How Important Is Total Factor Productivity for Growth in Central, Eastern and Southeastern European Countries?

Konstantins Benkovskis,
Ludmila Fadejeva,
Robert Stehrer,
Julia Wörz[1,2]

The evolution of total factor productivity (TFP) is a key determinant of long-run economic growth of a country. In this paper we analyze the contributions from technological change at the industry level to an economy's aggregate growth performance. Our derivation of economy-wide TFP growth entails three major improvements over the traditional Solow residual approach: First, we allow for non-constant returns to scale as well as changes in the utilization of input factors in our estimation of industry TFP growth. Second, we use a novel approach to aggregate TFP from the industry level to the macro level, which incorporates both direct and indirect effects through intermediate linkages within an economy. Third, we take account of open economy characteristics by assigning an explicit role to terms of trade shocks. Our calculations for the sample of ten Central, Eastern and Southeastern European EU member countries over the time period 1995–2009 are based on the newly available World Input-Output Database (WIOD).

JEL classification: C23, D24, E23, O47
Keywords: Total factor productivity, terms of trade, utilization, input-output table, Central, Eastern and Southeastern Europe

1 Introduction

The global economic crisis has had a severe impact on Central, Eastern and Southeastern Europe (CESEE), a region which is still in a process of catching up to their Western European peers. The catching-up process started only slightly more than two decades ago with the fall of the iron curtain and the transition from centrally planned to market economies. From the mid-1990s to 2008, CESEE countries recorded substantial economic growth supported by strong production factor accumulation, large inflows of foreign capital, and ample credit availability. The "traditional" CESEE growth model has come into question in the recent crisis as credit conditions deteriorated and foreign capital inflows receded. This redirects the focus of attention toward domestic growth drivers and the role of technological change for the region's growth potential. In the present paper we analyze growth drivers in order to allow for a deeper understanding of these countries' "technology improvement" structure. In particular we shift attention to total factor productivity (TFP) as the part of economic growth which cannot be attributed to the accumulation and varying utilization of production factors.

The literature on the growth potential of an economy is extensive but – for reasons of data availability – biased toward industrialized countries, often toward the U.S.A. Especially filtering methods require long time series; therefore calculations for the relatively young transition countries in Central, Eastern and Southeastern Europe are less abundant. Nevertheless, interest in the region rose in connection with the recovery from the transformation shock in the early 1990s.

[1] *Latvijas Banka, Monetary Policy Department, konstantins.benkovskis@bank.lv and ludmila.fadejeva@bank.lv; Vienna Institute for International Economic Studies, stehrer@wiiw.ac.at; Oesterreichische Nationalbank, Foreign Research Division, julia.woerz@oenb.at.*

[2] *This research was conducted during Julia Wörz's research stay at Latvijas Banka's Monetary Policy Department under the ESCB External Work Experience program. The authors are deeply indebted to Eduards Sidorovics for his excellent research assistance and would also like to thank Peter Backé, Mārtiņš Bitāns, Markus Eller, Doris Ritzberger-Grünwald, Uldis Rutkaste and two anonymous referees for their valuable comments.*

Later on, EU accession sparked interest in quantitative assessments of the speed of convergence, as the CESEE accession countries entered the EU with a considerably lower per capita income level compared to countries from previous enlargements. In this paper, we focus on the ten CESEE countries that joined the EU in 2004 and 2007.[3]

A number of features characterize the growth potential in CESEE: First, initial conditions at the outset of the transformation period have shaped the recovery path in the long run. Second, structural reform – representing to a large extent the heart of the transition process – has played an important role. With respect to TFP measurement, this renders the simple production function approach questionable. Very often, the production function approach is based on a one-sector model of the economy which by definition cannot take account of structural change. This simplification is clearly unrealistic and possibly already misleading when applied to countries with a long, uninterrupted economic history. It is all the more inappropriate in the context of transition countries with a short history of impressive convergence toward more advanced economies. Thus, multi-sector models are certainly required that take into account linkages between sectors as well as changes in the economic structure over time. Third, most authors find rather strong fluctuations in potential output for CESEE countries (see Benk et al., 2005). This may simply reflect the fact that these countries have yet to reach their true long-run equilibrium. They may still be going through different phases of adjustment toward mature market-based economies. It may, however, also reflect that cyclical factors are not fully identified by the estimation methods used so far.

Even in a more general setting, the estimation of TFP opens up a range of crucial questions. Ideally, TFP should be measured at the most detailed industry level in order to take account of different production technologies in different activities. Working at the industry level enables us to overcome a major shortcoming of previous production function approaches, i.e. measuring TFP growth in the CESEE region while relying on one-sector models of the economy. Our estimations of TFP consider differences in the production function of individual sectors and allow for non-constant returns to scale and variation in the utilization of input factors.

Not only the accurate estimation of TFP rates but also the correct aggregation of industry-specific results to the country level is a nontrivial task. If correctly done, however, this allows for highly policy-relevant conclusions concerning the contribution of individual sectors to overall TFP growth. Our input-output-based approach yields an estimate of economy-wide TFP growth and accounts for both direct and indirect effects. Thus, technological change in a certain sector not only directly influences aggregate TFP growth, but also produces indirect effects through the use of intermediate goods in production.

Finally, we pay special attention to the fact that the CESEE countries are small and open; hence their growth potential is strongly influenced not only by their domestic production structure, but also by their external linkages (purchase of intermediate inputs from abroad and their ability to export).

We base our estimations on the newly available World Input-Output Database (WIOD), which combines information on input-output tables and international

[3] *Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.*

trade in a global input-output table. The use of input-output tables and the time dimension implicit in the WIOD database also takes into account the impact of structural change, a factor which is particularly stressed in the existing literature on economic growth in transition countries. As mentioned above, the transition process by definition virtually implies a great deal of structural change in these economies with strong implications for potential growth prospects.

The paper is organized as follows: Section 2 presents the theoretical framework ranging from the estimation of industry TFP growth rates to their aggregation through input-output tables and their allocation to final use components of the economy. We take account of the high degree of openness of these economies by allowing changes in terms of trade to affect final consumption, investments and exports in subsection 2.3. Section 3 presents the WIOD database. The results are given in section 4 and section 5 concludes.

2 Theoretical Framework

2.1 Derivation of Total Factor Productivity by Industry

The traditional measure of TFP growth is the Solow residual, which is calculated under a set of very restrictive assumptions – perfect competition and constant returns to scale, costless adjustment and thus full utilization of production factors. As a result, the Solow residual systematically includes nontechnological effects like changes in capital utilization or variations in the intensity of workload. Basu and Kimball (1997) pioneered an approach based on more realistic assumptions including imperfect competition and unobserved changes in utilization, which was further implemented by Basu et al. (2001), Basu et al. (2006) and Groth et al. (2006). This approach was also used for CESEE countries by Katay and Wolf (2008) and Fadejeva and Melihovs (2009).

Our approach to evaluate TFP growth at the level of individual industries follows Basu and Kimball (1997). As in the standard approach, a representative firm produces gross output, using capital, labor and intermediate inputs. However, in addition, there are adjustment costs for changing the level of capital and labor. Alternatively, a firm may change the utilization of inputs, which also comes with some costs – higher wage rates for extra hours worked and premium payments for extra efforts of workers with respect to the utilization of labor as well as more rapid depreciation with respect to higher capital utilization. Starting from the intertemporal cost minimization problem of a representative firm, we obtain the following dynamic production function (for technical details, see Basu and Kimball, 1997, and Benkovskis et al., 2012):

$$dy = \gamma^* d\chi + \gamma^* du + dz \tag{1}$$

where $d(.)$ denotes the growth rate of the variable, lower-case letters refer to natural logarithms, and * implies the steady state value, dy is output growth, du denotes changes in utilization and dz corresponds to changes in TFP. $d\chi$ measures the overall input growth based on the observable variables: changes in capital stock *(dk)*, changes in the total number of employees *(dl)*, changes in hours worked per head *(dh)*, changes in the volume of intermediate inputs *(dn)*. Changes in input factors are weighted by their nominal cost shares s_k, s_l and s_n, respectively:

$$d\chi = s_K dk + s_L \left(dl + dh\right) + s_N dn \tag{2}$$

Unobservable growth in utilization du can be expressed by the growth rates of the following observable variables:

$$du = \beta_1 dh + \beta_2 \left(dp^N + dn - dp^I - dk\right) + \beta_3 \left(di - dk\right) \tag{3}$$

where $\beta 1$, $\beta 2$, and $\beta 3$ are complex functions of input cost shares, returns to scale, elasticities of the depreciation rate and adjustment cost functions (see Basu and Kimball, 1997), and therefore could be treated as unknown constants. The intuition for the change in hours per worker dh as a proxy for the dynamics of labor utilization is simple: in order to increase the utilization, the firm has to use more labor (more hours by worker or a shift in efforts). Thus, when the number of hours worked increases, the unobserved utilization also increases and the coefficient β_1 is positive. The intuition for the second term (changes in the ratio of real intermediate inputs to capital, $dp^N+dn-dp^I-dk$, whereby dp^N and dp^I are changes in intermediate consumption and investor deflators, respectively) in the utilization equation is related to the nature of capital and intermediate inputs: it is much easier to adjust the volume of intermediate inputs than capital or labor as there are no costs for changing the volume of intermediate inputs. Therefore a firm is likely to use existing capital more intensively when the ratio of intermediate inputs and capital rises. This positive relationship implies a positive sign for the coefficient β_2.

The interpretation of the third term, the ratio of investment to capital $di-dk$, is more complex. On the one hand, higher utilization intensity of capital is associated with a higher rate of depreciation and therefore also higher investments. On the other hand, a higher investment-to-capital ratio boosts adjustment costs and firms may therefore temporarily decrease capital utilization to reduce the depreciation rate and overall capital costs. Overall, the net effect of the third term depends on the relative size of the two effects above.

Given that the values of β_1, β_2, β_3, and γ^* are known, equations (1)–(3) can be used to estimate dz – changes in TFP. If γ^* is restricted to one and the level of utilization is assumed to be constant, equation (1) reduces to $dy=d\chi+dz$ and dz corresponds to the traditional Solow residual.

2.2 Measuring Aggregate Productivity from Industry Contributions

While the estimation of productivity growth should preferably be done at a disaggregate level in order to account for differences in production functions across industries, the aggregate effect of changes in TFP are of most interest for researchers and policy makers. Groth et al. (2006) note that such an aggregation requires the derivation of the relation between gross output and value added at the industry level, otherwise the aggregate contribution of productivity will be underestimated. In an input-output framework, Basu et al. (2010) go one step further and take advantage of the use table to derive direct and indirect effects of productivity changes. We follow the spirit of this latter approach here and refine it by accounting for the role of industry-specific returns to scale in TFP aggregation.

The previous section described the derivation of TFP growth at the industry level. However, this measures only the direct effects from technological change, while effects coming indirectly through the use of intermediate inputs are not taken into account. The best way to derive both direct and indirect effects of industry-level TFP growth at the macro level is through the use of input-output tables as they provide information on the use of intermediate products. Table 1 shows a very simplified version of an input-output table for a closed economy with only two products[4], the same price of a product regardless whether it is consumed or used as an intermediate input, and restricted to only one type of final use (consumption), while taxes and transport margins are ignored. Despite the above restrictions, this table is still useful for understanding how a positive technology shock in one industry transmits into other sectors of the economy and affects final use.

Table 1

Stylized Input-Output Table

		Product 1	Product 2	Consumption	Total output
Domestic	Product 1	P_1N_{11}	P_1N_{12}	P_1C_1	P_1Y_1
	Product 2	P_2N_{21}	P_2N_{22}	P_2C_2	P_2Y_2
Value added		VA_1	VA_2	...	VA
Total input		P_1Y_1	P_2Y_2	P^CC	

Source: Authors' compilation.

Note: P_i is the price of a product i, P^C is the price of a consumption basket, N_{ji} is the intermediate input of product j used in the production of i, VA_i is the value added of product i, Y_i is the gross output of product i, C_i is the consumption of product i and C is total consumption.

The assumption of a Cobb-Douglas production function F implies that the shares of inputs in total costs are unchanged, in other words, the structure of the first two columns in table 1 is constant. Another important assumption is that consumer utility is also represented by a Cobb-Douglas function, which implies constant nominal expenditure shares. From those assumptions it follows that the whole nominal structure of the input-output table depends solely on structural parameters of production and utility functions and is therefore unchanged.

Let's rewrite the dynamic production function (1), taking into account that the number of intermediate inputs can exceed one and adding product/industry subscripts:

$$dy_i = \gamma_i^*\left(s_{Ki}dk_i + s_{Li}\left(dl_i + dh_i\right) + \sum\nolimits_j s_{Nji}dn_{ji}\right) + \gamma_i^* du_i + dz_i \tag{4}$$

The constant structure of the nominal input-output table implies that the growth of real gross output, real net output (consumption) and real intermediate consumption of a product are equal *(dy_i=dc_i=dn_{ji})*, which means that the production function of gross output in equation (8) can be replaced by the production function of net output:

[4] *For the moment, we assume that product and industry are synonyms (as in Basu et al., 2010), i.e. each commodity is produced only within one corresponding industry. In reality, however, a commodity may be produced in different industries due to secondary production activities of firms. As a result, industry-by-industry input-output tables differ from product-by-product input-output tables. Only industry-by-industry input-output tables as well as use and supply tables are available in WIOD. Although one can simply use industry-by-industry input-output tables in aggregation, it will implicitly correspond to an industry technology assumption. However, a product technology assumption is more plausible from the theoretical point of view (see System of National Accounts, 1993); therefore in our final aggregation we will switch from industries to products. To implement a product technology assumption, we constructed a product-by-product input-output table from the supply and use tables, using Almon's method (see Almon, 2000, and Eurostat, 2008, for technical details).*

$$dc_i = \gamma_i^* \left(s_{Ki} dk_i + s_{Li} \left(dl_i + dh_i \right) + \sum\nolimits_j s_{Nji} dc_j \right) + \gamma_i^* du_i + dz_i \qquad (5)$$

Now we can express equation (5) in matrix form and apply inverse transformation.

$$dc = \gamma s_K dk + \gamma s_L \left(dl + dh \right) + \gamma B^T dc + \gamma du + dz \qquad (6)$$

$$dc = \left(\mathrm{I} - \gamma B^T \right)^{-1} \gamma s_K dk + \left(\mathrm{I} - \gamma B^T \right)^{-1} \gamma s_L \left(dl + dh \right) + \left(\mathrm{I} - \gamma B^T \right)^{-1} \gamma du + \left(\mathrm{I} - \gamma B^T \right)^{-1} dz \quad (7)$$

where $dc=||dc_i||_{J,1}$, $dk=||dk_i||_{J,1}$, $dl=||dl_i||_{J,1}$, $dh=||dh_i||_{J,1}$, $du=||du||_{J,1}$, $dz=||dz_i||_{J,1}$, $B=||s_{Nji}||_{J,J}$, $\gamma=diag(\gamma^*_i)_{J,J}$, $s_K=diag(s_{Ki})_{J,J}$, $s_L=diag(s_{Li})_{J,J}$, I is J by J identity matrix, J is the number of products/industries.

The production function in (7) contains both direct and indirect effects of changes in capital, labor and TFP on net output in different products/industries. In this paper we are primarily interested in the last term, $(I-\gamma B^T)^{-1}dz$, which shows the full effect of a change in technology (or a technology shock). The final step is to aggregate the contribution of a technology shock in all products/industries while taking into account their shares in final consumption (which are constant and given by a Cobb-Douglas utility function):

$$dz_C = s_C \left(\mathrm{I} - \gamma B^T \right)^{-1} dz \qquad (8)$$

where dz_C is the contribution of the technology shock to real consumption growth,[5] and s_C is the share of product i in total nominal consumption.[6]

2.3 Open Economy and Terms of Trade

The input-output table in table 1 has a very restrictive assumption of a closed economy that is absolutely unrealistic in today's world. To show how the inclusion of international trade will affect our analysis, we need to modify our stylized input-output table by including export and import flows.

Table 2

Stylized Input-Output Table including the External Sector

		Product 1	Product 2	Trade product	Consumption	Total input
Domestic	Product 1	P_1N^{11}	P_1N_{12}	P_1X_1	P_1C_1	P_1Y_1
	Product 2	P_2N_{21}	P_2N_{22}	P_2X_2	P_2C_2	P_2Y_2
Trade product		$P^M{}_1M_1$	$P^M{}_2M_2$	...	$P^M{}_CC^M$	P^MM
Value added		VA_1	VA_2	...	...	VA
Financial account		...	...	P^MM-P^XX	...	...
Total output		P_1Y_1	P_2Y_2	P^MM	P^CC	

Source: Authors' compilation.

Note: $P^M{}_i$ is the price of imported intermediate inputs in product i, $P^M{}_C$ is the price of imported consumption goods, P^M is the price of total imports, P^X is the price of total exports, M_i is the imported intermediate input used in the production of i, C^M is the imported consumption, M is total imports, X_i is exports of product i and X is total exports.

[5] *In this simplified example, real consumption coincides with real value added and real GDP.*

[6] *It can be replaced, for instance, by the nominal structure of government consumption, gross fixed capital formation or exports to calculate the contribution of a technology shock on the growth of these final use components.*

In addition to real domestic industries producing commodities 1 and 2, table 2 also includes a "virtual" trade product. It was pointed out by Basu et al. (2010) that the process of international trade can be viewed as a synthetic industry – in order to obtain imported goods, a country is forced to get involved in export activities. When using the terminology of a production function, exports are the inputs of the "virtual" trade industry and imports are the output.[7] As total nominal imports are equal to the sum of nominal exports and net financial inflows (given by negative net exports, $P^M M – P^X X$), the production function of this "virtual" trade commodity can be expressed by the following equation:

$$M = F_{trade}\left(X, P^M M - P^X X, P^X/P^M\right) = \left(X + \left(P^M M - P^X X\right)\right)\left(P^X/P^M\right) \quad (9)$$

Under the assumption that preferences of foreign consumers are also described by a Cobb-Douglas utility function and that the ratio of financial inflows to GDP is constant, the structure of nominal inputs of the "virtual" trade product is constant and its dynamic production function is given by

$$dm = dx + \left(dp^X - dp^M\right) \quad (10)$$

where $dp^X – dp^M$ are simply changes in terms of trade and are similar in spirit to changes in technology in (1). Indeed, improvements in terms of trade have the same effect as a positive technology shock in a domestic product – for the same amount of real exports (inputs) a country can obtain (or "virtually produce") a greater amount of imports (outputs). That is why terms of trade can be regarded as a specific type of TFP affecting final use and, hence, it should be included into analysis.

To analyze the aggregate contribution of changes in TFP and terms of trade, one can still use equation (8), although with a slight modification to include the "virtual" trade product (thus, the number of products increases to J+1). The "virtual" trade product has constant returns to scale, thus the diagonal of γ is augmented by one. In the open economy case, the column vector dz contains all J product-specific domestic technology shocks and as the last element – changes in terms of trade. The matrix B now contains the cost shares of domestic intermediate inputs, the cost shares of imported intermediate inputs (last row) and the shares of nominal exports of commodity i to total nominal imports (last column). The row vector s_C also includes the share of imported consumption.

It is important to note that in the presence of an external sector, total value added is no longer equal to total consumption, and to evaluate the contribution of changes in TFP to growth in value added, s_{VA} is used in equation (8) instead of s_C:

$$s_{VA} = \left[\; \left(P_1 Y_1 - \sum_i P_1 N_{1i}\right)/VA, \quad ..., \quad \left(P_J Y_J - \sum_i P_J N_{Ji}\right)/VA, \quad -\left(\sum_i P_i^M M_i\right)/VA \;\right] \quad (11)$$

Value added is equal to the sum of domestic final use net of imported intermediate inputs. The final element of s_{VA} in (11) is negative, which ensures that the total effect of changes in terms of trade on value added is zero.

[7] *This might sound counter-intuitive, but recall that we focus on domestic absorption. Thus, imports represent foreign-produced substitutes for domestically produced goods. Since the latter are clearly the output of domestic industries, imports are consequently considered to be the output of the "trade industry" while exports generate the revenue which is necessary to buy these imports from abroad. By selling exports, an economy can consume imports. Hence exports serve as inputs for the trade industry. See e.g. Krugman (1993) for intuitive reasoning.*

3 Database Description

To our knowledge, this methodology to calculate aggregate TFP growth has not yet been applied to any other country than the U.S.A. We base our calculations on the newly available World Input-Output Database (WIOD, Timmer et al., 2012), which is especially suited for our purpose as it combines harmonized national supply and use tables (SUTs) with international trade data for a range of countries. National SUTs are not only harmonized across countries in this dataset but also extra- and interpolated over time, which thus yields a panel dataset spanning 40 countries over the years 1995–2009. The sample includes all 27 EU Member States as well as 13 other major countries (such as the U.S.A., Japan, China, Russia and India). National accounts and trade data have been integrated into sets of inter-country (world) input-output tables and supplemented by satellite accounts containing environmental and socioeconomic indicators.

For our estimation of industry-level TFP growth rates, we make use of the socioeconomic accounts as these provide us with all the necessary information on factor inputs, cost shares, utilization and effort at the sector level. The WIOD database contains information for 35 goods- and service-producing industries. Since we merge several of them, our analysis is based on 28 industries.[8] Industry data are available on gross output, value added, capital stocks, employment levels, intermediate inputs, hours worked, factor compensations, and the respective deflators. With this dataset at hand, we are not only able to adjust for changes in factor utilization, but we can also account for qualitative changes in capital and labor inputs, as according to Basu and Kimball (1997), unaccounted changes in the quality of input factors can be one of the reasons for cyclical fluctuations in the Solow residual. We account for the quality of factors by using a composite of different asset types at different prices and, in the case of labor, a composite of different skill types at different wages.

Furthermore, we add macroeconomic data from the World Bank database which we are going to use as instruments in our TFP estimations. These include information on global prices for oil and other commodities, interest rates, real effective exchange rates, government expenditures as well as global and national GDP and exports and are described in more detail in subsection 4.1 below.

The second step in our analysis – the proper aggregation of industry-specific TFP growth rates – requires the use of the harmonized SUTs, which are the basic building blocks of the WIOD database. National SUTs are typically compiled for selected years (often every five years) and show methodological variations over time. One of the advantages of the WIOD database is the fact that SUTs have been harmonized both over time and across countries by benchmarking available national SUTs on consistent time series from the System of National Accounts.[9]

[8] *As mentioned in footnote 4, we applied Almon's iterative method to construct product-by-product input-output tables from supply and use tables. To achieve robust results, we reduced the size of SUTs by merging several industries. In particular, we merged all three trade and repair sectors (NACE codes 50 to 52), all transport sectors (60 to 63), and we merged the sector of households and employed persons (P, which in most countries was reporting zero output) with other community, social and personal services (O). Finally, we also merged coke, refined petroleum and nuclear fuel industry (23) with chemicals and chemical products (24). A list of all merged industries and their correspondence to original NACE industries and to the Statistical Classification of Products by Activity (CPA) can be found in the appendix to Benkovskis et al. (2012).*

[9] *The harmonization is based on Temurshoev and Timmer (2011); details of the various implementation issues in this respect are discussed in Timmer et al. (2012).*

4 Results

4.1 Evaluation of TFP Changes

Our empirical model for the estimation of industry TFP growth[10] is given by equation (12) below, which combines equations (1), (2) and (3) and expresses all necessary elements, including the utilization of production factors, in terms of observable variables as explained in section 2.1:

$$dy_{it} = b_0 + \gamma^* d\chi_{it} + b_1 dh_{it} + b_2\left(dp_{it}^N + dn_{it} - dp_{it}^I - dk_{it}\right) + b_3\left(di_{it} - dk_{it}\right) + \xi_{it} \qquad (12)$$

where $b_i = \beta_i \gamma^*$, the intercept b_0 allows for the existence of a trend in technical change, and ξ denotes a residual term. By estimating equation (12), we can obtain parameters b_1, b_2, b_3 and γ^* (see table 3 below), which allows us to evaluate changes in TFP ($dz = b_0 + \xi$). As we are working with a panel dataset spanning countries, years and industries, we can choose between alternative estimation strategies. Ideally, the estimations are conducted at the most detailed level available; i.e., equation (12) is estimated for every single industry in each country. Unfortunately, this approach cannot be implemented here as the time period covered in WIOD is rather short and covers only 14 observations between 1995 and 2009.

To increase the number of observations, we use panel estimates, whereby we can create the panel in three different ways. The global panel would include all industries and countries, where observations have to be stacked either by countries or by industries. This approach is the simplest but is overly restrictive, as it assumes that returns to scale and other fundamental parameters of the production function determining b_1, b_2, b_3 are the same in all industries across all countries. We can also construct a number of panels, separating the panel datasets either by industries or by countries. We choose to work with 28 industry-specific panel datasets, whereby each panel contains a country and time dimension. As the coefficients in equation (12) are driven by parameters which are specific to the underlying production and adjustment cost function of the respective industry, it seems reasonable to assume that coefficients of the same industry are homogenous across countries rather than to impose equal coefficients for different industries in one country.[11] We include country fixed effects to control for country-specific characteristics (therefore $\xi_{it} = \mu_i + v_{it}$). Although time-specific fixed effects would help isolate a world business cycle effect, these were not used in the regression. It is rather possible that TFP dynamics are correlated across countries in some industries e.g. due to worldwide technological progress. Thus, the inclusion of time-specific fixed effects would eliminate some part of TFP changes.

Another problem related to the empirical estimation is the potential correlation between input growth and the technology shock. This endogeneity problem is also mentioned in Basu et al. (2006); we argue that there may also be a potential correlation between other right-hand variables and the technology shock. Changes in hours worked per employee can be affected by technological progress related to process innovation and thus better work organization. New technologies may also

[10] *In subsection 4.2, industry TFP growth is transformed to product TFP growth by using Almon's procedure.*

[11] *To test the poolability of the data, we ran the regressions for reduced samples (excluding individual countries one by one) and compared the coefficients with those estimated from the full sample. In the vast majority of cases, the coefficients from these reduced samples came to lie within the 95% confidence interval of the full sample coefficients. The exceptions are transport equipment (34 and 35) and other social services and employed persons (O and P) when excluding Portugal.*

improve energy efficiency and hence reduce the ratio of intermediate inputs to capital. Finally, technological change is usually associated with the installment of new equipment, which can increase the investment-to-capital ratio.

Therefore we draw on a range of instruments which are uncorrelated with technological change but correlated with the right-hand variables[12] in the estimation of equation (12). The particular set of instruments used may differ from industry to industry. The instruments can be divided into four groups. The first group comprises industry-specific variables such as lagged values of input growth, changes in hours worked, intermediate inputs-to-capital and investment-to-capital ratios. Variables from the second group describe changes in external demand, which is uncorrelated to domestic technology shocks while it explains changes in total inputs. This group contains global GDP growth as well as an index of real external demand for each specific industry in every country (calculated by using WIOD data and applied only to industries producing tradable goods). The third group includes instruments that correlate with country-specific business cycles and therefore correlate strongly with variables proxying for the level of factor utilization.[13] These are the changes in the three-month money market rate, changes in the real effective exchange rate (both proxies for monetary policy), and changes in government expenditure to GDP (proxy for fiscal policy). Although monetary and fiscal policy react to changes in output (albeit with some time lag), we take advantage of the fact that these policies in general respond to the changes in overall output and not to fluctuations in output of a specific industry.[14] Hence, we argue that the above-mentioned instruments are uncorrelated with technology shocks at the industry level. The final instrument group contains various world prices (here we follow Basu et al., 2006, who use oil prices). All equations include changes in a general world commodity price index as an instrument, while for several industries we add specific commodity price indices – e.g. the food price index in the estimation for agriculture, hotels and restaurants, food, beverages and the tobacco industry, a metal price index for the basic metals and fabricated metal industry, a hardwood price index for the wood industry and construction.

The crucial condition in instrumental variable estimation is that the chosen instruments must be orthogonal to the error process. The orthogonality condition is verified by the Sargan test (also called J-test for overidentified restrictions). For all industries the null hypothesis that instruments are uncorrelated with the error term could not be rejected at the 1% confidence level, while only for three industries (food, beverages and tobacco; pulp, paper, printing and publishing; refined petroleum, chemical products) the null hypothesis was rejected at the 10% confidence level.

[12] *The results of the Sargan test for overidentifying restrictions are reported in table 3. The null hypothesis is rejected for the vast majority of industries. The results of first-stage regressions are available upon request.*

[13] *Basu et al. (2006) used Federal Reserve "monetary shocks" from an identified VAR as an instrument. Our approach is somewhat similar, although we do not have the opportunity to estimate shocks from a VAR model given the short length of the data.*

[14] *The recent global economic crisis has to some extent challenged this statement with respect to fiscal policies (recall the European car scrappage schemes in 2009). However, such policies were only applied in a minority of the 40 countries in our sample.*

Table 3

Estimation Results

Industry	Coefficients				No. of countries	No. of observations	Sargan test (p-value)
	$d\chi$	dh	$dn+dp^N-dk-dp^I$	$di\text{-}dk$			
Agriculture, forestry and fishing	0.032	–0.029	0.928***	0.018	40	360	0.620
Mining and quarrying	0.548***	0.171	0.121	–0.019	40	393	0.684
Food, beverages and tobacco	1.076***	0.155	–0.049	0.012	40	407	0.017
Textiles and textile products	0.909***	0.052	0.122	–0.004	40	398	0.254
Leather and footwear	0.940***	0.040	0.180*	0.021	39	350	0.463
Wood and products of wood and cork	0.975***	0.296	0.199	–0.034	40	394	0.669
Pulp, paper, printing and publishing	1.001***	0.103	0.031	0.003	40	407	0.080
Refined petroleum, chemical products	0.998***	0.007	–0.082	0.012	40	404	0.019
Rubber and plastics	0.936***	0.112***	0.120*	–0.007	40	407	0.705
Other non-metallic mineral products	0.997***	0.398	0.087	–0.018	40	404	0.226
Basic metals and fabricated metal	0.841***	0.275	0.132	–0.009	40	407	0.327
Machinery, n.e.c.	0.852***	0.447**	0.230	–0.051**	40	407	0.112
Electrical and optical equipment	1.159***	0.099	–0.113	–0.009	40	401	0.685
Transport equipment	0.497***	–0.073	0.734***	–0.069	40	399	0.599
Manufacturing, n.e.c; recycling	0.924***	0.281	0.147	–0.034	40	396	0.479
Electricity, gas and water supply	0.572***	–0.036	0.305**	0.011	40	403	0.134
Construction	0.942***	0.132	0.163*	–0.030	40	404	0.983
Trade	0.745***	0.110	0.360**	0.005	40	407	0.169
Hotels and restaurants	0.919***	0.038	0.419	–0.026	40	394	0.508
Transport	0.909***	0.189	0.155*	0.004	40	402	0.494
Post and telecommunications	1.168***	0.075	–0.028	–0.015	40	404	0.392
Financial intermediation	1.131***	0.174	–0.154	–0.015	40	401	0.504
Real estate activities	1.103***	0.015	–0.083	–0.012	40	407	0.925
Other business activities	1.177***	0.527**	–0.180	0.006	40	405	0.562
Public administration and defense	0.773***	0.137	0.088	0.006	39	392	0.463
Education	–0.684	–0.065	0.502	0.055	40	401	0.908
Health and social work	0.021	0.439	0.160	–0.084*	40	394	0.649
Other social services; employed persons	1.377*	–0.827	0.073	–0.088	40	401	0.346

Source: Authors' estimations.

*Note: Estimates were made by using a two-stage least square (TSLS) model allowing for country-specific fixed effects. The panel consists of 40 countries covered in the WIOD database (data for Luxembourg are missing for the "leather and footwear" industry and for India for the "public administration and defense" sector); the adjusted time period is 1997 to 2009. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively; heteroscedasticity and autocorrelation consistent (clustered) standard errors used.*

As a final technical detail, overall input growth $d\chi$ in equation (2) is defined as weighted growth of observed input factors: capital, hours worked, and the volume of intermediate inputs. Their weights in total factor input are given by their shares in total costs. In contrast to the theoretical model, these shares vary in the data, therefore we follow OECD (2001) and calculate $\tilde{s}_K$, $\tilde{s}_L$ and $\tilde{s}_N$ as an average of input shares in the current and previous period.

The estimation results of equation (12) are shown in table 3. We observe almost constant returns in most industries, as indicated by the coefficient $d\chi$, which is often near unity. The exceptions are agriculture, health and social work, and education, where estimated returns to scale are insignificant and close to zero (even negative for education), as well as mining, energy, trade, public administration and the manufacture of transport equipment with pronounced decreasing returns to scale. Most of these results seem plausible from an economic point of view. In the education sector, a doubling in the number of schools and teachers will not affect the number of pupils, and even if the quality of education increases, it will most likely not double. A similar logic can be applied to the public administration and health sectors. The output in mining and quarrying is obviously linked to the amount of natural resources within the territory of a country, and the output of agriculture is to a large extent driven by weather conditions, which explains diminishing returns to scale in these industries.

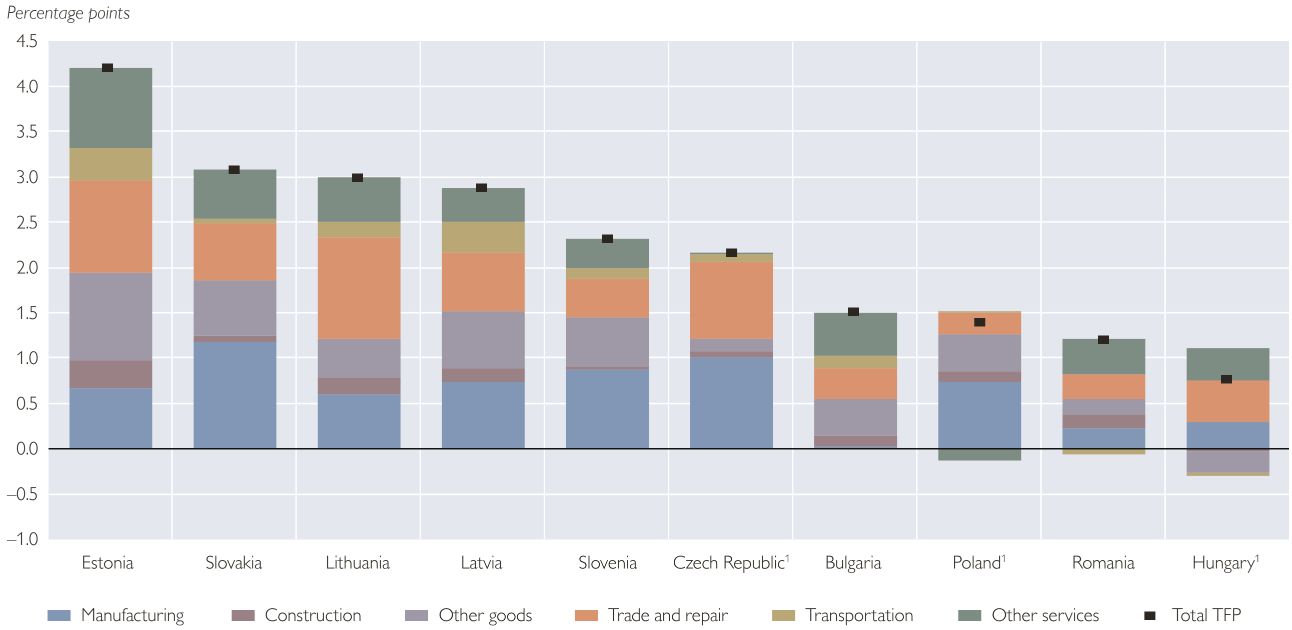
As to proxies for the level of utilization, all statistically significant coefficients have the expected sign; increases in hours worked per employee and in the intermediates-to-capital ratio lead to higher output growth, while a higher investment-to-capital ratio lowers output growth. The results in table 3 suggest that all three proxies for utilization are equally important and restricting the analysis only to one proxy (e.g. changes in hours, as in Basu et al., 2006) would imply a loss of important information. However, it should be noted that in many industries none of the above-mentioned proxies is significant, which may be due to a certain lack of homogeneity in industries across countries. We made an attempt to improve the regression by adding several cross terms and allowing coefficients to vary according to the capital intensity of an industry or to the income level of a country. This did not lead to worthwhile improvements of the results.

4.2 Aggregate Contribution of Technology and Terms of Trade Changes

Finally, we can now use the information on TFP growth in individual industries and calculate the contribution of TFP growth and terms of trade changes to the growth of real value added and various final use components. This is done in equation (8). Matrix γ is formed by results reported in table 3 (the negative and statistically insignificant coefficient reflecting negative returns to scale in the education sector was replaced by zero). The vector dz now contains product TFP changes. At first, we obtain industry-specific TFP changes from equation (12),

Chart 1

Total Factor Productivity and Industry Contributions to Value Added Growth, 1996–2009



Source: Authors' calculations.

[1] 1996–2007.

using the industry coefficients from table 3, and then transform them into a product TFP vector by using the Almon procedure (without sign restriction). Similarly to the cost shares used in the previous subsection, matrix *B* and row vectors s_C and s_{VA} are calculated as an average of current and previous period weights.

Chart 1 depicts the average percentage point contribution of TFP to real domestic value added growth after the aggregation of industry-specific TFP growth rates for the ten CESEE EU members over the period 1996 to 2009. The total contribution of TFP to real growth in the economy's value added (black dots) is broken down into contributions of individual sectors (stapled columns) accumulating both direct and indirect effects. As a first observation we see that the average contribution of TFP varied widely between the ten countries in the region. The Baltic states and Slovakia emerged as the top performers during our observation period, with an average contribution of above 2.5 percentage points per annum. But also Slovenia (2.3 percentage points) and Slovakia (2.2 percentage points) showed a high average annual contribution of TFP to value added growth. The remaining five countries lagged behind, with the average TFP contribution ranging from 0.8 percentage points in Hungary to 1.5 percentage points in Bulgaria. According to our calculations, Hungary had reasonably high TFP growth in the period from 2000 to 2004.

One explanation for these differences might be found in the initial gap to the technological frontier. For example, the comparison of Slovakia and the Czech Republic suggests that TFP growth (and hence its contribution to overall growth) was lower in the Czech Republic, simply because of the higher degree of industrialization of the economy at the beginning. As a result, foreign investors mainly acquired existing factories and improved existing technologies, while FDI in Slovakia more often comprised greenfield investments, thus laying the foundations for new technologies to be brought to the country. Another factor might be related to the exchange rate regime. With one exception (Czech Republic), the highest contributions of technological change to total value added growth were recorded in countries with a fixed exchange rate at the end of the observation period. Fixing the exchange rate can act as a "structural whip," i.e. the lack of the exchange rate as a cushion for external shocks may foster structural change and thus raise the efficiency in the economy.[15] Clearly, this can only be an additional explanatory factor as for some countries (i.e. Slovakia and Slovenia) the frequent realignments or crawling peg regime undermined the pressure on industrial restructuring.

In general, we observe considerably higher TFP growth rates in the CESEE countries compared with Western Europe. On average, the contribution of TFP growth to total growth amounted to 2.4 percentage points annually over the 1996–2007 period in this region. In the EU-15, TFP growth added on average 1 percentage point to overall growth in value added. Sweden and the U.K. showed the highest efficiency gains (TFP growth added an average 2 percentage points to GDP growth). Apart from these two outperformers, the contribution of TFP

[15] *Austria experienced such a "structural whip" in the 1980s with the schilling peg to the Deutsche mark.*

growth was often higher in small and peripheral countries (at around 1.5 percentage points) than in the more advanced, large EU countries.[16]

Not only the magnitude of the overall TFP contribution, which we associate very broadly with technological change, but also the contribution of individual industries or sectors to overall TFP differs between individual CESEE countries. Technological progress in goods-producing industries contributed strongly to overall TFP growth in Poland, the Czech Republic, Slovenia and Slovakia. In contrast, services TFP drove economy-wide TFP growth in Bulgaria, Hungary and Lithuania. Estonia, Latvia and Romania show a more balanced mix between TFP growth in services and goods-producing industries.

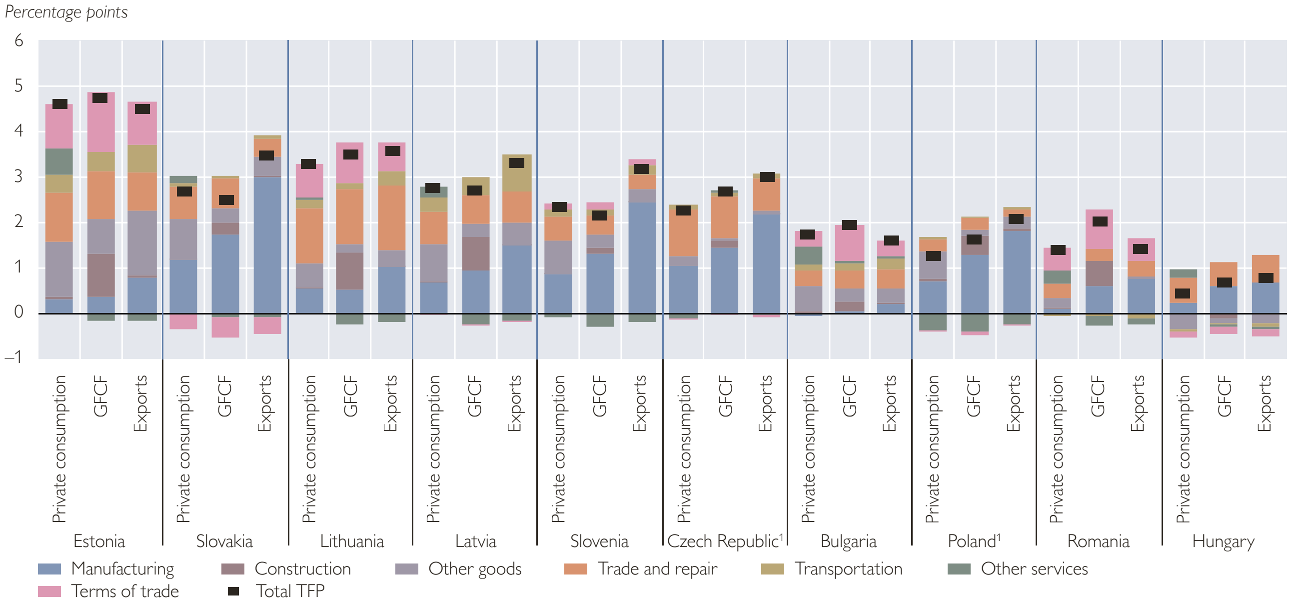
Within the goods sector, manufacturing TFP plays the most important role. It is worth noting that also Hungary shows on average stable positive TFP growth in manufacturing industries. In the Baltic states and Bulgaria, also technological progress in other goods-producing industries – comprising agriculture, mining and energy products – has had a stronger (or equally strong) influence on economy-wide TFP growth than manufacturing TFP. In Bulgaria, the dismantling of the predominance of heavy industry and the re-orientation toward light industries implied an initial negative contribution of TFP growth in manufacturing; however, since 1998 manufacturing TFP (in particular in textiles and chemicals) has been making an increasingly positive contribution to overall value added growth. Within the service sector, it is mostly TFP in trade and repair which impacts most strongly on total TFP growth. However, in Bulgaria it was financial and business services and in Romania public services (both subsumed under other services in chart 2) that contributed most markedly to services TFP. In Latvia and Estonia, TFP growth in the transportation industry is also of major importance.

So far we have aggregated the contribution of domestic industry-specific TFP growth to total value added TFP growth. As explained above, there is no theoretical role for terms of trade effects when we focus on total value added. In the following, we will trace out how industry TFP affects growth in different final use components of an economy. In this context, changes in terms of trade may improve or worsen the consumption or investment possibilities of the economy without altering the production possibilities. But before we turn to contributions to TFP growth by final use component, let us compare the contribution of TFP growth in three important GDP components. Chart 2 shows the contribution of TFP growth to growth in private consumption, gross fixed capital formation and exports for each country. Again, TFP growth in each final use component is broken down by contributions from individual industries. Most CESEE countries show the highest contribution of TFP in the export sector. This is particularly pronounced in the Czech Republic, Slovakia, Slovenia, Poland, Hungary, Lithuania and Latvia, which points toward rapid technological progress in outward-oriented industries. Set aside potential negative developments in external demand for these countries in the near future related to the euro area crisis, this constitutes a solid foundation for future export-led growth. Strong productivity gains in the export sector are certainly related to substantial foreign investment in outward-oriented industries. The analysis of explanatory factors behind TFP growth in this sector is, however,

[16] *Given the focus on CESEE countries, we do not display the results for all countries here. The results for all 27 EU countries are, however, available from the authors on request.*

Chart 2

Comparison of TFP Growth Contributions across Final Use Components, 1996–2009



Source: OeNB.

[1] 1996–2007.

beyond the scope of this paper. Estonia, Romania and Bulgaria exhibit the highest TFP contribution in the production of investment goods. Thus, in all countries, technological change was fastest in the production of either investment or export goods, which implies a sizeable long-term growth potential.

The contribution of individual sectors is rather similar for different end-use components. Again, efficiency gains in manufacturing account for a sizeable fraction of TFP growth in Slovakia, Slovenia, the Czech Republic, Poland, and Latvia. Services dominate TFP growth in Lithuania and Bulgaria. Chart 2 shows another interesting detail, namely the effect of changes in terms of trade on consumption, investment and export possibilities. Individual CESEE countries react rather differently to changes in relative export and import prices.

Table 4 displays more detailed results averaged over two periods of time: the precrisis period from 1996 to 2007 and the full sample period until 2009. Terms of trade changes only play a minor role as was to be expected; however, in some countries their contribution is nonnegligible. In general, a positive contribution of terms of trade changes should go hand in hand with a real appreciation tendency: if export prices increase faster than import prices, then more imports for domestic absorption can be purchased for the same amount of exports in the short run. However, as this also entails a loss in competitiveness, the substitution effect implies an ambiguous net effect. In Estonia, Lithuania, Romania and Bulgaria, the net effect was positive on average, and the positive contribution of terms of trade changes to consumption and investment growth was rather sizeable. In contrast, in Slovakia and Hungary, terms of trade changes affected consumption and investment growth negatively. In the remaining countries, the effects of terms of trade changes were negligible and TFP growth was driven primarily by technology shocks.

Table 4

Average Contribution of Total Factor Productivity and Terms of Trade to Growth of Real Final Use Components in CESEE

	Private consumption			Gross fixed capital formation			Exports		
	TFP	Technology	ToT	TFP	Technology	ToT	TFP	Technology	ToT
1996–2007									
Bulgaria	1.76	1.40	0.36	1.92	1.08	0.85	1.75	1.38	0.37
Czech Republic	2.27	2.28	–0.02	2.68	2.71	–0.03	2.99	3.03	–0.04
Estonia	5.10	3.83	1.28	5.14	3.41	1.73	5.04	3.78	1.25
Hungary	0.45	0.59	–0.14	0.67	0.84	–0.17	0.78	0.94	–0.16
Latvia	3.38	3.28	0.10	3.46	3.29	0.17	3.85	3.77	0.08
Lithuania	3.92	2.98	0.94	4.35	3.26	1.09	4.18	3.40	0.78
Poland	1.26	1.30	–0.04	1.64	1.70	–0.06	2.08	2.10	–0.02
Romania	1.43	0.78	0.65	2.31	1.19	1.12	1.64	1.01	0.64
Slovakia	2.77	3.02	–0.26	2.44	2.81	–0.38	3.54	3.81	–0.27
Slovenia	2.89	2.85	0.04	2.71	2.65	0.05	3.83	3.80	0.03
1996–2009									
Bulgaria	1.74	1.40	0.34	1.93	1.15	0.78	1.61	1.26	0.35
Czech Republic									
Estonia	4.59	3.64	0.95	4.72	3.38	1.34	4.50	3.54	0.96
Hungary									
Latvia	2.75	2.77	–0.02	2.71	2.73	–0.02	3.30	3.32	–0.01
Lithuania	3.29	2.54	0.74	3.50	2.62	0.88	3.58	2.96	0.62
Poland									
Romania	1.38	0.89	0.49	2.02	1.15	0.87	1.41	0.92	0.49
Slovakia	2.68	3.03	–0.34	2.48	2.94	–0.45	3.47	3.83	–0.35
Slovenia	2.34	2.21	0.13	2.15	1.98	0.17	3.19	3.06	0.12

Source: Authors' calculations.

Note: Calculated based on equation (8) and estimation results from table 3. Percentage point contribution to logarithmic growth (100dy). TFP = total factor productivity, ToT = terms of trade. Results for 2008 and 2009 are missing for the Czech Republic, Hungary and Poland due to the switch to NACE 2 and the consequent lack of NACE 1.1 data on capital stocks for those years.

Based on our industry TFP growth estimations, we can also trace the results over time.[17] Overall, TFP growth showed notable ups and downs in many countries in the late 1990s, with occasional negative TFP growth evident in the mid-1990s in the Czech Republic and Romania. The period 2000–2007 was characterized by particularly strong TFP growth in all countries. The 2008/09 crisis left its mark also in terms of lower or sometimes negative TFP growth. These fluctuations may partly reflect a methodological weakness in our industry-specific TFP estimations,[18] but there are also economic arguments for weaker technological progress in an uncertain and unfavorable economic environment. Both the financial means and the incentives to improve existing technologies may be impaired in times of economic distress. However, again, individual countries differ in their time path of TFP growth rates: In the 2000–2007 period, most countries – i.e. Estonia, Latvia, Lithuania and Slovenia, to name them in descending order – showed huge technological progress ranging on average from 4.9% to 2.7% per year over that period. In contrast, Poland recorded high TFP growth between

[17] *These results are not shown here for space constraints but are available from the authors on request.*

[18] *Our approach to estimate industry-specific TFP growth rates in country-year panels and separately for each industry may come at the cost of not being able to purge the residual from all cyclical factors. This potential caveat can arise as individual countries differ and we are not able to fully eliminate the effects of individual business cycles. The only remedy would be to include country-year fixed effects, but this is precluded by the panel dimension.*

1995 and 2000 but considerably weaker improvements since. As mentioned before, TFP growth in Hungary started to decline from relatively high levels as early as 2005 and became almost zero or turned negative even in the years prior to the crisis.

Unfortunately, due to data constraints, we cannot analyze the years 2008 and 2009 for all countries.[19] We observe a decline in TFP growth in most countries in 2008, in Latvia and Slovakia even one year earlier. Slovenia and Romania show an increase in TFP growth in 2008 compared with 2007, but a sharp drop into negative territory in 2009. In contrast, TFP growth in Slovakia and Estonia remained positive even in 2009.

5 Summary and Conclusions

According to endogenous growth theory, technological progress plays a vital role in ensuring economic growth. In this paper, we calculate total factor productivity growth, using a novel approach. We start by calculating TFP at the most detailed industry level in order to take account of different production technologies in different activities. This allows us to overcome a major shortcoming of previous production function approaches to measuring TFP growth in the CESEE region, which rely on a one-sector model of the economy. Our framework is flexible enough to incorporate non-constant returns to scale and variation in the utilization of input factors.

Being constrained by a short time dimension – which is typical of our country sample – we estimate TFP separately for each industry, thus pooling the data across all 40 countries available in the database. We employ instrumental variable estimation to control for endogeneity between factor growth, utilization and TFP and we include country fixed effects. Our results point to constant returns in most industries. Only mining, energy, trade and repair, public administration and the manufacture of transport equipment show decreasing returns to scale while estimated returns to scale are insignificant and close to zero in agriculture, health and social work and education. These results seem plausible from an economic point of view.

After this careful estimation of industry-specific TFP growth, we aggregate TFP growth from the industry level, using information from national input-output tables and following a methodology proposed by Basu et al. (2010). This procedure entails a number of crucial assumptions and decisions, in particular concerning the choice between the product-specific and industry-specific technology assumption. We work with the theoretically recommended product technology assumption. All our calculations are based on the WIOD database, which provides input-output tables that are harmonized across countries and interpolated over time. This gives us a rich panel dataset suitable for comparisons across countries and over the period 1996–2009.

On average, we find rather large differences in TFP growth between individual CESEE countries. The Baltics and Slovakia exhibit the highest TFP growth over this period. Their average annual TFP growth rates of roughly 3% (4.2% in

[19] *The Czech Republic, Hungary and Poland switched their national accounts classification to NACE 2 with the reporting year 2008, thus we were not able to obtain comparable data on capital stocks for the last two years in our sample.*

the case of Estonia) surpass those of Romania and Hungary (roughly 1%) by a wide margin. As a comparison, TFP growth in Germany averaged 0.5% over the same period; the unweighted EU-15 average TFP growth rate of almost 1% was very much influenced by rather high annual TFP growth of about 2% in the U.K. Thus, the positive TFP growth differential for most CESEE countries suggests technological convergence of these countries toward Western Europe and the international technological frontier. While technological progress in goods-producing industries contributed most strongly to overall value added growth in Poland, the Czech Republic, Slovenia and Slovakia, efficiency gains in the service sector were of greater importance in Bulgaria, Hungary and Lithuania.

We also looked at the contribution of TFP to the growth of individual final use components. Productivity gains in the export sector proved to be of particular importance in most economies. While TFP growth in the export sector also played an important role in Estonia, Bulgaria and Romania, its contribution was even higher in the production of investment goods in these three countries. This suggests that technological progress in outward-oriented industries was particularly fast, possibly fueled by foreign direct investment in the export sector. However, these developments also imply that export-led growth can be a viable option for the recovery of these countries, provided they are able to orient their export production toward fast-growing import markets.

While domestic TFP growth plays by far the most important role for the growth of individual GDP components, some countries also exhibit a nonnegligible contribution from terms of trade changes, especially in the investment sector. However, terms of trade changes may exert either a positive or a negative influence on overall growth depending on whether the price effect or the substitution effect of a real appreciation dominates. While the positive price effect clearly dominates in Bulgaria, Estonia, Lithuania and Romania, this was not the case in Slovakia and Hungary. The comparatively strong negative terms of trade effect for the production of consumption and investment goods in these countries may be related to the fact that – correcting for non-price factors such as, for example, improvements in quality – these countries hardly experienced a real appreciation over the observation period. Nevertheless, technological progress in domestic industries by far offset the negative terms of trade effect in all affected countries. Over time, we observe that the boom period 2000–2007 was accompanied by strong TFP growth in the region, whereas the reaction to the crisis differed substantially between countries. While TFP growth generally receded in 2008 (in Latvia and Slovakia already in 2007 and in Slovenia and Romania only in 2009), it remained positive and fairly strong in Estonia.

This novel approach to growth accounting gives interesting insights into drivers of economic growth and details concerning the sectoral origin of technological growth in an economy. Moreover, with this methodology, we can assess the importance of domestic as well as international linkages within an economy and between economies. We find that not only the growth contribution of productivity gains differs greatly between CESEE countries, but also terms of trade changes affect individual economies in the region in radically different ways. This effect depends on the degree of real appreciation in individual countries and is as such related to the specific combination of price and non-price developments impacting international competitiveness.

In general, the fact that the contribution of TFP growth was highest in the production of export and investment goods is quite encouraging. In contrast, lower TFP growth especially in recent years and already prior to the global economic crisis – for example in Hungary, which nevertheless showed average TFP growth rates comparable with Western European countries – deserves attention and a careful analysis of the underlying reasons.

References

Almon, C. 2000. Product-to-product tables via product-technology with no negative flows. In: Economic Systems 12(1). 27–43.

Basu, S., J. G. Fernald, J. Fisher and M. S. Kimball. 2010. Sector-Specific Technical Change. Unpublished manuscript. http://www.worldklems.net/conferences/worldklems2010_basu.pdf (retrieved on May 9, 2012).

Basu, S., J. G. Fernald and M. S. Kimball. 2006. Are Technology Improvements Contractionary? In: The American Economic Review 96(5). December. 1418–1448.

Basu, S., J. G. Fernald and M. D. Shapiro. 2001. Productivity Growth in the 1990s: Technology, Utilization, or Adjustment? NBER Working Paper 8359. July.

Basu, S. and M. S. Kimball. 1997. Cyclical Productivity with Unobserved Input Variation. NBER Working Paper 5915. February.

Benk, S., Z. M. Jakab and G. Vadas. 2005. Potential Output Estimations for Hungary: A Survey of Different Approaches. Magyar Nemzeti Bank Occasional Paper 2005/43.

Benkovskis, K., L. Fadejeva, R. Stehrer and J. Wörz. 2012. How Important is Total Factor Productivity for Growth in Central, Eastern and Southeastern European Countries? Bank of Latvia Working Paper 5/2012.

Berg, A., E. Borensztein, R. Sahay and J. Zettelmeyer. 1999. The Evolution of Output in Transition Countries: Explaining the Differences. IMF Working Paper 99/73.

Eurostat. 2008. Eurostat Manual of Supply, Use and Input-Output Tables. Luxembourg: Office for Official Publications of the European Communities.

Fadejeva, L. and A. Melihovs. 2009. Measuring Total Factor Productivity and Variable Factor Utilization: Sector Approach, the Case of Latvia. Bank of Latvia Working Paper 3/2009.

Groth, C., S. Nunez and S. Srinivasan. 2006. Productivity Growth, Adjustment Costs and Variable Factor Utilization: the UK Case. Bank of England Working Paper 295. April.

Katay, G. and Z. Wolf. 2008. Driving Factors of Growth in Hungary – a Decomposition Exercise. Magyar Nemzeti Bank Working Paper 2008/6. September.

Krugman, P. R. 1993. What Do Undergrads Need to Know About Trade? In: The American Economic Review 83(2). Papers and Proceedings of the Hundred and Fifth Annual Meeting of the American Economic Association. 23–26.

Majcen, B. and J. Damijan. 2001. Recovery and Growth in the Manufacturing Sectors of CEE Transition Economies: Short and Long-Term Efficiency Improving Factors. wiiw Balkan Observatory Working Papers 012. December.

Moore, D. and A. Vamvakidis. 2007. Economic Growth in Croatia: Potential and Constraints. IMF Working Paper 07/198.

OECD. 2001. Measuring Productivity. OECD Manual. Measurement of Aggregate and Industry-Level Productivity Growth. Paris: OECD Publications.

Room, M. 2001. Potential Output Estimates for Central and East European Countries Using Production Function Method. Working Papers of Eesti Pank 2/2001.

System of National Accounts 1993.
http://unstats.un.org/unsd/nationalaccount/docs/1993sna.pdf (retrieved on August 6, 2012).

Temurshoev, U. and M. Timmer. 2011. Joint Estimation of Supply and Use Tables. In: Papers in Regional Science 90(4). November. 863–882.

Timmer, M., A. Erumban, R. Gouma, B. Los, U. Temurshoev, G. J. de Vries, I. Arto, V. Genty, F. Neuwahl, J. M. Rueda-Cantuche, A. Villanueva, J. Francois, O. Pindyuk, J. Pöschl, R. Stehrer and G. Streicher. 2012. The World Input-Output Database (WIOD): Contents, Sources and Methods. April 2012. Version 0.9. Project funded by the European Commission, DG Research.
http://www.wiod.org/database/index.htm (retrieved on May 9, 2012).