Total Factor Productivity in Czech Manufacturing Industry – KLEM framework

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Labour productivity itself and its growth rate cannot give unbiased information on the total productivity and its dynamics. In this paper the total factor productivity is defined as a weighted sum of productivity of four production factors, K input of fixed capital, L input of labour, E input of energy consumption, M input of material consumption. Empirical approach based on a derived transcendental logarithmic (translog) production function employs as a starting point direct econometric application of this production function. Using the econometric estimate of translog production function, total factor productivity is subsequently derived and, as the next step, measured. Direct econometric estimates of the translog production function were obtained by using special technique of empirical estimates used in the cases of multicollinearity – the ridge regression.
Two frameworks were employed: KLE for the Czech Economy and KLEM for the Czech Manufacturing. Quarterly time series covered the periods of 1/1995 to 4/2004 and 1/1995 to 3/2006, respectively. Comparing KLE and KLEM results we find the role of TPF strikingly robust. Share of the calculated long-term growth of TFP on the long-term growth rate of gross product was 13 per cent in KLE case while calculation based on KLEM production function shows 13.1 per cent. It seems that the Czech economy has been still dominated by the manufacturing sector. The role of TFP in the process of long-term economic growth has from the qualitative point of view remained unchanged except possible turning point in 2007. Economic growth seems to be primarily attributable to the growth of factor aggregate input. From the point of view of quantitative importance of TPF growth its share has, however, risen in time and TPF growth contributed the growth of gross product in 2003 – 2006 twice as much as compared to the second half of the 90´s.

1. Introduction

This paper contributes further to our research project focused on the measurement of total factor productivity within the framework of the four factors KLEM translog production function. Previous contributions were devoted to theoretical backgrounds of multifactor productivity including measurement issues (Klacek, 2006) and the first empirical application based on KLE production function for the Czech economy (Klacek et al. 2007). Econometric estimate of the production function was obtained from the time series quarterly data for 1995-2004 period and the ridge regression was used as the estimation technique.
This time the framework was extended to four factors and the level of aggregation lowered from National Economy to Manufacturing Industry. Quarterly time series data covers 1/1995 to 3/2006 period and as the exclusive data source the Czech Statistical Office data were employed. Thus the data include the fast growth period of 2005 and 2006 years. In spite of the differences between KLE and KLEM production functions estimates and the resulting calculations of total factor productivity some comparisons between the two can be drawn. Finally, we comment on our new and still preliminary findings where data on 2007 are included.

2. KLEM Production Function and Total Factor Productivity

The translog KLEM production function applied in our research project is of the form:

$$\begin{aligned} \ln Q = {} & \alpha_0 + \alpha_K \ln K + \alpha_L \ln L + \alpha_E \ln E + \alpha_M \ln M + \gamma_{KL} \ln K \ln L + \\ & + \gamma_{KE} \ln K \ln E + \gamma_{KM} \ln K \ln M + \gamma_{LE} \ln L \ln E + \gamma_{LM} \ln L \ln M + \\ & + \gamma_{EM} \ln E \ln M + \tfrac{1}{2} \gamma_{KK} (\ln K)^2 + \tfrac{1}{2} \gamma_{LL} (\ln L)^2 + \tfrac{1}{2} \gamma_{EE} (\ln E)^2 + \\ & + \tfrac{1}{2} \gamma_{MM} (\ln M)^2 + \lambda T \ , \end{aligned} \qquad (1)$$

where Q is gross product, K stands for fixed capital input, L for labour input, E for energy and M for material input. Parameters α_i , γ_i reflect productivities of the respective factors, λ is the parameter of Hicks neutral technological change and T is time trend.

Parameters of the translog KLEM production function (1) transformed into a stochastic form can be estimated empirically. In the literature values of the parameters of translog production functions as well as the measures of total factor productivity are usually derived from the prices of factor inputs or from growth accounting procedures in which the data on prices of factor inputs play crucial role (Eurostat, 2005). It is assumed that in perfectly competitive markets these prices equal marginal products.

We do not, apriori, make these assumptions, and estimate the parameters of the translog production function directly from the time series data on gross product and approximation data on production factor inputs. Due to the evidence of multicollinearity in the time series we opted as estimation technique for ridge regression. Employing the estimated parameters we could calculate the resulting data on total factor productivity.

In order to derive a formula for the total factor productivity the aggregate input I_t in the period t has to be defined:

$$I_t = \sum_{i=1}^{4} v_{it} X_{it} , \qquad (2)$$

where v_{it} are weights of production factors inputs X_{it} . For the weights it follows (Klacek and Nešporová, 1983):

$$v_{it} = ½ \alpha_i + ½ \beta_{it} , \qquad (3)$$

where β_{it} in equation (3) are output elasticities in relation to respective factor inputs. The following relations hold:

$$\begin{aligned} \beta_K &= \alpha_K + \gamma_{KK} \ln K + \gamma_{KL} \ln L + \gamma_{KE} \ln E + \gamma_{KM} \ln M \qquad (4) \\ \beta_L &= \alpha_L + \gamma_{LL} \ln L + \gamma_{KL} \ln K + \gamma_{LE} \ln E + \gamma_{LM} \ln M \\ \beta_E &= \alpha_E + \gamma_{EE} \ln E + \gamma_{KE} \ln K + \gamma_{LE} \ln L + \gamma_{EM} \ln M \\ \beta_M &= \alpha_M + \gamma_{MM} \ln M + \gamma_{KM} \ln K + \gamma_{LM} \ln L + \gamma_{EM} \ln E \end{aligned}$$

Then for total factor productivity (TPF) it holds:

$$TPF_t = Q_t / I_t \qquad (5)$$

3. Alternative Measures of Factor Inputs

When one tries to apply a theoretical model in order to describe an object in question and draw some analytical conclusions one has to resolve, i.a. the question of adequacy of disposable data to the model variables. In our case we dispose of alternative time series data that could be employed as proxies for individual factor inputs and those alternatives have to be assessed both from theoretical as well as statistical point of view.

One differentiation criterion is that the variables representing factor inputs in the translog production function are dimensionally flow variables. Therefore, the data approximating variables the dimensions of which are flows should dimensionally correspond or should be transformed so as to approximate flow dimensions (de Jong, 1967).

3.1. K – capital input

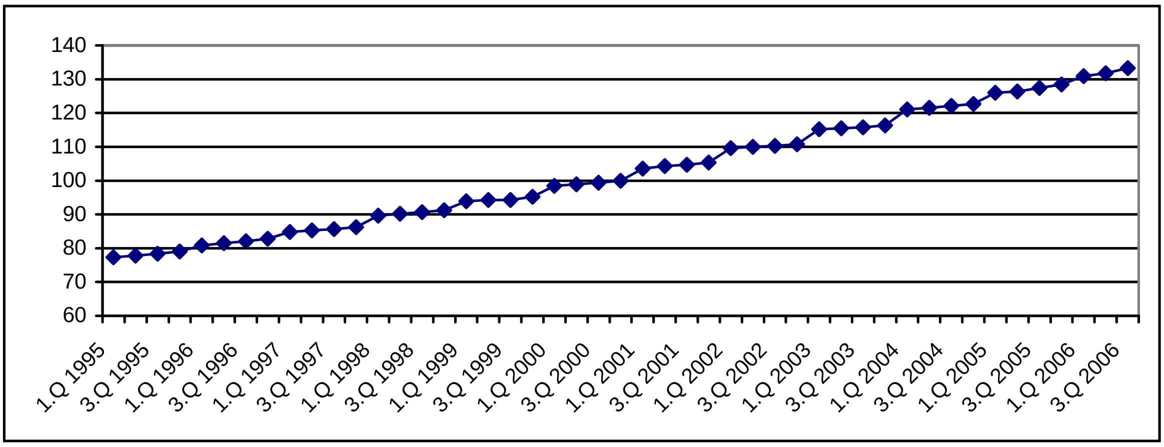
In the case of capital input direct observations are not available and the original data are those on fixed capital stock expressed in constant prices. Fixed capital stock comprises both machinery equipment and fixed structures. There are different options as to how this stock variable could be

transformed in order to approximate a flow variable. We tried three of them and the resulting variants are denoted as K1, K2 and K3.
The first one is so called *method of capital intensity*, which introduces the factor of utilization of capital stock u . The highest observed capital intensity K_{t*} / Q_{t*} is assumed as full utilization of fixed capital stock K1. In all other cases utilization of capital stock is below that level, certain amount of capital stock remains idle, and the data on fixed capital stock have to be deflated by the utilization gap. Formally:

$$\Delta K1_t / K1_t = \Delta K_t u / K_t u =$$
$$= \Delta\{ K_t (K_{t*}/ Q_{t*}) : (K_t/ Q_t)\} / \{ K_t (K_{t*}/ Q_{t*}) : (K_t / Q_t)\} \qquad (6)$$

Dynamics of K1 is relatively stable and as the Graph 1 shows that a trend in the underlying data is dominating.

Graph 1: Capital input – K 1 (index number)

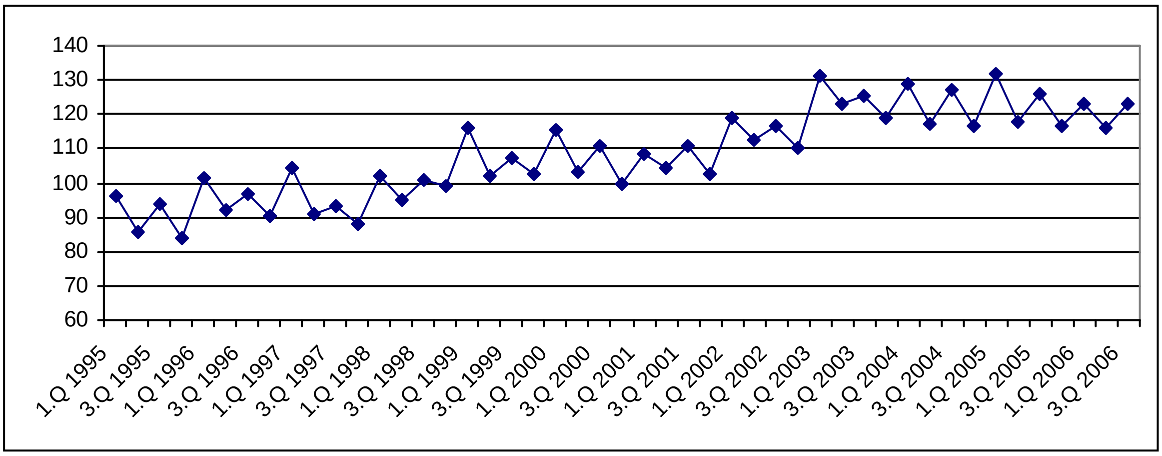


In another approach, *consumption of electricity* in the production process is substituted for input of fixed capital. It is assumed that machinery equipment in industry is powered by electricity and that as long as electricity is consumed machines are operated. In turn dynamics of the consumption of electricity in industry El is taken directly as a proxy to the dynamics of capital input of machinery equipment K2.
Then:

$$\Delta K2 / K2 = \Delta El / El \qquad (7)$$

Data on K2 depicts flatter dynamics compared with K1 and the last 14 observations do not show any positive trend at all.

Graph 2: Capital input – K 2 (index number)

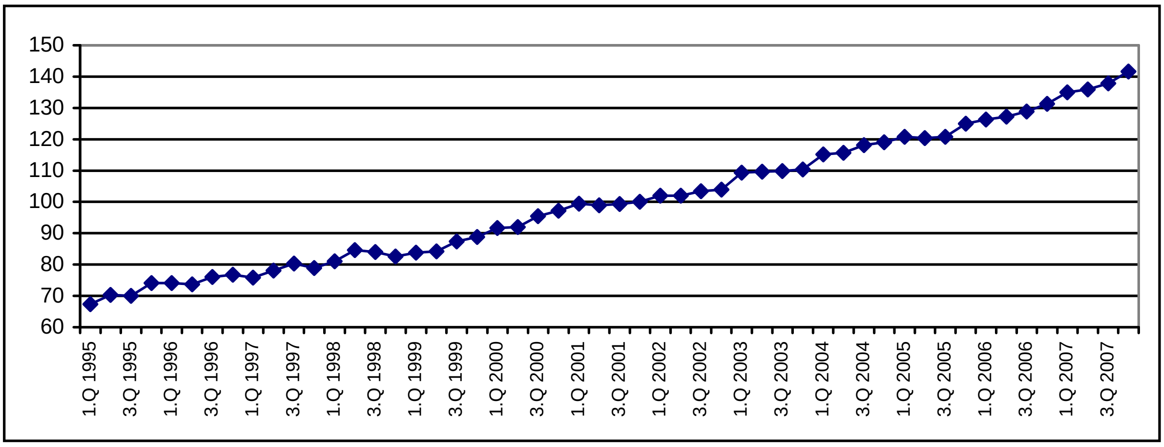


The third method utilizes regular *opinion polls* conducted amongst managers of industrial enterprises. Managers answer the question how much, in quantitative terms, the capacities of installed fixed capital are utilized. Stock of fixed capital can be then multiplied by this utilization rate *u* expressed in per cent of full utilization. Again the resulting growth rates of K3 are employed:

$$\Delta K3 / K3 = \Delta Ku / Ku \qquad (8)$$

As shown on the Graph 3, dynamics of K3 changes throughout the period of observations. For the last two years data reflect fast increase of utilization of capital stock in manufacturing.

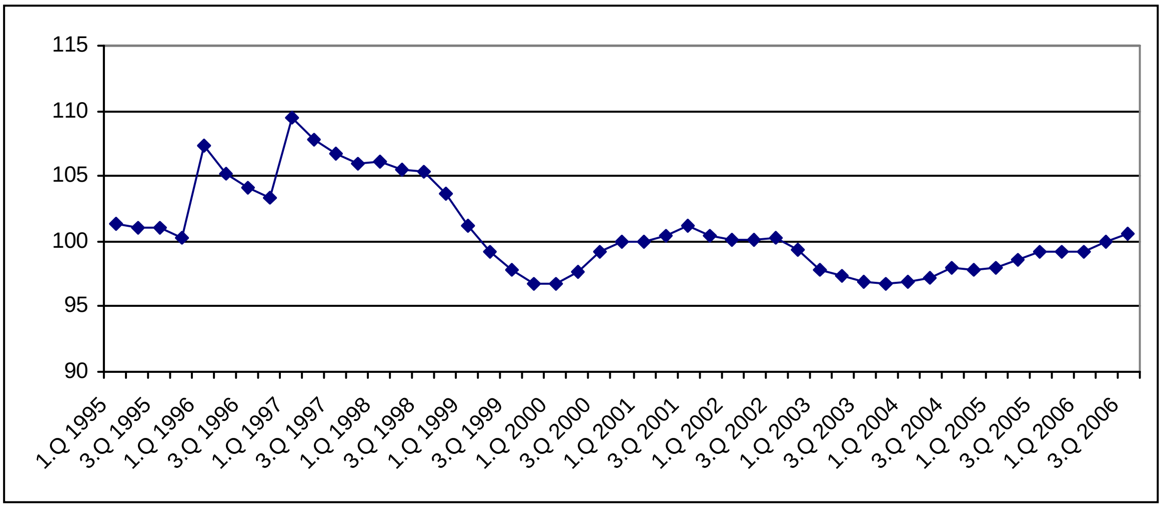
Graph 3: Capital input – K 3 (index number)



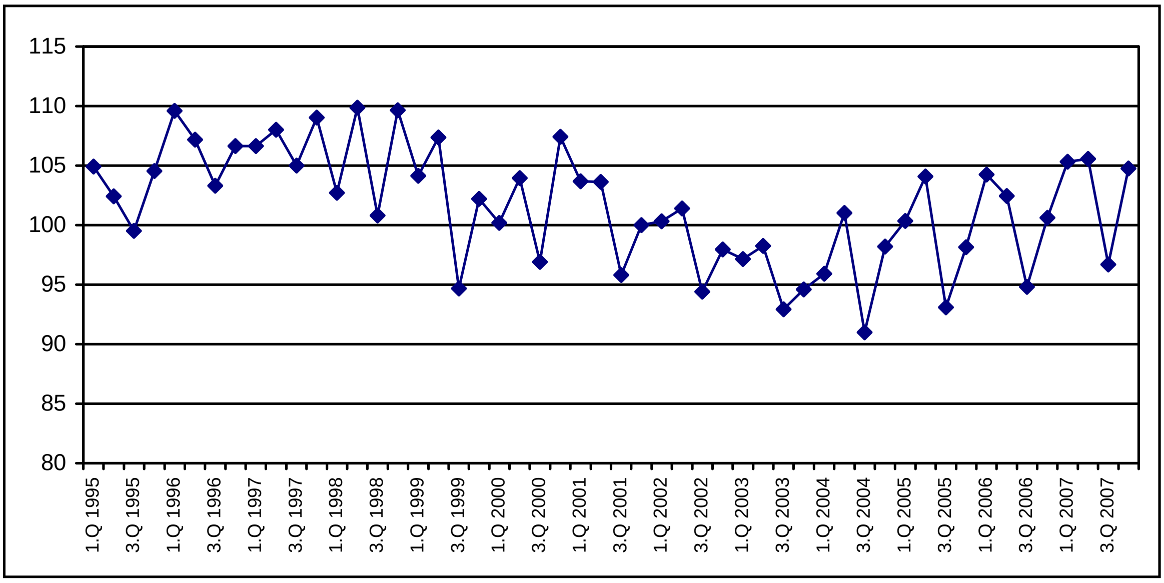
3.2. L - Labour input

For the input of labour two variant proxies were tried: L1 - number of persons employed and L2 - menhours worked. We did not attempt to differentiate among educational levels and skills attained since the data in the required breakdown were not available.

Graph 4: Number of persons employed – L 1 (index number)



Graph 5: Menhours worked – L 2 (index number)

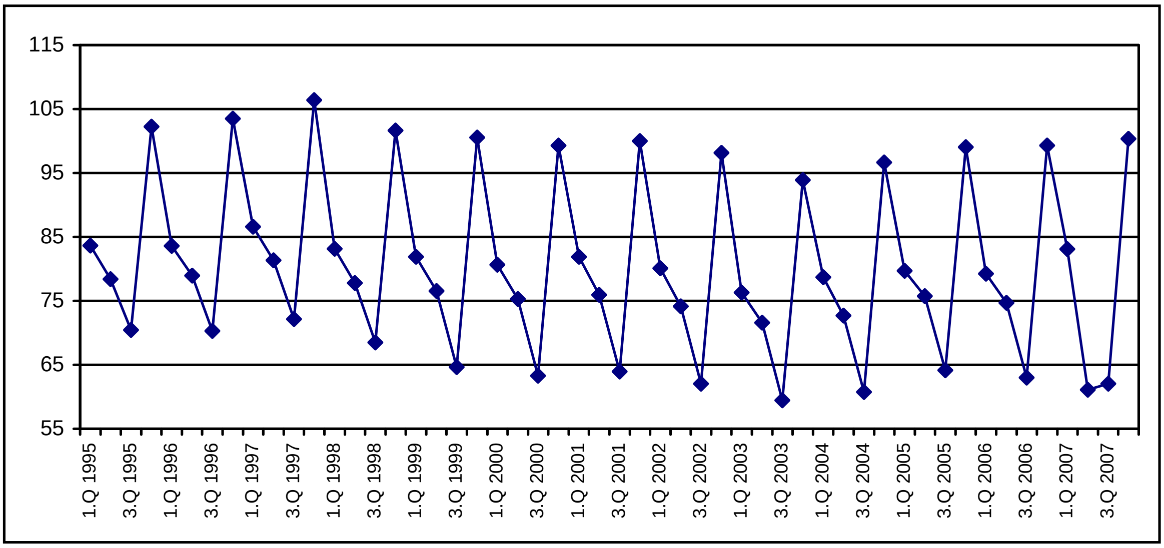


Difference in the measurement of labour input is clearly visible when Graph 4 and 5 are compared. Quarterly changes in the number of persons employed are smoothed out by the changes in the number of hours worked. Since the year 2000 L2 seems to remain stable with small changes quarter by quarter.

3.3. E - Energy

Input of Energy was approximated by the final consumption of energy in manufacturing expressed in Joules. The data include energy consumed for operation of machines and equipment and consumption of energy for heating, lighting etc. The data reflect almost uniform pattern of seasonal change without any longer term trend.

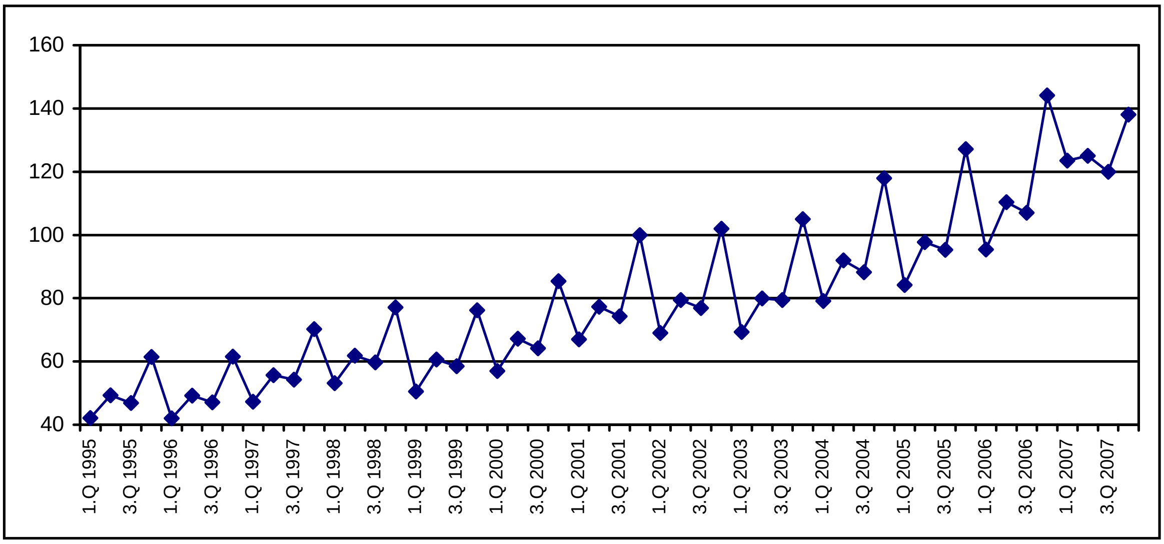
Graph 6: Consumption of energy – E (index number)



3.4. M – Material

As a proxy for material input we used intermediate material consumption net of consumption of energy and services. One should bear in mind that the intermediate consumption is measured as subcontracted supplies of row materials, semi-finished products etc., industry by industry, and therefore due to this measurement consumption of materials is covered in a multiple way. The same concept is applied to the measurement of gross output. This deficiency is partially overcome since the original data were transformed into growth rates. Detailed description of the origin of the data employed is given in the appendix.

Graph 7: Material consumption – M (index number)



4. Alternative measurements of inputs and regression results

Alternative methods of measurement of individual inputs as given above served as a basis in the process of transformation of the original time series data. The transformed data were used in the next step, and different regressions of a stochastic form of the translog production function (1) were run. Comparisons of alternative measurement specifications allowed us finally to select a favourite case and to calculate total factor productivity.
We tried to apply some methods to address possible seasonality in the underlying data. Dummy variables (0,1) capturing seasonality effects were introduced into the stochastic form of equation (1). The seasonality effects are reflected in the values of estimated parameters of the dummies. The results obtained did not, however, provide any indication of robust seasonality in the underlying data. In all attempts the parameters' values of the dummies were too small and their inflation factors extremely high. Similar results were obtained in the previous research when the data at the national economy level were employed (Klacek, J., Vošvrda, M., Schlosser, Š.). Therefore, our tentative conclusion on seasonality within KLEM framework is that a symmetry asserts itself on the explanatory and explained variables and as such cannot be captured by the dummies.
In all cases the ridge regressions with dependent variable Q were run. The number of observations was 47 (quarterly data from 1st quarter 1995 up to 3rd quarter 2006). We employed the Statgraphics® software. The regression results were obtained with ridge parameter fixed at the value of 0,01. Short description of Statgraphics® is given in the Appendix 2. Below, empirical estimates of four different KLEM specifications are commented.

4.1. Model K_1L_1EM

Table 1: Model K1L1EM

Parameter	Estimate	Variance Inflation Factor
CONSTANT	0,346762	
E	-0,001367	0,51297
EE	-0,017870	2,07641
EM	0,003370	2,69364
K1	0,158272	0,89475
K1E	0,015963	4,15057
K1K1	0,025746	1,94720
K1L1	0,048395	1,27516
K1M	0,017441	1,57073
L1	0,083199	0,41951
L1E	-0,001251	0,69883
L1L1	0,000008	0,44854
L1M	0,028024	2,36940
M	0,098851	1,55827
MM	0,005849	4,39229
T	0,000923	6,10530

R-Squared = 98,044 percent
R-Squared (adjusted for d.f.) = 97,0976 percent
Standard Error of Est. = 0,0387938
Mean absolute error = 0,0263347
Durbin-Watson statistic = 1,81215

The empirical estimate of K1L1EM Model resulted in a very high value of the estimated elasticity of capital input in relation to gross output as compared with the estimated elasticity of labour input. Such difference cannot be substantiated on the basis of independent studies. The estimated value of the elasticity of energy input is very small with a negative sign. Tentatively, we proceed to alternative approximations of both labour and capital input.

4.2. Model K1L2EM

Table 2: Model K1L2EM

Parameter	Estimate	Variance Inflation Factor
CONSTANT	-0,186981	
E	-0,063462	0,54560
EE	-0,014235	1,70511
EM	0,004906	2,61716
K1	0,145305	0,97797
K1E	0,006235	4,08017
K1K1	0,024477	2,10996
K1L2	0,053728	1,39311
K1M	0,018627	1,78663
L2	0,234437	0,60447
L2E	-0,012120	0,92665
L2L2	0,015882	0,64201
L2M	0,027530	2,81021
M	0,096731	1,56333
MM	0,010912	4,78296
T	0,001019	6,19487

R-Squared = 98,8177 percent
R-Squared (adjusted for d.f.) = 98,2456 percent
Standard Error of Est. = 0,0292576
Mean absolute error = 0,018501
Durbin-Watson statistic = 1,7049

The results of the empirical estimates of Model K1L2EM provide much more realistic value of the elasticity of labour but the estimated parameter of the elasticity of energy remains small and negative.

4.3. Model K2L2EM

Table 3: Model K2L2EM

Parameter	Estimate	Variance Inflation Factor
CONSTANT	2,72975	
E	0,004511	0,63518
EE	-0,012005	1,93094
EM	0,003420	2,89503
K2	-0,124616	0,84543
K2E	-0,011781	3,18444
K2K2	-0,003608	1,94629
K2L2	-0,021663	1,55662
K2M	0,011875	1,32551
L2	0,317009	0,52554
L2E	-0,002637	1,07731
L2L2	0,024179	0,63072
L2M	0,020501	2,63280
M	0,068696	1,44972
MM	0,008063	5,69892
T	0,013709	21,04020

R-Squared = 98,558 percent
R-Squared (adjusted for d.f.) = 97,8603 percent
Standard Error of Est. = 0,0250652
Mean absolute error = 0,0160307
Durbin-Watson statistic = 1,8117

Another combination of capital and labour inputs K2L2 did not provide acceptable results since the estimated parameters of capital as well as energy elasticities have negative signs.

4.4. Model K3L2EM

Table 4: Model K3L2EM

Parameter	Estimate	Variance Inflation Factor
CONSTANT	-0,032078	
E	0,090779	1,64999
EE	-0,014350	1,67099
EM	0,003205	2,61834
K3	0,130094	1,81231
K3E	0,008323	4,56064
K3K3	0,020898	3,02083
K3L2	0,047045	2,46456
K3M	0,016991	2,13390
L2	0,260260	0,62866
L2E	-0,011280	0,93410
L2L2	0,020082	0,65048
L2M	0,025729	2,90046
M	-0,061780	0,64310
MM	0,010479	4,71304
T	0,001751	18,60200

R-Squared = 98,9133 percent
R-Squared (adjusted for d.f.) = 98,3874 percent
Standard Error of Est. = 0,0279144
Mean absolute error = 0,0181275
Durbin-Watson statistic = 1,73388

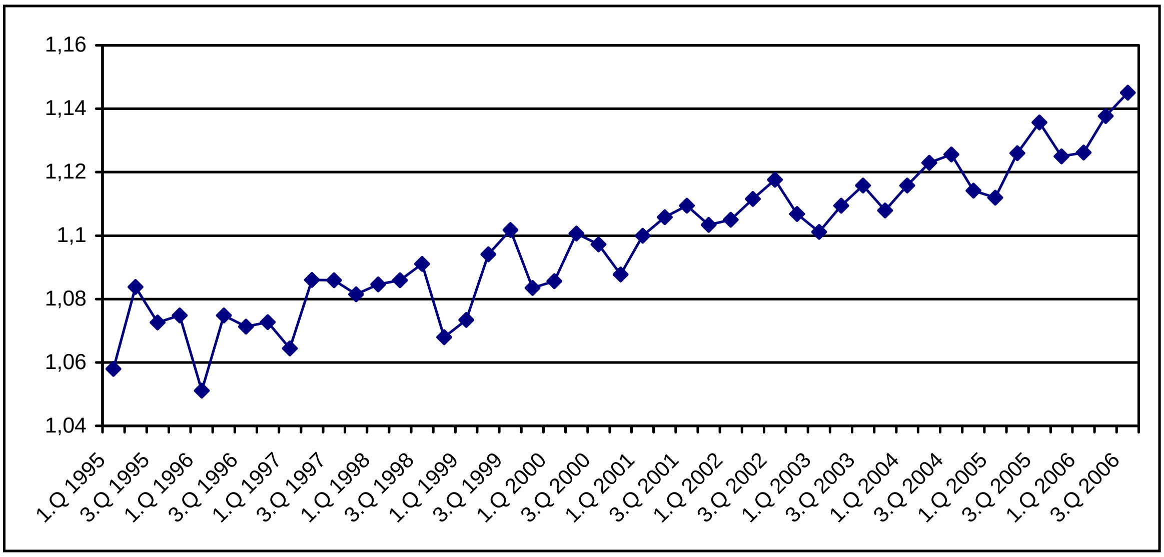
Finally, the Model K3L2EM seems to provide a relatively reasonable empirical estimate of the stochastic form of the KLEM production function (1). There are two issues to be dealt with in the next phase of our research. The estimated material elasticity is small and negative and the value of variance inflation value of the parameter of technical change is very high.
Negative value of material elasticity may reflect the way the underlying data are derived from the time-series on intermediate material consumption that could be upward biased due to the process of multiple counting. Construction of a new indicator for material input net of multiple counting will require additional research.
As to the time trend representing the effects of Hicks neutral technical change, our result may indicate that the technical change is in reality not Hicks neutral and that the effects may be embodied in the inputs of capital and labour. Again, some additional research is necessary in order that we could provide more concrete answer.

These findings call for some reservation in interpreting final results for total factor productivity.

5. Calculation of total factor productivity

Estimated parameters of the Model K3L2EM are the basis for calculations of total factor productivity in Czech manufacturing. Using equations (2) to (5) results shown on Graph 8 were obtained. Total factor productivity rose by 13.1 per cent over the period 1.Q 1995 to 3.Q 2006. In the same period gross output in Czech manufacturing grew by 132.3 per cent which means that 86.9 per cent of the observed long term growth rate of gross output is attributable to the growth of aggregated factor input and 13.1 per cent to the of total factor productivity.

Graph 8: TFP Model K3L2EM



If these figures are analysed in more detail three different periods could be distinguished. In the period 1.Q 1995 to 4.Q 1998 total factor productivity almost stagnated. Growth of total factor productivity started from 1.Q 1999 and certain acceleration could be observed starting from 1.Q 2003 and continued till the end of our time series.

This observation is also reflected in the ratio of the growth rate of total factor productivity on the growth rate of gross output. While in the first period the ratio stood at 11 per cent it grew to 13.8 per cent in the second period reaching 16.2 per cent in the last four years (Table 5).

Table 5: Growth rates of gross output and total factor productivity in Czech manufacturing (in per cent, 1.Q 1995 – 3.Q 2006)

	Periods		
	1.Q 1995 – 4.Q 1998	1.Q 1999 – 4.Q 2002	1.Q 2003 – 3.Q 2006
Δ Q/Q	35.5	46.2	42.6
Δ TFP/TFP	3.9	6.4	6.9
Δ Q/Q / Δ TFP/TFP	11.0	13.8	16.2

Comparing this result with the experimental calculation based on the empirical estimate of KLE production function for Czech national economy we find the role of TPF strikingly robust. Share of the calculated long-term growth of TFP on the long-term growth rate of gross product was 13 per cent while calculation based on KLEM production function shows 13.1 per cent (Klacek et al. 2007). Besides, it seems that the Czech economy has been still dominated by the manufacturing sector.

On the other hand, acceleration of this share from 11.0 to 13.8 and 16.2 in the last period seems to be quicker within the KLEM framework as compared to KLE one. These findings are consistent with the hypothesis that starting from 1995 - when institutional economic reforms were already completed - the role of TFP in the process of long-term economic growth has from the qualitative point of view remained unchanged. Economic growth seems to be primarily attributable to the growth of factor aggregate input. From the point of view of quantitative importance of TPF growth its share has, however, risen in time and TPF growth contributed the growth of gross product in 2003 – 2006 twice as much as compared to the second half of the 90´s. Thus the acceleration of economic growth was accompanied by a higher growth of TFP.

Furthermore, according to our new and so far preliminary findings based on KLEM framework the process of increasing the share of TFP growth on the growth of gross product continued in 2007 and did so in even faster pace than before. For the first time (within our time series starting from 1995) more than 50 per cent of the growth rate of gross product was attributable to the TPF growth rate. If ongoing research verifies these new findings the year 2007 may represent a turning point in the long-term economic development of the Czech Republic.

Conclusions

In this paper different empirical estimates of KLEM translog production function for the Czech manufacturing sector are presented. They are used for calculations of total factor productivity. Quarterly time series data taken over from the Czech Statistical Office cover the period 1.Q 1995 to 3.Q 2006, number of observations is 47.

Econometric estimates of the parameters of KLEM production function were run using ridge regression from Statgraphics® statistical software. Variant measures approximating individual factor inputs were tried. Among them the model K3L2EM outperformed other specifications.

According to the results obtained the share of the calculated long term growth of TFP on the long-term growth rate of gross product was 13 per cent. From the quantitative point of view this share increased from 11.0 per cent in the second half of the 90´s to 16.2 per cent in the period of 2003 – 2006. TPF growth contributed to the growth of gross product twice as much in 2003 – 2006 as compared to the second half of the 90´s. Thus the acceleration of economic growth in the period 2005-2006 was accompanied by a higher growth of TFP.

Our calculations differ in substance from those applying two factor KL concept in the form of growth accounting approach (Hájek, 2005; Hájek, 2008). The reasons for this difference probably lay in the contrast between two factors vs. four factor production process concepts. Also, our approach is based on direct econometric estimate of the parameters while KL approach derives them from the national accounts.

Although different specifications of the KLEM model were tried we still consider the outcomes as tentative. There are some issues to be addressed in the next stage of research. More adequate indicator approximating material input is required since intermediate material consumption is likely upward biased due to a process of multiple counting.

As to the time trend representing effects of Hicks neutral technical change our result may indicate that the technical change is in reality not Hicks neutral and that the effects are embodied in the inputs of capital and labour. Again, some additional research is necessary in order that we could provide more robust results.

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