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ESTIMATING THE IMPACT OF SBTC ON INPUT DEMAND ELASTICITIES IN HUNGARY

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Abstract

Recent changes in the distribution of income have drawn significant attention to the changing relationship between factors of production in the aggregate production function. These changes entail corresponding changes in factor rewards and relative income levels. This paper examines how the position and income of skilled labour relative to unskilled labour have changed during the recent years in Hungary. A popular explanation to their changing position is offered by the concept of skill biased technological change (SBTC) that increases relative demand for skilled labour and can be captured through capital-skill complementarity.

In this paper, own- and cross-price elasticities of factor demand are derived from a flexible functional form: a translog cost function. The estimation is based on aggregate time series data for capital, skilled labour and unskilled labour in the Hungarian economy between 1980 and 2002.

Keywords: skill premium, translog, cost function

JEL codes: E25, F20, J31

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Introduction

Empirical studies have pointed out a substantial rise in wage and income inequality in both developed and developing countries during the past decades. The main sources of wage inequality are educational wage differentials, occupational (physical and non physical), age related and within group inequality (which means growing wage differentials even within the same age, education and experience groups). (Katz and Murphy, 1992) A possible explanation for the increase in wage inequalities is that they result from changes in the demand and supply for skilled and unskilled labour. As a result of this process, factor rewards have changed and the skill premium – defined as the ratio of the wage of skilled labour to the wage of unskilled labour – has increased.

In many countries, the skill premium and the relative quantity of skilled labour employed increased at the same time. This phenomenon seemingly contradicts the law of supply, i.e. an increase in the supply of skilled labour should result in lower wages for skilled labour, other things being constant. Therefore it is reasonable to assume that factors other than supply are responsible for the increasing skill premium and they are significant enough to over-compensate the negative impact of increasing supply of skilled labour on the skill premium.

Several attempts have been made in the literature to explore the fundamental causes of these changes. The literature offers two major explanations to these structural changes: numerous studies demonstrate the effects of increased factor movements (trade hypothesis), and skill biased technological change (SBTC). The effect of organisational changes is also emphasised in the literature. This latter group of explanations suggests that changes in pay norms, minimum wage and in the role of unions are responsible for changes in relative wages. (Aghion and Williamson, 1998, Brunello et al., 2001)

The Hecksher-Ohlin theorem explains how increased factor mobility – including trade and FDI – affects wages. Countries specialise in the production of commodities, which use intensively factors of production they are abundantly endowed with. The assumption of the model is that developing countries are abundant in unskilled labour but scarce in skilled labour, thus tend to export goods that are intensive in unskilled labour. Developed countries are relatively abundant in skilled labour and export goods that are intensive in skilled labour. The trade hypothesis suggests that increasing imports from developing countries decreases production in unskilled-labour-intensive industries in the developed country and that there is a general shift towards sectors that are intensive in education and skill rather than in physical labour. Increased trade and trade liberalisation induce a reallocation of labour from low to high skill industries in skill abundant countries. This increases demand for skilled labour while employment and wages of unskilled labour decrease. As such, trade liberalisation increases both relative wages and demand for skills in developed countries at the same time. Feenstra and Hanson (2001) provide a review of the studies that estimate the importance of these effects.

Another popular explanation offered by labour economists is the concept of skill biased technological change (SBTC). SBTC impacts the demand side of the labour market in such a way that favours those jobs that require higher skill levels. More skilled or better-educated workers are needed to operate the new generations of machinery and equipment, thus the introduction of new, more effective technologies may entail structural changes in labour demand. When technological change is skill biased, relative demand for skilled labour increases as the level of technology increases. This means that both the relative supply and relative wages of skilled labour may increase at the same time.

Many attempts have been made in the literature to explore the possible causes of SBTC but there is no standard theory to interpret the mechanism. One approach is to include SBTC as an unobservable trend change that explains changes in increased wage inequality that can not be explained on the basis of observed changes in input or output prices. A possible way to explicitly represent and examine SBTC in the production function is through the mechanism of capital-skill complementarity. This was first formalised by Griliches in 1969 and since then many studies have provided evidence for and against it. (See for example Berman et al., 1998, Card and DiNardo, 2002, DeSantis, 2002, Fallon and Layard, 1975, Goldin and Katz, 1996, Haskel and Slaughter, 1999, Juhn et al., 1993)

In this model, capital-skill complementarity can be directly examined through the estimation of substitution elasticities between the factors of production. The basic framework contains three factors of production – capital equipment, skilled labour and unskilled labour. The main assumption is that capital equipment and unskilled labour are perfect substitutes while capital equipment and skilled labour are considered as complementary factors. The skill premium is calculated according to the neoclassical assumption that each factor of production is paid its marginal product. If all the other variables are kept constant, an increase in the stock of capital equipment increases the marginal productivity of skilled labour and decreases the marginal productivity of unskilled labour, which results in an increase in the skill premium. (Griliches, 1969)

There is ample of evidence that since the beginning of the transition period, similar processes have taken place in the Hungarian economy. Foreign direct investment (FDI) played a dominant role in the restructuring of the economy through the provision of capital, advanced technologies and managerial know-how. (Kaminski and Riboud, 2000, Szanyi, 2002, Kroska, 2001, Hovley et al., 1996, Barrell and Holland, 2000) Empirical evidence suggests that FDI was mainly attracted to regions where well educated, skilled labour was readily available. Demand for skilled labour and the skill premium increased significantly. Wages of the well-educated young skilled workers increased the most. FDI was one of the main factors to increase demand for skilled labour. (Ábrahám and Kézdi, 2000, Fazekas, 2003, Kertesi and Köllő, 2001, Kőrösi, 1997) Since FDI increased demand for skilled labour in part through the introduction of new production technologies, it is reasonable to assume that it contributed to SBTC. A study by Kézdi (2002) also supports this assumption and provides evidence that SBTC took place, especially in the second period of transition.

This paper attempts to examine the effects of possible SBTC through capital-skill complementarity. The paper proceeds as follows. A brief literature review is presented in Section 2 for the purpose of modelling and methodological comparisons. The main features of the data are discussed in Section 3. The analytical framework is derived in Section 4. The estimation procedure and the resulting elasticities from the experiments are reported in Section 5. Section 6 concludes the paper.

Literature review

There is a large number of studies that examine substitutability between technology and factors of production. (See for example Berndt, 1991, Binswanger, 1974, Card and DiNardo, 2002, Devroye and Freeman, 2001, Greenwood et al., 1997, Griliches, 1969, Krusell et al., 1997, Kohli, 1991, 1993, 1994, Stone et al., 2002, Tombazos, 1999, 2003a) They use different samples (containing data for the manufacturing sector or the whole economy), different definitions for skilled and unskilled labour (ranging from only broad occupational categories to groups defined on education-experience-position) and different assumptions regarding the production function (from CES to flexible functional forms). Hamermesh (1993) provides a detailed review of many of these studies.

Most of the studies that are included in his review are based on data for manufacturing, where data is more readily available. (In this context, terms of production and non-production labour are used as proxies for blue collar (physical) and white collar (non-physical) employment.) These studies provide evidence that in many cases capital and non-production labour are relative price complements, and that the price elasticity of unskilled labour with respect to capital is higher than that of skilled labour with respect to capital. They also agree on that the own-price elasticity of production labour is higher in absolute value than the own-price elasticity of non-production labour. This means that demand for production workers reacts more to its price changes and production workers are in a more sensitive position compared to their skilled counterparts.

The most important reference point for comparison of estimates of Hungarian elasticities is a study by Kertesi and Köllő (2002) that uses a translog cost function to estimate, among other things, substitution elasticities between capital, unskilled labour, old-skilled labour and young-skilled labour in Hungary. Their study is based on cross-panel data for the years of 1992-1999. (Detailed employment and wage data is available only after 1992.) Their estimates of the own- and cross-price elasticities of unskilled, young-skilled and old-skilled labour and capital are summarised in Table 1.

Concerning own price elasticities, for the three types of labour they found values around zero and some positive values around 1992-1995. After that own-price elasticities started to decrease reaching -0.5 to -1 for skilled labour and -1 to -1.5 for unskilled labour. The own price elasticity of capital exhibited significantly negative values during the sample period, with the lowest values occurring between 1992-1996.

The study also found that skilled and unskilled labour were price complements in this period. All types of labour exhibited substitutability with capital, however they suggest that because of the statistical insignificance of the parameters used in the calculation of these elasticities, only small substitution values occurring in the later part of the sample should be accepted credible. Their main conclusion supports *relative* capital-skill complementarity as the elasticity of substitution between capital and unskilled labour is higher than that of capital and skilled labour.

Although these findings confirm the results of the literature, they should be interpreted with care. First, the unreliability of capital-stock data sheds doubt on the reliability of the estimates. The authors admit that their estimation might suffer from the mismeasurement of the capital stock and capital cost data. (Kertesi and Köllő 2002, pg. 7.) Second, the authors do not report whether their results satisfy concavity conditions of the underlying cost function. Since some positive eigenvalues occur in some years for the matrices of the elasticity estimates reported, it is reasonable to assume that concavity of the cost function does not hold. (The importance of violating curvature conditions is discussed in detail in the next section.)

Because of these reasons, the main purpose of this paper is to derive elasticity estimates from a more reliable capital stock data covering a longer period, that also satisfy the curvature conditions required by the cost function.

Analytical framework

The translog functional form was originally developed as a flexible approximation to the CES production function. The main advantage of using such a simple flexible form is that it does not require any a priori restrictions and assumptions on the possible relationship between the factors of production. This implies that the estimates are not biased by any preliminary assumptions regarding factor substitutability. (Greene, 2000)

The derivation of the translog cost function follows Berndt (1991) though numerous studies specify the function in a similar manner. For the three inputs of capital, skilled labour and unskilled labour the translog cost function is expressed by (1):

$$\ln C = \alpha_0 + \alpha_k \ln P_k + \alpha_s \ln P_s + \alpha_u \ln P_u +$$
$$\frac{1}{2}\gamma_{kk} \ln P_k \ln P_k + \frac{1}{2}\gamma_{ks} \ln P_k \ln P_s + \frac{1}{2}\gamma_{ku} \ln P_k \ln P_u +$$
$$\frac{1}{2}\gamma_{sk} \ln P_s \ln P_k + \frac{1}{2}\gamma_{ss} \ln P_s \ln P_s + \frac{1}{2}\gamma_{su} \ln P_s \ln P_u +$$
$$\frac{1}{2}\gamma_{uk} \ln P_u \ln P_k + \frac{1}{2}\gamma_{us} \ln P_u \ln P_s + \frac{1}{2}\gamma_{uu} \ln P_u \ln P_u + \quad (1)$$
$$\alpha_Y \ln Y + \frac{1}{2}\gamma_{YY} (\ln Y)^2 +$$
$$\gamma_{kY} \ln P_k \ln Y + \gamma_{sY} \ln P_s \ln Y + \gamma_{uY} \ln P_u \ln Y$$

Where C denotes total cost, Y is output, and P_i is the price of input i. (i =k, s, u).

According to Shephard`s Lemma, the optimal cost minimising demand for an input can be derived through differentiation of the cost function with respect to its price. As shown by equation 2, in case of the translog cost function this equals the cost share of input *i*.

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{P_i}{C} * \frac{\partial C}{\partial P_i} = \frac{P_i X_i}{C} = S_i; \quad (2)$$

Where X_i measures the quantity of input *i*. Monotonicity of the partial derivatives requires the LHS of (2) be positive. For the inputs of capital, skilled and unskilled labour differentiation of (1) with respect to ln P_i yields the following equations:

$$\frac{\partial \ln C}{\partial \ln P_k} = S_k = \alpha_k + \gamma_{kk} \ln P_k + \gamma_{ks} \ln P_s + \gamma_{ku} \ln P_u + \gamma_{kY} \ln Y$$
$$\frac{\partial \ln C}{\partial \ln P_s} = S_s = \alpha_s + \gamma_{ks} \ln P_k + \gamma_{ss} \ln P_s + \gamma_{su} \ln P_u + \gamma_{sY} \ln Y \quad (3)$$
$$\frac{\partial \ln C}{\partial \ln P_u} = s_u = \alpha_u + \gamma_{ku} \ln P_k + \gamma_{su} \ln P_s + \gamma_{uu} \ln P_u + \gamma_{uY} \ln Y$$

Thus the system of cost share equations for the three inputs is expressed by (3), where the cost-shares must sum up to one. The equality of cross derivatives is ensured through the imposition of the following symmetry criteria:

$$\gamma_{ks} = \gamma_{sk} \qquad \gamma_{ku} = \gamma_{uk} \qquad \gamma_{su} = \gamma_{us} \quad (4)$$

As the cost-shares sum up to one, only two of the three equations are independent. Linear homogeneity is imposed through the following conditions on the estimated values of α_i (a_i) and γ_i (g_i):

$$
\begin{aligned}
&a_k + a_s + a_u = 1 \\
&g_{kk} + g_{ks} + g_{ku} = 0 \\
&g_{ss} + g_{su} + g_{sk} = 0 \\
&g_{uu} + g_{uk} + g_{us} = 0 \\
&g_{kY} + g_{sY} + g_{uY} = 0
\end{aligned}
\qquad (5)
$$

Stochastic specification of the function is done through adding a random disturbance term to each cost-share equation. It is assumed that the vector of $\{\varepsilon_k, \varepsilon_s, \varepsilon_u\}$ is multivariate, normally distributed, with a mean vector of zero and with a constant covariance matrix. As the cost share equations sum up to one and only two of them are linearly independent, the sum of random errors sums up to zero for each observation. Because of these properties, the covariance matrix is singular and non-diagonal.

A commonly applied procedure to overcome the problem of singularity is to drop one cost-share equation from the system. This way, only two equations need to be directly estimated. The parameter estimates give the same result regardless of the choice of which equation is to be dropped. In the case that the cost-share equation of unskilled labour is dropped, after the imposition of symmetry and constant returns to scale the two equations to be estimated are:

$$
\begin{aligned}
&S_k = \alpha_k + \gamma_{kk} \ln(P_k / P_u) + \gamma_{ks} \ln(P_s / P_u) \\
&S_s = \alpha_s + \gamma_{ks} \ln(P_k / P_u) + \gamma_{ss} \ln(P_s / P_u)
\end{aligned}
\qquad (6)
$$

From the estimated coefficients of the system of equations in (7), Allen-elasticities of substitution[1] can be derived through calculating:

$$\sigma_{ij} = (\gamma_{ij}+S_iS_j)/(S_iS_j) \quad \text{and} \quad \sigma_{ii}= (\gamma_{ii}+S_i^2-S_i)/S_i^2 \qquad (7)$$

Own- and cross-price elasticities of demand are calculated according to:

$$\varepsilon_{ij}= (\gamma_{ij}+S_iS_j)/S_i \quad \text{and} \quad \varepsilon_{ii}= (\gamma_{ii}+S_i^2-S_i)/S_i \qquad (8)$$

In addition to these point estimates of substitution elasticities, confidence intervals can also be constructed following a method suggested by Anderson and Thursby (1986). However, it must be emphasised that since the estimated coefficients are used together with the cost shares in calculating elasticities, magnitude of the cost shares asserts significant influence on the elasticity values. (Frondel and Schmidt, 2003)

It should be noted that there are a number of difficulties associated with the translog functional form. The function is not necessarily concave or monotonically increasing in input prices.

When the estimation is based on minimising a cost function, underlying economic theory requires that the function is concave in input prices. This expresses that the demand curve slopes downward as costs are minimised, which is a basic assumption in the model. However, estimates derived from a translog specification very often fail to satisfy concavity of the cost function. There are a number of studies emphasising the importance of curvature conditions and derive methods for checking and reinforcing them. (See Ryan and Wales, 2000, Diewert and Wales, 1987, Morey, 1986, Tombazos, 2003a, b, Kohli, 1991, 1994) There are a number of techniques available to impose curvature conditions locally, but they often fail to result in proper estimates globally. Using a method that was developed by Wiley, Schmidt and Bramble (1973) the imposition of curvature conditions locally delivers results that satisfy curvature conditions globally in most cases. However, even this procedure is shown to endanger the flexibility of the function, as it may eliminate the possibility for a complementary relationship between inputs in the whole sample (Kohli 1991, Tombazos, 2003b) or the reparametrised function may become

[1] The Allen elasticity of substitution measures the proportionate change in the ratio of quantities of factors employed given a proportionate change in the ratio of their prices. (Tombazos 1999.) For a more detailed explanation see Ghosh, S. K. (1991) *Econometrics - Theory and applications,* Englewood Cliffs, Prentice-Hall, Inc.

Cobb-Douglas for some observations. (Diewert and Wales, 1987) In such cases, choice of other functional forms might serve the estimation purposes better.

Data

Data on the quantities and prices of the three factors of production is required for the estimation of the elasticities. This means data on the aggregate capital stock, price of capital, wages of skilled and unskilled labour, and number of people employed in the skilled and unskilled categories are needed for the full period. The sample period is set from 1980 to 2002, in order to capture the effects of changes before 1992 as well.

Data was derived from four main sources. Macroeconomic data was derived from the National Accounts of Hungary. The Hungarian National Labour Centre's Labour force survey provided data on the number of employees and wages from 1992. For years before that, Statistical Yearbooks published by the Central Statistical Office of Hungary were used for both employment data and national accounts statistics. Wages of manual and non-manual employees were collected from the Statistical Yearbooks from 1980-1992. In those years when wages of manual and non-manual workers had not been not explicitly reported, aggregate wages were calculated in both categories using manual and non-manual wages in separate industries and were weighted according to the share of the industry in total employment. To approximate the total cost of labour, company social security contributions and taxes paid by employers were added to gross wages. Data on employment is more readily available than on wages. The average number of manual and non-manual employees is used as a proxy quantitative measure of skilled and unskilled labour.

However, including more years in the sample comes at the cost of using less detailed employment data. The Wage Survey that contains such detailed data according to highest education, years of experience, occupational position, etc. is available only from 1992. For the full period of 1980-2002, wage and employment figures for all sectors of the economy are available in the broadest categorisation for manual and non-manual categories only. (These categories are equivalents of physical (blue collar) and non-physical (white collar) employment.) Therefore skilled and unskilled labour in this paper are defined on the basis of these categories, with unskilled labour referring to people employed in manual positions and skilled labour employed in non-manual positions.

Undoubtedly, the availability and reliability of the data limit the scope of research and the reliability of results. It is even more difficult to obtain data on the capital stock, as the Hungarian Statistical Office stopped publishing capital-stock data in the early 1990s due to inefficiencies in the method employed to construct data. (Darvas and Simon, 2000 and Pula, 2003 for details.) One of the motivations of this paper is to make use of a more reliable, consistent capital stock data that was constructed by the National Bank of Hungary for the years of 1980-2002. The price of capital was calculated indirectly, from the national accounting identity. Total output data was constructed through the Tornquist aggregation of categories of consumption, investment and exports. (This equals the sum of payments to domestic factors of production, and imports on the sources side.) Net capital expenditure is defined as the difference between the sum of wages and imports and total output. The price of capital is derived by dividing capital expenditure by the capital stock.

Descriptive statistics of the data are reported in Table 2. Figures 1 and 2 show the evolution of the cost shares and the skill premium. According to Figure 1, capital exhibited the highest cost share during the whole period. The share of unskilled labour has been continuously decreasing , while that of skilled labour has been continuously increasing. From 1991, the share of skilled labour of the total cost of production has been higher than the share of unskilled labour. Figure 2 shows a steady increase in the skill premium through the whole period. By the end of the period its value has nearly doubled. Egger and Stehrer (2003) suggest, that this increase would have been even more significant without outsourcing and downstream processing of imports that generated demand for unskilled labour.

Estimation Procedure and Results

The system of cost share equations was estimated using Zellner's seemingly unrelated regressions (SUR) method. The SUR method offers an efficient solution to handle potentially correlated disturbances and multiple regressors across the system of equations. (Berndt 1991.) The data was adjusted through the Cochrane-Orcutt procedure to eliminate serial correlation. The R^2 - value[2] of the model indicates a fairly good fit with a value of 0.96.

Parameter estimates derived from estimating the system of equations in (6) are reported in Table 3.[3] Average Allen-substitution elasticities calculated at sample means were derived from these parameter estimates according to (7) and are listed in Table 4. Price elasticities derived from the original system of equations are reported in Table 5. Many of the elasticity values calculated at sample means are statistically insignificant and they exhibit sign reversals.

Also, as mentioned in the previous section, concavity in input prices must be examined at each observation for a translog cost function before we can interpret these results. Concavity of the function can be checked through calculating the eigenvalues of the substitution elasticity matrices for each year. Concavity prevails if all the substitution matrices are negative semidefinite, i.e., no positive eigenvalues occur. Since elasticity estimates calculated from the coefficients in Table 3 violate concavity in some years – i.e. positive eigenvalues occurred – reparametrisation of the estimated equations was necessary on both sample periods.

Reparametrisation of the estimated equations was done through imposing additional criteria on the coefficients, using a method that was developed by (Wiley et al., 1973) as adopted in Kohli (1991)[4].

The matrices of substitution elasticities for each observation are calculated as:

$$E = \begin{bmatrix} \frac{\gamma_{ss} + s_s^2 - s_s}{s_s^2} & \frac{\gamma_{sk} + s_s + s_k}{s_s s_k} & \frac{\gamma_{su} + s_s + s_u}{s_s s_u} \\ \frac{\gamma_{sk} + s_s + s_k}{s_s s_k} & \frac{\gamma_{kk} + s_k^2 - s_k}{s_k^2} & \frac{\gamma_{uk} + s_u + s_k}{s_u s_k} \\ \frac{\gamma_{su} + s_s + s_u}{s_s s_u} & \frac{\gamma_{uk} + s_s + s_u}{s_u s_k} & \frac{\gamma_{uu} + s_u^2 - s_u}{s_u^2} \end{bmatrix} \qquad (9)$$

[2] Using Berndt`s adjusted R^2 measure for *systems* of equations Berndt, E. (1991) *The practice of econometrics*, Addison - Wesley.

[3] Although the data does not allow for a proper testing of structural break, the estimations were carried out on two sample periods: 1980-2002 and 1992-2002, to test if there is systematic difference between the elasticities derived from the two periods.

[4] For a detailed explanation of this procedure see Kohli (1991), p 110.

Since $s_j = \beta_j + \Sigma\gamma_{jk}\ln(w_k)$, after normalisation of wages for a given year, matrices of $\beta \equiv \lfloor \beta_j \rfloor$, $B \equiv diag(\beta)$, and $\Lambda \equiv B\Sigma B$ can be derived, where Λ has the form:

$$\Lambda \equiv \begin{bmatrix} \gamma_{11} + \beta_1^2 - \beta_1 & \gamma_{1j} + \beta_1\beta_j & \gamma_{1J} + \beta_1\beta_J \\ \gamma_{j1} + \beta_j\beta_1 & \gamma_{jj} + \beta_j^2 - \beta_j & \gamma_{jJ} + \beta_j\beta_J \\ \gamma_{J1} + \beta_J\beta_1 & \gamma_{Jj} + \beta_J\beta_j & \gamma_{JJ} + \beta_J^2 - \beta_J \end{bmatrix} \tag{10}$$

It is then a sufficient and necessary condition for Σ to be negative semidefinite that Λ is negative semidefinite and can be written in the form of: Λ= -TT'. This can be ensured by replacing the coefficients of the estimated equations by:

$$\begin{aligned} \gamma_{11} &= -(\tau_{11}^2 - \beta_1^2 + \beta_1) \\ \gamma_{12} &= -(\tau_{11}\tau_{22} - \beta_1\beta_2) \\ \gamma_{13} &= -(\tau_{11}\tau_{13} - \beta_1\beta_3) \\ \gamma_{22} &= -(\tau_{12}^2 + \tau_{22}^2 - \beta_2^2 + \beta_2) \\ \gamma_{23} &= -(\tau_{12}\tau_{13} + \tau_{22}\tau_{23} - \beta_2\beta_3) \\ \gamma_{33} &= -(\tau_{13}^2 + \tau_{23}^2 - \beta_3^2 + \beta_3) \end{aligned} \tag{11}$$

Symmetry and linear homogeneity must be also imposed on the new parameters. The starting point for the procedure is normally the observation where the violation is most severe. Through the estimation of the new parameters local concavity can be ensured, but global concavity may not prevail. However in most cases, according to Kohli (1991), after the first round of reparametrisation concavity is fulfilled for all observations.

Parameter estimates derived from the reparametrised equations are summarised in Table 3. Average Allen elasticities of substitution calculated from these coefficients at sample means are reported in Table 4.

Although some of these values might look rather high for a substitution elasticity figure, they are normal compared to other studies that derive Allen-elasticities from a translog specification. (See for example Berndt, 1991 on p 475.) After checking the eigenvalues of the new substitution elasticity matrices we can conclude that no positive eigenvalues occur that are significantly different from zero. Therefore with the coefficients reported in Table 3, concavity holds for the cost function. These substitution elasticities also pass the criteria on monotonicity: the sum of substitution elasticities between any factor and the others is positive. (Stone and Laplagne, 2001) Conditions of:

$S_k\sigma_{sk}+S_u\sigma_{su}>0$; $S_s\sigma_{sk}+S_u\sigma_{ku}>0$ and $S_s\sigma_{su}+S_k\sigma_{ku}>0$

are all fulfilled by these estimates.

Price elasticities are calculated from the new parameters according to (8). Their average values calculated at the sample means together with their standard error are reported in Table 5. Annual values of the price elasticities are reported in Figures 3 and 4[5].

All the price elasticities derived this way are "well-behaving": all the own-price elasticities are negative, while cross-price elasticities are all positive, suggesting substitutability between all factors of production. However, this behaviour warns that these results might be distorted by the reparametrisation procedure.

Capital exhibited the lowest own-price elasticity in absolute terms and was fairly stable during the whole period with values between -0.85 and -0.68. This suggests that demand for capital was stable and inelastic, which indicates its importance in economic restructuring. The own-price elasticity of skilled labour decreased until 1992 from -1.72 to -1.28 and after this stabilised at around -1.35, which shows that the demand for skilled labour became less responsive to the increase in its price during this period. This might be the result of increasing demand for skilled labour as suggested by the literature. The hypothesis that the transition placed skilled labour in a more favourable position relative to unskilled labour is supported by these results. The own-price elasticity of unskilled labour is the highest among the factors of production, showing that demand for unskilled labour reacted most sensitively to changes in its price. With a starting value of -1.44 in the beginning of the period, demand for unskilled labour was less responsive to changes in its price than demand for skilled labour. However, by the end of the period its own-price elasticity reached -2.15, which shows a more responsive position both in relative terms to skilled labour and in absolute terms. It suggests that, as a result of technological advancement it was no longer necessary to maintain the same level of unskilled labour employed in production.

[5] It must be noted that these price elasticities pertain to different P and Q values from year to year

The cross-price elasticities are positive between all inputs in all of the observed years. The lowest cross-price elasticity values mark the relationship between skilled and unskilled labour. Its value decreased continuously during the whole period showing that skilled labour became less substitutable with unskilled labour. Again, a possible explanation might be that unskilled workers could not substitute for skilled workers in production under increasingly advanced technology.

Capital and skilled labour also exhibited positive values in all years, thus rejecting the hypothesis of absolute capital-skill complementarity. The price-elasticity of skilled labour with respect to capital decreased from 1.22 to 0.92 and stabilised around unit elasticity by the end of the period. Therefore, it was still possible to substitute skilled labour for capital in production, but to a lesser extent over the transition period. Unskilled labour and capital produced the highest elasticity values that increased from 1.18 in the beginning of the period to 1.75 by 1998 and decreased afterwards. These positive elasticity values could be explained in relation to the patterns of FDI. Before the economic transition started, capital was scarce and unskilled labour was used as substitute for capital equipment. After 1990, Hungary received a large amount of FDI. Many of these investment projects were motivated by the availability of cheap labour and foreign owners moved the labour intensive part of their production to Hungary, where both skilled and unskilled labour was much cheaper. This explains why both skilled and unskilled labour were closer substitutes for capital during this period.

Since the price elasticity between capital and skilled labour is smaller than that of capital and unskilled labour, unskilled labour is relatively more easily substitutable for capital than skilled labour. These results confirm *relative* capital-skill complementarity and suggest that the technological development that took place during the period increased the demand for, and the wages of skilled labour relative to unskilled labour. Positive price elasticity values between capital and both types of labour also support the findings of the Kertesi-Köllő study. However, estimates of the price elasticity of skilled labour with respect to unskilled labour and the own-price elasticities presented in this paper contradict their findings. Most importantly, relative capital-skill complementarity is confirmed by both studies.

Results derived from the 1992-2002 sample confirm the results derived from the estimation on the full period: all the own-price elasticities are negative and the factors of production are found to be substitutes in production. Since the sizes and magnitudes of these price elasticity estimates are nearly identical, they reinforce the conclusions drawn above. Comparison of the estimates from the reparametrised model on the full sample and only the second half of the sample suggests that the structural break did not change the relationship between the inputs of production significantly.

Conclusions

This paper investigates the potential effects of SBTC on the demand for skilled and unskilled labour through capital-skill complementarity in Hungary during the 1980-2002 period. Although the available data does not allow for proper examination of a structural break, to test whether the relationships between the factors of production changed significantly the system of equations was also estimated on a sample from 1992-2002. Results turned out to be similar in both cases.

Input demand elasticities were estimated using a three-factor translog cost function that allows for time-varying inference of elasticities. After curvature-reinforcing reparametrisation of the estimated system of equations was applied, estimation of the model resulted in statistically significant parameter estimates that also ensured concavity of the cost function. Own- and cross Allen-elasticities of substitution and price elasticities were derived from the coefficients to enable the analysis of SBTC and capital-skill complementarity.

Both the Allen- and price-elasticities of substitution were "well-behaving": the own-substitution elasticities were all negative while the cross-elasticities were all positive for all observations. Capital and skilled labour were substitutes throughout the period, thus *absolute* capital-skill complementarity is rejected. However, the elasticity of substitution between unskilled labour and capital was much higher. This means that it was easier to substitute unskilled labour for capital than skilled labour and suggests *relative* capital-skill complementarity.

Although these results are significant and correspond to the findings of similar studies in the literature, they must be interpreted with care. While imposing curvature conditions is necessary to derive meaningful results, reparametrisation might distort the elasticity estimates. On both samples reparametrisation is suspected to eliminate potential complementarity, as discussed in Kohli (1991). Tombazos (2003b) provides further evidence that reparametrisation destroys flexibility in the case of the translog function. In such cases, a different specification of the production function might deliver more credible results. For example, reparametrisation does not challenge the flexibility of the symmetric normalised quadratic function (SNQ) to measure substitutability between factors of production and thus it may provide the ideal alternative to the translog specification to derive demand elasticities. This issue is left for further research.

Tables

Table 1. Price elasticity estimates from the Kertesi – Köllő (2002) study

	Range
ε_{UU}	–1.7 to –0.004
ε_{YY}	–1.026 to 0.63
ε_{OO}	–0.99 to 0.8
ε_{KK}	–4.1 to –2.48
ε_{UY}	–1.09 to –0.042
ε_{UO}	–1.47 to –0.007
ε_{YO}	–0.265 to 1.2
ε_{UK}	1.56 to 2.18
ε_{YK}	0.08 to 1.1
ε_{OK}	0.34 to 1.01

Table 2. Descriptive statistics of data

Name	No. Of Observations	Mean	ST. DEV.	Variance	Min.	Max.
Skilled wages	23	0.73949	0.80091	0.64146	0.066	2.733
Unskilled wage	23	0.40258	0.39865	0.15892	0.054	1.362
Price of capital	23	0.19083	0.18375	0.033766	0.033	0.553
Cost share Skilled	23	0.18012	0.030477	0.000928	0.132	0.224
Cost share Unskilled	23	0.20760	0.046672	0.002178	0.145	0.274
Cost share Capital	23	0.61228	0.033658	0.001132	0.567	0.668

Table 3. Parameter estimates derived from the original and reparametrised system of equations

	1980-2002				**1992-2002**			
	Original		**Reparametrised**		**Original**		**Reparametrised**	
	Value	S. E.	Value	S. E.	Value	S. E.	Value	S. E.
α_s	192.07	1890.6	–100.7	1333.6	-74.09	178.93		0.0403
α_k		0.129	731.72	9701.9	-81.93	200.2		0.102
α_u	–192.3	1889.4	–	8368	157.2	379.1	0.183**	0.0665
γ_{ss}	0.165***	0.0418	–	0.346E-	0.108***	0.1972E-	-	0.122E-
γ_{sk}	–	0.0147	0.08***	0.208E-	-0.143***	0.112E-		0.556E-
γ_{su}	–0.0528	0.04		0.331E-	0.0349*	0.191E-		0.117E-
γ_{kk}	0.221***	0.0384	–	0.1E-06	0.252***	0.150E-	-	0.78E-
γ_{uk}	–	0.0328		0.179E-	-0.109***	0.965E-		0.123E-
γ_{uu}		0.0578	–	0.404E-		0.226E-	-	0.166E-

Based on the t- values, *** represents statistical significance at the 1 percent level; ** at the 2 percent level and * at the 10 percent level with a two tailed test.

Table 4. Average Allen-substitution elasticities derived from the original and reparametrised system of equations

	1980-2002				1992-2002			
	Original [1]		**Reparametrised** [2]		**Original** [3]		**Reparametrised** [4]	
	Value	S. E.	Value	S. E.	Value	S. E.	Value	S. E.
σ_{ss}	0.56	1.289	-8.09^{***}	0.106E-	-1.293^{**}		-7.69^{***}	0.2999E-
σ_{kk}	–0.043	0.102	-1.269^{***}	0.267E-	0.0509		-1.133^{***}	0.1947E-
σ_{uu}	–0.0843	1.342	-8.28^{***}	0.938E-	-2.325^{***}		-9.587^{***}	0.6088E-
σ_{sk}	–0.025	0.133	1.729^{***}	0.188E-	-0.122			0.4359E-
σ_{su}	–0.412	1.094	1.919^{***}	0.887E-	2.047^{***}			0.3516E-
σ_{uk}	0.15	0.258	2.242^{***}	0.141E-	-0.0452			0.1184E-

Based on the t- values, *** represents statistical significance at the 1 percent level; ** at the 2 percent level and * at the 10 percent level with a two tailed test.

[1] The highest eigenvalue occurred in 1981, with value of 3.06. This suggests that under these coefficients, the cost function violates concavity, therefore imposition of curvature conditions is necessary.

[2] The highest eigenvalue occurred in 1994, with value of 0.266E-14.

[3] The highest eigenvalue occurred in 1998 with value of 0.6255. This suggests that under these coefficients, the cost function violates concavity, therefore imposition of curvature conditions is necessary.

[4] The highest eigenvalue occurred in 1992, with a value of 0.2629E-14.

Table 5. Average price elasticities derived from the original and reparametrised system of equations

	1980-2002				1992-2002			
	Original		**Reparametrised**		**Original**		**Reparametrised**	
	Value	S. E.	Value	S. E.	Value	S. E.	Value	S. E.
ε_{ss}	0.101 ^{SR}	0.23	–	0.192E-	-0.26**	0.097	–1.55***	0.605E-
ε_{kk}	-0.026		–	0.163E-	0.032	0.023	–0.717***	0.123E-
ε_{uu}	-0.017 ^{SR}		–	0.194E-	-0.384***	0.136	–1.585***	0.100E-
ε_{sk}	-0.015 ^{SR}		1.058***	0.115E-	-0.077	0.055	1.251***	0.275E-
ε_{su}	-0.085		0.398***	0.184E-	0.338***	0.095	0.299***	0.581E-
ε_{uk}	0.091 ^{SR}		1.372***	0.864E-	-0.028^{SR}	0.058	1.219***	0.749E-

Based on the t- values, *** represents statistical significance at the 1 percent level; ** at the 2 percent level and * at the 10 percent level with a two tailed test.

^{SR} shows that the elasticities exhibit sign reversals during the observed period.

Figures

Figure 1. Evolution of the cost-shares data (1980-2002)

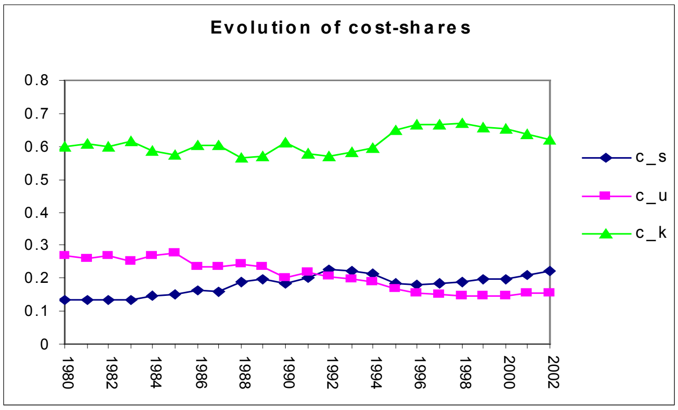


Figure 2. Evolution of the skill premium (1980-2002)

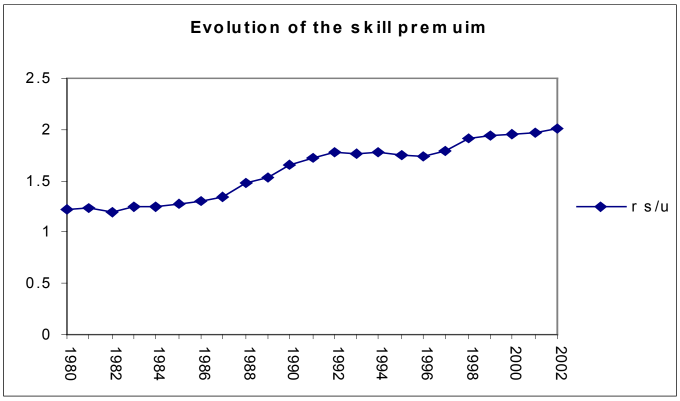


Figure 3. Own- and cross-price elasticities from reparametrised equations (1980-2002)

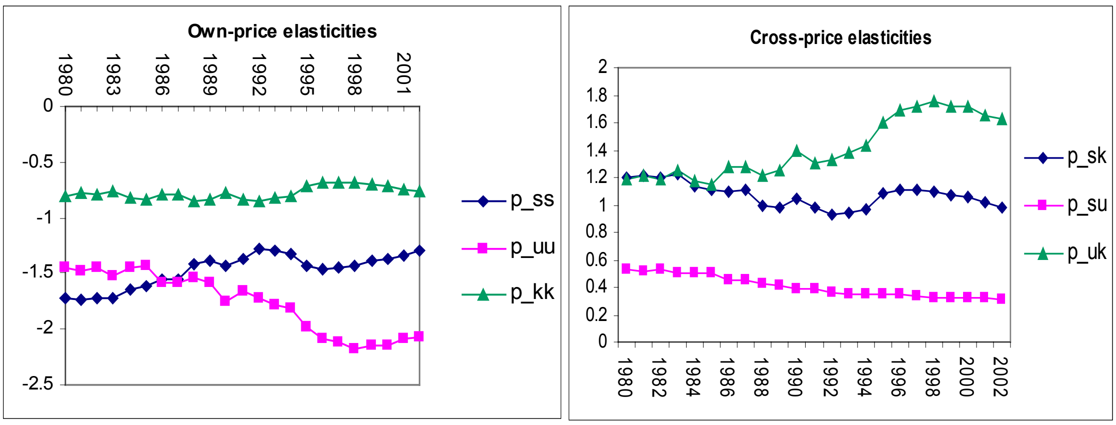
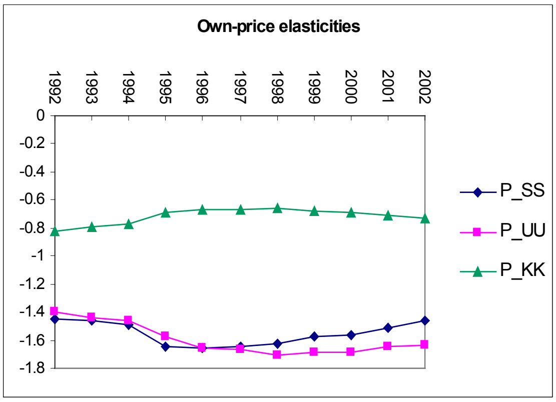
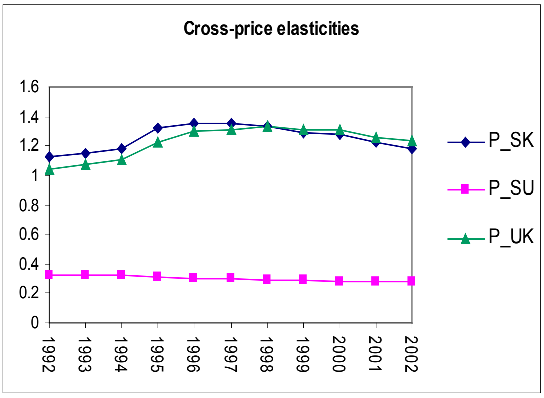


Figure 4. Own- and cross-price elasticities from reparametrised equations (1992-2002)





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