between high-skilled and low-skilled workers seems to have decreased in the period 1985-1996 whereas relative employment of high-skilled workers increased. In the considered period the share in value added of high-skilled workers increased substantially in Germany and the UK but hardly changed in Belgium, Denmark and France. These stylised facts should caution for generalizing conclusions of US based studies or studies based on a single EU country.

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 actually not very flexible and only appropriate under strict assumptions on substitution elasticity. They propose minflex Laurent functional forms, which have better global properties. In this paper I compared a traditional GL cost function 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 six out of eleven 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 forms.

Other functional specifications may outperform the Laurent generalized Leontief specification. It may be interesting to compare Laurent specifications to other functional forms such as the CES-translog form proposed by Pollak, Sickles and Wales (1984). For other data sets the Laurent translog specification could be a valid candidate as well. It may be, as shown in this paper, that different functional forms may be appropriate for different industries.

There is not much evidence of capital-skill complementarity in the data set. Especially with regard to the relationship between high-skilled labour and capital a traditional GL and a Laurent GL specification give substantially different and sometimes conflicting results.

Foreign outsourcing seems to have had a significant impact on labour demand in the five considered EU countries. 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 the demand for low-skilled and high-skilled workers.

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## Annex

### Data

- Employment

Data on employment of operatives and non-operatives is taken from the the UNIDO General Industrial Statistics database for the period 1985-1991 and from 1992 onwards data for manual and non-manual workers from the Labour Force Surveys data, provided by 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

Data on monthly wages of non-manual workers were taken from EUROSTAT's NewCronos (Earnings). For manual workers this data source gives gross hourly wages. The data on the hours worked per month by manual workers are too scarce to compute monthly wages. For the period 1985-91 the UNIDO data gives 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).

- Foreign outsourcing

Foreign outsourcing is measured using data from the OECD Input-Output database. At present the OECD data cover the period 1973-1990 but the OECD is in the process of updating the database.

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 (from the OECD Trade by Commodities database) are considered to decompose flows of imported intermediate inputs into flows imported from three country groups: the NIC group consisting of Newly Industrialized Countries from Central and East Europe (Czech Republic, Hungary and Poland); (South-) East Asia (Hong Kong, Indonesia, Republic of Korea, Malaysia, Philippines, Singapore and Thailand) and Central and South America (Argentina, Brazil, Chile and Mexico); the EULS-group of relatively low-skill abundant EU countries (Greece, Ireland, Portugal and Spain) and finally the HSC-group of high-skill abundant countries from the EU (Austria, Belgium-Luxembourg, Denmark, France, Finland, Germany, Italy, the Netherlands, Sweden and the U.K.) as well as high-skill abundant OECD countries (Australia, Japan, New Zealand, Norway and the U.S. ). There is 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:

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

- Price of capital

In Berndt and Hesse (1986) the price of capital is calculated as:  $P_{K_{i,t}} = q_{i,t} * (r_t + \delta_i)$ , 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  $\delta_i$ : depreciation rate of  $i$ th type capital.

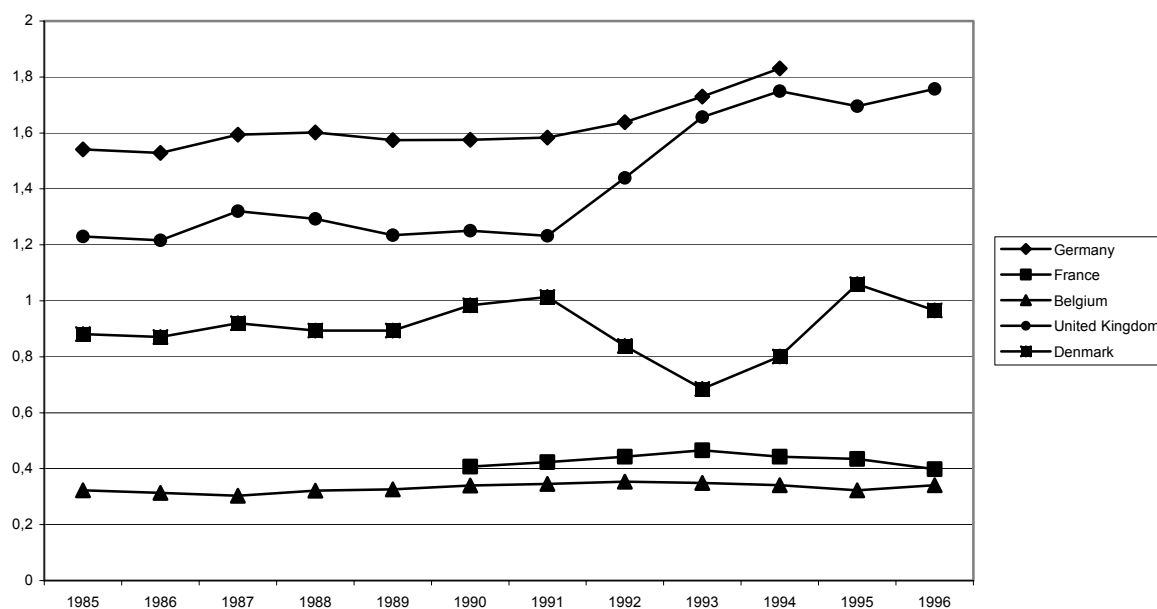
Data on long-term government bond yields were taken from the IMF International Financial Statistics. The same source contains data on fixed capital consumption from which depreciation rates can be computed. Unfortunately this information is given for few countries, sectors and years. Rather than using 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 stock

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).

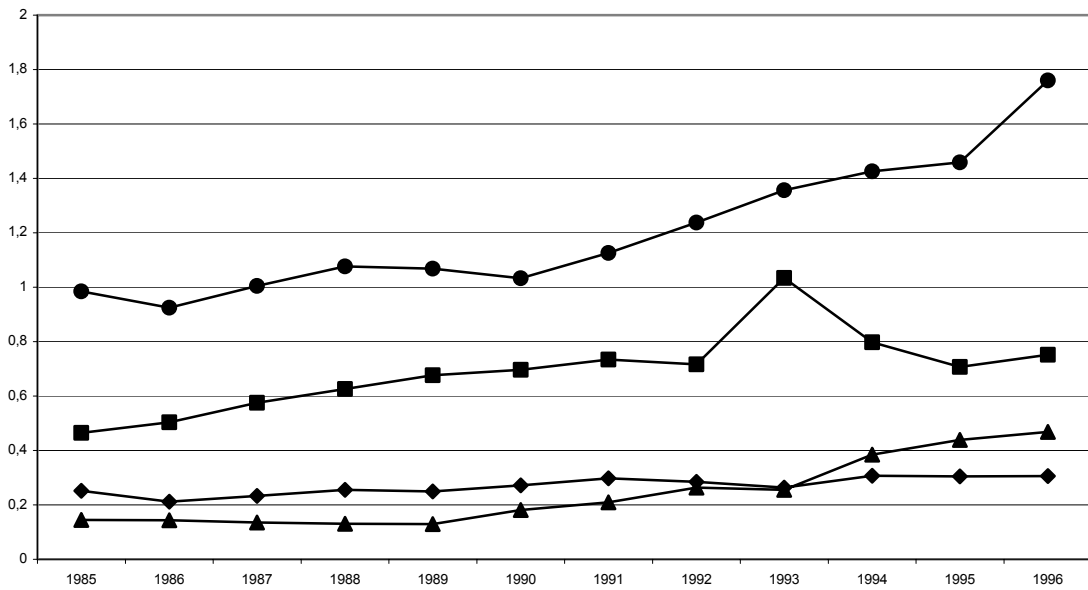
**Figure A.1 Evolution of ratio VA share non-production workers to VA share production workers in five EU countries in the period 1985-1996**



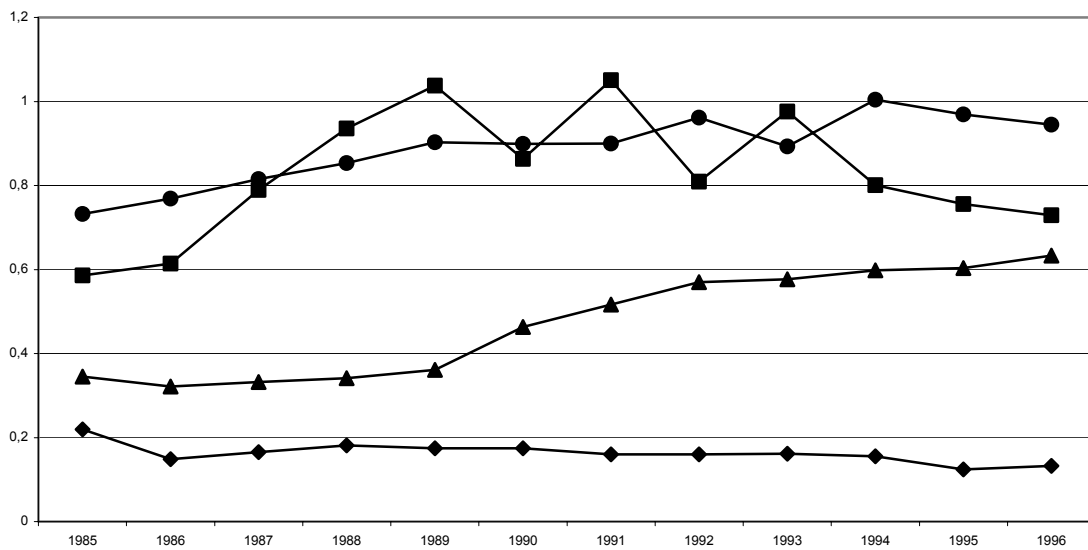
**Source:** own calculations from the UNIDO General Industrial Statistics database, Labour Force Surveys data (Eurostat) and OECD Structural Analysis industrial (STAN) and International Sector database (ISDB).

**Figure A.2: Average percentage of foreign outsourcing (narrow sense) from NIC in the period 1985-1996**

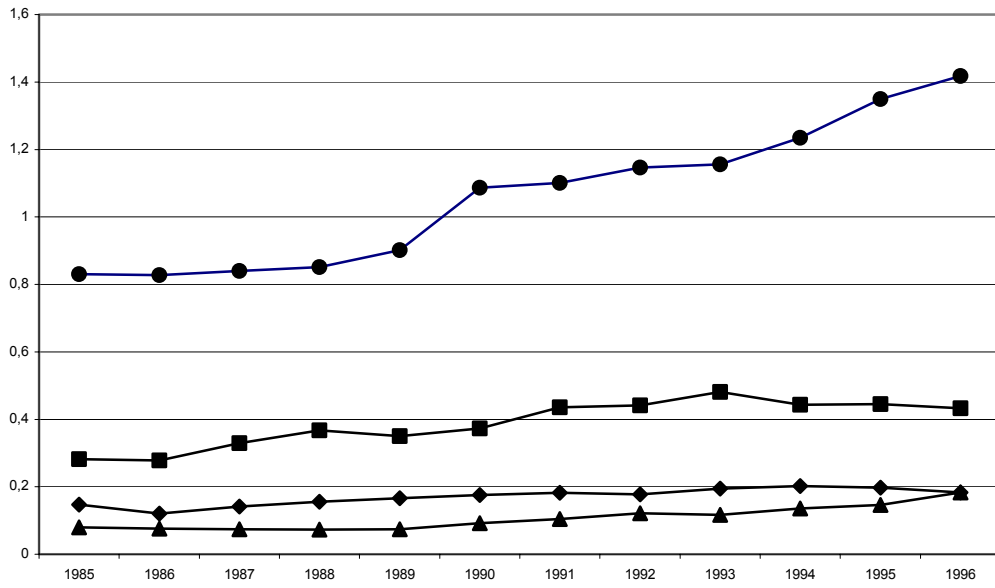
BELGIUM



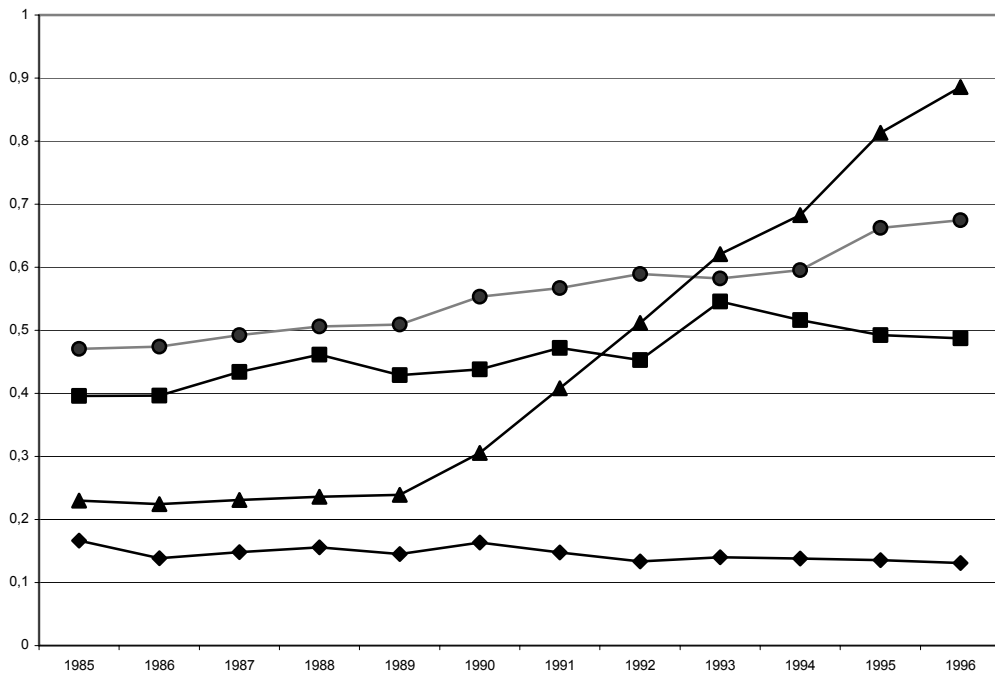
DENMARK



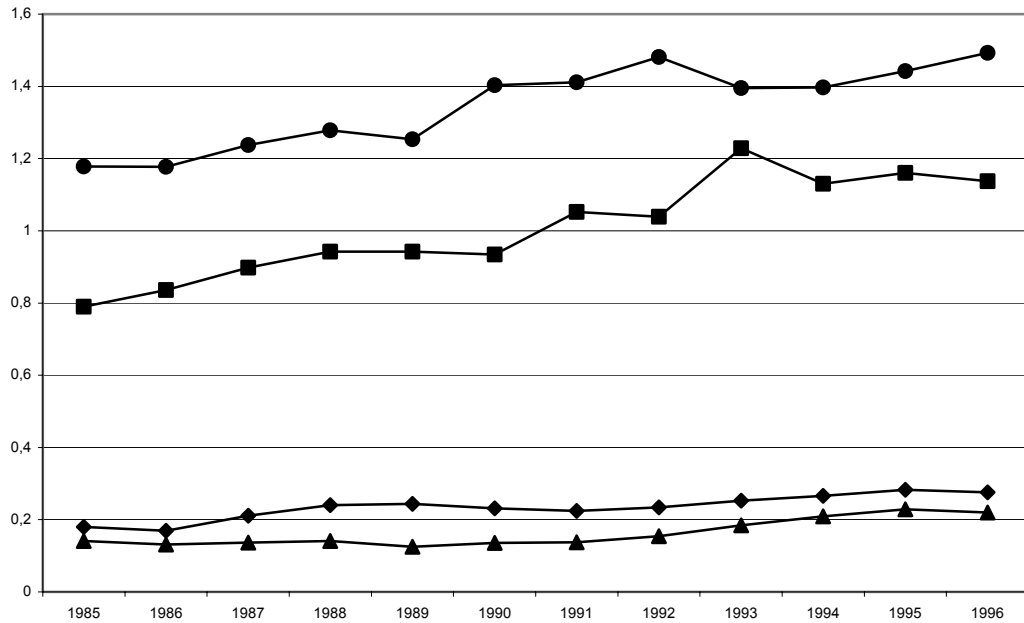
## FRANCE



## GERMANY



## UNITED KINGDOM



**Source:** OECD DSTI Input/Output database and International Trade by Commodities Statistics (ITCS). See data annex for a definition of the outsourcing variable.

