Sources and Determinants of Output Growth in Albania and other Transition Economies

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Abstract

This article applies stochastic frontier methodology to analyze the sources and determinants of output growth in Albania and other 23 transition economies over the period 1980-2006. Empirical investigation reveals that TFP growth is important in explaining output growth, whereas input accumulation does not appear to play an important role in growth performance. In addition, the article demonstrates that technological change and efficiency are important components of TFP growth. The article shows that human capital, quality of institutions and trade liberalization have statistically significant and economically relevant effects on the technology catch-up.

JEL Codes: O47, O57

key words: growth accounting; stochastic frontiers; TFP growth; technical efficiency and trade liberalization.

1 Introduction

This paper contributes to the debate on the sources and the determinants of growth of transitional economies. The economic growth literature has taken two approaches to understand what determines the growth experience of countries. While exogenous growth theory (Solow 1956) highlights technological progress as the source of growth, endogenous growth theory (e.g., Romer 1986, Lucas 1988, Acemoglu et al. 2006) emphasizes the role of capital, both physical and human, as the main determinant of growth. In addition, exogenous growth theory stresses capital accumulation as the driver of conditional convergence, while endogenous growth theory looks at the differences in technology across countries or time to explain divergence. Total Factor Productivity (TFP), together with human capital, can explain a large part of income differences across countries (Parente and Prescott 2005). This debate has provided many insights to the convergence literature (see, e.g., Caselli et al. 1996).

After the transition to a market economy in 1991, many East European countries were confident of reaching high and stable output growth. These optimistic expectations were supported by the belief that removal of controls on economic activity and reallocation of resources to more productive activities would lead to higher welfare. However, the average per capita income in Easter Europe is about 30 per cent of that in West Europe and, with the exception of Poland, economic performance of transitional economies has been disappointing. There is still scope for boosting the catching-up process to technological frontier of West Europe. It appears that the success of growth performance will depend on mix of structural and institutional reforms.

The impressive growth performance of the last decade has in fact prompted new concerns about transition economies' long term economic prospects;

leading to questions whether these countries have in fact found the recipe for endogenous self-sustained growth. One of the main concerns of policy-makers is to develop a strategy to sustain productivity growth. Insufficient productivity growth may also be pivotal to country's competitiveness problem, which would determine the continual erosion of the world export market shares and its rather limited ability to attract foreign investments.

Looking in more detail at growth in individual countries, a well known stylized fact is that, since the 1990s, there are differences in the success of the transition to capitalism in different East European countries. On one hand, Poland, which performed strikingly unsatisfactory in 1973-90, has had more rapid income growth since 1990 than any other European country except Ireland. The Czech and Slovak republics and Hungary have registered positive productivity trends and, more or less, recovered their 1990 levels of per capita income. On the other hand, the economies of Yugoslavia, Bulgaria and Romania have slowed considerably, in part because their economies were severely affected in various ways by wars in Bosnia and Kosovo.

Among transition economies, Albania's growth experience during the transition has been a success story. Growth performance has been impressive with a stable growth rate of 6.6% per year from 1992 to 1997 when there was the crisis of economic activity because of the collapse of the pyramid saving schemes. Annual real GDP growth rises to 7 percent between 1998-2006. This economic growth has been due mainly to reduction in deficit financing, low inflation, increase in total factor productivity and consumption sustained by remittances (Maddison 2001).

The problems of transition are very serious. Freeing prices and the opening of trade with the West leaded to improved of quality of goods available and increased consumer welfare in ways not properly captured in the GDP measures. However, much of the capital stock became obsoleted, the labor force needed to acquire new skills, the legal and administrative system had to be transformed and the distributive and banking system had to be rebuilt (Maddison 2001). The attempt to address these issues, has stimulated a great debate aimed at identifying the main causes and driving forces (see, e.g., OECD, 2001). The understanding of the sources of growth may mirror the larger debate between the neoclassical and new growth theories, but economists overall agree that endogenous self-sustained growth has largely been a result of the high growth in TFP, that is the part of the rise in productivity which is neither due to the increase in capital per labour employed nor to the rise in the skill level of the labour force. This is particularly true for emerging countries where the transfer of new technologies from advanced economies contributes significantly to the growing competitiveness. If macroeconomic policies are sound, financial stabilization is accomplished and political institutions perform well, then, in the long term, technology transfer bring an acceleration of the rate of growth of transitional economies. Technology transfer is raising also the level of labor skill.

This paper analyses transitional economies, with particular focus on Albanian economy, over the period 1980-2006 contributing to the debate on the sources and the determinants of growth by introducing few improvements to the literature on growth empirics. The first regards the method used to decompose the output rates of growth. Starting with Färe *et al.* (1994), many studies decompose productivity growth into components attributable to technological change, technological catch-up and input accumulation by linking the literature on convergence and the efficient frontier. These studies go beyond the standard growth accounting method, and hence can avoid (Caselli, 2004) the caveats in the assumptions made in using the growth accounting approach, such as constant returns to scale, Hicks neutral technological change and competitive factor markets. In fact, when these assumptions are violated, the standard approach to growth accounting yields a biased measure of technology (Barro and Sala-i-Martin, 2004).

We depart from standard growth accounting and propose a decomposition of output growth based on the stochastic frontier approach (SFA). Many studies in this field of research (see, e.g., Kumar and Russell, 2002 and Maffezzoli, 2006) are based on deterministic approaches, e.g., Data Envelopment Analysis (DEA), that impute all the distance from the frontier to inefficiency. SFA, on the other hand, takes into account the measurement and other errors and, hence, ensures a better fitting of the data (Lovell, 1993), leading to a more reliable decomposition of output.

In addition, SFA permits the determinants of efficiency to be taken explicitly into account and hence allows the identification of the driving factors explaining TFP growth. In other words, we propose a model for output growth decomposition that can shed light on the statistical and economic significance of the main determinants of growth. Among these, we specifically investigate the role of human capital, sound macroeconomic policies and trade liberalization, that is those factors that are suggested as being the most relevant in explaining the output growth of transitional economies (see, for instance, Khan 2004, Maddison 2001). Finally, in order to identify the statistically relevant component(s) in the output decomposition, we compare their relevant empirical distributions, smoothed via a kernel estimator, and perform non-parametric tests of closeness (Li, 1996; Fan and Ullah, 1999; Kumar and Russell, 2002) developed by Mastromarco (2007) for SFA.

Besides these methodological refinements, another original element lies in the data used. Our capital stock is calculated using the method proposed by Maffezzoli (2001) and we compare our estimates with other measures obtained applying the mostly used approaches. We propose a measure of capital stock which takes into account differences in quality among countries, i.e., the incidence of depreciation. This latter choice is crucial given the role that capital quality plays in the production process. Our proposal is in contrast with the studies following Nehru and Dhareshwar (1994), who suggest a fixed depreciation rate of capital stock equal to four per cent for all countries.

The empirical analysis considers a unbalanced panel of 24 transition economies observed yearly from 1980 to 2006, a span period encompassing the recent controversial phase of the transition economies. The first evidence shows that TFP is important in explaining the performances of transition economies. Another key result emerging from our analysis is that the technological variation and efficiency change, i.e., the technological catch-up, are the most statistically significant component of TFP growth. Finally, we demonstrate that that human capital, quality of institutions and trade liberalization have statistically significant and economically relevant effects on the technological catch-up which occurred in transition economies over the period considered.

The paper is organized as follows. Section 2 outlines the model and the algorithms we use in the empirical analysis. Sections 3 presents the data. Section 4 discusses the results, while Section 5 summarizes and concludes the paper.

2 Model specification and empirical implementation

The product of a country i at time t, Y_{it}, is determined by the levels of labour input and gross fixed capital, L_{it} and K_{it}. The level of technology or multi-factor productivity is given by the parameter A. The production function is expressed as follows:

$$Y_{it} = F(A_{it}, L_{it}, K_{it}) \tag{1}$$

The parameter A_{it} describes the Hicks-neutral productivity and is assumed to be affected by a set of variables, Z_{it}. Equation (1) may be rewritten as:

$$Y_{it} = A_{it}(Z_{it})F(L_{it}, K_{it}) \tag{2}$$

Equation (2) indicates that the level of total factor productivity, $TFP_{it} = A_{it}(Z_{it})$, depends on the (embodied and disembodied) technological progress A_{it} and on external covariates, i.e., a set of growth determinants, Z_{it}. Among these latter we can consider, for instance, the contribution of human capital, trade, FDI and quality of institutions.

Following the efficient frontier literature (see, e.g., Färe *et al.*, 1994), the TFP_{it} component can be further decomposed into the level of technology A_{it}, an efficiency measure $0 < \tau_{it} < 1$,[1] which depends on the covariates Z_{it}, and a measurement error w_{it} which captures the stochastic nature of the frontier:

$$TFP_{it} = A_{it}\tau_{it}(Z_{it})w_{it}. \tag{3}$$

[1] When $\tau_{it} = 1$ there is full efficiency, in this case the country i produces on the efficient frontier.

By writing equation (2) in translog form we thus have:

$$y_{it} = \alpha+\beta_1 k_{it}+\beta_2 l_{it}+\beta_3 \frac{1}{2} k_{it}^2+\beta_4 \frac{1}{2} l_{it}^2+\beta_5 l_{it} k_{it}+\beta_6 t+\beta_7 \frac{1}{2} t^2+\beta_8 t l_{it}+\beta_9 t k_{it}-u_{it}+v_{it} \tag{4}$$

where lower case letters indicate variables in natural logs [i.e., $y_{it=}\ln(Y_{it})$], whereas $u_{it} = -\ln(\tau_{it})$ is a non-negative random variable, and $v_{it} = \ln(w_{it})$. Expected inefficiency is specified as:

$$E(u_{it}) = \mathbf{z_{it}}\delta, \tag{5}$$

where u_{it} are assumed to be independently but not identically distributed, $\mathbf{z_{it}}$ is the (1x K) vector of covariates which influence TFP via inefficiency, and δ is the (K x 1) vector of coefficients to be estimated.

We thus model the inefficiency of contries as a function of human capital (H), openness (Op), foreign direct investments (FDI), index of democracy (Dem), index of political risks ($PolRisk$), general government expenditure (G), health ($Health$):

$$u_{it} = \delta_0+\delta_1 H_{it}+\delta_2 Op_{it}+\delta_3 FDI_{it}+\delta_4 Dem_{it}+\delta_5 PolRisk_{rt}+\delta_6 G_{it}+\delta_7 Health_{it}+\varepsilon_{it} \tag{6}$$

where all variables are defined as above and are more thoroughly described in section 3. Finally, ε_{it} is a white noise.

In order to estimate the parameters of the production function (4) together with the parameters in eq. (6), we use a single-stage Maximum Likelihood procedure proposed by Kumbhakar *et al.* (1991) and Reifschneider and Stevenson (1991), in the modified form suggested by Battese and Coelli

(1995) for panel data with time-variant technical efficiency.[2] As also discussed in Kumbhakar and Lovell (2000: 284), this stochastic approach allows the decomposition of output growth into its sources, that is input accumulation and TFP growth, and this latter can be further decomposed into technological change (or technical progress), efficiency change (i.e., technological catch-up) and scale efficiency change.[3]

We further analyze the distributions of the productivity components based on a nonparametric kernel density estimator. Following Fan and Ullah (1999) and Kumar and Russell (2002), the standard normal kernel

$$K(\psi) = \frac{1}{\sqrt{2\pi}} \exp -\frac{\psi^2}{2} \tag{7}$$

is used to derive the test statistic for the comparison of two unknown densities $f(x)$ and $g(x)$ which represent two distinct distributions. The null hypothesis $H_0 : f(x) = g(x)$ is tested against the alternative $H_1 : f(x) \neq g(x)$ (see Appendix A for details).

The use of the test in eq. (7), allows the assessment of the relevance of the output growth components of our sample of countries(see § 3). Furthermore, after constructing the counterfactual growth distributions, we are able to identify the main sources of country growth.

[2]MLE is used to take into consideration the asymmetric distribution of the inefficiency term (Aigner *et al.*, 1977). Greene (1990) argues that the only distribution which provides a maximum likelihood estimator with all desirable properties is the Gamma distribution. However, following van den Broeck *et al.* (1994), the truncated distribution function, which better distinguishes between statistical noise and inefficiency terms, is preferred.

[3]Due to data constraint, we only consider technical and not allocative efficiency.

3 Data

The data set under analysis is a panel for 24 transition economies[4] for the period 1980-2006. The dependent variable is the log of real GDP and the independent variables are the log of labor and the log of real physical capital. The explanatory variables for the efficiency terms are openness, democracy, political risks, secondary education enrolment ratio, general government final consumption expenditure (in percentage to GDP), health, foreign direct investments (in percentage to GDP). In order to compare different countries and different years, all the monetary variable are expressed in 1990 US dollar.

The series of GDP and general government final consumption expenditure are from the United Nations Statistics Division (UNSD). Openness is an index of international economic openness. It is the sum of imports and exports of goods and services over GDP. The series of imports and exports are from UNSD. The series of labor and foreign direct investment are from World Development Indicators CD-ROM 2003 by World Bank.

The index of democracy series is from the institute of research Freedom House. Democracy is computed as the mean between the two indexes published by the Freedom House: Political Rights and Civil Liberties. Both are measured on a one-to-seven scale, with one representing the highest degree of freedom – full representative democracy - and seven the lowest – complete totalitarian system. Finally, for the years previous the declaration of independence of a country we have taken the values of democracy of the mother-country.

The secondary education enrolment rate series is from the transMONEE

[4]The countries are: Albania, Armenia, Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyyz Republic, Latria, Lithuania, Macedonia FYR, Moldova, Poland, Romania, Russian Federation, Slovak Republic, Slovenia, Tajikistan, Turkmenistan, Ucraine, Uzbekistan.

dataset by UNICEF[5]. This rate is the ratio of the number of children who are enrolled in school to the population between 15 and 18. The health series is a proxy for the quality of national health system. Following Barro and Sala-i-Martin (2004), it is defined as the reciprocal of life-expectancy. While Barro and Sala-i-Martin use the life expectancy at age one, we use the same variable at birth because of the availability of data for the countries under analysis. The life expectancy in from WDI 2003.

The political risk index comes from a subjective measure provided in International Country Risk Guide by the international consulting company Political Risk Service. The index is measured on a zero-to-one hundred scale, with zero representing the highest political risks and one hundred the lowest, and it is the sum of the scores assigned to a set of sub-variables. We list the total points for each of the following political risk components out of the maximum points indicated:

- government stability (12p.),
- socioeconomics conditions (12p.),
- investment profile (12p.),
- internal conflict (12p.),
- external conflict (12p.),
- corruption (6p.),
- military in politics (6p.),
- religious tensions (6p.),

[5]We have not used the data from WDI 2003 because in this dataset it is not possible comparing the value pre-1996 and post-1996 because of a change in the definition of this variable.

- law and order (6p.),
- ethnic tensions (6p.),
- democratic accountability (6p.),
- bureaucracy quality (4p.).

The net capital stock series have been calculated using the standard Perpetual Inventory Method (PIM). It requires assumptions on retirement patterns, depreciation and average service lives. The assumptions used by our study are:

- simultaneous retirement patters,
- straight-line depreciation,
- average service lives which are fixed over time.

The simultaneous exit mortality function assumes that all assets are retired from the capital stock at the moment when they reach the average service life (time L). As a result, the survival function shows that all assets remain in the stock until time L, at which point they are all retired together.

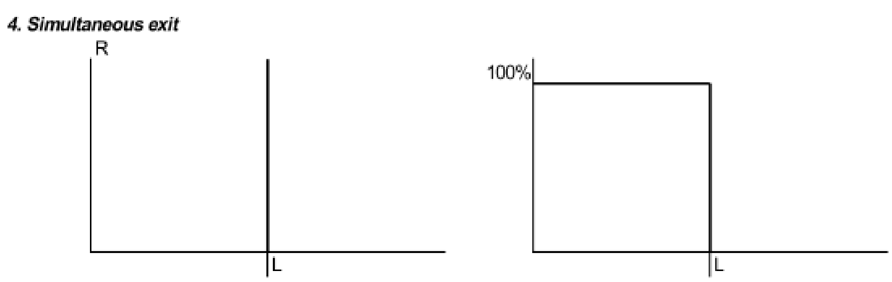


Figure 1: Simultaneous exit: mortality (left-side) and survival (right-side) functions

The straight-line depreciation (D) implies that every year the capital stock depreciates by the same amount, equal to the value of the gross capital stock $\tilde{K}_t$ over the expected service life of capital (d):

$$D_t = \frac{\tilde{K}_t}{d} \tag{8}$$

This method of depreciation, unlike the geometric or hyperbolic ones, has the advantage of non overestimating the capital stocks because an asset is considered in the stock only for its expected service life and not for an infinite time horizon.

Under these hypothesis and under the PIM procedure, the gross capital stock is simply

$$\tilde{K}_t = \sum_{i=0}^{d-1} I_{t-1} \tag{9}$$

where

d represents the expected service life of capital,

I represents the investments flow in a given year

While the net capital stock (K_t) obtains directly from

$$K_t = \sum_{i=0}^{d-1} I_{t-1}[1 - \frac{2i+1}{2d}] \tag{10}$$

where "i" is the depreciation rate; or via the accumulation equation

$$K_t = K_{t-1} + I_t - D_t \tag{11}$$

where

K_{t-1} is the net capital stock in t-1

I_t are the investments in t

D_t is the depreciation in t

This study uses equation (3); such procedure has the advantages of estimating directly the net capital stock without computing the gross capital stock. A similar procedure is used by the United States Bureau of Economic Analysis (BEA). The BEA goes directly to the calculation of consumption of fixed capital (depreciation) which is then cumulated and subtracted from the sum of past investments to obtain the net capital stock. Unlike this paper, the BEA assumes a geometric consumption of fixed capital, an expected service life of capital not constant over time and a implicit mortality function. The mortality function is used only to determine the geometric depreciation rate.

Followin Maffezzoli 2006, we have estimated the capital stocks using the Törnqvist index to take the discrete-time bias into account. Hence the (1) becomes

$$D_t = \frac{\tilde{K}_t + \tilde{K}_{t-1}}{2d} \tag{12}$$

The System on National Accounts 1993 (SNA 1993) prescribes that the countries publish data on investments (Gross Fixed Capital Formation – GFCF) and depreciation (Consumption of Fixed Capital – CFC). Using these variables Maffezzoli (2006) estimates the expected service life of capital using equation (5) and expliciting it in function of d. Such a procedure has been used in our paper. Once estimated the expected service life of capital, we have estimated the net capital stock using equation (3). Nevertheless, this series of net capital stock is not reliable for all the years of the time-series. Indeed, by considering an investments time-series from time 0 to 100 and an expected service life of capital equal to x, the series of the capital stock is reliable only for the years [(100 - x + 1) ; 100]. In the years previous (100

- x + 1) the capital stock is underestimated because it doesn't consider the investments carried out before year 0 that contribute however to the capital stock formation in the years before (100 - x + 1). In particular, in order to obtain a reliable estimate of the capital stock from year 0 to 100, we need an investments series from year $--x$ to 100.

In order to estimate the net capital stock for the year [0;(100 - x + 1)] we apply the following procedure. We have first computed the geometric mean of the investment for all the years in which the data was available – from 0 to 100 in the example. Second, we have used this mean to extend backward the investment series from year 0 to $--x$. Third, we have applied equation (3) for the interval [0 ; (100 - x + 1)].

A possible alternative to this procedure is the one proposed by Harberger (1978) and by Nehru and Dhareshwar (1993). They first estimate the initial net capital stock by the following equation

$$K_0 = \frac{I_0}{g + \rho} \tag{13}$$

where

I_0 is the initial investment flow,

g is the growth rate of investments,

ρ is the rate of depreciation.

Second they estimate all the next t-th net capital stock using the PIM with a geometric rate of depreciation instead of a linear one:

$$K_t = (1 + \rho)^t K_0 + \sum_{j=0}^{t-1} (1 + \rho)^t I_{t-j-1} \tag{14}$$

Nehru and Dhareshwar (1993) make a rough assumption about ρ, assuming it equal to 4% for all the countries. In order to make more reliable the Nehru and Dhareshwar procedure, we have estimated the depreciation rate for all the countries under analysis. Following Maffezzoli (2006) the depreciation rate is

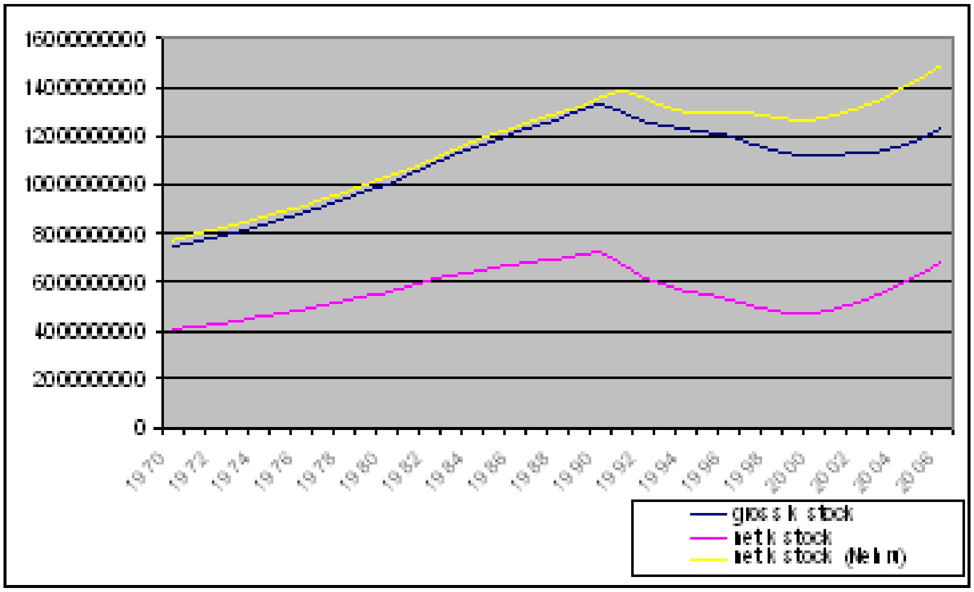
$$\rho_t = \frac{D_t}{K_{t-1}} \tag{15}$$

Where the data were available, we have estimated the time-varying series of the depreciation rate for each country. Then we have computed the geometric mean (ρ) of these rates. Finally we have constructed the series of the net capital stock using equations (6) and (7).

The two methods lead to series of net capital stock analogous in the growth path but different in the levels. The following graph shows the case of Albania; on the x-axis there are the years while on the y-axis there are the values of the capital stocks in US dollar 1990. The blue line and the pink line represent respectively the gross and net capital stocks proposed by this paper, while the yellow line represents the net capital stock computed with the Nehru-Dhareshwar procedure but without assuming a 4% depreciation rate for all countries but using our estimates.

The Albanian investments series starts in 1970, while the estimated expected service life of capital is 21 years. Hence, following the procedure suggested by this paper, we obtain estimates reliable for the capital stocks (gross and net) from 1990 (equal to 1970 + 21 – 1). In general, the net capital stock proposed by this study and the one proposed by Nehru-Dhareshwar follow the same path but differ in the level.

As expected, the second method overestimates the net capital stock because of the geometric rate of depreciation. In detail, the Nehru-Dhareshwar method gives values of the net capital stock in mean 2.102 times superior with respect to the method proposed by this paper. While the low variance



(equal to 0.095) of the ratio between the values, taken year by year, by the two series constitutes a statistical evidence of the same path.

Moreover the Nehru-Dhareshwar's net capital stock series (yellow line) persists over our gross capital stock (blue line) along all the period under analysis. Hence the Nehru-Dhareshwar seem to be unreasonable.

4 Results

4.1 Production Function Results

The parameters of the model defined by (4) and (6) are estimated simultaneously using a maximum likelihood estimator with Matlab. The results of this estimation are displayed in table 2, where we report the coefficients of the translog form. The coefficients of the translog production function cannot be directly interpreted economically, therefore in table 3 we report the estimated values of the output elasticities calculated at the average value for each input. From the estimates of output elasticities we can retrieve in-formation on the most appropriate specification of the production function. By using a Likelihood-Ratio (LR) test we reject the null that the production function is the Cobb-Douglas in favour of the translog form.[6] The results displayed are based on variable means for the whole panel and for Albania in the observation period 1980-2003. As expected, all elasticities are positive and significant: output is elastic especially with respect to capital (about 0.60 for all countries and 0.75 for Albania), while the output elasticity with respect to labour is much lower (around 0.50 for the panel and 0.40 for Albania).

[Insert tables 2 and 3 about here]

As a further investigation into the technology characterizing countries' production function, we investigate the presence of linear homogeneity by testing the null hypothesis that the sum of the estimated elasticities is not statistically different from one. If we reject the null hypothesis, then we can infer that the technology presents increasing (decreasing) returns to scale when the sum of elasticities is above (below) unity. Table 4 (top panel) shows that the hypothesis of constant returns to scale can be rejected for all countries and for Albania.

[Insert table 4 about here]

We calculate the elasticity of substitution, which represents the percentage change in the input ratio induced by a one percent change in the marginal rate of substitution. In the two-variables translog case this elasticity is a nonlinear function (its variance is obtained by applying the delta method). Table 4 (panel at the bottom) shows that all elasticities for the panel of countries

[6] The LR is used to test the null hyphotesis of a Cobb-Douglas functional form, i.e., $H_0 : \{\beta_3 = \beta_4 = \beta_5 = 0\}$. The Cobb-Douglas is to be rejected: the test is equal to 92.48, while the critical value of the χ^2_3 (at the 1% s.l.) is equal to 10.501.

and for Albania are significantly equal to one. In other words, if the marginal rate of substitution changes by one percent, then the induced change in the input ratio will be one percent.

4.2 Growth decomposition results

To understand the relative importance of the different sources of growth in countries' output, we look at the distributions in output and productivity growth. This approach includes all the distribution moments and thus is to be preferred to the standard regression analysis which considers the conditional mean and the variance (Quah 1996, Kumar and Russell 2002). To test for changes in the growth distributions across countries, we use a non parametric test of the closeness between two distributions based on a kernel nonparametric estimator (Li, 1996) and adapted to stochastic estimators by Mastromarco (2007).

In essence, using this approach it is possible to investigate the decomposition of output growth in the period 1980-2006 and identify its main sources provided one knows the counterfactual output distribution. Therefore, the output growth rate ($\dot{Y}/Y$) is decomposed into the contribution due to weighted input growth ($\dot{X}/X$, where X represents the sum of the inputs k, l) and TFP growth, $\left(\frac{\dot{TFP}}{TFP}\right)$.

First, we perform an analysis of the importance of TFP by testing the null hypothesis

$$H_0 : f\left(\frac{\dot{Y}}{Y}\right) = g\left(\frac{\dot{X}}{X}\right).$$

We thus test the null that the output growth distribution $f\left(\dot{Y}/Y\right)$ can only be explained by the input accumulation growth, i.e., $g\left(\dot{Y}/Y\right)$ (see

Appendix A). If the null hypothesis is rejected, then one can conclude that the TFP variations contribute to significantly explain the variations in the output growth distribution. The test results (reported in table 5) show that the null can be rejected: indeed, we obtain a value of around 68, when the critical value is 2.86 at the 1% significance level. Therefore, we can infer that output growth for our sample of transition economies is significantly affected by the TFP growth. This result is not a novelty in growth empirics (see, e.g., Parente and Prescott, 2004).

[Insert table 5 about here]

Second, in order to assess the contribution of input growth, we test the null hypothesis that the output growth distribution $f\left(\dot{Y}/Y\right)$ is equal to the TFP growth distribution, i.e., $g\left(\frac{T\dot{F}P}{TFP}\right)$:

$$H_0 : f\left(\frac{\dot{Y}}{Y}\right) = g\left(\frac{T\dot{F}P}{TFP}\right).$$

If the null is rejected, then it is possible to conclude that input accumulation can significantly explain the changes in the output growth distribution. The results of the test show, as expected, that input growth is important: we can reject the null since the test is around 51 against a critical value of 2.86 (for a 1% s.l.).

Furthermore, the TFP growth $\frac{T\dot{F}P}{TFP}$ is decomposed into technical change $(\dot{A}/A)$, scale effects and the contribution of efficiency (or catch-up effect, $\dot{u}$). TFP contains the measurement error. If TFP growth plays an important role, which is indicated by the evidence emerging from our sample of transition economies, the identification of the precise sources of this contribution is a relevant issue to be addressed, because of the "grab-bag" nature of this measure. The importance of technical change, scale effects and efficiency in explaining the variations in the TFP growth distribution is determined by testing whether the output growth distribution is equal to the distribution considering input accumulation growth and TFP growth determined by just two (out of three) of these components. More formally, the following three hypotheses help to understand the contribution of each component:

$$H_0: \quad f\left(\frac{\dot{Y}}{Y}\right) = g\left(\frac{\dot{X}}{X} + \frac{T\dot{F}P}{TFP} - \frac{\dot{A}}{A}\right); \qquad \text{(Technological Change)}$$

$$H_0: \quad f\left(\frac{\dot{Y}}{Y}\right) = g\left(\frac{\dot{X}}{X} + \frac{T\dot{F}P}{TFP} - (\varepsilon - 1)\left(\frac{\varepsilon_l}{\varepsilon}\frac{\dot{L}}{L} - \frac{\varepsilon_k}{\varepsilon}\frac{\dot{K}}{K}\right)\right); \qquad \text{(Scale Effects)}$$

$$H_0: \quad f\left(\frac{\dot{Y}}{Y}\right) = g\left(\frac{\dot{X}}{X} + \frac{T\dot{F}P}{TFP} - \dot{u}\right), \qquad \text{(Efficiency)}$$

where ε_k and ε_l are the output elasticities with respect to physical capital and labour respectively and $\varepsilon_k + \varepsilon_l = \varepsilon$. As the results show, only the second and third null hypothesis can clearly be rejected (a test value of 4.33 and 8.40, against the usual 2.86 critical value for a 1% s.l.), meaning that only the change in technological change and efficiency (catch-up effect) has a significant role in explaining the TFP growth (table 5).

To summarise, two key conclusions may be already drawn from the analysis so far presented. Firstly, the tests based on a comparison of the empirical distributions which are smoothed out via a kernel estimator show that TFP growth is statistically significant in explaining the performance of transition economies over the period 1980-2006. This evidence is qualitatively consistent with the results presented in previous literature (Maddison 2001, Khan

2004).

Secondly, we add that technology and efficiency are the main sources of TFP growth in transition countries. In addition, our approach overcomes some of the problems of standard growth accounting, and it may also help in investigating the determinants of growth, a question to which we turn in the next section.

4.3 Efficiency results

The decomposition of output growth has shown that the variation in technology and efficiency can explain much of the variations in the production in the transition economies. In this section we look at the inefficiency from a different perspective. Firstly, we further investigate the statistical relevance of inefficiency and analyze the distribution of efficiency across countries. Secondly, we explore the determinants of inefficiency, that is the factors that have an impact on countries' TFP.

The first issue is thus the testing of the statistical (and economic) relevance of countries' inefficiency. The stochastic approach allows to explicitly test for the presence of technical inefficiency in a specific production process. Econometrically, one needs to test the null of the joint significance of the coefficients in eq. (6), that is ($H_0 : \gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = 0$). The test is based on the variance parameter

$$\gamma = \frac{\sigma_u^2}{\bar{\sigma}^2}, \qquad \bar{\sigma}^2 = \sigma_u^2 + \sigma_v^2 \tag{16}$$

derived from eq. (4). This parameter can be used to perform a diagnostic likelihood-ratio test.[7] The more robust LR test statistic is approximately

[7] Coelli et al. (1998) point out that if $\gamma = 0$, the deviations from the frontier are entirely due to noise.

distributed following a mixed chi-square distribution. We find that the null hypothesis is decisively rejected at the 1 per cent level of significance.[8] Therefore, these results allow us to reject the null hypothesis of no inefficiency at the 1% significance level.

After having explored the TFP components and found that efficiency significantly explain countries' TFP (§ 4.2), it might be interesting to investigate its determinants, i.e., the factors that exert an impact on countries' efficiency and, hence, on TFP. The analysis is based on eq. (6), whose estimates are reported in table 6.

[Insert table 6 about here]

The coefficient on H has a negative sign and is statistically significant, suggesting that countries which higher level of human capital are significantly more efficient.

With regards to the results regarding trade liberalization, openness Op is not statistically significant, whereas foreign direct investments FDI have a positive effect on efficiency, suggesting that foreign capitals help the technology catching up process of transitional economies.

Countries with lower political risk (higher value of index $PolRisk$) are more efficient. The degree of democracy (lower value of index Dem) seems not be important for efficiency. The quality of national heath system $Health$ has not statistically significant effect on technology catching up process; whereas General government expenditure G generates improvements in the efficiency.

To summarize, in this section we have estimated the impact of some of the major determinants of growth of 24 transitional economies. The estimations

[8] Test statistic LR=158.6, with a critical value of 16.074 for 6 degrees of freedom (for the critical values see Kodde and Palm 1986).

confirm that these determinants have a statistically significant impact. For policy implications, the political leaders in these countries must renew their commitment to structural reforms and sound macroeconomic policies which drive sustainable growth.

5 Concluding remarks

In this study we combine growth accounting with efficient frontier techniques to investigate empirically the sources and the determinants of output growth in 24 transition economies over the period 1980-2006. By applying stochastic frontier techniques, we introduce some methodological improvements to the existing empirical literature. First of all, we measure the efficiency scores for each country, i.e., its distance from the efficient frontier, taking care of measurement and other random errors. Moreover, we compare the distributions of the possible sources of growth using a series of nonparametric tests based on kernel smoothing. This makes it possible to decompose output growth into its components, that is input accumulation and TFP growth, and to decompose this latter further into technological change, efficiency change, and scale effects, and rigorously test for their statistical significance. Furthermore, using a specific formulation of the asymmetric error component, we also investigate the determinants of TFP growth and their relative importance. Finally, we propose and use new series of capital stocks that avoids possible drawbacks of commonly used approach of perpetual inventory method with fixed capital depreciation and, we believe, that represents an improvement on it.

We find that factor growth is important in explaining output growth. In addition, technology and efficiency change (*technological catch-up*) are the most significant component of productivity growth. We also document that sustainable growth in transitional economies requires improvements in total factor productivity through the improved of technological efficiency. Transition economies should increase their educational attainment by raising school enrollment rates. Moreover, a higher of degree of trade integration and improvement in institutional quality generate improvements in total factor productivity by leading to an improved of efficiency.

A Appendix

The efficiency scores distributions compared in this study are smoothed using standard normal kernel function and optimal bandwidth:

$$f(x) = \frac{1}{Kh} \sum_{j=1}^{K} k(\frac{x_j - x}{h}), \tag{17}$$

with bounded kernel functions $k(\cdot)$ that satisfy $\int_{-\infty}^{\infty} k(\alpha) d\alpha = 1$, where $\alpha = x_j - x/h$ and $h \to 0$ as $K \to \infty$. Notice that h is the optimal window width, based on the optimal of Silverman (1986, 45-48) and K is the sample size.

As a measure of the closeness between two distributions, the integrated squared error metric, defined as $I(f,g) = \int_x (f(x) - g(x))^2 dx \geq 0$ and which holds as an equality iff $f(x) = g(x)$, has been used to develop the t-statistic to test for the difference between the two density functions:

$$T = \frac{K\sqrt{hI}}{\widehat{\sigma}}.$$

This test statistic is asymptotically distributed as a standard normal $N(0,1)$ with a critical value, for a 1% significance level, of 2.33.

I can be estimated as (Li, 1996)

$$I = \frac{1}{K^2 h} \sum_{i=1}^{K} \sum_{j=1, j \neq i}^{K} \left[k\left(\frac{x_i - x_j}{h}\right) + k\left(\frac{y_i - y_j}{h}\right) - k\left(\frac{x_i - y_j}{h}\right) - k\left(\frac{y_i - x_j}{h}\right) \right]$$

and the variance is estimated with:

$$\widehat{\sigma}^2 = \frac{1}{K^2 h \sqrt{\pi}} \sum_{i=1}^{K} \sum_{j=1}^{K} \left[k\left(\frac{x_i - x_j}{h}\right) + k\left(\frac{y_i - y_j}{h}\right) + 2k\left(\frac{x_i - y_j}{h}\right) \right].$$

Notice that given the limited number of observations, it is not possible to rely on the asymptotic distribution of the test statistic (Kumar and Russel, 2002). The distributions are therefore approximated using a bootstrap procedure. 2,000 realizations of the test statistic are generated under the null that $f(x) = g(x)$. A small Montecarlo simulation allows us to assess the extent of the small-sample-bias problem. 2000 replications of two standard normally distributed random variables are generated (sample size: 32, 50, 100, 250, 500). Since the asymptotic distribution of the statistic is standard normal, we expect that with the increase in the sample size the difference between the simulated results and the standard normal distribution diminishes. The simulation results confirm the small sample bias and thus support the use of a bootstrap procedure to approximate the statistic distribution under the null. The empirical distributions are displayed in Table 1. Bootstrap procedure results used for the critical values are in the first line; the other part of the table contains the outcome of the simulation.The findings provide clear evidence of small sample bias.

Table 1: Empirical Distribution of T

N	0.900	0.950	0.975	0.990	μ	σ
24	0.76	1.11	1.48	1.98	-0.03	0.59
50	0.87	1.21	1.63	2.51	-0.02	0.68
100	0.90	1.37	1.79	2.37	-0.01	0.70
250	0.95	1.34	1.76	2.13	-0.02	0.71
500	1.02	1.42	1.81	2.47	-0.03	0.77
∞	1.28	1.64	1.96	2.33	0.00	1.00

Notes:
$N = \infty$ indicates the critical values from the standard normal distribution.

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Table 1. Transiton Economies's Production

Variable	Estimate	Standard Error	t-Ratio
Const	**-7.7678**	**7.9421**	**-0.9781**
k	**3.9385**	**1.1228**	**3.5077**
l	**-3.3985**	**1.7490**	**-1.9431**
$0.5(l)^2$	**0.1229**	**0.1097**	**1.1205**
$0.5(k)^2$	**0.9571**	**0.1809**	**5.2911**
lk	**-0.4145**	**0.1338**	**-3.0968**
t	**-0.1547**	**0.2020**	**-0.7656**
$0.5t^2$	**0.0795**	**0.0120**	**6.6137**
tk	**-0.0025**	**0.0113**	**-0.2229**
tl	**-0.0326**	**0.0176**	**-1.8556**

Table 2. Transiton Economies's Production Efficiency

Variable	Estimate	Standard Error	t-Ratio
const	**0.8937**	**1.8069**	**0.4946**
H	**-0.7270**	**0.4369**	**-1.6639**
Op	**-0.0017**	**0.0518**	**-0.0323**
FDI	**-6.7969**	**3.1096**	**-2.1858**
Dem	**0.0230**	**0.0438**	**0.5247**
PolRisk	**-0.0656**	**0.0125**	**-5.2430**
G	**-2.4933**	**1.2533**	**-1.9894**
Health	**4.6100**	**5.3500**	**0.8617**
σ_u	**0.5066**	**0.0243**	**20.8696**
σ_v	**0.2187**	**0.0562**	**3.8902**

Number of observations: 672, Log-Likelihood: -155.45, $LR = 52.205$ (9 restrictions), mean efficiency: 0.45.

Table 3. Output Elasticities

		Capital	Labour
Albania	Elasticity	0.745***	0.378***
	Standard Error	0.121	0.185
Panel	Elasticity	0.589***	0.494***
	Standard Error	0.062	0.099

***: significant at the 1 per cent level.

Table 4. Returns to Scale

	$\sum \beta_j$	Standard Error
Albania	1.123**	0.106
Panel	1.083**	0.061

$H_0 : \sum \beta_j = 1$; **: H_0 rejected at the 5 per cent level.

Table 5. Elasticity of Substitution

	Elasticity	Standard Error
Albania	-0.677***	33.219
Panel	-1.095 ***	63.463

Null hypothesis: $\sigma = 1$; ***: accepted at the 1 per cent significance level.

Table 6: Test Results

H_0	T	%10	%5	%1
$f\left(\frac{\dot{Y}}{Y}\right)=g\left(\frac{\dot{X}}{X}\right)$	1.99	1.11	1.48	1.98
$f\left(\frac{\dot{Y}}{Y}\right)=g\left(\frac{\dot{\theta}_S}{\theta_S}\right)$	0.246	1.11	1.48	1.98
$f\left(\frac{\dot{Y}}{Y}\right)=g\left(\frac{\dot{X}}{X}+\left(\frac{\dot{\theta}_S}{\theta_S}-\frac{\dot{\theta}}{\theta}\right)\right)$	4.21	1.11	1.48	1.98
$f\left(\frac{\dot{Y}}{Y}\right)=g\left(\frac{\dot{X}}{X}+\left(\frac{\dot{\theta}_S}{\theta_S}-(e-1)\frac{e_L}{e}\frac{\dot{L}}{L}+\frac{e_k}{e}\frac{\dot{K}}{K}\right)\right)$	0.00	1.11	1.48	1.98
$f\left(\frac{\dot{Y}}{Y}\right)=g\left(\frac{\dot{X}}{X}+\left(\frac{\dot{\theta}_S}{\theta_S}-\dot{u}\right)\right)$	2.97	1.11	1.48	1.98

Notes:

The critical values are based on the simulation results, $N = 24$.