THE INTERPLAY BETWEEN INTERNATIONAL TRADE AND TECHNOLOGICAL CHANGE AND THE WAGE INEQUALITY IN THE OECD COUNTRIES*

Nikolina Stojanovska[1] (Faculty of Applied Economics, University of Antwerp, Belgium)

Ludo Cuyvers[2] (Faculty of Applied Economics, University of Antwerp, Belgium)

WP November, 2009

Keywords: price competition, technological competition, wage inequality

JEL: F1; O3

Abstract

We estimate the impact of international trade and of trade-induced technological change on the wage inequality in the OECD countries, by estimating a two-stage mandated-wage regression.

From our estimation we find no evidence on the Stolper-Samuelson effect of trade with the developing and newly industrialized countries. On the other hand, the evidenced technological change from technological competition did not have a strong effect on the increase of the wage differential between the different types of labour in the analyzed sample of OECD countries, which would have indicated that the bias of the technological change towards the skilled-intensive sectors is determined by trade in innovation-intensive goods.

*We appreciate the comments of Michel Dumont. The representations and the conclusions presented herein are those of the authors. This is a first draft, please do not quote.

[1] Nikolina.Stojanovska@ua.ac.be
[2] Ludo.Cuyvers@ua.ac.be

1. Introduction

As part of the analysis of the interplay between international trade, technological change and the labour market position of the lower-skilled, the aim of this paper is to provide an estimate of the significance of the impact of international trade, but also of the technological change that is trade-induced on the wage inequality in the OECD countries, by estimating a two-stage mandated-wage regression.

The value-added of this paper is the development of a regression where technological change is dependent on a variable reflecting the technological competition at the world market, i.e. in the estimation of the effect of the technological change induced by this underlying factor on the wage inequality.

Apart from deriving the potential determinants of technological change from the assumptions in the literature, an attempt is also made of differentiation of the trading partners of the OECD countries in order to distinguish different channels through which international trade induces technological change (spillovers, R&D competition, price competition) and to contrast the price competition from the diversified South from the price competition from the North in the regression of the goods price change. The two-stage estimation methodology is based on the one in Feenstra and Hanson (1999) and even more to the one in Haskel and Slaughter (2001).

2. Theoretical considerations and theoretical justification for the choice of (new) variables

Using a two-stage mandated wage regression procedure, based on Haskel and Slaughter (2001), Cuyvers et al. (2003b) estimate two effects: the effect of (sector-biased) technological change and the Stolper-Samuelson (sector-biased) effect of endogenous goods price change on the inter-sectoral factor flow. If an aggregate factor flow is assumed to the (more profitable) skill-intensive sectors stemming from either of the two effects, the expected effect on the wage differential between high skilled and low skilled labour is positive, i.e. the wage differential increases, and is reflected in the adjustment of the economy relative factor prices “mandated” to restore zero profits in each sector of the economy. In the first stage of the estimation in Cuyvers et al. (2003b) the trade-induced technological change is regressed on imported goods' relative price change reflecting the international trade *price* competition, and on R&D spillovers since foreign R&D spillovers are facilitated by international trade (Grossman and Helpman, 1991) and, thus, it is another way for trade to have impact on technological change.

In the first stage of a two-stage mandated-wage estimation, following Cuyvers et al. (2003b) we propose to trade-endogenize the technological change by regressing TFP (total factor productivity) growth on a *technological competition proxy* in addition to the relative import prices change as underlying force, and on the traditional regressors such as domestic and foreign technological spillovers and domestic sectoral accumulated R&D expenditures.

2.1. How well are the underlying forces of TFP growth consistent with the assumptions of the basic neoclassical equilibrium model?

Capron and Cincera (2001) analysed the R&D rivalry (race) at firm level by estimating the R&D expenditures reaction function of a firm to the current R&D expenditures of the competitors, on inter-industry and on intra-industry samples. A significant coefficient reflects an aggressive competitive reaction, the firm being a technological follower. In contrast, the firm whose R&D activity is not affected by the current change in other firm's R&D expenditures is a technological leader or there is a technological intra-industry gap between the countries of origin of the firms. In the overall models of competition and innovation there has been no attempt so far to approximate the direct *competitive effect of foreign R&D on domestic productivity growth* (as remarked by Cincera and van Pottelsberghe de la Potterie, 2001). Capron and Cincera (2001) disentangle the effect of foreign R&D on spillover and on competition (adoption or imitation, and innovation, respectively) as the "two sources of technological interdependencies". The authors consider that "the R&D activity *implemented* by firms is expected to stimulate their productivity" (as, for example, evidenced in Madden et al., 2001 and in other empirical literature on technological spillovers), while TFP is often considered as a "measure of production efficiency" (Berstein and Mohnen, 1998) and net productivity gain. Following Cuyvers et al. (2003b) we also regress the TFP growth variable on changes in domestic and foreign R&D spillovers.

Further, based on the growth model in Aghion et al. (2006), where a country's distance to the technological frontier, i.e. the country's position relative to the position of the technological leader *F* in the technological race, reflects innovation incentives of the domestic country, we include the period change in a country's relative position vis-à-vis the technological leader as explanatory variable of productivity growth. Aghion et al. (2006) find that the interaction of the proximity *t*o the technological frontier with the skilled labour fraction is positive, which signifies that employment of skilled labour, i.e. employment in innovation, is more important for countries closer to the technological frontier, under the assumption that innovation is more skill-intensive than imitation. In other words, the countries that are closer to the technological frontier are more likely to innovate, while countries that are very distant to the technological frontier are more likely to imitate (or adopt) the existing technology as a driving force for the country's technological progress.

The technological race literature is based on the premise that innovation is the major non-price competition factor in the R&D-intensive industries[3], and is related to the hypothesis that international trade is "driven by differences in knowledge between countries", which is also underlying the theoretical model in Dinopoulos and Segerstrom (1999) and other models of the 'new trade theory' that assume imperfect competition in the goods market. In Dinopoulos and Segerstrom (1999) North-North trade liberalization increases R&D investment, i.e. the annual R&D expenditures, and the rate of technological change in each industry since *firms* choose to undertake R&D in order to improve the quality of their products and by this to be more competitive *in the international market*. The innovation process in the competitive firms creates an R&D race, from which results a quality leader and a number of followers. Whether an industry leader is a domestic or a foreign firm changes over time in the structurally identical Northern countries. Furthermore, under the assumption that the relatively higher skill-intensity of the R&D activity is basic for the skill-bias of this trade-induced technological change, the authors conclude that trade-induced technological change increases wage inequality. The mandated-wage analysis gives us a possibility to estimate what is the final effect of technological change induced by technological competition, on the wage inequality.

[3] Note that also the international competitiveness of a country in the 'traditional' industries is shown as dependent on the technological activity in these industries (See Fagerberg, 1996 for a review)

On the other hand, it is worth noting that the mandated wage regression is based on the HOS model, which assumes 1) same technologies in the trading countries and 2) perfect competition in the goods market. Regarding the assumption of identical technologies, the technological change effect is part of the mandated wage regression starting from Leamer (1996) when it is analysed as exogenous, and in the mandated-wage literature following Leamer (1996) that we elaborate in the following section. As for the second assumption, perfect competition at the goods market is about price competition. However, as pointed-out by Haskel and Slaughter (2001), imperfect competition as usually modelled as competition in product variety or product quality, in order the firms to preserve their market share, "need not be inconsistent with the zero-profit assumption […]. Helpman and Krugman (1985) modify the HO model by having one sector be monopolistically competitive *with entry*. This sector still [in equilibrium] earns zero profits, and, [thus], price change still generate Stolper-Samuelson wage adjustments". Deriving the mandated wage equation from the zero-profit condition, the mark-up 'disappears' in the mandated wage equation where the equilibrium is restored. Moreover, Cuyvers et al. (2003b) perform a test for a pass-through variable that reflects the market structure and find that there is no sufficient indication that market imperfections cause deviations from the zero-profit condition.

Technological competition in our model would mean that international trade that induces technological change is intra-industry trade. Still, the economies may be considered as multi-sectoral and sectors inside the economy may differ in their relative factor intensity. Therefore, regressing TFP growth on technology-based competition doesn't have to affect the pattern of the country's (incomplete) specialization (see Gustavson et al., 1999). The country will still specialize depending on the relative factor endowments as comparative advantage rather than on the difference in technologies, i.e. a country's competitiveness will not be simply the aggregation of the competitiveness at industry level (see Krugman, 1996, for discussion). This allows us to consider the inter-sectoral factor flows from inter-sectoral change in profitability. Even if the intra-industry trade induces a factor-biased technological change, it may be assumed that the factor bias is at the same time relatively more present in one sector, and this is what we assume in our analysis.

Also, the choice of analysing technological change as induced by technological competition is reasoned in the conclusion from the empirical simulations by Dinopoulos and Segerstrom (1999) where *"in contrast to exogenous skill-biased, skill-complementary technological change, the endogenous technological change* *coming from technology competition increases the trade openness".* This allows an analysis of the effect of the demand-side factors on the wage inequality to include a further aspect of conjunction of technological change and trade.

3. <u>The development of the methodological framework</u>

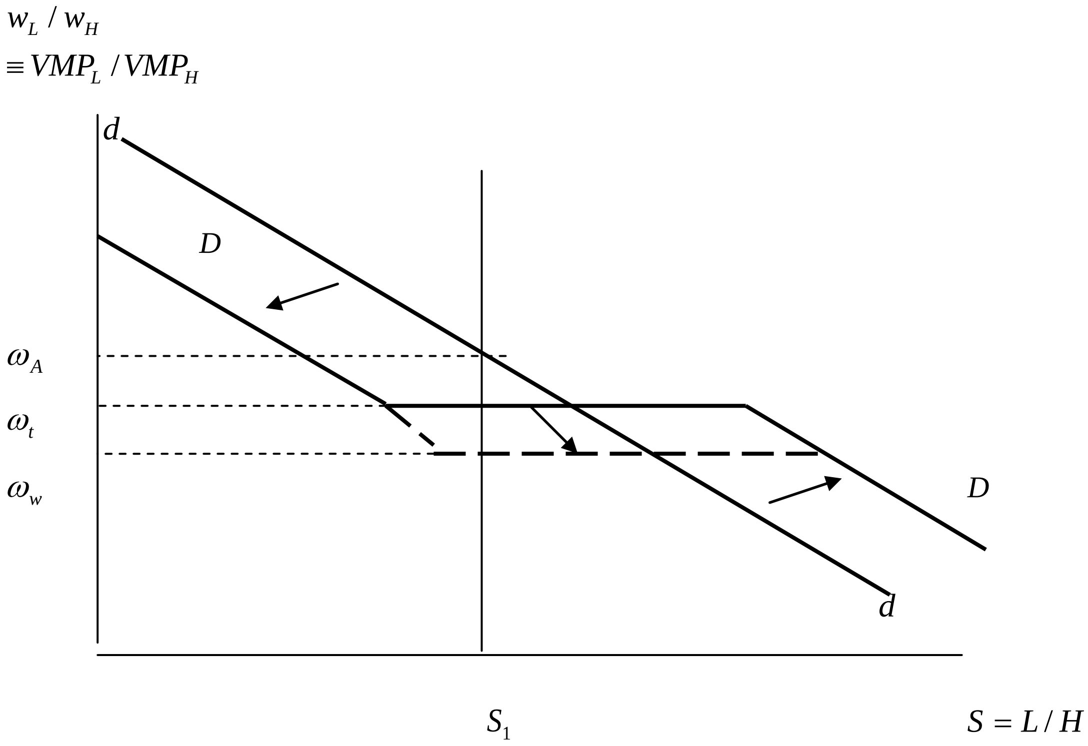
In a HO framework sector *i*'s output Y_i will change as a result of change in the demand of products from opening of the economy to the international market. This output change, in turn, will affect the relative factor demand, since the factor of production intensively used in the non-competitive, contracting sector will be partially 'released' from this sector but not demanded in the same proportion in the competitive, expanding sector intensive in the other factor (and the opposite holds for the other factor and the other sector). Assuming full employment of the factors there will follow a HO sectoral 'output effect' on the relative factor prices, coming from the neoclassical assumption of each factor being paid its marginal revenue product. Still, the relative (two-) factor demand function *DD* (Graph 1) will show a horizontal part, where for the same relative factor prices there is no unique relative factor demand (Varian, 1992) and the relative factor demand depends on the chosen combination of technological processes for producing the output mix, which employ factor bundles that are all cost-minimizing. Any effect (of a demand shock) to this open economy is analysed henceforth in the text below from the aspect of what happens on/with this kinked relative factor demand curve.

First, what if the character of the technology used changes economy-wise? In Wood (2005) the effect of factor-saving sector-neutral technological change is considered to cause the kind of change in the relative demand of the factors that happens as a movement along the flat part of *DD* in Graph 1 without reflection on relative factor-prices change. With the same cost for different relative employment of the factors, the output in this two (or multi-) sector economy will change in order to absorb the 'saved' factor by expansion of the saved-factor-intensive industries or industry processes but not by contraction of the others. In Leamer (1996) this is called absorption of the deployed factor in the non-tradables sector when the demand for the non-tradable goods is very elastic. The factor-bias of a sector-neutral technological change will change the aggregate relative demand of factors and their relative factor rewards only in a one-sector economy. In a two- or in a multi-sector economy *it is the sector-biased, not the sector-neutral technological change,* that changes the relative factors prices since it causes inter-sectoral change in profitability (Haskel and Slaughter, 2001). The aggregate relative demand for a factor in a multi-sector economy would reflect in a change in the relative factor reward only if in its flow from one sector to another the factor moves from a less to a more profitable sector where, in order to restore the zero profit condition, the reward to the factor increases. The increase in the factor reward in the profitable sectors further reflects an increase of the economy-level reward of the factor that is more intensively used, relative to the other factor's reward.

Second, Haskel and Slaughter (1999) discuss a small change in the supply of inputs that does not necessarily reflect in a change of the relative factor price[4](meaning excluding supply shocks from the analysis). A change in the relative supply of a factor *j* is absorbed by a change in the economy-level relative factor demand that happens on the flat part of the *DD* demand curve, and does not affect the factor prices as long as the number of factors is lower or equal to the number of industries in a multi-sector multi-product setting (Haskel and Slaughter, 1999). There is a change in the economy-level output that ensures complete absorption of the increased factor supply without change in the output mix but proportional change in the quantities of industry output forming the output mix. If the changes in supply of labour caused output mix changes, the economy would have moved from the flat part of the demand curve to the downward-sloping parts by leaving production of some/one product and specializing in others/the other. This brings us to assume in our empirical estimation that the output mix didn't change in the analysed period.

[4] Factor-price intensivity (FPI) theorem

Graph 1: Changes in relative demand for skills, adopted from Wood (1995)



With w_L / w_H the ratio of wages of low-skilled and high-skilled labour,

MP_L / MP_H and VMP_L / VMP_H the ratio of the marginal product and the value of marginal product respectively, of low-skilled and high-skilled labour,

p_H^h / p_L^h the ratio of the domestic prices of a skilled labour intensive and an unskilled labour intensive good in autarky,

p_H^* / p_L^* the ratio of the foreign prices of a skilled labour intensive and an unskilled labour intensive good in autarky, and

p_H^w / p_L^w the ratio of the world prices of a skilled labour intensive and an unskilled labour intensive good, the following holds due to international trade:

*Change in o*utput $\leftarrow p_H^h / p_L^h < p_H^* / p_L^* \Rightarrow$ ⋮ $p_H^h / p_L^h < p_H^w / p_L^w < p_H^* / p_L^* \rightarrow$ *Relative increase of skill-intensive good price*

$MP_L / MP_H \downarrow$ ⋮ $VMP_L / VMP_H \downarrow$

$w_L / w_H \downarrow$

isolated from the price effect (p constant) *isolated from the output effect*

Third, following the "Stolper-Samuelson effect" in the neoclassical trade model, of change in the factor prices induced by change in the relative output prices, zero profits in all sectors are restored by change in the factor prices (w_j in equation 3.1 below) in the sectors positively and negatively affected by the international price competition. This change in factor prices depends on the intensity (a_{ij} in equation 3.1. below) by which the factor is employed in a positively or negatively affected sector. The factor intensively used in the profitable sector will experience an increased economy-level factor reward. We say 'economy-level' factor prices, as in a competitive market with perfect factor mobility (again in accordance with the HOS framework) the price of each factor will be equalized at the economy level.

Since not only the Stolper-Samuelson effect of change of the relative prices of goods, but also the effect of sector-biased technological change theoretically changes the profitability of one sector in difference to another, Leamer (1996) aims to express the sector-biased effect of technology and of price changes on the changes of the factor prices in one equation (3.6.). By assuming no effect from small change in the factor supply and by adopting Wood's argument (Wood, 2005) that factor-biased sector-neutral technological change doesn't affect the relative factor prices in a multi-sector economy, only the changes in relative prices of goods (Stolper –Samuelson effect) and the sector-biased technological change will shift the flat part of the *DD* demand curve. In other words, in a multi-sector model the factor prices will adjust at economy level only due to goods prices and sector-biased technological change. (Haskel and Slaughter (1998, 1999, and 2001) further argue that not only factor-neutral technological change but also factor-biased technological change can be sector-biased and only by this included in the estimation model initially developed by Leamer (1996)).

All this economic intuition approves for the derivation from the zero profits condition (3.1) to the mandated wage equation (3.6) in Leamer (1996), as follows:

(3.1.) $p_i = \sum_j a_{ij} w_j$; i=1…I, indexing the number of sectors

By differentiating the all-sectors zero profits condition in (3.1.), and replacing by $\theta_{ij} = a_{ij} \dfrac{w_j}{p_i}$, which represents the two-period (*t-1* and *t*) average cost shares of input *j* in gross output (unit input price per unit gross output price times the input intensity), equation (3.2.) gives the change in world goods prices decomposed in factor price change and change in factor intensity (employment of inputs per unit of output).

(3.2.) $\frac{\Delta p_i}{p_i} = \sum_j \theta_{ij} \frac{\Delta w_j}{w_j} + \sum_j \theta_{ij} \frac{\Delta a_{ij}}{a_{ij}}$, *j* refers to inputs, *i* refers to industries,

The TFP growth measurement in equation (3.3.) is based on the growth of gross output decomposition and is expressed as 'the primal Torqvist index of TFP'. Output growth other than from the growth of inputs weighted by the share of input compensation of the value of output is defined as total factor productivity growth and reflects the technological change:

(3.3.) $\frac{\Delta TFP_i^{GO}}{TFP_i^{GO}} = \frac{\Delta Y}{Y} - \theta_{iX} \frac{\Delta X_i}{X_i} - \theta_{iK} \frac{\Delta K_i}{K_i} - \theta_{iL} \frac{\Delta L_i}{L_i}$, where X are intermediate inputs, K is capital and L is labour, or in general for any input v_j the gross output-based total factor productivity growth is expressed as:

(3.3.1) $\frac{\Delta TFP_i^{GO}}{TFP_i^{GO}} = \frac{\Delta Y_i}{Y_i} - \sum_j \theta_{ij} \frac{\Delta v_{ij}}{v_{ij}}$

where $\Delta v_{ij} / v_{ij}$ stands for growth of input v_j in industry *i*. The primal Torqvist index of TFP implies that the input cost shares are two-period averages. This measurement of TFP growth conforms to the variable measurement in the EU KLEMS database, which TFP data we will use for estimation.

If we replace in (3.3.1.) v_{ij} and Y_i by input intensity a_{ij} , differentiating $a_{ij} = v_{ij} / Y_i$ i.e. from the equation $\Delta a_{ij} / a_{ij} = \Delta v_{ij} / v_{ij} - \Delta Y_i / Y_i$, we reach an expression of the TFP growth in the same terms as the change of goods prices in 3.2. :

(3.4.) $\frac{\Delta TFP_i^{GO}}{TFP_i^{GO}} = -\sum_j \theta_{ij} \frac{\Delta a_{ij}}{a_{ij}}$

, for $\sum_j \theta_{ij} = 1$

From here, by replacing in (3.2.), Leamer (1996) reaches the following price equation, (3.5) $$\frac{\Delta p_i}{p_i} = \sum_j \theta_{ij} \frac{\Delta w_j}{w_j} - \frac{\Delta TFP_i^{GO}}{TFP_i^{GO}}$$

which is mathematically the basis for estimation of the mandated changes (the estimated coefficients of input cost shares θ) of input prices from a change in goods prices and a change in technology in the following equation:

(3.6.) $$\frac{\Delta p_i}{p_i} + \frac{\Delta TFP_i^{GO}}{TFP_i^{GO}} = \sum_j \theta_{ij} \frac{\Delta w_j}{w_j}$$

From the decomposed price change in (3.2) and from the TFP on the right side of (3.5) there is indication that the industry prices are affected by the change in technology measured by TFP growth, i.e. the change in product prices in part results from the increased effectiveness by which the inputs are used to produce a unit of output (in 3.2). Therefore, in Leamer (1996) the TFP growth effect is disentangled in its effect on factor price change, on the one hand, and in the product price change, on the other hand, the latter as a pass-through that reflects in price reduction and can be measured or alternatively assumed to happen by a constant rate λ (Krugman, 1995). In a regression of goods prices, we will estimate the pass-through of technological change to price change.

If we separate the inputs on intermediate inputs *k* and *f* for capital and labour, we can express the zero-profit condition in (3.1) as in Haskel and Slaughter (2001) and in Cuyvers et al. (2003b),

(3.7.) $$p_i = \sum_f b_{if} w_f + \sum_k c_{ik} p_k$$

where b_{if} is intensity of primary factor f (K and L intensity), and c_{ik} is the intermediate input *k* intensity.

If we differentiate this zero-profit condition, we reach

(3.8.) $$\frac{\Delta p_i}{p_i} = \sum_f \theta_{if} \frac{\Delta w_f}{w_f} + \sum_f \theta_{if} \frac{\Delta b_{if}}{b_{if}} + \sum_k \theta_{ik} \frac{\Delta p_k}{p_k} + \sum_k \theta_{ik} \frac{\Delta c_{ik}}{c_{ik}},$$

where $\theta_{if} = b_{if} \frac{w_f}{p_i}$ and $\theta_{ik} = c_{ik} \frac{p_k}{p_i}$.

The TFP growth, based on the decomposition of growth of gross output in (3.3.) can be expressed as

$$(3.9.)\quad \frac{\Delta TFP_i^{GO}}{TFP_i^{GO}} = \frac{\Delta Y_i}{Y_i} - \sum_f \theta_{if} \frac{\Delta v_{if}}{v_{if}} - \sum_k \theta_{ik} \frac{\Delta v_{ik}}{v_{ik}}$$

If we replace in (3.9.) v_{if} and v_{ik}, differentiating the input intensity in b_{if} and c_{ik} expressions,

$$\frac{\Delta v_{if}}{v_{if}} = \frac{\Delta Y_i}{Y_i} + \frac{\Delta b_{if}}{b_{if}}, \qquad \frac{\Delta v_{ik}}{v_{ik}} = \frac{\Delta Y_i}{Y_i} + \frac{\Delta c_{ik}}{c_{ik}},$$

we obtain:

$$(3.10.)\quad \frac{\Delta TFP_i^{GO}}{TFP_i^{GO}} = -\sum_f \theta_{if} \frac{\Delta b_{if}}{b_{if}} - \sum_k \theta_{ik} \frac{\Delta c_{ik}}{c_{ik}} \text{ , for } \sum_f \theta_{if} + \sum_k \theta_{ik} = 1$$

If we further replace (3.4.) in (3.8.)

$$\frac{\Delta p_i}{p_i} = \sum_f \theta_{if} \frac{\Delta w_f}{w_f} + \sum_k \theta_{ik} \frac{\Delta p_k}{p_k} - \frac{\Delta TFP_i^{GO}}{TFP_i^{GO}}$$

Further, as the change in price of goods in industry *i* can be expressed by the change in value added prices and the change in price of intermediate inputs,

$$\frac{\Delta p_i}{p_i} = \frac{\Delta p_i^{VA}}{p_i^{VA}} + \sum_k \theta_{ik} \frac{\Delta p_k}{p_k}$$

the mandated wages equation is:

$$(3.11.)\quad \frac{\Delta p_i^{VA}}{p_i^{VA}} + \frac{\Delta TFP_i^{GO}}{TFP_i^{GO}} = \sum_f \theta_{if} \frac{\Delta w_f}{w_f}$$

In this final equation, the share of intermediates $\sum_k \theta_{ik}$ of gross output is excluded from (falls off from both sides of) the equation (mathematically the intermediates share is set to 0). Since the value of gross output can be assumed to be divisible into the value of intermediate inputs and the value added, and the value added is function of K and L, in the mandated wage equation (3.11.) the cost share of inputs K and L ($\sum_f \theta_{if}$) is analysed as share of value added instead as share of gross output. In this way, the sum of the cost shares of the primary factors f=L, K (in value added) equals one. It should be noted that Haskel and Slaughter identify the variables in the mandated wage regression as a change in VA prices, TFP growth as gross output (GO) based and θ_{ijt} as the cost share of inputs in GO; in the study by Cuyvers et al. (2003a,b) the variables are identified as change in VA prices, TFP growth as GO based but calculated as the difference between the output growth and the weighted growth of capital and labour as only inputs following a Cobb-Douglas production function, and θ_{ift} as the share of capital/labour in VA. In contrast, following the derivation until equation (3.11.) in this study, we will use the variables expressed as: $\Delta \log p_{it}^{VA}$ as percentage change in VA prices in the analysed period; $\Delta \log TFP_{it}$ as GO based; and θ_{ift} as end dates average share of (high-skilled, middle-skilled, low-skilled) labour, and capital in VA.

The two-stage mandated wage approach is first elaborated in Feenstra and Hanson (1997) and further developed in Feenstra and Hanson (1999). In the first stage of the two-stage-estimation Haskel and Slaughter (1999) are the first to regress the technological change and the price change in separate equations, each on its own different set of underlying factors. The estimated coefficients of the underlying factors explain the contribution of the change in the underlying factors they refer to in the change of TFP or value-added prices.

The selection of the determinants of technological change in Haskel and Slaughter (1999) is based on the Woods' intuition on "trade-induced" technological change. Wood (1995) claimed that technological change in the developed countries is defensive against international competition from the developing countries. The defensive innovation is considered to disable technological spillovers to the labour-abundant developing countries and to enable a persistent response to the increased international competition with new methods of production. Since according to Wood (1995) the defensive technological change is biased to the sectors that experience international trade price competition i.e. the labour-intensive sectors, Haskel and Slaughter (1999, 2001) and Cuyvers et al. (2003b) capture the sector-biased technological change by TFP growth in sector *i* regressed on import-price competition at the goods market variable (change in domestic gross output prices in sector *i* relative to import prices). The trade-induced technological change will increase TFP in the labour-intensive sector because this is the sector that responds by innovation to the price competition on the international market. The derivation of the basic TFP regression is elaborated in Coe and Helpman (1995), where it is derived from an extended Cobb-Douglas production function, which can be further extended. Since TFP is measured as ratio of production output and production inputs, based on the gross-output method, the R&D capital stock can be included in the specification of the TFP regression in addition to the conventional inputs as a determinant of the output. The R&D capital stock can be treated as another production factor since it is complimentary or substitutable to the other factors of production (Nadiri, 1993). (See Keller, 1998, p.1471-1475 for empirical implementation of the theoretical model in Coe and Helpman, 1995).

4. Use of the two-stage mandated wage model for looking into the interplay between international trade and technological change and their impact on the wage inequality in the OECD countries

In the first stage of our intra-industry mandated wage regression we regress TFP growth as a measure of technological change. In this stage we also estimate a regression of the change in value added prices on industry level determinants following Cuyvers et al. (2003b).

$$\Delta \log TFP_{jit} = \alpha_1 \Delta \log RD_{jit} + \alpha_2 \Delta \log RD_{jgt} + \alpha_3 \Delta \log \Sigma_{fi} RD_{fit} + \alpha_4 \Delta \log \mathrm{RTFP}_{\mathrm{jit}} + + \alpha_f \Delta \log p_{fit} / p_{ji,baseyear} + \mu_{ji} + \lambda_t + \varepsilon_{jit} \tag{4.1}$$

where μ_{ji} stands for individual and λ_t for time fixed effects.

The first stage regression equation on total factor productivity growth for a given industry *i* in country *j* during period *t*, is modelled in 4.1. We include the *period change in the distance to the technological frontier* variable ($\Delta \log \mathrm{RTFP}_{\mathrm{jit}}$) reflecting the change in the competitive position of the domestic country *j* in the technological race in an industry *i*, driven by innovations. Following Scarpetta and Tressel (2002) it is specified as change in the ratio of country's *TFP level* in the industry *i* to the industry *i* TFP level of the country *F* with highest *'productivity of innovation'* . The country that is initially distant to the technological frontier is likely to follow the leader. Its positive competitive reaction by innovations is expected to outburst the productivity growth in the industry *i* ($\Delta \log TFP_{jit}$).

Still, considering non-price competition at the international market does not mean that price competition should be left out. To the extent that in Cuyvers et al. (2003b) the latter plays a significant role, leaving it out would lead to an omitted variable bias. The price competition regressor $\Delta \log p_{fit} / p_{ji,baseyear}$ is measured as a period change in import prices of goods of industry *i* of the trading partner *f* relative to the domestic value added prices in the base year (1988 or 1997), (where *f*= OECD, Asian NICs[5], the developing Asian countries[6], and the Latin American NICs[7].). By introducing this variable in the TFP growth regression, we test Wood's assumption (Wood, 1995) of defensive technological change due to the competitive threat in the industries that experience international trade price competition.

The industry-level foreign R&D capital stock calculated as R&D capital stock in the corresponding sector cumulative for the OECD sample of trading partners ($\Sigma_{fi} RD_{fit}$) captures the industy-level international spillovers amongst the analyzed OECD countries. In equation 4.1, $\Delta \log RD_{jit}$ captures the period change of the sectoral domestic R&D capital stock, while $\Delta \log RD_{jgt}$ represents change in the non-sectoral R&D stock calculated as R&D stock of all other domestic manufacturing industries ($i, g \in I, i \neq g$).

In the stage-one price regression in equation 4.2, $\Delta \log p_{jit}$ is domestic industry price change, $\Delta \log p_{fit}$ are changes in import prices for a range of trading partners *f* (OECD, Asian NICs, Asian developing countries, and Latin American NICs). The TFP change in the price regression accounts for the pass-through from increased productivity to price decrease. The coefficient is expected to be below or equal to 0 (see Feenstra and Hanson, 1997).

$$\Delta \log p_{jit} = \beta_1 \Delta \log p_{fit} + \beta_2 \Delta \log TFP_{jit} + \mu_{ji} + \lambda_t + \varepsilon_{jit} \qquad (4.2)$$

In the second stage of the estimation, the estimated contribution of import prices as determinants of the *price change* is regressed on the cost shares of the production factors. The estimated contribution of the import prices reflect the sector bias of the price change, as alternative to the sector bias of technological change,

---

[5] Hong Kong, Singapore, Taiwan (Chinese Taipei)
[6] Indonesia, Malaysia, Philippines, Thailand, China, India
[7] Argentina, Chile, Brazil

which affects the inter-sectoral change in profitability and leads to a change in economy-level factor prices (Stolper-Samuelson effect).

Alternatively, as in regression 4.3, the estimated contribution of the determinants of *trade–induced technological change* reflects the sector bias of the technological change that has its own final response in the change of factor prices, holding the product prices constant. The estimated coefficients of the factor cost shares are the estimated change in factor rewards that are mandated to restore the zero profit condition in the sectors of the economy.

For θ_{pit} is the cost share of factor *p* in sector *i* and w is a cost share coefficient that represents the mandated change in the factor reward of factor *p* (*p*=capital *c*, lower-skilled labour *ls*, middle-skilled labour *ms*, and high-skilled labour *hs*) we can write the second stage regression equations as it follows where $\hat{\alpha}_4 \Delta \mathrm{logRTFP}_{\mathrm{jit}}$ is the fitted value of the change in the technological proximity variable:

$$\hat{\alpha}_4 \Delta \mathrm{logRTFP}_{\mathrm{jit}} = (\Delta \log w_{ls})\theta_{ls,jit} + (\Delta \log w_{ms})\theta_{ms,jit} + (\Delta \log w_{hs})\theta_{hs,jit} + (\Delta \log w_c)\theta_{c,jit} + \varepsilon'_{jit} \quad (4.3)$$

We repeat the second stage for the import price competition variables as underlying factors of the technological change (regressors in regression 4.1) and also for the import price change as determinants of domestic price change (regressors in regression 4.2).

Following Lücke (1998) we can rewrite 4.3 by taking into account the factor shares restriction of summing one ($\theta_{c,jit} = 1 - \theta_{ls,jit} - \theta_{ms,jit} - \theta_{hs,jit}$), and analyse the mandated change in the factor reward as relative to the change in the remuneration of capital.

$$\hat{\alpha}_4 \Delta \mathrm{logRTFP}_{\mathrm{jit}} = \Delta \log w_c + (\Delta \log w_{ls} - \Delta \log w_c)\theta_{ls,jit} + (\Delta \log w_{ms} - \Delta \log w_c)\theta_{ms,jit} + \\ + (\Delta \log w_{hs} - \Delta \log w_c)\theta_{hs,jit} + \varepsilon'_{jit} \quad (4.4)$$

5. Empirical findings

The intersection of the datasets from several databases allows us to create a panel of data for 13 two-digit manufacturing industries[8] in 10 OECD countries[9] over

[8] The industries are: Food products, beverages and tobacco (ISIC Rev. 3 code 15t16); Textiles, textile products, leather and footwear (ISIC Rev. 3 code 17t19); Wood and products of wood and cork (ISIC Rev. 3 code 20); Pulp, paper, paper products, printing and publishing (ISIC Rev. 3 code 21t22); Coke,

the period 1988-2003. The estimation required data in first differences that reflect changes over the period 1988-1997 and changes over the period 1997-2003.

For the total factor productivity growth regression, the plain OLS estimation method was rejected after performing (Chow) F-test on the significance of the country and industry individual effects. The time effect was also reported significant after performing the F-test. The F-test statistic reported also (joint) significance of the individual effects in presence of time effects. Hausman's specification test result showed that the individual effects are correlated to the set of explanatory variables. For the LSDV model specification of the TFP growth regression with D-1 industry, country and time dummy variables, the BPG test reported heteroscedasticity. In order to account for a cross-sectionally heteroscedastic model, we have estimated a White heteroscedasticity-consistent covariance matrix.

Table 1. TFP growth stage-one regression, dependent variable: $\Delta \log TFP_{jit}$

$\Delta \log RD_{jit}$	0.012 (0.009)
$\Delta \log RD_{jgt}$	-0.012 (0.025)
$\Delta \log \Sigma_{fi} RD_{fit}$	0.166 (0.028)**
$\Delta \log \mathrm{RTFP}_{jit}$	0.858 (0.056)**
$\Delta \log p_{oecd,it} / p_{ji,baseyear}$	0.003 (0.003)
$\Delta \log p_{asnics,it} / p_{ji,baseyear}$	0.002 (0.001)
$\Delta \log p_{asdev,it} / p_{ji,baseyear}$	0.002 (0.001)
$\Delta \log p_{latnics,it} / p_{ji,baseyear}$	-0.001 (0.002)
R^2	0.875

Note: Heteroscedastic consistent standard errors in brackets.

** and * denote that the estimates are significant at 1% and 5% respectively.

refined petroleum products and nuclear fuel (ISIC Rev. 3 code 23); Chemicals and chemical products (ISIC Rev. 3 code 24); Rubber and plastics products (ISIC Rev. 3 code 25); Other non-metallic mineral products (ISIC Rev. 3 code 26); Basic metals and fabricated metal products (ISIC Rev. 3 code 27t28); Machinery and equipment, n.e.c. (ISIC Rev. 3 code 29); Electrical and optical equipment (ISIC Rev. 3 code 30t33); Transport equipment (ISIC Rev. 3 code 34t35); Manufacturing n.e.c. and recycling (ISIC Rev. 3 code 36t37)

[9] The countries are: Australia, Denmark, Finland, France, Italy, Japan, the Netherlands, Spain, the UK and the USA.

The coefficients' estimates of the TFP growth regression are given in Table 1. The foreign R&D spillovers have the expected significant and positive effect on the domestic technological progress. The coefficient of the technological competition proxy ($\Delta \log \mathrm{RTFP}_{jit}$) is positive and significant. A positive change in the position of a country to the technological frontier due to technological competition is positively related to country's technological progress. The suspected endogeneity of the relative TFP variable was not detected after performing Hausman test with the period change of R&D expenditures of the frontier country (USA) as instrumental variable. Price competition appears to have no significant effect on technological change. Thus, we find no evidence to support Wood's idea (Wood, 2004, 2005) of defensive technological change under import price competition.

The second stage estimates give the mandated change of the prices of the production factors *ls*, *ms*, and *hs* , respectively, relative to the price of the production factor *c*, due to the underlying factors. We estimate if the effect of the relative TFP as an underlying factor on the TFP growth in a country, which appeared significant in the first stage of the TFP growth regression, mandates a change in wage inequality by comparing the coefficients of the various labour factors. By intuition, if inequality increases, then the skill-intensive sector gains in profitability from the effect of the underlying factor on TFP growth, which is reflected in the increase of the reward to the intensively used factor-skilled labour. The connection between the sector-wise and the factor-wise effect is established by the cost share θ_{jit} of factor j in industry *i*, which is larger when the factor is relatively more intensively used. The effect of the underlying factor on wage inequality exists either because the underlying factor caused effects biased to the skill-intensive sector or because it caused an effect that is concentrated in one sector, otherwise biased to one of the production factors.

Because in the second stage we use the first-stage estimate instead of the actual effect of the underlying factor on the domestic price or TFP change which cannot be measured, we correct the second-stage standard errors by applying the methodology developed in Dumont *et al*. (2005), in order "to account for the additional variance of the first stage estimation" (Dumont *et al*., 2005).

The F-test on the second stage model of foreign technological competition determinant of technological change reported significant fixed cross-section and period effects. The country-specific intercepts are indication of intra-OECD divergence in income inequality that would be caused by the technological progress induced by the technological competition. However, we find no strong evidence on the change in wage inequality from the effect of technological competition on technological progress (see Table 2). The coefficients are of the expected sign that would have indicated an increased profitability of the skilled-intensive sectors due to the indirect effect of trade in innovation-intensive goods.

Table 2. Stage-two TFP growth regression

	$\hat{\alpha}_4 \Delta\log \mathrm{RTFP}_{\mathrm{jit}}$	$\hat{\alpha}_{as}\Delta\log p_{asnics,it}$ / $p_{ji,baseyear}$	$\hat{\alpha}_{dev}\Delta\log p_{asdev,it}$ $p_{ji,baseyear}$	$\hat{\alpha}_{lat}\Delta\log p_{latnics,it}$ $p_{ji,baseyear}$
$\Delta\log w_{hs} - \Delta\log$	0.057 (0.003)	-0.000 (-0.001)	-0.000 (-0.002)	-0.001 (-0.011)
$\Delta\log w_{ms} - \Delta\log$	-0.031 (-0.009)	0.000 (0.032)	0.000 (0.020)	0.000 (0.001)
$\Delta\log w_{ls} - \Delta\log$	-0.017 (0.000)	0.000 (0.009)	0.000 (0.014)	0.000 (0.004)
$\Delta\log w_c$	0.007 (0.003)	-0.000 (-0.014)	-0.000 (-0.048)	0.000 (0.021)
R^2	0.585	0.011	0.006	0.098
Note	Heteroscedastic-consistent t-statistics in brackets, based on corrected standard errors	t-statistics in brackets, based on corrected standard errors	t-statistics in brackets, based on corrected standard errors	t-statistics in brackets, based on corrected standard errors

We estimate the stage-one price regression with LSDV specification with country, industry and time dummies, after performing Hausman specification test and F-test for the join significance of the individual and time effects. The estimation results (Table 3) report that TFP growth has a negative and significant effect on the change of the domestic prices with a pass-through of 0.59 in absolute value. The change in the prices of the imported goods from the Asian developing countries has a significant but negative effect on the domestic price change. This reflects an impact of Asian price competition on non-price competitive factors (quality, design, etc.) in the OECD countries, which allows these even to increase their price due to product differentiation. In the second stage of the price regression (Table 4) we find no evidence of the price effect of trade with the Asian developing countries on the wage differential.

Table 3. Price stage-one regression, dependent variable: $\Delta \log p_{jit}$

$\Delta \log p_{oecd,it}$	-0.007 (0.013)
$\Delta \log p_{asnics,it}$	0.007 (0.016)
$\Delta \log p_{asdev,it}$	-0.029 (0.012)*
$\Delta \log p_{latnics,it}$	-0.018 (0.013)
$\Delta \log TFP_{jit}$	-0.592 (0.260)*
R^2	0.586

Note: Heteroscedastic consistent standard errors in brackets; * denotes that the estimates are significant at 5%

Table 4. Stage-two price regression

	$\hat{\alpha}_{as} \Delta \log p_{asnics,it}$	$\hat{\alpha}_{dev} \Delta \log p_{asdev,it}$	$\hat{\alpha}_{lat} \Delta \log p_{latnics,it}$
$\Delta \log w_{hs} - \Delta \log w_c$	0.002 (0.004)	-0.002 (-0.007)	-0.016 (-0.020)
$\Delta \log w_{ms} - \Delta \log w_c$	0.002 (0.015)	-0.004 (-0.034)	0.000 (0.001)
$\Delta \log w_{ls} - \Delta \log w_c$	0.002 (0.006)	-0.011(-0.033)	0.002 (0.004)
$\Delta \log w_c$	-0.001 (-0.014)	0.005 (0.092)	0.003 (0.040)
R^2	0.012	0.007	0.079
Note	t-statistics in brackets, based on corrected standard errors	Heteroscedastic-consistent t-statistics in brackets, based on corrected standard errors	Heteroscedastic-consistent t-statistics in brackets, based on corrected standard errors

We find no evidence on the Stolper-Samuelson effect of trade with the developing and newly industrialized countries. On the other hand, the evidenced technological change from technological competition did not have a strong effect on the increase of the wage differential between the different types of labour in the analyzed sample of OECD countries, which would have indicated that the bias of the technological change towards the skilled-intensive sectors is determined by trade in innovation-intensive goods.

References

1. Aghion, P., Meghir, C., Vandenbussche, J. (2006) Growth, distance to frontier and composition of human capital, *Journal of Economic Growth,* 11, 2, 97-127.
2. Berstein, J., Mohnen, P. (1998) International R&D spillovers between U.S. and Japanese R&D intensive sectors, *Journal of International Economics*, 44, 315-338.
3. Capron, H., Cincera, M. (2001) Technological competition, economic performance and strategic behaviour of international firms, *Brussels Economic Review*, 169, 33-62
4. Cincera, M., Van Pottelsberghe de la Potterie, B. (2001) International R&D spillovers: A survey, *Brussels Economic Review*, 169, 3-32
5. Coe, D.T., Helpman, E. (1995) International R&D spillovers, NBER working paper 4444, National Bureau of Economic Research, Cambridge, MA
6. Cuyvers, L., Dumont, M., Rayp, G. (2003) Impact of international trade with Asian newly industrialized countries on wages in the European Union, *Asian Economic Journal*, 17,4, 361-382
7. Cuyvers, L., Dumont, M., Rayp, G., Stevens, K. (2003) Wage and employment effects in the EU, *Review of World Economics*, 139, 2, 248-275
8. Dinopoulos, E., Segerstrom, P. (1999) A Schumpetartian model of protection and relative wages, *The American Economic Review*, 89, 3, 450-472
9. Dumont, M., Rayp, G. , Thass, O., Willemé, P. (2005) Correcting standard errors in two-stage estimation procedures with generated regressands, *Oxford Bulletin of Economics and Statistics*, 67, 3, 421-433
10. Engelbrecht, H. (1997) International R&D spillovers amongst OECD economies, *Applied Economic Letters*, 4, 315-19
11. EU KLEMS (2007) *Growth and productivity accounts Version 1.0 Part I: Methodology*, http://www.euklems.org/, last visited on 12 November 2009
12. Feenstra, R., Hanson, G. (1997) Productivity measurement and the impact of trade and technology on wages: Estimates for the U.S., 1972-1990, NBER working paper 6052, National Bureau of Economic Research, Cambridge, MA
13. Feenstra, R., Hanson, G. (1999) The impact of outsourcing and high-technology capital on wages: Estimates for the United States, 1979-1990, *Quarterly Journal of Economics*, 114, 907-940
14. Grossman, G. M., Helpman, E. (1991) *Innovation and growth in the global economy*, Cambidge, MA: MIT Press
15. Haskel, J., Slaughter , M. J. (2001) Trade, technology and U.K. wage inequality, *The Economic Journal*, 111, 163-187
16. Helpman, E., Krugman, P. (1985) *Market structure and foreign trade*, Cambidge, MA: MIT Press

17. Keller, W. (1998) Are international spillover trade-related? Analyzing spillovers among randomly matched trade partners, *European Economic Review*, 42, 1469-1481
18. Krugman, P. (1996), Making sense of the competitiveness debate, *Oxford Review of Economic Policy,* 12, 3, 17-25.
19. Krugman, P.(1995) Growing world trade: Causes and Consequences, *Brookings Papers on Economic Activity*, 1, 25th Anniversary Issue,327-377
20. Leamer, E. (1996) In search of Stolper-Samulson effects on U.S. wages, NBER Working Paper 5427, National Bureau of Economic Research, Cambridge, MA
21. Lücke, M. (1998) Trade with low-income countries and the relative wages and employment opportunities of the unskilled-An exploratory analysis for West Germany and the UK. In P. Brenton and J. Pelkmans (eds.), *Global Trade and European Workers*, Basingstoke: Macmillan
22. Madden, G., Savage, S., Bloxham, P. (2001) Asian and OECD international R&D spillovers, *Applied Economics Letters*, 8, 431-435.
23. Nadiri, M. I. (1993) Innovations and technological spillovers, NBER Working Paper 4423, National Bureau of Economic Research, Cambridge, MA
24. Scarpetta, S., Tressel, T. (2002) Productivity and convergence in a panel of OECD industries: Do regulations and institutions matter?, OECD Economic Department working paper, 28, 342
25. UN Classification Registry, http://unstats.un.org/unsd/cr/registry, last visited in July 2009
26. Varian, H. (1992) Microeconomic Analysis, third edition, W. W. Norton & Company, Inc
27. Wood, A. (2005) How trade hurt unskilled workers, The Journal of Economic Perspectives, 9, 3, 57-80

Appendix: Data processing and measurement of the variables

The data on the variables are implicitly measured in logs, while the number of observations equals 260 (JxIxT), 160 of which refer to low-tech and 100 to high-tech two-digit ISIC Rev.3 industry groups. The observations are ordered by country, by industry, and by period.

TFP growth and relative TFP

The TFP in indices with 1995 as base year are extracted from the EU KLEMS database. The measurement of TFP (gross output-based) conforms with the way the variable is derived in the mandated wage equation. The data are translated from NACE Rev.1 to ISIC Rev.3 industrial classification, because of the need of this study of a world level rather than an EU level industrial classification.

R&D capital stock

The R&D capital stock industry level data are extracted from the EU KLEMS database, and as originally classified by the NACE Rev.1 classification, are translated into ISIC Rev.3 industrial classification. The R&D capital stock data originally expressed in millions of local currency are converted in Euro by using gross output-based industry-specific constant PPPs, with 1997 as a base year and Germany as a base country.

Domestic value added prices

The log change in value added prices is calculated by using price deflators VA with 2000 as base year from the OECD STAN industry database, edition 2008.

Unit value import prices

Unit value import prices were calculated by using the OECD ITCS data on the value of imports in current US dollars and by using the OECD ITCS data on imports in quantity units of a reporting country from 42 partner countries separately, at disaggregated, i.e. at the lowest, (5 digit) level of the SITC Rev 3 product classification. This method of computation of the unit value import prices is an improvement to the shift-share approach used in Cuyvers *et al.* (2003b). However, ITCS data at more detailed classification level (6 digit) are offered in the HS96 (Harmonized System 1996) product classification, but these can be obtained only for 1996 and onwards. The data on imports value were converted in Euro, by using gross output-based industry-specific constant PPPs, with 1997 as a base year and Germany as a base country.

The calculation of the unit value of imports is done at the lowest level since the quantity data, expressed in different (14) types of quantity units, cannot be simply aggregated at industry level. Also, in time, a type of a 5-digit level product class is expressed in a different but similar quantity unit, and a concordance of the units could be done where necessary (e.g. ‘9: Thousands of items’ (divide by 1000) into ‘5: Number of items’). Still, the different quantity units make it difficult for translation since some of these are not comparable, for example those for volume with those for mass (weight). An option was to take into consideration only the net weight data since it is the most common quantity unit for products, although this would have caused analysis of unit value import prices of a smaller sample of imported goods. Instead, we excluded unit value data when the quantity unit was different in the end dates of an analysed period. Missing values on the unit value of imports also resulted from missing data on imports quantity or value, or both. After calculation followed conversion of the unit value of imported goods data from SITC Rev. 3 into ISIC Rev.3 industrial classification, by using a conversion key provided by United Nations Statistics Division (UNSD) Classification Registry. Converted into industrial classification, a country's unit value imports matrix reflects the unit value of imports coming from a relevant industrial sector of the partner country that competes with the same sector’s products of the importing country (as according to the OECD Bilateral Trade database (BTD)).

Since the import unit value price *over time* cannot be measured as average of the unit value of *different* goods, the frequency of the classes of goods entering the translation into industry unit value was controlled to be the same for the two end dates of each analysed period. This allowed calculation of the change in the industry unit value of imports, for example, from 1988 to 1997, for the same group of products classes, grouped according to their industry of origin.

While data on total imports of a reporting OECD country from the rest of the OECD countries are available from the database, we summed the total imports from each of the Asian NICs, Asian developing countries, or Latin American NICs on a group level. This was possible especially because the imports data as a customs record of goods entering a country are all expressed in quantity units by using the same classification by the reporting country, in a certain period of time. Hence, the summed data on quantity and value of imported 5-digit level goods of a reporting country from different trading partners could be further used for calculation of the unit value of imports of the reporting country from the group of trading partners. Still, it is evident that the uncontained change in quality of the imported goods of a product class in the quantity data has impact on the larger change in the unit value of the imported class of goods over the analyzed period. Also, some product classes is better to be more disaggregated since the large period change in their calculated unit value may be influenced by the fact that these product classes include products with a large difference in value (for example, the class 72139: *Parts* for milking machines & dairy machinery, or class 74489: *Other* lifting, handling, loading, unloading machinery). Hence, the large period change of their calculated unit value may be due to a change in the imported pattern of units rather than a change in the value.

Note that due to a lack of imports data for the USA in 1988 we used data referring on 1989.

Factor shares of value added

The labour share of value added is mainly calculated using EU KLEMS data on labour compensation and value added at current prices in millions of national currency. The calculation of this variable is in accordance with the methodology used in the OECD STAN Indicators Database. As from the EU KLEMS data the labour compensation can be calculated for each type of labour, we calculated high-skilled, medium-skilled and low-skilled labour shares of value added. The data are translated from NACE Rev.1 to ISIC Rev.3 industrial classification.

Since labour compensation and capital compensation are the components of value added, the capital compensation in the EU KLEMS database is derived as a residual (nominal value added minus labour compensation). Total labour compensation in the EU KLEMS database refers to total gross wages, i.e. the sum of compensation of employees, compensation of the self-employed and taxes on production allocated to labour inputs. The compensation of the self-employed is estimated by assuming that compensation for one hour worked by a self-employed equals the hourly compensation of employees. As this is done at industry level, industries with a large share of self-employed may show higher total labour compensation than value added. Hence, the capital compensation, as a residual, may become negative (EU KLEMS, 2007). We set to zero all negative values of the capital compensation.

For each period (from 1988 to 1997 and from 1997 to 2003), the factor shares of value added are calculated as averages between the start and the end date percentage shares.

R&D expenditures of the frontier country

The data are collected from the OECD ANBERD database, 2006. The data originally expressed in national currency are converted in Euro by using gross output-based industry-specific constant PPPs, with 1997 as a base year and Germany as a base country.

The industries were translated into STAN ISIC Rev.3 industrial classification.