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2008/6

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Driving Factors of Growth in Hungary – a Decomposition Exercise

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September 2008

MNB Working Papers 2008/6

Driving Factors of Growth in Hungary – a Decomposition Exercise

(A gazdasági növekedés tényezői Magyarországon)

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Published by the Magyar Nemzeti Bank

Szabadság tér 8–9, H–1850 Budapest

http://www.mnb.hu

ISSN 1585 5600 (online)

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Abstract

Applications tend to ignore that measured TFP reflects the variation of output that cannot be explained by changes in inputs. Such a change is not necessarily technological, so measured TFP differences across firms are an amalgam of technological, efficiency and other differences in attributes, which calls for further refinement in the treatment of TFP. To control for cyclical effects, we modify a standard technique in firm-level production function estimation using a capacity utilization proxy.

Based on a large panel of Hungarian manufacturing firms, we decompose value added growth to input factor, capacity utilization and estimated TFP growth contributions. We find that using an hours worked proxy, the variance of the residual drops considerably. We also find that TFP's role has not been stable over the period: it contributed to value added growth mostly in periods when/after institutional reforms, privatization or FDI inflow took place and lost its importance several years after the shocks.

JEL Classification: C14, C23, D24, O12, O47.

Keywords: economic growth, production function, input factor contributions, total factor productivity, capacity utilization, aggregation, panel data.

Összefoglalás

Az alkalmazott kutatások hajlamosak megfeledkezni arról, hogy a megbecsült teljes tényező termelékenység (TFP) a felhasznált inputok változásával nem magyarázható kibocsátás-változást méri. Ilyen változás nem szükségszerűen technológiai eredetű, így a vállalatok közötti TFP különbségek technológiai-, hatékonysági- és egyéb különbségek egyvelegét tükrözik. Mindez szükségessé teszi a TFP értelmezésének további pontosítását. Módosítva a vállalati termelési függvény becslési eljárásán a ciklikus hatások kiszűrésére egy kapacitás-kihasználtság proxyt használunk.

Magyar feldolgozóipari vállalatokat tartalmazó panel adatbázison felbontjuk a hozzáadott-érték növekedését inputok-, kapacitáskihasználtság- és TFP növekedésből adódó változásokra. Megmutatjuk, hogy a ledolgozott munkaórák proxy felhasználásával a reziduum szórása jelentősen csökkenthető. Eredményeink szerint Magyarországon az elmúlt időszakban a TFP növekedés messze nem volt egyenletes: legfőképp intézményi reformok, privatizáció és külföldi működőtőke beáramlás (FDI) idején és azokat követően járult hozzá a növekedéshez, majd ezen sokkok után évekkel számottevően csökkent a jelentőssége.

1 Introduction

Relating output to production factors has a two-century-old history, as this relationship provides the basis for understanding economic growth. A large number of economists have been focusing on estimating production functions and decomposing aggregate growth into contributions of different production factors. This exercise conceals a multitude of difficulties and challenges.

Apart from the search for the most accurate functional form[1], a primary issue is the identification of the production function. The seminal contribution of Marschak & Andrews (1944) points out that OLS estimates of production function parameters may be biased due to the correlation between inputs and the unobservable component of output. This latter term is usually referred to as total factor productivity (TFP). As firms observe individual productivity innovations, the state variables in their policy functions are not only capital and labour but also TFP. The main problem of gauging TFP comes from this fact because as it is unobservable to the econometrician, it is part of the unobserved heterogeneity. As TFP and factor decisions are endogenous, a simultaneity problem is generated rendering the identification of production function parameters more difficult.

One line of the literature got around the simultaneity problem applying conventional method of moments techniques in production function estimation (an example is Blundell & Bond (1999)). This involves differencing, which removes much of the variation in the explanatory variables. In general, instruments are often only weakly correlated with the differenced explanatory variables (see Wooldridge (2005)) which may lead to serious bias in finite samples. The laborious task of finding good instruments motivated another set of studies. The idea of these is to find variables that comove with productivity and then use the information in the proxies to nonparametrically "invert out" productivity from the residual (Olley & Pakes (1996), Levinsohn & Petrin (2003)). These iterative algorithms can be used to at least partly correct for the simultaneity bias but they still suffer from identification problems. These can only be circumvented making strict timing assumptions in the decision problem of the firm and some of these can be hard to substantiate in some cases. For instance, one has to assume that labour input is more flexible than intermediate inputs or capacity utilization (Ackerberg & Caves (2004)).

Another issue is that, there is no consensus in the literature over the question of whether TFP defined as Solow residual measures technology shocks. Applications tend to ignore that measured TFP reflects the variation of output that cannot be explained by changes in inputs. Such a change is not necessarily technological; it might be due to changes in scope efficiency, managerial quality, technological properties or cyclical effects. This implies that measured TFP differences across firms remain an amalgam of technological, efficiency and other differences in attributes, which calls for further refinement in the treatment of TFP. For instance, Basu & Kimball (1997) and Basu *et al.* (1998) found that 40-60 percent of the cyclicality of the Solow residual in U.S. manufacturing is accounted for by capacity utilization. Indeed, costly capital adjustment implies a variable utilization rate and if one does not account for this, it is absorbed in the Solow residual and distorts the measure what is usually referred to as technical change.

The decomposition of growth and the interpretation of the results on macro level give rise to another inevitable difficulty, the aggregation problem. It is as old as economics, but the gap between micro and macro level is still to be filled. Indeed, in nonlinear (as in loglinear) models, we cannot simply add up individual relationships to arrive at the aggregate function. As we will see later, the main challenge in aggregating individual production functions is to find the appropriate weighting scheme. Fortunately enough, the literature proposed a large number of possible decompositions.

This paper focuses on two of the aforementioned issues. First, we make an attempt to estimate production functions on firm level data controlling for variable capacity utilization. Second, as a step towards filling the

[1] Some problems about the existence of production function itself, as advocated e.g. in Felipe & Fisher (2003), are present – mainly because of aggregation concerns – but are generally ignored in empirical research. The argument goes usually that production functions are thought experiments, and the relationships they describe between output and inputs illustrate technology.

gap between micro and macro level data analysis, we decompose aggregate growth in Hungarian manufacturing to primary inputs and TFP growth. For this purpose, we use the above mentioned three lines of research as the frame of the paper.

The next section is devoted to the production function estimations. First, we briefly introduce the two identification methodologies developed by Olley & Pakes (1996) and Levinsohn & Petrin (2003). Then, drawing on the work of Basu & Kimball (1997), Basu *et al.* (1998) and Basu *et al.* (2004), we construct a new proxy for capacity utilization, which is used to construct firm-level TFP estimates that are clean of cyclical capacity utilization[2]. Section 3 describes the method for aggregating firm-level results and section 4 presents different decompositions. We also present a more detailed analysis of the aggregate TFP. Before concluding, we break down the analysis into sectoral level.

[2]Since some of the variables need to be treated differently in the regressions, we slightly modify the identification procedure.

2 Estimating production functions

We applied two procedures developed by Olley & Pakes (1996) and Levinsohn & Petrin (2003) (OP and LP henceforth). We briefly present the two estimation methodologies, for further discussion of the two estimation procedures and the remaining issues in these techniques, see Ackerberg & Caves (2004).

2.1 ESTIMATION STRATEGY

Consider a Cobb-Douglas production function (indices i and t were dropped for simplification)

$$y = \beta_0 + \beta_l l + \beta_k k + \omega + \varepsilon, \tag{1}$$

where y is log value-added, k is log capital, l is log labour, ω is a productivity shock and ε is assumed to be an iid disturbance. ω is unobservable by the econometrician but known[3] to the decision-maker. Since ω is in the information set of the firm on which it conditions its optimal choices of inputs, there will always be a non-negative correlation between input factors and ω. This dependence causes simple OLS parameter estimates to be biased.

One of the key assumptions in both OP and LP is that capital is fixed, ie its level is chosen before production takes place. Hence, the orthogonality of k to the innovation in ω can be used to identify β_k.

To solve the endogeneity problem with respect to the freely variable labour input, both estimation methods make use of a proxy. A common assumption is that the proxy is monotonic in ω. This is indispensable because the proxy is used to invert out the unobserved productivity shock in both OP and LP. OP assume that optimal investment is a strictly increasing function of current productivity: $i = i(\omega, k)$. If investment is strictly monotonous in ω then TFP can be solved for: $\omega = i^{-1}(\omega, k)$, where the inversion takes the form of a polynomial in i and k. Then the polynomial approximation of ω is used as the productivity proxy and, eventually this non-parametric function is used to substitute for TFP in the production function.

LP criticized the investment proxy on several grounds. First, it is well known that capital adjustment is lumpy and the sluggish response of capital to productivity shocks can violate the strict monotonity condition. Second, lumpiness also implies that zero investment observations have to be truncated from the data to preserve strict monotonicity. This leads to efficiency loss and to endogenous selection bias that one should control for. Therefore, LP suggest to use intermediate inputs as a proxy: $m = m(\omega, k) \Longrightarrow \omega = m^{-1}(m, k)$. One can argue for the validity of this proxy as follows. Higher productivity implies higher marginal product for capital for price-taking firms. As a response, firms increase production until the marginal product of capital equals its rental rate. To increase output, firms increase all inputs including intermediate inputs. Therefore, high intermediate input usage informs us about the change in the productivity change of firms. LP's second criticism about the possible negativity of the investment proxy is also not present here as intermediate consumption is positive in almost every case.

Technically, the first step is to apply a simple OLS regression of value-added on labour, the cross product and the nonparametric function $m^{-1}(m, k, p^y - p^m)$. For convenience, we use the generic notation m for the proxy (investment in OP and input material consumption in LP). We included output prices relative to input material/investment prices $(p^y - p^m)$ in the input/investment demand function because firms' input consumption or investment might increase without positive productivity shocks just because output prices might rise faster than prices of input materials or investment.[4] In the original procedures, both OP and LP assumed that investment/input material and output prices were constant across firms.[5] As the investment/input material demand function is time varying, changes in relative prices are captured by changes in

[3] at least up to its expected value

[4] Therefore, it might be optimal to adjust the capital stock or increase input consumption even in absence of a productivity shock. Therefore, a more proper specification should incorporate price effects as well.

[5] This is equivalent to assuming that firms face competitive output and factor markets within an industry.

the form of the function. In the estimation process, we used a third order polynomial approximation of m^{-1} with fixed parameters across firms and time. Consequently, relative prices should also be included in the regression process as a second proxy.

In the above regression $\hat{\beta}_l$ is identified but $\hat{\beta}_k$ is not. This is because the polynomial $\phi(m,k,p^y - p^m)$ contains capital terms so k is collinear with the non-parametric function:

$$y = \beta_l l + \phi(m,k,p^y - p^m) + \varepsilon, \tag{2}$$

where $\phi(m,k,p^y - p^m) = \beta_0 + m^{-1}(m,k,p^y - p^m) + \beta_k k$. In this step, one obtains an estimate of $\hat{\phi}$ along with $\hat{\beta}_l$.

The second step identifies k's parameter. Here LP assume that ω follows a first order Markov process: $\omega_t = E\left[\omega_t | \omega_{t-1}\right] + \xi_t$, where the conditional expectation $E\left[\omega_t | \omega_{t-1}\right]$ is obtained from a nonparametric regression of $\left(\hat{\phi}_t - \beta_k k\right)$ on its lagged values. In short, an initial value of $\beta_k k$ permits to obtain ω_t, $E\left[\omega_t | \omega_{t-1}\right]$ and thus $\xi_t\left(\beta_k\right)$. As capital is fixed, the orthogonality of innovation ξ_t and k_t provides a moment condition: $E\left[\xi_t | k_t\right] = 0$. Additional moment conditions are available as innovations should also be uncorrelated with lagged values of labour or intermediate materials. To estimate standard errors a bootstrap procedure is used.

In OP, a bit stricter assumption about the data generating process of productivity allows a simpler algorithm. Assume that TFP follows a random walk. Then, the linear projection of output in excess of freely variable inputs can be written as

$$\begin{aligned} E\left[y_t - \hat{\beta}_l l_t\right] &= \beta_0 + \beta_k k_t + E\left[\omega_t | \omega_{t-1}\right] = \beta_0 + \beta_k k_t + \hat{\phi}_{t-1} - \beta_k k_{t-1} - \beta_0 \\ &= \beta_k\left(k_t - k_{t-1}\right) + \hat{\phi}_{t-1}. \end{aligned} \tag{3}$$

That is, if use the random walk assumption, all we need to do to get $\hat{\beta}_k$ is to regress $\left(y_t - \hat{\beta}_l l_t\right)$ on $\left(k_t - k_{t-1}\right)$ and $\hat{\phi}_{t-1}$ without a constant.

However, there are several remaining issues in the above methodologies. First, it is not straightforward that intermediate input material consumption or investment should increase in response to a positive productivity shock at all times. One can think of cases when a positive productivity shock is associated with constant or even decreasing input usage. For instance, firms can improve their productivity by reducing intermediate input consumption by improving the quality control system and thus reducing the number of defective items produced (see Javocik (2004)).

Some of the identification assumptions of the procedures need further attention. Both assume that firms decide on labour having decided about the proxy. Otherwise – first labour then proxy – labour would be part of the state space on which the optimal amount of proxy is determined, ie. l would enter the input materials/investment demand functions. Technically, this would imply that the m function would contain l as an argument and that the inverse function m^{-1} would also contain l terms. This, in turn, would mean labour and the cross product would be collinear with the polynomial approximation $m^{-1}(m,k,l)$ and as an obvious consequence, labour and cross-product parameters could not be identified separately from this polynomial.[6]

On top of these subtle issues the strict timing requirement is not enough. One also needs to assume that productivity does change between the decisions about the proxy and labour. If it does not, then it is as if the two were determined on the same information set. However, if TFP evolves between the two decisions then labour responds but the shocks are not controlled for by the proxy since that has been already decided

[6] This is the same story LP and OP tells about the capital parameter and this is the reason why the capital parameter can only be obtained through a two-step procedure.

upon. In other words, the uncontrolled productivity innovation feeds into the error term and since labour responds by assumption, labour and the cross product are correlated with the error term rendering their OLS parameter estimates upwardly biased.

2.2 A CLEARER TREATMENT OF TECHNOLOGY

Although OP and LP are capable of controlling for productivity changes taken up by the proxies, it is an empirical question whether these procedures can control for non-technological cyclical effects in the residual. We do not argue that the TFP should not be cyclical. However, isolating these effects from the error term is crucial as discussions about economic growth most often associate TFP with technical development.

Basu & Kimball (1997) emphasized the role of the intensity of unmeasured factor utilization, which accounts for a relevant portion of the cyclicality of the TFP. Basu *et al.* (2004) demonstrated that under some assumptions, changes in both unobserved capital and labour utilization (including overtime work and increased effort) can be expressed as some function of output elasticities and changes in hours worked. In their approach, firms are assumed to be price-takers in input markets and can freely vary average hours worked (H), effort (E) and capital utilization (A). As employees must be compensated for overtime-work and higher effort, wages are strictly increasing in H and E. Moreover, assuming that the major cost of increasing capital utilization is that firms must pay a shift premium to compensate employees for working at night or other undesirable times, employees' wages create a link between H, E and A.

Since we do not have data on firm-specific hours worked, we modify the proxy for capacity utilization. As in Basu *et al.* (2004), we express wage as a function of an hourly base wage $\bar{W}$, hours worked H, effort E and shift premium A. $\bar{W}$ is assumed to be determined in a perfectly competitive labour market.[7] Thus, the ratio of per capita wages and effective hourly wages is a function of H, E and A: $\frac{W}{\bar{W}} = g(H,E,A)$. Since H comoves with both E and A[8], the above expression can be simplified to $\frac{W}{\bar{W}} = g(H)$, where $g(.)$ is a convex and continuous function. Inverting out H yields $H = g^{-1}\left(\frac{W}{\bar{W}}\right)$. Thus, if firms are price-takers in the labour market, a functional form of the ratio of wage per worker and effective hourly wage can be interpreted as average effective hours worked and can be used to control for capacity utilization.[9] For simplicity, we used a simple linear function in our regressions, a possibly more appropriate functional form is to be tested in further work.

In the original OP and LP strategies, labour was assumed to vary freely while capital was quasi-fixed. Introducing capacity utilization, it makes no sense to assume that labour is a freely variable input. The argument is that if labour adjustment is costly, then it is worth hiring or laying off employees only if these costs are lower than the costs of adjusting capacity utilization (the cost of additional work hours and shift premia). If labour adjustment is costly or there are rigidities in the labour market, firms will refrain from frequent employment adjustment. There are several arguments suggesting that adjustment costs may exceed additional expenses of extra work. First, labour market frictions may hamper firms looking for additional employees. Second, the training of new employees can be a lengthy an expensive process, especially if production needs skilled work. Third, administrative costs can also discourage firms from hiring. Based on these arguments, we treat labour as quasi fixed and capacity utilization as freely variable.

[7] Technically, one can think of $\bar{W}$ as the predicted value of a wage eq., regressing wages on firm-level data and employees' characteristics such as age, experience, gender, etc. We do not have detailed information on workers in our database. Therefore, we assume that wages are constant within a specific industry in a specific region.

[8] for demonstration, see Basu *et al.* (2004)

[9] Certainly, if the assumption of homogenous labour fails empirically, our proxy embodies not only capacity differences but also differences in labour quality. Although this framework built on Basu *et al.* (2004), we are not worried about this possible second interpretation of our proxy. As proposed by Griliches & Ringstad (1971), several papers make use wage bill to proxy effective labour in production function estimations. Griliches and Ringstad suggested to use the ratio of wage bill and the national minimum wage. However, the Hungarian economy was hit by two salient statutory minimum wage increase, by 57 per cent in January 2001, and by 25 per cent a year later. These hikes had large effect on the wage distribution, which casts doubt on the pertinence of this approach. Calculating effective labour following their methodology, we observe a sharp decrease in effective labour input after 2001. Our proxy is normalized by the average hourly wage (constant within an industry in a year), so wage shocks are controlled for.

The setup does not necessarily violate the timing assumption in the OP procedure. It is reasonable to assume that investment decisions precede labour decisions, even if this latter is not perfectly variable. Therefore, the proxy for capacity utilization can simply be treated as an additional "freely variable input" and the parameters of labour and capacity utilization can be estimated in the first step.

On the other hand, the quasi-fixity of labour input makes the LP identification procedure somewhat more complicated. Obviously, it makes no sense to assume that decisions on input materials precede decisions on labour. Therefore, we change the timing assumption: capital stock is decided on the information available at the end of time $t-1$. Then, developments in TFP make the firm adjust labour, which is followed by changes in input material usage. As the last step, firms decide on capacity utilization and production takes place in time t. This timing implies that labour would be part of the state space on which utilization is decided on rendering identification more difficult.[10]

We escape inconsistency the following way. The intermediate input demand function changes as labour is included: $m = m(\omega, k, l, p^y - p^m)$, and after inversion: $\omega = m^{-1}(m, k, l, p^y - p^m)$. Then, as the polynomial ϕ contains capital and labour, but no capacity utilization, this latter is identified in the first step. In the second step, we identify capital's and labour's parameter simultaneously (the same way as in the original LP procedure). Note that capital is still orthogonal to the innovation in productivity, so the moment conditions for identification remain $E\left[\xi_t | k_t\right] = 0$. On the other hand, we do not assume that labour is uncorrelated with the innovation term. In this case, lagged values of labour can be used to identify its parameter: $E\left[\xi_t | l_{t-r}\right] = 0$, with $r \geq 1$.

2.3 ESTIMATION RESULTS AND SPECIFICATION TESTS

Our data contained balance sheet and income statement information of double entry book keeping manufacturing companies over the years 1993-2004. After the removal firms with less then five employees, missing observations and outliers, our sample still covers about 85 percent of total output/value added in manufacturing. We also removed the Office machinery and computers industry (NACE 30) because data on output and value added proved to be unreliable due to deflator problems.

Detailed information on the database and the variables used are presented in the Appendix. The total number of observations and the sample size is shown in Table 1.

Estimations were carried out separately for each 2-digit level industry, however, some adjacent industries (marked in red in Table 1) were merged to ensure reasonable samples sizes.

Parameter estimates

Parameter estimates are presented in Table 2. The first two columns compare parameter estimates using OP and LP procedures. In both cases, results seem plausible. As expected, the textile industry (NACE 17-19) has the highest labour share, while branches within machinery (NACE 29-35) have the highest capital share.[11]

As expected, labour shares decreased when we used the LP-technique. On average, the change was about -.19.[12] Intuitively, as capital adjustment is lumpy, investment as a proxy is likely to take up less of productivity developments leaving more of it in the residual as the input-to-capital ratio is more likely to closely respond TFP developments. However, we do not see a dramatic increase in the parameter of capital.

[10] A similar timing problem is present in the original LP (see Ackerberg-Caves for further discussion).

[11] In most of the industries, the sum of the two parameters is below unity, somewhat lower in case of LP.

[12] The direction of bias in the coefficients are hard to predict in general. What we know is that it depends on the responsiveness of input factors to TFP and the correlation between labour and capital. A typical case is when $0 < \text{cov}(K, \varepsilon) < \text{cov}(L, \varepsilon)$ and $\text{corr}(K, L) \geq 0$, which biases the labour parameter upwards and the capital parameter downwards. Now, if we have a proxy that correlates more strongly with TFP, these biases might be mitigated. This is exactly what we see with the decrease in labour parameter when LP is used.

The coefficient of capacity utilization is significant in both cases (third and fourth columns). In the case of OP, point estimates are generally higher then in LP. Also, it is seen from Table 2 that the introduction of capacity utilization did not change labour and capital coefficients significantly. We also checked how the variance of TFP estimates changed after controlling for capacity utilization and found that it dropped by roughly 30% in OP and 50% in LP. We assess these as evidence of the variable capacity utilization effect.

Specification tests

The most important specification test is to verify whether the monotonicity condition holds, i.e. whether intermediate input usage or investment is strictly increasing in productivity. We regressed the proxies on a third order polynomial approximation of all variables influencing the choice of intermediate input consumption or investment[13]. Then, we evaluated the first derivative of the function with respect to the productivity shock for each firm. The value of the derivative was negative or zero in less than 1% of the total number of observations for both procedures. We assess these results as strong evidence indicating that higher productivity leads to higher investment and intermediate input consumption and that the monotonicity assumption is not too restrictive in the dataset.

As a second check, we tested whether the innovation in productivity was correlated with lagged values of labour. This correlation varies between -0.16 and 0.24 depending on industry, and equaled 0.09 on the whole sample in the LP case. We carried out the same test to see if innovation is correlated with lagged input material consumption. The correlation coefficients are all between -0.11 and 0.27, and equals to 0.11 for the whole sample. In the OP case these correlations were even closer to zero (labour: 0.01 for the whole sample and -.03-0.07 across industries, investment: 0.00 and -0.08-0.06). All in all, these results suggest that proxy levels may be considered uncorrelated with the innovation in productivity.

In the LP case we had an alternative proxy so we tested whether the results change if a more restrictive intermediate input materials definition is used. We performed the same estimations using only raw materials and consumables as a proxy. Although parameter estimates do not change significantly, the monotonicity condition did not seem to hold.

As a final check, we tested if parameter estimates were subject to possible structural breaks. We recursively reestimated the same model after discarding observations before 1994, 1995, … 1998, then by dropping observations after 2001, 2000 … 1997. With few exceptions, the LP procedure resulted in parameter estimates falling inside the 95% confidence interval of original estimates on the entire sample.

[13] Hence, estimated productivity, capital and output/input relative prices were the explanatory variables in these regressions.

3 The aggregation problem

Our empirical analysis, which builds on the work of Hulten (1978), concerns the drivers of economic growth. A natural way to tackle the question is to compute contributions of different production factors. This leads us to a growth accounting exercise. Firm-level estimations provide us with firm-specific productivity measures, which are interesting on their own right but proceeding this way would leave a gap between the micro and macro level. If we view macroeconomic phenomena as a set of aggregate processes that are generated by a continuum of entities, then changes in the distributions are of similar interest, as reallocation can play a key role in aggregate dynamics. This motivates the second part of our analysis, where genuine TFP and reallocation contributions are in the focus.

3.1 WEIGHTING SCHEME

Appendix B shows that if one wants to decompose output/value added growth in the growth accounting framework one has to apply value added shares. It also derives equations that reveal different sources of output growth. Here we only note that we found that the Thornquist indices[14] give a good approximation of the optimal weights as shown in Figure 1. Using these weights to calculate the average of log-differences of factor inputs multiplied by estimated elasticities leads to input growth contribution. The contribution of TFP to aggregate value added growth is shown by the last term in 5:[15]

$$\frac{\dot{Y}}{Y} = \sum_{i=1}^{N} s_i \left(\beta_l \frac{\dot{L}_i}{L_i} + \beta_k \frac{\dot{K}_i}{K_i} \right) + \sum_{i=1}^{N} s_i \frac{\dot{\Omega}_i}{\Omega_i} = \tag{4}$$

$$\sum_{i=1}^{N} s_i \left(\beta_l \Delta l_i + \beta_k \Delta k_i \right) + \sum_{i=1}^{N} s_i \Delta \omega_i, \tag{5}$$

where we approximated factor growth rates by logarithmic differences.

3.2 THE BHC CONCEPT: THE ROLE OF REALLOCATION

The previous growth accounting exercise does not allow composition effects to be formulated within the analysis. We now briefly discuss a way how these factors can be measured.

The literature almost exclusively employs some form of the BHC index (see Baily *et al.* (1992)). This is says that aggregate productivity change is

$$\sum_i s_{it} \omega_{it} - \sum_i s_{it-1} \omega_{it-1}. \tag{6}$$

It is clear that reallocation effects, entry/exit and genuine growth are concealed here. For a detailed discussion, see section C in the Appendix. To give these composition effects an explicit role, Levinsohn & Petrin (2003) show that a suitable definition of a *change* in productivity growth does introduce a reallocation term.

Henceforth we use the BHC-concept as it better captures how aggregate productivity change is viewed in the macro sense. As we deem aggregate productivity as a weighted average of individual productivity levels, aggregate productivity change is the difference in this metric between two consecutive time periods.

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[14] $\text{dlog}\left(\sum Y_i\right) \approx \sum \frac{s_{it} + s_{i,t-1}}{2} \text{dlog}\left(Y_i\right)$

[15] Note that the above formula "thinks" within a growth accounting framework. That is, it relates the change in aggregate growth to individual growth rates.

The BHC index can be decomposed to separate out genuine individual TFP changes and reallocation effects:

$$\sum s_t\omega_t - \sum s_{t-1}\omega_{t-1} = \sum \frac{s_t + s_{t-1}}{2}(\omega_t - \omega_{t-1}) + \sum \frac{\omega_t + \omega_{t-1}}{2}(s_t - s_{t-1}) = \sum \bar{s}d\omega + \sum \overline{\omega}ds. \tag{7}$$

The last term can be further decomposed to show (details in Appendix D):

$$\sum \overline{S_k}\overline{\omega}ds_k + \sum_{i=1}^{N} \overline{s_k}\overline{\omega}dS_k, \quad k = 1\ldots J, \tag{8}$$

where the $S_{kt} = \sum_{i=1}^{j} s_{it}$ denote industry k's share in overall manufacturing value added in time t, and s_{ki} is firm i's value added share within an industry.

The first sum in 8 shows the effect of individual share changes within industry k holding TFP and sector weights constant at their means and the second term shows that of industry share changes holding TFP and within-industry weights constant at their means. In other words, these expressions reveal the effects of intra- and inter-industry share changes in aggregate TFP change.

4 Driving factors of growth in Hungary

4.1 DETERMINANTS OF GROWTH

In what follows, we describe historical developments of capital, labour, value added and TFP in Hungary. The results of decomposition 5 is presented in Figure 2.[16]

Overall results suggest that the contribution of TFP to growth in manufacturing is definitely higher then in advanced economies. This result is in line with our expectation, as transition economies usually perform better in terms of efficiency gains than countries where production is already close to the production frontier.

The contribution of TFP has been far from stable over time. The fluctuation is only partly explained by changes in regulation or other positive shocks; demand side effects included in the residual appear to be significant. Following the business cycle in Hungary, three episodes seem to emerge.

The first period (1994-1997) is characterized by stabilization. Indeed, Hungary and other transition economies suffered from a surprisingly severe and persistent recession during the first few years following the collapse of the socialist regime. Firms gradually decreased employment in the course of transition. The new bankruptcy law introduced in 1992, coupled with the relatively rigourous accountancy law introduced next year, forced many firms to initiate reorganization or liquidation proceedings. This shock presumably cleaned the economy of inefficient production but also led to mass layoffs[17]. Manufacturing employment continued to decline in 1994-1996 and began to increase only in the second half of the 1990s.

These mass layoffs yielded efficiency gain and consequently, high growth in our measured TFP. Price liberalization, privatization, decrease in costs of market entry and other institutional reforms seemed to catalysed this transformation.[18]

On the other hand, macroeconomic stabilization lagged behind institutional reforms and privatization. Stabilization measures were introduced only in 1995.[19] As a consequence of credible macroeconomic policy, FDI jumped, which, in turn, generated further productivity gains. The negative effect of the stabilization shows up one year later, in 1996, but it promoted macroeconomic growth afterwards.

The three years from 1998 to 2000 were characterized by opposite shocks. A new wave of FDI inflows reached the country, although other Eastern and Central European countries[20] saw heavier inflows in this period. The new wave of foreign capital encapsulated mainly in greenfield investment projects. Thanks to these, capital accumulation boosted growth. Moreover, a new wave of particularly active baby boom generation entered the labour market[21], the sharp raise in labour demand in '97-'98 fortunately coincided with "fresh" qualified labour supply. This phenomena is translated to increasing employment and growing

[16] We only present the Levinsohn-Petrin estimates here, the Olley-Pakes results are mainly the same.

[17] The greatest initial reduction in manufacturing employment occurred in Hungary among all transition economies (about 30 percent).

[18] Most of the countries in transition proceeded quickly and surprisingly effectively with the first phase of these reforms, however, in-depth transformation policies differed across countries. Hungary opted for case-by-case privatization of individual state-owned enterprises, instead of mass privatization techniques as for example in the Czech Republic, Lithuania and to a lesser extent Slovakia. This method had the advantage that it assigned clear property rights to the new owners and provided much-needed managerial skills and external funds for investment. As pointed out in Brown *et al.* (2006), Hungary got off to an early start in ownership transformation and accomplished it relatively quickly. Not only the speed of the privatization was remarkable, but also its sudden and high impact on productivity. In our view, these effects did not die out in the early years of the transition, the high productivity growth until 1997 is largely explained by the transformation of privatized firms.

[19] The fiscal consolidation included cuts in general government expenditures, the devaluation of the Hungarian national currency, the introduction of an exchange rate regime based on a pre-announced crawling peg devaluation aiming at establishing predictable conditions for exporters and cooling speculation, the increase of taxes. The package helped reduce external and internal imbalances as well as the share of general government revenues and expenditures. The decisions also included the speeding up of privatization with the involvement of foreigners.

[20] Indeed, until 1997, Hungary was the only transition economy receiving a significant flow of foreign direct investment. But starting in 1998, major foreign investments flew to the Czech Republic, Poland and Slovakia.

[21] A baby boom generation caused by the stringent abortion policies of the early 1950's.

labour contribution. In fact, this was the only period of considerable aggregate employment growth in Hungary.

TFP's contribution turned negative in this second period. The drop in efficiency can be partly due to the direct and prolonged effects of the Russian crisis.[22]

Since 2001, productivity has seemed to be a key driver of growth again. However, some caution is in order, as this 2001 saw changes in accounting legislation. We attempted to control for possible biases, but to be on the safe side, we assess these numbers only as qualitative evidence of positive TFP contribution.[23] Labour has become considerably more expensive over these years. First, real wages shot up as disinflation proceeded. Second, the bargaining power of firms worsened in the wake of various negative labour market shocks[24]. Most firms reacted by gradually substituting capital for labour and by rationalizing production. This might explain the lower demand for labour and thus the decreasing labour and increasing TFP contribution.[25]

Labour contribution began to increase only in 2003 and seemed to play a decisive role in 2004, while aggregate employment in manufacturing kept on decreasing. This might be explained by a structural reallocation within the labour force. On the one hand, large, high value added enterprises expanded their workforce (mainly in communication equipment industry). On the other, the textile industry, which still accounts for a large part of the total employment in manufacturing, saw mass layoffs.

4.2 AGGREGATE PRODUCTIVITY AND REALLOCATION

As the second part of our exercise we present various TFP-decomposition results. It is readily seen from Figure 3, that genuine TFP growth, though dominant, was not the only driving factor behind aggregate productivity developments, reallocation played a key role as well. This reinforces what theory suggests: less productive firms lose weight and eventually exit the marketplace.

As for distribution-dynamics, it is seen from Figure 4 that the period under investigation saw both intra- and inter-industry reallocation. We can infer from these numbers that FDI inflows (1997-1998) caused significant interindustry reallocation effects. Figure 5 shows that the quickly increasing importance of machinery contributed to aggregate TFP growth during the entire timespan of the sample. The increasing contribution was especially significant during the period of heavy FDI inflow.

Figure 5 shows also that aggregate production gradually shifted towards capital intensive sectors such as machinery while labour intensive industries has been losing weight (textile industry, food and tobacco) in total value added.

4.3 INDUSTRY-LEVEL STORIES

A clear common pattern of industry dynamics could not be identified in our sample, so we briefly summaries the findings about the evolution of the most important industries (machinery, chemicals, metal products, food and textiles). The description below is highly stylized and based on different sources of information. Our purpose here is to put estimation results into perspective and to draw a better picture of the turbulent dynamics in manufacturing.

[22]The financial crisis hit the Hungarian economy on several fronts. First, Hungarian export to Russia fell by more then 30 percent in 1998 and have stabilized at a relatively low level during 1999. The agricultural sector was hit the most severely, within manufacturing, the chemical industry registered the greatest loss. Despite the serious decline in Russian exports, the direct trade effect of the crisis was limited at aggregate level.

The crisis fed through international financial markets as well. Investors withdrew from all emerging markets, which led to exchange rate pressures, rising risk premia and thus increasing interest rates and falling equity prices. Turbulances calmed down relatively quickly, however, as inflation came down faster then nominal interest rates, increasing real interest rates continued to influence growth via falling investment and private consumption.

[23]Moreover, it is clear from Figure 2 that TFP contribution is much smaller after 2001 than before 1997.

[24]Labour supply stuck at a low level, there were a shortage of trained skilled workers; the large rises in minimum wages in 2001 and 2002 and the significant wage increases in the government sector coupled with an increase in employment; all reduced the potential labour force of the private sector.

[25]Earlier studies confirm that although the first rise in minimum wages in 2001 was larger than that in 2002, the first labour market intervention was less effective. (see e.g. Kertesi & Köllõ (2003)). Indeed, the Kaitz index in 2001 slightly exceeded 30 percent, which is very low in international comparison.

Machinery

Machinery is important not only because it is the largest within manufacturing but also it is the most closely linked to export markets which gives it a key role also from a small-open-economy perspective. The main contributors in terms of capital growth were motor vehicles and electrical machinery. As for output, while machinery accounted for only 18% of overall industrial output in 1995, its rapid growth inflated this ratio to 43% in 2000. The driving force behind this dynamic growth has been exports (exports accounted for 85-95% of sales). Another important stylized fact is that investment was financed through foreign capital more heavily than in other industries[26].

Capital growth has been influential up to the middle of the 1990s. As shown by sectoral decompositions (figure 8), capital growth was uniformly positive across sectors, of which machinery was the greatest contributor. The deepest point of the post-transformation recession was 1992. Output halved compared to 1988 because the collapse of previous export markets hit machinery much harder than manufacturing as whole (where the level of production was 60% of that of 1988). From 1992 onwards, machinery experienced dynamic growth and showed significant restructuring.

In the first years of the nineties, investment in machinery concentrated in motor vehicles: capital inflows were higher than in others by orders of magnitude. These flows materialized in the form of new and large-scale capacities. This sector is the realm of multinational companies throughout the world and correspondingly, multinationals showed much interest towards Hungary already at the beginning of the transition.[27]

From the middle 1990's onwards, overall machinery continued to saw buoyant investment. However, electrical machinery took over as the engine of aggregate capital growth[28] and caught up in terms of investment and output. It is clear from capital contributions that capital growth was continuous but labour's positive contribution came to a halt in 1999. Specifically, labour was growth-neutral in motor vehicles that year and its contribution was even negative in 2000, reflecting huge layoffs. In fact, electrical equipment saw the most rapid development across machinery in the period under investigation. After the short period of turbulent transition to market economy at the beginning of the 1990's, fresh foreign capital injections by the world's well known manufacturers[29] created competitive capacities. The new establishments were dedicated to produce not only end-products but also intermediate inputs. At the same time, a significant number of new small firms appeared in this industry.[30]

With the rise of the new star, machinery & equipment gradually lost its importance. This segment offered ample opportunities for small and medium size firms as huge FDI inflows seemed to keep off investing here. The industry produces mainly agricultural and durable household equipment and shows little restructuring in terms of change in product profiles and portfolios.

Metal products

Similarly to machinery, the industry of metal products is also highly export-oriented. Based on Central Statistics Office data in 2000, about half of the production is exported. Another 25 percent of the production constitutes intermediary inputs of mainly machinery and equipment. Therefore, business cycle characteristics of this sector broadly similar to that of machinery.

[26] One third of all foreign capital inflows in 2000 to overall manufacturing materialized in machinery industries.

[27] General Motors (OPEL), Audi-Rába and Suzuki. Interestingly, anecdotal evidence shows that local firms did not manage to enter upstream industries. It is said that – except for Suzuki – the rate of Hungarian suppliers remains below 10% on average at these multinational companies suggesting that the potential for vertical spillover effects to spread might not have been as great as it is often thought.

[28] Motor vehicle companies showed another wave of restructuring these years, which is reflected in labour developments.

[29] Philips, Flextronix, Nokia, Samsung, Sony.

[30] Although not included in our analysis, office machinery and computers was also a major contributor to manufacturing capital growth and, therefore, value added. It has experienced steep growth fueled by FDI so it is not surprising that this sector is owned almost completely by foreigners. Production is capital intensive but the ratio of value added to sales is the lowest within machinery showing that several firms are specialized to spare parts and computer components (semiconductors) beside communication equipment.

The shift towards market economy drove most of firms into depression for several years. Following the collapse of the CMEA market, demand for metal products halved. At the same time, Hungarian metal producers were exposed to increased import pressure coming from neighbouring countries. Albeit the sector is dominated by few large enterprises, their size remains relatively small on an international scale.

The sudden decline in demand for products coupled with increased supply provenance from large foreign companies pushed several enterprises near bankruptcy. Although the market has stabilized in 1994 and most of the firms saw increasing sales during the second half of the nineties, they could not overcome financial difficulties. As a result development remained subdued.[31]

By the end of the nineties, new, mainly foreign players entered the market. Although their appearance did not change market concentration after all, these enterprises contributed more and more to aggregate productivity growth and capital accumulation. Despite the remaining financial difficulties, it is now viewed as a propulsive industry.

Chemical industry

The chemical industry exhibits lots of heterogeneity. Large companies with international ownership structure, up-to-date production technologies and environment-conscious management (Oil refining, Pharmaceuticals, medicinal chemicals and Basic chemicals) live together with small, low-value-added plastic product manufacturers (Rubber and plastic products).

Across chemical industries, oil refining is the most important (37% of chemical production). Here, firms are soundly capitalized, they are mainly affiliates of international oil companies. [32]. Similarly to machinery, the chemical industry experienced restructuring throughout the transition process. At the beginning of the nineties output dropped significantly and production stagnated up until 1996. Chemical firms seemed set to grow only from 1997 onwards but crisis events in Asia and Russia prevented them from entering a stable growth path and eventually output dropped again. In fact, the chemical industry shows negative productivity contributions in most of the period under investigation, which is unexpected in some sense. In general, a negative TFP contribution can be interpreted as an efficiency-loss emanating from scale efficiency, mismanagement, etc. However, some industry-specific factors help explain why TFP's contribution is often negative.

First, old capacities had to be disassembled because they could not serve firms' new market endeavours. Second, competitive capacities had to be first physically developed and then built. Third, this industry is a hazardous business requiring special caution and prudence, which might further elongate the period before new investments begin to yield capital services. On top of that, there have been ongoing takeovers in the industry up until recently, suggesting that technologies might still be changing at these firms. All this suggests that time-to-build lags are probably longer than in other manufacturing industries. Clearly, our econometric analysis could not capture this structural reorganization. Presumably, the capital measures we constructed do not reflect the true value of capital, as old, less efficient structures are not depreciated but less and less used in reality.

[31] The privatization of the industry cannot be viewed as a success story. The first wave took place in the metallurgical center located in the northern part of Hungary with the privatization of two major raw steel producers (Ózdi Acélművek and Diósgyőri Acélművek). To avoid bankruptcy, the state was forced to buy back the companies. After several attempts, Ózdi Acélművek was finally sold in 1997. On the other hand, the destiny of the other North-Hungarian company was uncertain until 2004, when the group Dunaferr - dominant enterprise in the sector - finally bought it.

Although the entire privatization of Dunaferr took place only late 2003, the firm managed to successfully counterbalance the collapse of the CMEA market with increasing export sales to EU members. In fact, investments of Dunaferr accounted for the major part of the total investment of the sector for several years. Also, the relatively high productivity growth within the group Dunaferr accounts for the major part of the total TFP growth registered in the sector during the first half of the nineties.

[32] There are at least two arguments why oil refining is key to understanding factor and TFP developments in the chemical industry. First, its weight renders it a decisive role. Second, most production technologies in the chemical industry are energy intensive and use a variety of oil products. This second claim is supported by the correlation of TFP contributions across chemical industries: in years when oil refining exhibited negative (positive) TFP contributions, the other industries did so, too.

Food and tobacco

Contrary to the chemical and machinery industries, food & tobacco is driven by domestic demand: only 20% of total production goes abroad.

Transition hurt this industry, too. High inflation, pale economic activity rendered domestic demand to be steadily low. The worsening economic environment was reflected in the deteriorating domestic demand. As food & tobacco feeds primarily on domestic spending, industry revenues experienced continuous, year-by-year decreases, showing only slightly higher production level in 2000 than in 1990.

The food industry developed in a heterogenous way. On the one hand, traditional, commodity-type production gradually lost its importance and eventually was ceased by post-privatization foreign owners. On the other, fresh capital embodied in the form of new and competitive capacities gave rise to high value added segments within the industry (65% foreign share in subscribed capital).

Despite the diffusion of new technologies, the industry still suffers the heritage of the planned economy. Although the number of employed decreased dramatically due to continued layoffs, the productivity of labour is still 20% below EU-average (in 2000).

Textile industry

Textile manufacturers adjusted to the market environment relatively well: they set foot in western markets soon after the regime change. The fast adjustment was facilitated by foreign (German, in particular) companies as they began relocating capacities to exploit the low cost of labour. The employment share of the textile industry within manufacturing remained relatively stable till the end of 1998 (about 17%).

The sudden rise in labour costs after 2000 combined with the increasing competition due to cheap Asian products forced more and more firms to cut back on production, relocate operations or close down. Between 1998 and 2006, employment declined by almost 60% and continues to decrease ever since.

5 Conclusion

This paper explored what roles different production factors played in value added growth using a large panel of Hungarian manufacturing firms between 1993-2004. Although results cannot be generalized to the whole economy, they deserve attention as manufacturing efficiency is key to international competitiveness.

We paid particular attention to measuring total factor productivity and its contribution to output growth. We used earlier techniques developed by Olley-Pakes and Levinsohn-Petrin as a starting point and modified their framework to arrive at TFP measures that are clean of cyclical demand effects. We isolated cyclical effects using a capacity utilization proxy and found that TFP-variance dropped by 30-50% depending on the estimation method. We assess these as evidence of the capacity utilization effect.

Our decompositions have the attractive property of explicitly showing to what extent reallocation effects influence aggregate TFP growth. We found strong evidence that reallocation positively affected aggregate TFP growth. Though being significant in the past, we expect this effect to ease in the long run as the catching up process loses momentum.

One important conclusion that may have policy consequences is that firms' efficiency-improvement was the most important source of growth only after periods when various shocks hit the economy. First, Hungary had experienced comprehensive institutional reforms, privatisation and macroeconomic stabilization during the transition process. TFP growth proved the be the most significant contributor to growth only those times. To a lesser extent, it gained ground again as an engine of growth at times of heavy FDI inflows. This suggests that adapting new technologies might have improved firms' efficiency. It is clear from the analysis that as these shocks passed, TFP growth and its contribution to value added growth moderated considerably.

The overall picture suggests that total factor productivity has been growing much slower lately than in the first half of the 1990s. It bears at least one long-run implication for policy makers: we cannot expect productivity to be the old-new engine of economic growth unless economic policy changes considerably.

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Appendices

A The data

Our database contains balance-sheet information of double entry book keeping manufacturing companies for the years 1992-2002. However, the investment ratio is stable only from 1993 – suggesting that capital revaluations during and after the transition period had still been in process in 1992 – so we did not use data in 1992 for the analysis.

The smallest firms, with number of employees less then five in a given year, were dropped from the analysis because their tax return data appeared to be imperfect and unreliable in many cases.

We filtered out missing or non-positive observations for value added, employees, total wage costs, capital and input materials for the whole database. We also checked for outliers: we eliminated firms for which the capital to value-added ratio, the input material to value-added ratio or the average wage cost is 1.5 times the inter-quartile interval below the first quartile or over the third quartile in a specific year in a specific industry. The number of firms and observations in our database are summarized in Table 1. In certain cases, we merged consecutive industries due to the small sample size.

Capital: The capital stock was constructed following the procedure described in Kátay & Wolf (2004). The construction bears on the assumption that investment occurs at the beginning of each year and disinvestment occurs at the end of each year. If K_t is the real capital stock at the end of the year, investing firms use K_t and disinvesting firms use K_{t-1} for production in a given year t. In other words, the real capital stock at the beginning of each year is given by K_t if the firm invests in t and by K_{t-1} if the firm disinvests in t. Therefore, we used K_t or K_{t-1} in the production function estimation procedure depending on the investment decision of the firm.

Labour: Annual average full-time equivalent employment at the firm, rounded to the nearest integer.

Value added: Value added was calculated by subtracting the value of input material costs from the value of turnover net of indirect taxes, deflated by the 2-digit sectoral GDP deflator. Due to change in accounting legislation in 2001, total turnover includes indirect taxes as well. As we have no information in the database on the magnitude of this latter, we corrected for this bias by subscribing the industry-level mean fraction of indirect taxes from total turnover. The following numbers are provided by the Hungarian CSO, expressed as the ratio of indirect taxes in total turnover and in input material costs:

	NACE	Turnover	Input materials
2001	15	0,0232	0,0044
	16	0,5622	-
	23	0,2239	0,0894
2002	15	0,0233	0,0044
	16	0,5915	-
	23	0,2265	0,0861
2003	15	0,0229	0,0005
	16	0,6713	-
	23	0,2165	0,0791
2004	15	0,0234	0,0005
	16	0,7265	-
	23	0,2520	0,0912

Proxies: We used input material costs including raw materials and consumables, contracted services, other service activities, original cost of goods sold, value of services sold (intermediated)[33], deflated by sectoral input material price deflator. As yet, the Hungarian Central Statistics Office has not published industry specific input material price indices, hence we simply calculated them as the ratio of intermediate input material consumption (the difference between sales and GDP) at current and constant prices. We also used firm-level real investment data in case of OP procedure. For further details on how investment was calculated, see Kátay & Wolf (2004).

Capacity utilization: Average wage per worker (W) was calculated from within our database for every firm. Average hourly wage $\left(\bar{W}\right)$ is the ratio of average wage bill and aggregate hours worked. We calculated the average wage bill for every region in each year and industry, and used official aggregate hours worked given for each industry-year by the Central Statistics Office.

[33]terminology is taken from the official translation of the Act C of 2000 on Accounting.

B Growth accounting framework

One can show that aggregate productivity should be calculated using value added shares if the production function is estimated using value added as the dependent variable. Let

$$Y_i = f(J_i, \Omega_i) \quad i = 1...N, \tag{9}$$

where Y_i is real value added of firm i, J_i $(1 \times K)$ is the vector of factor inputs used by firm i, and Ω_i is the Hicks-neutral productivity shock.[34] Intermediary inputs are dropped as value added is the dependent variable. Total differentiation of 9 yields:

$$\frac{dY_i}{dt} = \sum_{k=1}^{K} \frac{\partial Y_i}{\partial J_i^k} \frac{dJ^k}{dt} + \frac{\partial Y_i}{\partial \Omega_i} \frac{d\Omega_i}{dt}, \tag{10}$$

which implies

$$\frac{\dot{Y}_i}{Y_i} = \sum_{k=1}^{K} \frac{\partial Y_i}{\partial J_i^k} \dot{J}_i^k \frac{J_i^k}{J_i^k} \frac{1}{Y_i} + \frac{\partial V_i}{\partial \Omega_i} \dot{\Omega}_i \frac{\Omega_i}{\Omega_i} \frac{1}{Y_i} = \sum_{k=1}^{K} \left[\frac{\partial Y_i}{\partial J_i^k} \frac{J_i^k}{Y_i} \right] \frac{\dot{J}_i^k}{J_i^k} + \frac{\dot{\Omega}_i}{\Omega_i}, \tag{11}$$

where $\dot{Y}_i, \dot{J}_i$ and $\dot{\Omega}_i$ are time derivatives.

This shows how firm level value added growth decomposes into factor input growth and TFP growth. Since we assumed TFP to be Hicks-neutral, the last equality holds. The expressions in brackets are elasticities of value added w.r.t. primary input factors and are captured by production function parameters.

As we have estimated all the elasticities:

$$\frac{\dot{Y}_i}{Y_i} = \sum_{k=1}^{K} [\beta_{ki}] \frac{\dot{J}_i^k}{J_i^k} + \frac{\dot{\Omega}_i}{\Omega_i}. \tag{12}$$

What we have here is a firm-level decomposition, where value added growth is written in terms of TFP growth and weighted input factor growth rates for each firm. The weights are elasticities of value added w.r.t. primary factor inputs.

To arrive at the industry level, write industry value added as

$$Y = \sum_{i=1}^{N} Y_i \tag{13}$$

where N is the number of firms in an industry. Total differentiation of 13 yields

$$\dot{Y} = \sum_{i=1}^{N} \dot{Y}_i. \tag{14}$$

This aggregate value added growth can be written as

$$\frac{\dot{Y}}{Y} = \sum_{i=1}^{N} s_i \frac{\dot{Y}_i}{Y_i}, \tag{15}$$

with $s_i = \frac{Y_i}{Y}$, the share of firm i in total value-added. Thus, change in aggregate value-added equals to the value-added share-weighted average of individual growth rates.

[34] If written in terms of output and factor inputs the above equation would look like $Y_i = \Omega_i f(M_i, J_i)$, where Y_i would denote gross output and M_i intermediate inputs.

To complete the derivation, 12 is substituted to 15:

$$\frac{\dot{Y}}{Y} = \sum_{i=1}^{N} s_i \left(\sum_{k=1}^{K} [\beta_{ki}] \frac{\dot{J}_i^k}{J_i^k} + \frac{\dot{\Omega}_i}{\Omega_i} \right), \tag{16}$$

which is:

$$\frac{\dot{Y}}{Y} = \sum_{i=1}^{N} s_i \left(\beta_l \frac{\dot{L}_i}{L_i} + \beta_k \frac{\dot{K}_i}{K_i} \right) + \sum_{i=1}^{N} s_i \frac{\dot{\Omega}_i}{\Omega_i}, \tag{17}$$

where we approximated the factor growth rates $\left(\dot{J}^k/J^k\right)$ by logarithmic differences. This formula gives a clear indication as to what kind of weighting scheme should be used.

First, one calculates value added shares at the firm level $\left(s_{it}\right)$. However, equation 15 does not necessarily hold when we use discrete observations. In this case the decomposition presented in equation 5 is not valid either. As shown in Figure 1, we found that using Thornquist indices gives a good approximation, that is: $\text{dlog}\left(\sum Y_i\right) \approx \sum \frac{s_{it} + s_{i,t-1}}{2} \text{dlog}\left(Y_i\right)$. Then adding up log-differences of factor inputs multiplied by estimated elasticities leads to input growth contribution. The contribution of TFP to aggregate value added growth is shown by the last term in 5.[35]

[35] Note that the above formula "thinks" within a growth accounting framework. That is, it relates the change in aggregate growth to individual growth rates.

C Decomposing productivity growth

The literature almost exclusively employs some form of the Bailey et al (1992) index. This is says that aggregate productivity change is

$$\sum_i s_{it}\omega_{it} - \sum_i s_{it-1}\omega_{it-1}. \tag{18}$$

Reallocation effects and genuine growth are mixed here. To see this, write aggregate growth as the weighted average of individual TFP growth rates:

$$d\omega = \sum_{i=1}^{N} s_{vi} d\omega_i. \tag{19}$$

This formulation relates genuine growth and aggregate growth. The s_{vi}'s are usually approximated by some fixed shares (average share, base shares etc.), while the $d\omega_i$ denotes instantaneous productivity growth and is approximated by $\Delta\omega = \omega_t - \omega_{t-1}$using discrete data (Thornquist-approach). This is what growth accounting usually uses as a starting point.

In light of these, 18 can be rewritten (i indices are dropped for convenience) and can be decomposed as:

$$\begin{aligned} &\sum \frac{s_t + s_{t-1}}{2}(\omega_t - \omega_{t-1}) + \sum \frac{\omega_t + \omega_{t-1}}{2}(s_t - s_{t-1}) = \\ &= \sum \frac{s_t + s_{t-1}}{2}\Delta\omega_t + \sum \frac{\omega_t + \omega_{t-1}}{2}(s_t - s_{t-1}) = \\ &= d\omega + \sum \frac{\omega_t + \omega_{t-1}}{2}(s_t - s_{t-1}) = d\omega + \sum \overline{\omega} ds. \end{aligned} \tag{20}$$

The last term in 20 is what is often referred to as the reallocation term. The BHC formulation can be further decomposed to account for entry/exit effects:

$$\begin{aligned} &\sum s_{it}\omega_{it} - \sum s_{it-1}\omega_{it-1} = \\ &\sum_i s_{it}\Delta\omega_{it} + \sum_i \omega_{it}\Delta s_{it} + \sum_i \Delta s_{it}\Delta\omega_{it} + \sum_i^J s_{it}\omega_{it} - \sum_i^K s_{it-1}\omega_{it-1} \end{aligned} \tag{21}$$

The first two terms are the same as the ones in 20. The third is similar to what covariance means: how close share changes follow TFP changes. The last two terms are the contributions of entrants (J) and exiters (K). This equation shows reallocation as an amalgam of share changes and TFP changes.

The problem with the above formulations is that neither of the additional terms – masked by the simple BHC formulation in 18 – can be directly originated from the growth accounting framework. As is shown in 19, there is no reallocation term similar to the last term of 20.

D Reallocation

Now we show that reallocation - the last term - can be further decomposed to show intra- and inter-industry reallocation effects. We assume there are $k = 1... J$ industries and there are j firms within each industry. These add up to $J * j = N$ firms in the manufacturing sector.

The last term in 20 can be written as

$$\begin{aligned}\sum_i^N \overline{\omega_i} ds = \sum_i^N \overline{\omega_i}\left(s_{it} - s_{it-1}\right) = \sum_i^N \overline{\omega_i} s_{it} - \sum_i^N \overline{\omega_i} s_{it-1} = \\ = \sum_k^J \left[\sum_i^j \overline{\omega_i} s_{it} - \sum_i^j \overline{\omega_i} s_{it-1}\right]_k,\end{aligned} \tag{22}$$

Let $S_{kt} = \sum_{i=1}^j s_{it}$ denote industry k's share in overall manufacturing value added in time t. After regrouping observations belonging to the same industry in the second line. Rewriting and multiplying/dividing by industry shares yields:

$$\begin{aligned}\sum_{k=1}^J \left[\left(\sum_{i=1}^j s_{it}\right)\left(\sum_{i=1}^j \overline{\omega_i}\frac{s_{it}}{\sum_i^j s_{it}}\right) - \left(\sum_{i=1}^j s_{it-1}\right)\left(\sum_{i=1}^j \overline{\omega_i}\frac{s_{it-1}}{\sum_i^j s_{it-1}}\right)\right]_k = \\ = \sum_{k=1}^J S_{kt}\left(\sum_{i=1}^j \overline{\omega_i}\frac{s_{it}}{\sum_i^j s_{it}}\right)_k - \sum_{k=1}^J S_{kt-1}\left(\sum_{i=1}^j \overline{\omega_i}\frac{s_{it-1}}{\sum_i^j s_{it-1}}\right)_k,\end{aligned} \tag{23}$$

where the $S_{kt} = \sum_{i=1}^j s_{it}$ denote industry k's share in overall manufacturing value added in time t.

Now using the identity showed by 20, with $A_{kt} = \left(\sum_{i=1}^j \overline{\omega_i}\frac{s_{it}}{\sum_i^j s_{it}}\right)_k$:

$$\begin{aligned}\sum_{k=1}^J S_{kt}\left(A_{kt}\right) - \sum_{k=1}^J S_{kt-1}\left(A_{kt-1}\right) = \sum_{k=1}^J \frac{S_{kt}+S_{kt-1}}{2}(A_{kt} - A_{kt-1}) \\ + \sum_{k=1}^J \frac{A_{kt}+A_{kt-1}}{2}(S_{kt} - S_{kt-1}), \\ = \sum_{k=1}^J \frac{S_{kt}+S_{kt-1}}{2}\left(\sum_{i=1}^j \overline{\omega_i}\left(\frac{s_{it}}{\sum_i^j s_{it}} - \frac{s_{it-1}}{\sum_i^j s_{it-1}}\right)\right) + \\ + \sum_{k=1}^J \frac{1}{2}\left[\sum_{i=1}^j \overline{\omega_i}\left(\frac{s_{it}}{\sum_i^j s_{it}} + \frac{s_{it-1}}{\sum_i^j s_{it-1}}\right)\right](S_{kt} - S_{kt-1}).\end{aligned} \tag{24}$$

Rearranging this expression yields

$$\sum_{k=1}^{J}\sum_{i=1}^{j}\frac{S_{kt}+S_{kt-1}}{2}\overline{\omega_i}\left(\frac{s_{it}}{\sum_i^j s_{it}}-\frac{s_{it-1}}{\sum_i^j s_{it-1}}\right)+$$
$$\sum_{k=1}^{J}\sum_{i=1}^{j}\frac{1}{2}\left(\frac{s_{it}}{\sum_i^j s_{it}}+\frac{s_{it-1}}{\sum_i^j s_{it-1}}\right)\overline{\omega_i}(S_{kt}-S_{kt-1})= \tag{25}$$
$$\sum_{i=1}^{N}\overline{S_k}\overline{\omega_i}ds_{ki}+\sum_{i=1}^{N}\overline{s_{ki}\omega_i}dS_k,\ k=1...J.$$

At the equality in 25 we made use of the fact that we first summed within an industry and then over industries, i.e. over the whole manufacturing sector.

E Tables and figures

Table 1

Number of observations

NACE	Nb of firms in the database	Nb of firms with emp>=5	Nb of firms in the analysis (missing obs, outliers)	Nb of obs. in the database	Nb of obs. with emp>=5	Nb of obs. in the analysis (missing obs, outliers)
15	8 122	3 984	3 270	38 260	18 914	14 977
16	9	9	8	90	80	55
17	2 355	1 169	1 036	10 833	5 335	4 589
18	3 666	1 617	1 362	14 854	7 524	6 394
19	922	588	510	4 692	2 962	2 560
20	4 267	1 818	1 521	16 872	7 394	5 996
21	712	342	306	3 351	1 763	1 494
22	9 476	2 364	2 059	37 743	10 416	8 994
23	37	15	10	150	66	41
24	1 248	611	552	6 939	3 350	2 922
25	2 714	1 415	1 279	13 563	7 132	6 196
26	3 408	1 468	1 273	11 260	5 275	4 584
27	552	303	255	2 912	1 669	1 394
28	8 312	3 969	3 541	37 498	18 610	16 484
29	6 108	2 816	2 612	29 870	14 077	12 712
31	1 753	795	727	8 830	4 130	3 623
32	1 507	629	573	7 329	3 070	2 667
33	2 362	856	802	11 190	4 345	3 915
34	533	315	272	2 704	1 636	1 427
35	411	163	150	1 718	705	623
36	4 135	1 541	1 331	15 768	6 569	5 571
37	415	129	64	1 378	464	198
TOT	63 024	26 916	23 513	277 804	125 486	107 416

Industry: (15) Food products and Beverages; (16) Tobacco products; (17) Textiles; (18) Wearing apparel, Dressing and Dyeing of fur; (19) Leather and Leather products; (20) Wood and Wood products; (21) Paper and Paper products; (22) Publishing and printing; (23) Coke, Refined petroleum products and Nuclear fuel; (24) Chemical products; (25) Rubber and plastic products; (26) Other non-metallic mineral products; (27) Basic metals; (28) Fabricated metal products; (29) Machinery; (31) Electrical machinery; (32) Communication equipment; (33) Medical, Precision and Optical instruments; (34) Motor vehicles; (35) Other transport equipment; (36) Manufacture of furniture; (37) Recycling

Table 2

Estimation results

NACE	(1) OP without capacity utilization		(2) LP without capacity utilization		(3) OP with capacity utilization			(4) LP with capacity utilization		
	L	K	L	K	L	K	Cap. Util.	L	K	Cap. Util
15 + 16	0.67	0.24	0.48	0.31	0.68	0.22	0.78	0.56	0.35	0.64
17	0.67	0.29	0.60	0.26	0.67	0.26	0.79	0.61	0.25	0.66
18	0.78	0.12	0.72	0.16	0.78	0.12	1.01	0.74	0.17	0.94
19	0.76	0.23	0.74	0.33	0.78	0.19	0.85	0.77	0.34	0.73
20	0.73	0.29	0.50	0.33	0.71	0.29	0.71	0.52	0.34	0.59
21	0.51	0.24	0.36	0.21	0.51	0.21	0.52	0.38	0.20	0.47
22	0.70	0.19	0.41	0.21	0.65	0.20	0.73	0.46	0.23	0.62
23 + 24	0.53	0.23	0.27	0.42	0.60	0.25	0.67	0.39	0.41	0.56
25	0.65	0.32	0.50	0.29	0.64	0.31	0.66	0.53	0.31	0.62
26	0.65	0.25	0.52	0.25	0.68	0.26	0.72	0.58	0.27	0.57
27	0.67	0.19	0.42	0.24	0.65	0.20	0.70	0.46	0.28	0.52
28	0.72	0.27	0.52	0.30	0.69	0.24	0.76	0.55	0.30	0.69
29	0.76	0.22	0.54	0.26	0.71	0.23	0.83	0.57	0.25	0.76
31	0.62	0.33	0.49	0.37	0.61	0.32	0.66	0.50	0.36	0.54
32	0.66	0.28	0.48	0.29	0.68	0.28	0.74	0.54	0.27	0.58
33	0.69	0.27	0.40	0.30	0.67	0.23	0.86	0.48	0.28	0.66
34	0.72	0.32	0.46	0.49	0.69	0.27	0.53	0.46	0.44	0.45
35	0.82	0.13	0.59	0.22	0.81	0.13	0.31	0.55	0.23	0.37
36 + 37	0.75	0.26	0.50	0.27	0.76	0.25	0.86	0.55	0.28	0.71
MEAN	**0.69**	**0.25**	**0.50**	**0.29**	**0.68**	**0.24**	**0.72**	**0.54**	**0.29**	**0.61**

black: significant at 1% blue: significant at 5%; red: non significant

Industry: (15) Food products and Beverages; (16) Tobacco products; (17) Textiles; (18) Wearing apparel, Dressing and Dyeing of fur; (19) Leather and Leather products; (20) Wood and Wood products; (21) Paper and Paper products; (22) Publishing and printing; (23) Coke, Refined petroleum products and Nuclear fuel; (24) Chemical products; (25) Rubber and plastic products; (26) Other non-metallic mineral products; (27) Basic metals; (28) Fabricated metal products; (29) Machinery; (31) Electrical machinery; (32) Communication equipment; (33) Medical, Precision and Optical instruments; (34) Motor vehicles; (35) Other transport equipment; (36) Manufacture of furniture; (37) Recycling

Figure 1

Manufacturing VA growth rates (without computer industry)

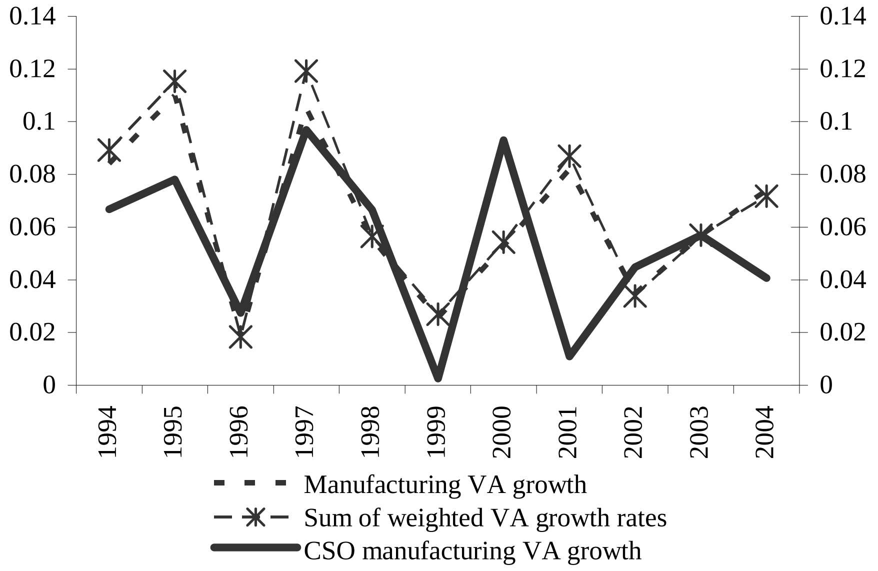


Figure 2

Decomposition of growth

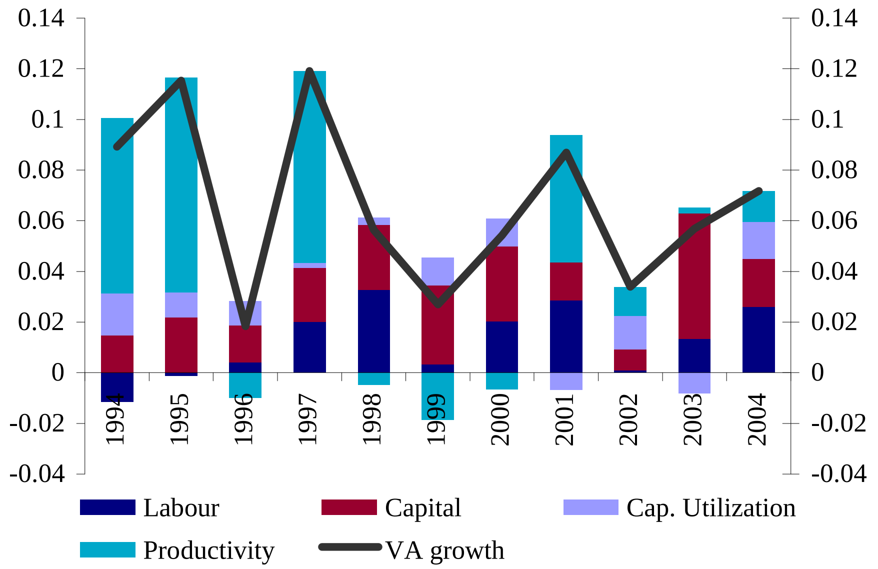


Figure 3
TFP growth and reallocation effect

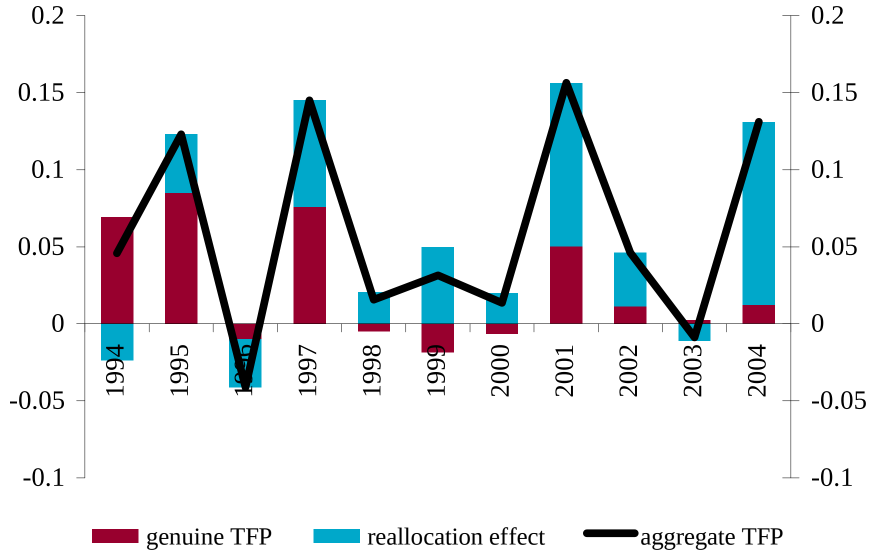


Figure 4
Intra- and intersectoral reallocation effects

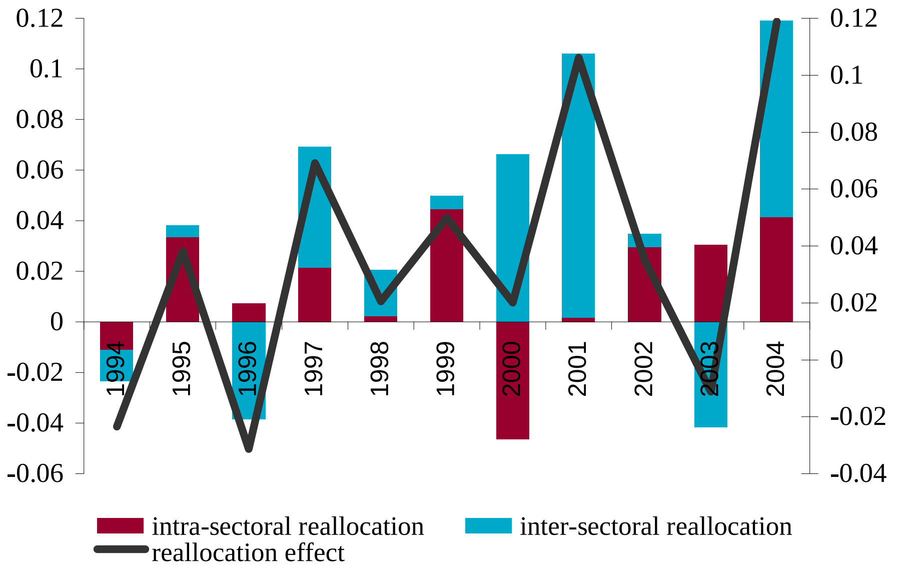


Figure 5

Intersectoral reallocation effects by industry

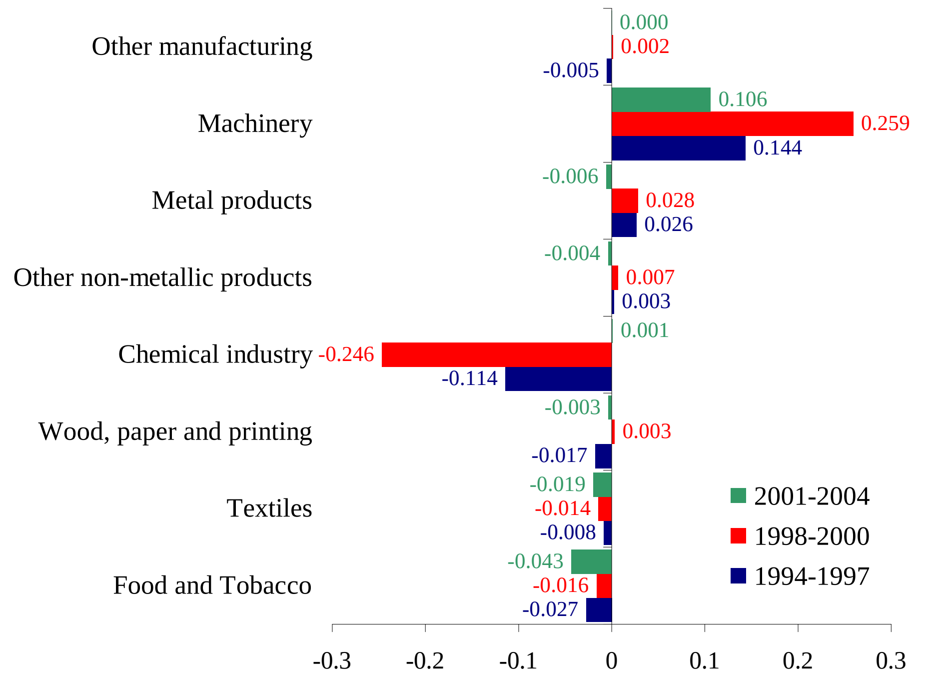


Figure 6

Contribution of industry-level genuine TFP growth to aggregate VA growth

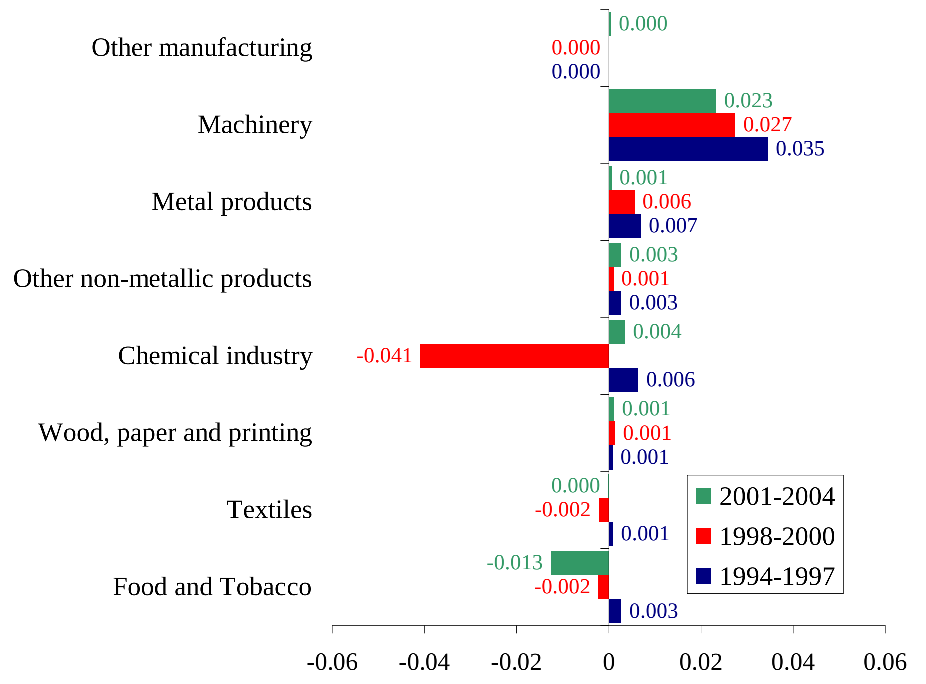


Figure 7

Input contributions by industry (sum to 100%)

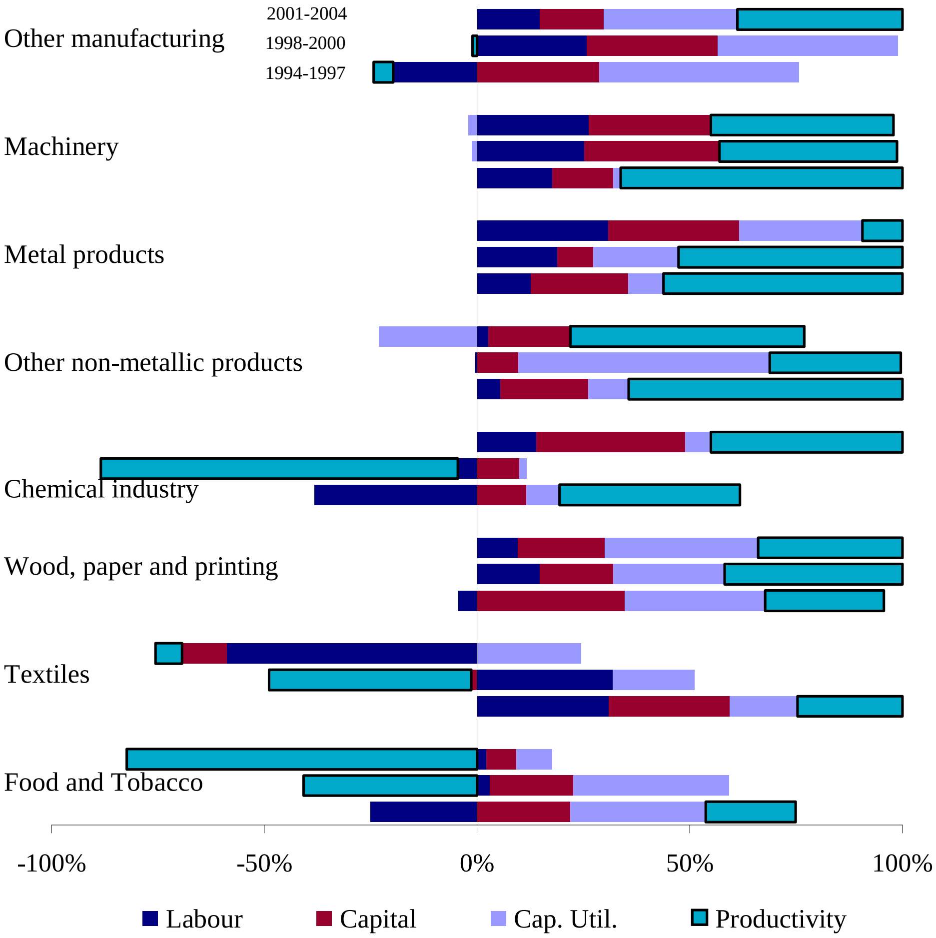


Figure 8

Input contributions in machinery

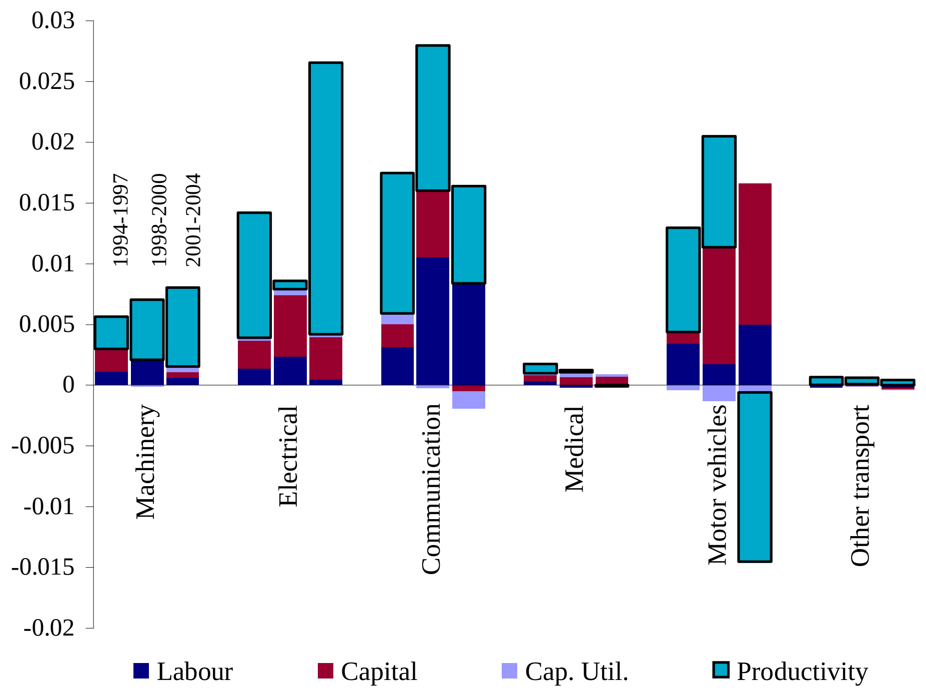
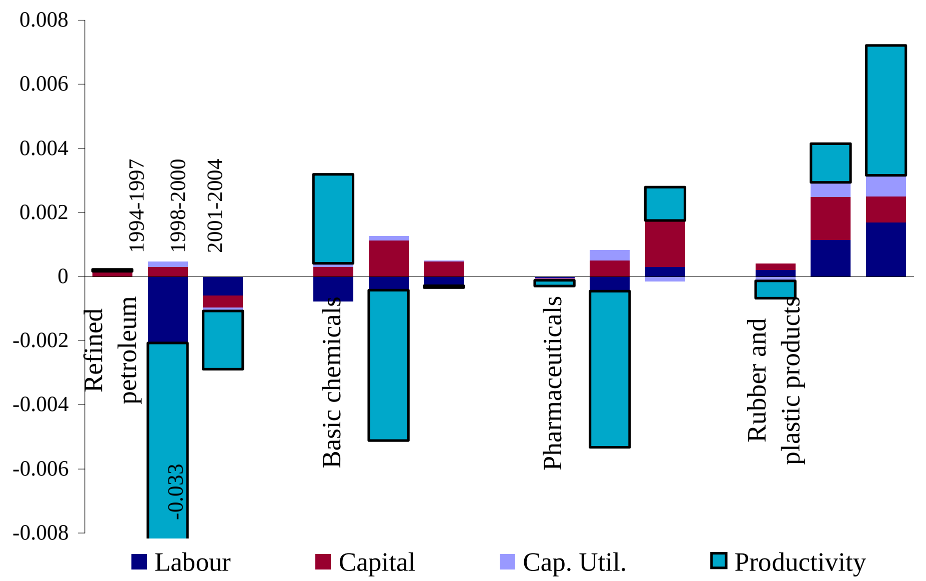


Figure 9

Input contributions in selected chemical subsectors



MNB Working Papers 2008/6
Driving Factors of Growth in Hungary – a Decomposition Exercise

Print: D-Plus
H–1037 Budapest, Csillaghegyi út 19–21.