The Role of the Elasticity of Substitution in Economic Growth: A Cross-Country Test of the de La Grandville Hypothesis

Debdulal Mallick*
Emory University

December 2006

Preliminary: Comments Welcome

*** I would like to acknowledge the helpful comments and assistance offered by Robert Chirinko, Zheng Liu, Richard Luger, Kaz Miyagiwa, Elena Pesavento and participants in Emory's Macro Lunch Group and at seminar at the 76th Southern Economic Association Meeting. Martin Rama and Raquel Artecona have generously made their dataset on union workers available. All errors, omissions, and conclusions remain the sole responsibility of the author.**

The Role of the Elasticity of Substitution in Economic Growth:
A Cross-Country Test of the de La Grandville Hypothesis

Abstract

The elasticity of substitution between capital and labor (σ) is a second-order parameter of the production function but has a first-order effect on economic growth. Although the importance of this elasticity has long been recognized in several branches of economics, it has received too little attention in the growth literature. Grandville (1989) showed theoretically that at any stages of an economy's development, the growth rate of income per capita is increasing with σ. The higher is σ, the greater the similarity between capital and labor in the production function, and thus diminishing returns sets-in very slowly.

To the best of our knowledge, this is the first paper that tests the Grandville hypothesis at the cross-country level. We estimate σ for 90 countries from direct estimation of the normalized CES production function and then include these estimators as an explanatory variable in cross-country growth regression. We investigate the sign and significance of the coefficient of σ conditioning on country characteristics, initial conditions, institutions and a set of policy variables. Since the unobservable σ is "generated" from the first-step estimation of the CES production function, in the second-step cross-country growth regression it is measured with sampling errors (Pagan, 1984; Murphy and Topel, 1985). After accounting for measurement errors and other sources of endogeneity, we find strong support for the de La Grandville hypothesis. We check the robustness of our results by Leamer's (1983) extreme value analysis, and the coefficient of σ remains positive and the *t*-statistics remain large for all combinations of the conditioning variables.

JEL Nos.: O47, C31

Correspondence:
Debdulal Mallick
Department of Economics
Emory University
Atlanta, Georgia 30322-2240
Email: dmallic@learnlink.emory.edu
Phone: 404-727-2840
Fax: 404-727-4639

Table of Contents

1 Introduction

The elasticity of substitution between capital and labor (σ) is a second-order parameter of the production function but has a first-order effect on economic growth. Although the importance of this elasticity has long been recognized in several branches of economics, it has received too little attention in the growth literature. Many important growth issues depend on the precise value of σ. It affects the possibility of perpetual growth or decline, the growth rate and level of steady state income per capita, the speed of convergence to the steady state, the rate of return on capital, the impact of biased technical change, and the relative role of productive factors and technical efficiency in explaining differences in per capita income. De La Grandville (1989) was the first to systematically explore the relationship between σ and economic growth. He showed theoretically that at any stages of an economy's development, the growth rate of income per capita is an increasing function of σ. To the best of our knowledge, the de La Grandville (1989) hypothesis has not been tested empirically.[1] This paper is intended to fill this gap by testing the hypothesis at the cross-country level.

We begin in Section 2 with a discussion of the relationship between σ and growth rate of income per capita. Drawing on de La Grandville and Solow (2004), we sketch a proof of the de La Grandville (1989) hypothesis.

In Section 3, we discuss the analytical framework and econometric issues associated with testing the hypothesis. Since economic theory does not provide any guide, we follow the Barro (1991) framework by regressing growth rate of per capita real GDP on σ and a set of variables related to growth. We investigate the sign and significance of the coefficient of σ, the key variable in our cross-country growth regression, after controlling for other explanatory variables. Since σ is a "generated" regressor, the OLS estimator of the variance of the coefficient of σ in the cross-country regression is inconsistent, and the asymptotic *t*-statistic generally overstates the true value. The 2SLS estimation has been suggested to overcome the problem (Pagan, 1984, p. 226). So we need some valid instruments for correct inference. Many of the possible determinants of σ such as rate of technological progress, innovations, and level of

---

[1] Yuhn (1991) conjectured that higher value of σ for South Korea may be a reason for its faster growth than the United States, which has a low σ.

institutional development are affected by the growth rate of a country, and therefore cannot be valid instruments as they are not exogenous. Maki and Meredith (1987) argued that if unions raise wages employers respond by substituting capital for labor. In other words, low value of σ is associated with the presence of strong labor union. Easterly and Fischer (1994, p. 23) argued that σ is low in a centrally planned economy compared to a capitalist economy because the former accumulated a narrow rather than broad range of capital goods. Some forms of market-oriented physical or human capital such as entrepreneurial skills, marketing and distribution skills, and capital sensitive to information were missing in a command economy. Many (ex) socialist countries are excluded from our sample because data are not available for a longer period. We, therefore, use the percentage of union workers and the share of general government consumption in GDP, which is a proxy for inclination to socialist ideas, as the instruments for σ. Musgrave (1969, p. 4-5) also defined inclination to the socialist ideas in terms of relative public consumption expenditures because a socialist country interferes more with consumer (private) preferences for goods and services by public financing of “merit” goods.

Section 4 discusses the data set and estimation method of σ. We obtain data from a variety of sources including the Penn World Table 6.1 and the World Bank. We estimate σ for 90 countries from direct estimation of the normalized CES production function and then include these estimates as an explanatory variable in the cross-country growth regression discussed in Section 3.

Results are presented in Section 5. After controlling for country characteristics, initial conditions, institutions, and a set of policy variables we find a positive and significant coefficient of σ that indicates strong support for the de La Grandville hypothesis. We check the robustness of our results by Leamer’s (1983) extreme value analysis (EVA). The coefficient of σ remains positive and the *t*-statistics remain large for all combinations of the conditioning variables.

Section 6 concludes.

2 σ and per capita output growth

De La Grandville (1989, p. 479) showed theoretically that "at every instant the growth rate of income per capita is an increasing function of σ". This hypothesis can be conceived intuitively. The higher is σ, the greater the similarity between capital and labor; thus, an increase in capital with labor held fixed does not substantially change the capital-labor ratio, which in turn resists the pull of diminishing returns to capital (Brown, 1968; p. 50). Therefore, a higher value of σ not only alters the production possibilities, it also expands them.

In the following, we sketch a proof of the de La Grandville hypothesis. The proof is drawn on de La Grandville and Solow (2004; 2006),[2] but relaxes their assumption that the level of capital stock is independent of the value of σ. We start with the following normalized CES production function.

$$Y_t/Y_0 = \left[\alpha\left(K_t/K_0\right)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)\left(L_t/L_0\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \qquad \text{--- (1)}$$

where, Y_t, K_t, and L_t are real output, real capital stock and labor input respectively. The α and σ represent the distribution parameter and the elasticity of substitution respectively. The Y_0, K_0, and L_0 are benchmark values of Y_t, K_t, and L_t respectively. We assume constant returns to scale and no technological progress. We follow Klump, McAdam and Willman (2005) in using the normalized CES production function.[3] To establish the relationship between σ and growth rate, countries are distinguished only by their value of σ, so common benchmark points for variables and marginal rate of substitution are required. Without normalization, a change in σ in the CES function not only alters the curvature of the isoquant but also shifts the whole isoquant map so that comparison of growth paths at different values of σ becomes difficult. Moreover, the unusual situation that shares of capital and labor in total output approach one-half in the special case of Harrod-Domar in which σ =0, is avoided with normalization to the CES

---

[2] De La Grandville and Solow (2004) also prove that the hypothesis holds if the economy exhibits either labor- or capital-augmenting technological progress or both.

[3] Also see Klump and de La Grandville (2000), Klump and Preissler (2000), Rutherford (2003), de La Grandville and Solow (2004).

production function (Klump and de La Grandville, 2000, p. 287; Klump and Preissler, 2000, p. 46). Equation 1 can be written in per capita terms as

$$y_t = f_\sigma(k_t) = \left[\alpha k_t^{\frac{\sigma-1}{\sigma}} + \left(1-\alpha\right)\right]^{\frac{\sigma}{\sigma-1}} \qquad \text{--- (2)}$$

where, $y_t = \left(Y_t/Y_0\right)/\left(L_t/L_0\right)$ is per capita output, and $k_t = \left(K_t/K_0\right)/\left(L_t/L_0\right)$ is the capital-labor ratio.

Growth rate of per capita output is given by $\frac{\dot{y}}{y} = \left(\frac{\partial y}{\partial k}\frac{k}{y}\right)\frac{\dot{k}}{k}$. The first ratio in the parenthesis is the marginal product of capital, which under perfect competition equals price of capital relative to price of output. So the above expression can be rewritten as $\dot{y}/y = \left(P^K k / P^Y y\right)\left(\dot{k}/k\right)$. The term in the first parenthesis is the capital share of output (μ^K) and given by $\mu^K = \alpha\left[\alpha + (1-\alpha)k^{\frac{1-\sigma}{\sigma}}\right]^{-1}$. It is straightforward to show that μ^K is increasing in σ.

$$\frac{\partial \mu^K}{\partial \sigma} = \frac{1}{\sigma^2}\alpha(1-\alpha)k^{\frac{1-\sigma}{\sigma}}(\log k)\left[\alpha + (1-\alpha)k^{\frac{1-\sigma}{\sigma}}\right]^{-2} > 0 .$$

The term in the second parenthesis is the growth rate of capital-labor ratio, and from the dynamics of the Solow growth model it is given by $\dot{k}/k = sf_\sigma(k)/k - (n+\delta)$.[4] The average product of capital, $f_\sigma(k)/k$, can be derived from equation 2 as

$f_\sigma(k_t)/k = 1/M_\sigma$, where $M_\sigma = \left[\alpha + \left(1-\alpha\right)k_t^{\frac{1-\sigma}{\sigma}}\right]^{\frac{\sigma}{1-\sigma}}$. Using fundamental properties of general means we show that $\partial M_\sigma/\partial\sigma < 0$. We first express M_σ as a general means of 1 and *k*, of order $\frac{1-\sigma}{\sigma} = \rho$ as $f_\sigma = \left(\sum_{i=1}^{2} g_i x_i^\rho\right)^{1/\rho}$, for all i =1, 2; x_i = (1, *k*)>0; g_i = (α , 1-

[4] For derivation, see Barro and Sala-i-Martin (1995, chapter-1, p. 18).

α); and $\sum_{i=1}^{2} g_i = 1$. The first of the properties is that general mean is increasing in the order ρ,[5] so that $\partial M_\sigma / \partial \rho > 0$. But $\partial \rho / \partial \sigma = -1/\sigma^2 < 0$, so that $\partial M_\sigma / \partial \sigma < 0$. This in turn implies that $\partial\left(f_\sigma(k_t)/k\right)/\partial \sigma = \partial\left(1/M_\sigma\right)/\partial \sigma > 0$. Combining with the earlier result $\partial \mu^k / \partial \sigma > 0$, we have that $\partial(\dot{y}/y)/\partial \sigma > 0$.

De La Grandville (1989) attributed the rapid economic growth rate experienced by Japan and East Asian countries to the higher value of σ between factors in their industrial sectors, in addition to the higher savings rate in these countries. His argument is based on Hicks' (1932) idea that larger value of σ also entails high transformation rates between sectors of different factor intensity. When one activity is decreasing to the benefit of the other, the increase in production in the second sector can be made larger if the value of σ is high.[6]

3 Analytical framework

Recent empirical literature on economic growth is built on Barro (1991) framework that regresses growth rate of per capita GDP on a number of variables related to growth. Since economic theory does not provide any guide, we follow the tradition,

$$g_i^y = \alpha + \beta \sigma_i + \eta C_i + \gamma X_i + \varepsilon_i \qquad \text{---(3)}$$

where g_i^y is the growth rate (average) of per capita real GDP in country *i* over the sample period, σ_i is the elasticity of substitution in country *i*, C_i is a vector of country characteristics (country-specific fixed effects), X_i is a vector of other variables. Our focus is on the sign and significance of the β coefficient after conditioning on C_i and X_i.

The choice of variables in C_i and X_i is no easy task. The small size of the sample limits the number of explanatory variables that we can use. The total number of variables in any growth regressions has exceeded 65, but there is no consensus on the significance

[5] For proof, see Theorem 16 in Hardy, Littlewood and Pólya (1952).

[6] This is, in general, not true. The effect of σ on reallocation effect is indeterminate, and depends on the distribution parameter in the CES production function and price of capital relative to price of output. For a discussion, see Chirinko and Mallick (2006b).

of these variables evincing lack of our understanding of the process of economic growth. Some empirical economists have simply used combinations of variables, which they consider potentially important determinants of growth such as market imperfections, distortionary taxes, rule of law, degree of monopoly, climate, geography, and so on. Most of these variables are not robust to inclusion or exclusion of other variables in the regression. For example, variable x_1 is found to have significant effect on economic growth if variables x_2 and x_3 are included, but becomes insignificant if x_4 is included. This led Levine and Renelt (1992) to try to single out some of the most compelling determinants of economic growth by Extreme Bound Analysis (EBA). The only variable that survived the EBA is capital accumulation (investment output ratio). Interestingly, this variable becomes insignificant when the endogeneity is accounted for by using initial investment rate as the instrument (Barro, 1998; Devrajan, Easterly and Pack, 2003).

The EBA has been criticized as too restrictive a test for any variable to pass (Sala-i-Martin, 1997; Sala-i-Martin et al. 2004). Sala-i-Martin et al. (2004), instead of labeling a variable as "robust" or "fragile", determine its significance with a certain level of confidence. These authors have sorted out 67 variables appearing in any growth regressions but many of them overlap. For example, the following five variables—proportion of country's land area within geographical tropics, malaria prevalence in 1960s, proportion of country's population living in geographical tropics, fraction tropical climate zone, and absolute latitude—are highly correlated. In addition to several country characteristics, Sala-i-Martin et al. (2004) find that primary schooling enrollment rate in 1960, price of investment goods between 1960 and 1964, initial level of per capita GDP, life expectancy in 1960, and public investment share are significantly related to growth. The variables that are marginally related to growth are overall density in 1960, real exchange rate distortion and fraction of population speaking a foreign language (a measure of social capital and openness).

Keeping the above in mind, we consider similar initial conditions and policy variables that Sala-i-Martin et al. (2004) found significantly or marginally related to growth, while ensuring that the variables do not overlap. These include initial per capita real GDP, initial infant mortality rate, initial primary school enrollment, investment-output ratio, openness measured as the sum of export and import as percentage of GDP, black market premium on foreign exchange as a proxy for market imperfection. We also condition on country characteristics such as absolute latitude, dummy for landlocked countries, ethnic fractionalization, and dummies for legal origin. In addition, we include (political) constraints on executives in 1950-94 as a proxy for institutions. Acemoglu et al. (2001) found this variable an important predictor of economic development.

There are three potential sources of endogeneity. Both current investment output ratio and current institutions might be affected by growth rate. A positive coefficient on the investment-output ratio may not necessarily indicate positive effect of investment on the growth rate; rather it may indicate the positive relation between growth opportunities and investment. Barro (1998, p. 33) argues that this reverse causation is more likely to apply for open economies. The decision to invest domestically rather than abroad reflects the domestic prospects for returns on investment, which is related to domestic opportunities for growth. This is true even if cross-country differences in saving rates are exogenous with respect to growth. We use initial investment rate as the instrument to account for endogeneity (Barro, 1998; Easterly and Levine, 2001). Acemoglu et al. (2001) argued that initial institutions affect current institutions, which in turn affect per capita income. We employ constraints on executives in 1900 as the instrument for constraints on executives in 1950-94.

The final source of endogeneity stems from the fact that σ is a "generated" regressor[7] from the first-step nonlinear estimation of the CES production function. This unobservable regressor has been estimated in calculating the coefficient and standard error in the second-step cross-country growth regression. The imputed unobservable applied in the second-step are therefore measured with sampling error (Murphy and Topel, 1985, p. 371). They proposed an adjustment to the standard errors of the second-step coefficient. Pagan (1984, p. 226-229) showed that the OLS estimator of the variance of the coefficient of σ is generally inconsistent, and the asymptotic *t*-statistic connected with the second-step OLS estimator generally overstates the true value. The 2SLS or IV will give a consistent estimator.[8] We therefore need to find valid instruments for σ for

[7] For a survey on the issues related to "generated" regressors, see Oxley and McAleer (1993).

[8] Dufour and Jasiak (2001) have suggested two methods for estimation and inference with "generated" regressors. The first is instrument substitution method that uses the instruments directly, instead of

correct inferences. However, the second-step OLS estimator is perfectly efficient and yields correct inferences for the null hypothesis $\beta = 0$.

Hicks, when he invented σ in 1932, realized it as a pure technological parameter. He pointed out the three possible ways in which substitution can take place—intra-sectoral substitution of known method of production, inter-sectoral substitution of production, and substitution arising from new innovations.[9] Capital can be more easily substituted for labor if demand shifts from labor intensive to capital intensive goods and services for change in factor and commodity prices. This type of easy substitution is also a mechanism for fending off diminishing returns (Solow, 2005, p. 8). This can also be true in a dual economy where agriculture and industry are the two major sectors. In our single-sector economy, aggregate σ is in principal a property of the production function; therefore, it is a purely technological parameter, but there is no reason for not considering it as an "object of policy" as well (de La Grandville and Solow, 2004, p. 37; Solow, 2005, p. 8). This simple model economy is a prototype model for a multi-sector economy in which the interpretation of σ also as a policy parameter is easy to comprehend.

In a multi-sector economy, choice among various known production methods by reallocating factors both within and between sectors, as well as application of new production methods are influenced by institutional framework such as labor union (Klump and Preissler, 2000, p. 51). If unions raise wages, then employers respond by substituting capital for labor (Maki and Meredith, 1987). In other words, low value of σ is associated with the presence of strong labor union.[10] De La Grandville and Solow (2004,

---

"generated" regressors, in order to test hypotheses and build confidence sets about the structural parameter. In our case, this method will not estimate the coefficient of σ, although inference about it can be made. The second method is based on splitting the sample. The "generated" regressors are obtained from a fraction of the sample, while the rest of the sample is used for the main regression (in which "generated" regressor is used). We also cannot apply this method because we estimate σ from another data set.

[9] Miyagiwa and Papageorgiou (2006) develop a two-sector model in which aggregate σ in the final consumption good sector is endogenously determined by σs in the two intermediate good sectors, and the substitution possibility between these two sectors. Chirinko and Mallick (2006a, p. 18) show that aggregate σ is the sum of the weighted average of industry σs and a reallocation effect across industries.

[10] The author is not aware of any empirical work that tests the relationship between σ and unionization at the aggregate level but there are empirical evidences of low σ in the sectors or industries where labor union is relatively strong. Freeman and Medoff (1982) estimated σ both in unionized and non-unionized sectors using two distinct set of data—a 2-digit SIC industry data set based largely on 1972 Census of manufacturing, and Bureau of Labor Statistics' 1968, 1970 and 1972 Expenditures for Employee Compensation surveys. In both cases σs were found to be lower in unionized than non-unionized sectors.

p. 36) conjecture that a country having strong customary and regulatory barriers to large changes in capital-labor ratios will have a lower σ than a country with less or no such barriers. This type of substitution does not originate either in supply or demand side substitution; only long run behavior can substantiate this characterization.

Yuhn (1991, p. 344) considered σ a "menu of choice" available to entrepreneurs. He argued that over a long period the government of South Korea distorted factor prices by artificially cheapening the price of capital goods, which may have been the main reason of the country's very high σ. Saam (2005), in basic models of trade, showed that a partial liberalization of trade affects the aggregate σ. Klump and Preissler (2000, p. 52) argued that σ should also be related to a country's monetary and financial system. Efficient factor allocations are endangered if money no longer fulfills its function as reliable units of account and medium of exchange. Therefore, higher inflation should be expected to be associated with less efficient resource allocation, which in turn implies a lower σ.

Easterly and Fischer (1994, p. 23) argued that σ is low in centrally planned economy compared to capitalist economy because the former accumulated a narrow rather than broad range of capital goods. Some forms of the physical or human capital that were missing would have been market-oriented entrepreneurial skills, marketing and distribution skills, and information-sensitive physical and human capital.[11]

The above discussion demonstrates that the possible determinants of σ are technological progress, innovations, level of institutional development, openness to trade, degree of unionization, and a country's inclination to the socialist ideas. However, institutions and openness to trade already appear in X_i in equation 3. On the other hand, technological progress and innovations take place mostly in developed and rapidly

---

Maki and Meredith (1987) also found strong evidence of lower σ in the unionized sector. Their estimates were based on pooled data for twenty 2-digit SIC Canadian manufacturing over the period 1971-81.

[11] The author is not aware of any study that compares the values of σ for capitalist and socialist countries. However, some case studies can be found in the literature. For example, Easterly and Fischer (1994) showed that rapid growth of the Soviet economy in the 1930s through the 1950s was due to the rising capital-output ratio (they defined it as "extensive" growth). The market-oriented economies such as Japan and South Korea had also similar capital-output ratio, but marginal product of capital declined very rapidly in the Soviet Union because of its very low σ, which in turn caused its economic retardation. This view is also supported by Bairam (1991) and Blitzer (1991). Bairam (1991, p. 70) demonstrated that the main reason behind the retardation in Soviet growth rates is low and declining σ, not the retardation in rate of technological progress.

growing countries, so that these variables cannot be valid instruments because these are correlated with the residual in equation 3. This leaves the remaining two variables—degree of unionization and inclination to the socialist ideas—as the natural candidates for instruments for σ. We consider percentage of union workers as a valid instrument. This variable is also not among the 67 variables included in any growth regressions listed by Sala-i-Martin et al. (2004). Many (ex) socialist countries are excluded from our sample because data are not available for a longer period. We, therefore, use the share of general government consumption in GDP as proxy for inclination to socialist ideas. Musgrave (1969, p. 4-5) also distinguished between socialist and capitalist economies in terms of relative public consumption expenditures because a socialist country interferes more with consumer (private) preferences for goods and services by public financing of "merit" goods. The choice of the share of general government consumption in GDP as an instrument for σ requires explanation because this variable has been included as a regressor in many growth regressions.

There are opposing arguments on the role of government expenditure on economic growth. One argument views government expenditure detrimental to growth because government operations are conducted inefficiently, the regulatory process imposes excessive burdens and costs on economic system, and many of the government's fiscal and monetary policies tend to distort economic incentives and lower the productivity of the system. On the other hand, another point of view suggests that larger government expenditure stimulates growth by harmonizing conflicts between private and social interests, preventing exploitation of the country by foreigners, securing an increase in productive investment, encouraging human capital formation, and providing a socially optimal direction for growth and development (Ram, 1986, p. 191). But it may be the type of government expenditure that positively or negatively affects economic growth. Barro (1990, p. 123), in a cross-country growth regression, obtained a negative impact of government size on growth. He defined government size as the ratio of government expenditure to GDP excluding education and defense expenditures. However, the impact was positive (not significant) when he used the ratio of public investment to GDP as a proxy for government size. We use the share of general government consumption in GDP that includes all current expenditures for purchases of goods and services by all levels of government including capital expenditures on national defense, and security. This variable has also not been found significant by Sala-i-Martin et al. (2004). Tanzi and Schuknecht (2000, p. 119) also find that government size, defined in terms of public expenditure, has no significant effect on socioeconomic indicators.

4 Data

Data have been obtained from a variety of sources. First, σ is estimated from the normalized CES production function that requires data on real output, labor (workforce) and capital stock. Capital stock is calculated using perpetual inventory method from investment data (for detail, see Appendix-A.1) obtained from the Penn World Table 6.1 for the period 1950-2000. Data on per capita real GDP at constant price (RGDPL) and labor are collected from the same source. Our institution variable is the (political) constraints on executives, obtained from Polity-II dataset constructed by Ted Gurr and Associates (an update of Gurr 1997). We take the average for the period starting from 1950 to the latest available (for most of the countries, the sample period ends in 1994). Union workers data are constructed by Martin Rama and Raquel Artecona, and these are available at five-year interval for the period 1945-1999. General government consumption share in GDP is collected from the World Development Indicators (WDI). We use ethnic fractionalization data constructed by Matthew Krain.[12] We use Global Development Finance (GDF), the World Bank data for the period 1960-1999 for all other variables. Sources of data are described in Appendix-A.2.

Since σ is the most important data series, it is imperative to discuss its estimation method in detail. The most popular and frequently used equations to estimate σ in the literature are the three first-order conditions of the CES production function for the capital-output, labor-output and capital-labor ratios. These equations are linear in parameters and therefore, convenient for estimation. The first of these three equations relates capital-output ratio with the Jorgensonian user cost of capital, which combines interest, depreciation, and tax rates and the relative price of investment goods. Under constant returns to scale, the estimated coefficient of the user cost is the aggregate σ. The

[12] It is defined as $1-\sum_{j=1}^{J}\left(\frac{Population\ in\ j-th\ ethnic\ group}{Total\ \ population}\right)^2$.

user cost variable cannot be constructed as data on the tax rates are not available at the cross-country level. The simplest way to overcome the problem could be to treat the tax rates invariant over time so that only the constant term in the equation would be affected. But this would undoubtedly be a flawed assumption as taxes on capital goods have decreased in many countries over last couple of decades. In addition, Chirinko and Mallick (2006a, p. 15) have raised concerns about the estimation of σ from the capital-output equation using aggregate data. They show that if capital-output ratio and user cost of capital are I(1) and cointegrated, and factor shares are constant in the long the run, then capital-output equation will always give a value of σ equal 1 independent of the production technology. The second equation equates labor-output ratio with real wage. Data for the latter variable are also not available at the cross-country level. The third equation that equates capital-labor ratio with the ratio of two input prices can also not be estimated because of the reason mentioned above.

Another possibility could be estimation of the second-order Taylor approximation to the CES production function around σ =1, first introduced by Kmenta (1967, p. 180) and estimated by, among others, Zarembka (1970) and Duffy and Papageorgiou (2000). This equation is also linear in parameters, and requires data on output-labor and capital-labor ratios.[13] However, Thursby and Lovell (1978) showed that σ is estimated from the Kmenta approximation of the CES function with large bias and mean square error. The direction of bias can be upward or downward and does not get smaller with larger sample size. When σ departs from 1, the bias in all parameter estimates increases. Since the Kmenta approximation is a truncated series of second order, the remainder term becomes an omitted variable in the regression. Moreover, the Taylor series itself converges to the underlying CES function only on a region of convergence and the Kmenta approximation is a divergent Taylor series outside that region.

---

[13] The second-order Taylor approximation to equation-2 is $\log y_t = c + \alpha \log k_t + \beta \{\log k_t\}^2 + e_t$, where y_t is that output-labor ratio, k_t is the capital-labor ratio, and $\beta = \alpha(1-\alpha)(\sigma-1)/2\sigma$. The value of σ is recovered as $\sigma = \left[\alpha(1-\alpha)/\left(\alpha(1-\alpha)-2\beta\right)\right]$. For detail, please see, Mallick (2006, p. 9-10).

Given the limitations mentioned above, we are led to estimate the following normalized CES production function using non-linear least squares (NLS) to obtain σ for each country.

$$Y_t/Y_0 = A_t\left[\alpha\left(K_t/K_0\right)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)\left(L_t/L_0\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \qquad \text{--- (4)}$$

To calculate the normalized value of each variable, we divide each series by its initial value. In equation 4, a Hicks neutral technology term appears and we assume its exponential growth, $A_t = A_0 \exp(\lambda t)$, where A_0 is the initial level of technology and λ is its constant growth rate. By taking logarithm to both side of equation 4, we obtain

$$\log \overline{Y}_t = \log(A_0) + \lambda t + \rho \log\left[\alpha \overline{K}_t^{\frac{1}{\rho}} + (1-\alpha)\overline{L}_t^{\frac{1}{\rho}}\right] \qquad \text{--- (5)}$$

where, $\rho = \sigma/(1-\sigma)$, $\overline{Y}_t = Y_t/Y_0$, $\overline{K}_t = K_t/K_0$ and $\overline{L}_t = L_t/L_0$. We estimate ρ by NLS and then recover value of σ, and calculate its standard error by 'delta method' (For a detail discussion of the NLS estimation, see Appendix A.3).

We retain in our sample the countries for which data for at least 30 years are available. We also exclude the countries for which the iteration did not converge due to non-concavity with different preset values (there are 14 such countries).

Now we discuss the value of σ estimated for various countries. These are presented in Table 1. The value of σ is less than 0.1 for 18 countries of which nine are from Sub-Sahara Africa. Sierra Leone and Burundi have the lowest value of σ of 0.031. Countries in this region have also experienced very low growth of output per capita. Sixty-seven out of 90 countries have a value of σ lower than 0.5. Value of σ for the United States is 0.643. The value is the largest for Hong Kong of 2.18, and it is the only country with a value of σ larger than 2. Eight countries have a value of σ greater than 1, among which five are from East Asia. The East Asian countries have also been experiencing very high growth rates since 1960s.

Insert Table 1 here

Appendix A.4 reports the mean value of σ by region and growth rate of per capita GDP. The mean value for all 90 countries is 0.338 with a standard error of 0.380. The mean values for the East Asia and Sub-Sahara African countries are 0.737 and 0.275 respectively. For the OECD countries the mean is 0.340. A clear pattern is evident that, on average, value of σ increases secularly with growth rate of per capita GDP. For example, the mean value of σ is 0.203 for the countries with average growth rate less than 1% per year. These values increase to 0.257, 0.336, and 0.491 for the countries with growth rates ranging 1%-2%, 2%-3%, and higher than 3% respectively.

5 Results

In previous sections, we have explained our analytical framework and estimation method of σ. In this section, we present the results from cross-country growth regressions. We start with a simple OLS regression of per capita real GDP growth on the value of σ for the full sample of 90 countries. The coefficient of σ is 1.771 with a relatively low standard error of 0.370. The R-square is 0.171.

$$\text{Per capita real GDP growth} = \underset{(0.197)}{1.596} + \underset{(0.370)}{1.771} * (\sigma)$$

R-square = 0.171, N = 90

(Figures in the parentheses are robust standard errors)

This result shows positive and significant impact of σ on economic growth. However, other explanatory variables considered to be related to growth have not been controlled for. Some of these omitted variables, such as institutions and openness, may also be correlated to the value of σ, so the coefficient of σ is estimated with bias.

Insert Table 2 here

Table 2 reports some benchmark results by OLS. We report the sign and significance of the coefficient of σ conditioning on country characteristics, initial conditions, a set of policy variables, and institutions. In column 1, we condition on the country characteristics that include absolute latitude, landlocked dummy, ethnic fractionalization, and legal origin dummies. The coefficient of σ slightly decreases to 1.491 with a standard error of 0.262, and R-square increases to 0.414. The coefficient of σ, reported in column 2, remains positive and statistically significant at 1% level after adding the initial conditions (initial per capita real GDP, initial infant mortality rate, initial primary school enrollment). The sign and significance level also do not alter even after including investment-output ratio, openness, black market premium, and constraints on the executives in 1950-1994 in the regression. These results are reported in columns 3 and 4. However, the estimators for Table 2 are biased and inconsistent as we have not corrected for the endogeneity of investment output ratio and institutions, and the measurement errors in σ.

Insert Table 3 here

To account for endogeneity, we now estimate equation 3 by Fuller's (1977) modified Limited Information Maximum Likelihood (Fuller-*k*) method. Before presenting the results, we discuss the reason for employing the Fuller-*k* estimation. Recent work with instrumental variables has raised concerns about weak instruments and biased estimates (beginning with Nelson and Startz, 1990). Instrumental relevance is assessed with the test statistic proposed by Stock et al. (2002), which involves an auxiliary regression of the model variable on the instruments and a comparison of F-statistic for goodness of fit to a critical value. We find that, in several cases, the first-stage F-statistics from the regression of σ on the set of instruments are less than the critical value prescribed by Stock et al. (2002). However, the F-statistics from both regressions of investment-output ratio and constraints on the executives on their instruments are larger than the critical value. We therefore suspect that the 2SLS or GMM would estimate the coefficient of σ with bias. Stock et al. (2002, p. 525) have suggested the Fuller-*k* estimation for robust inference with weak instruments. Rotemberg (1984) has shown that this estimator is best unbiased to second order. In their Monte Carlo simulations using the Fuller-*k* estimator, Hahn et al. (2004) have found that bias and mean square error substantially reduce relative to IV and Limited Information Maximum Likelihood (LIML) when instruments are weak.

Results are presented in Table 3. Column 1 reports the results after conditioning on the country characteristics. The only source of endogeneity is the measurement errors in σ, which we account for using the percentage of union workers and the share of general government consumption in GDP as the instruments. The sample size now decreases to 70 as data on unionization are available for only this number of countries. The coefficient of σ is 1.871 with a relatively large standard error of 0.821 but the coefficient is significant at 5% level. The *p*-value of the chi-square statistics of the Anderson-Rubin (1950) over-identification test is 0.253 indicating the validity of the instruments. In column 2, we include the initial conditions to the conditioning variables in column 1. In column 3, we include openness and black market premium. In column 4, we add investment-output ratio, and account for the endogeneity using its initial value as the instrument. Constraints on the executives for the period 1950-94, which is a proxy for institutions, are added in column 5. We use the constraints on the executive in 1900 as the instrument. In all cases, both the sign and significance of the coefficient of σ do not change, and the instruments are found to be valid. It is important to mention that the coefficient of σ is uniformly larger from the Fuller-*k* than the OLS estimation with the same conditioning variables in the equation.

To get an idea about the magnitude of the effect of σ on growth rate, we consider two regions, East Asia and Sub-Sahara Africa. The fourteen East Asian countries in our sample have had the highest average annual growth rate of 3.771%. On the other hand, the twenty-eight Sub-Sahara African countries have had the lowest average growth rate of 0.985%. The mean (unweighted) values of σ for these two regions are 0.737 and 0.275, respectively. The value of β, the coefficient of σ, from the Fuller-*k* estimation with the full set of variables is 1.831 (column 5 in Table 3). With a difference of 0.462 in σ, there should be on average 0.846 points difference between growth rates of the two corresponding regions. The actual difference is 2.786 points implying that σ explains about 30% of the growth rate differential, which is fairly large although much less the actual difference.

The comparison between the East Asia and OECD (excluding the East Asian member countries) regions is more revealing. The differences in the average value of σ and per capita GDP growth rates for these two regions are 0.438 and 0.913, respectively.

With the value of β of 1.831, σ alone explains about 87% of the difference in the growth rates of the two corresponding regions. Even if we consider the most conservative estimate of β from the Fuller-*k* estimation, which is 1.307 (column 2 in Table 3), σ explains about 67% of the difference in their growth rates.

5.1 Robustness tests

5.1.1 Extreme value analysis: Although we have taken considerable care about the choice of the conditioning variables, the sign and significance of the coefficient of σ may still be subject to combinations of the variables included in the regression. To check the robustness, we perform extreme value analysis (EVA) first proposed by Leamer (1983). For a variable of interest, the extreme values of the distribution of the associated coefficient are their smallest and largest values when combinations of other regressors enter the regression model. When the two extreme values are of the same sign, then the variable is considered to be "robust", otherwise it is "fragile".[14] To determine the robustness of σ we estimate the following regressions,

$$g_i^y = \alpha_j + \beta_j \sigma_i + \eta_j C_i + \gamma_j x_{i,j} + \varepsilon_{i,j} \qquad \text{---(6)}$$

where, the j subscript refers to the j-th model, C_i is the vector of the country characteristics, $x_{i,j} \in X_i$ is a vector of 1 to 7 variables taken from X_i. We estimate equation 6 with all possible combinations of the initial conditions, institutions and policy variables, while we held σ and the country characteristics fixed in all regressions. The reason for the latter choice is that the country characteristics are fixed and do not depend in any way on past or present policies of a country. We have a total of 2^J models (with J = 7, we have a total of 128 models). If the minimum and maximum values of β_j are of the same sign, then we consider σ as robust predictor of economic growth.

The mean and standard deviation, minimum value, and maximum value of the distribution of estimated coefficient of σ are reported in column 1 of Table 4. Results

[14] Levine and Renelt's (1992) extreme bound analysis (EBA) is a more restrictive test. For each model j in equation 8, β_j and its standard deviation are estimated. The lower extreme bound (LEB) is defined as *Lowest value of [* β_j *- 2(stand. dev.)$_j$]* and the upper extreme bound (UEB) as *Largest value of [* β_j *+ 2(stand. dev.)$_j$]*. Their EBA test suggests that if the LEB for σ is negative and the UEB for the same is positive, then σ is not robust.

show that regardless of the linear combinations of the initial conditions, institutions and policy variables, we always obtain a positive coefficient of σ with a minimum and maximum of 0.511 and 2.253, respectively. Similar characteristics for the distribution of its *t*-statistics are reported in column 2. The relatively large *t*-values indicate that these coefficients are usually well above zero in a statistical sense.[15]

Insert Table 4 here

5.1.2 <u>Estimation correcting the effect of outliers:</u> Although our results are robust to the EVA, in this sub-section and the following we perform more robustness tests. As mentioned in section 4, the value of σ is relatively high for the East Asian countries and low for the Sub-Sahara African countries. These countries have also been experiencing very high- and low-growth, respectively. One can raise the question of whether our results are driven by larger and smaller values of σ for these two sets of countries. We answer this question by estimating the model including East Asia and Sub-Sahara Africa dummies to the full set of conditioning variables. Results are reported in column 1 of Table 5. The value of the coefficient of σ is 1.591 with a standard error of 0.749.

Insert Table 5 here

We also estimate the model after deleting six most extreme σ data points from our sample, three from each tail of the distribution of σ. Results are presented in column 2 of Table 5. The estimated coefficient of σ increases to 2.740 with a standard error of 1.316, so that it is significant at 5% level.

5.1.3 <u>Analysis with refined sample:</u> The standard errors of the σ estimators are large for a number of countries, and thus these estimators are not statistically different from zero. In our next robustness test, we retain the countries for which the σ estimator is

[15] Although our robustness test does not pass the extreme bound analysis (EBA) of Levine and Renelt (1992), in 89.8%, 82% and 44.5% cases, the coefficient of σ is statistically significant at 10%, 5% and 1% levels, respectively.

statistically significant at least at 5% level, and rerun some of the regressions with the full set of conditioning variables. Results for 44 such countries are presented in column 3 of Table 5. In column 4, we also add the East Asia and Sub-Sahara Africa dummies to check if the results are driven by high and low σs for these two types of countries respectively. After controlling for endogeneity, we find that, in both regressions, the coefficients of σ are positive and statistically significant at 1% and 5% level, respectively.

The PWT recognizes poor quality of its data for many countries, especially the developing ones. It has categorized the countries in terms of the quality of data with types A and B having better quality data, while types C and D having relatively poor quality data. Although the Fuller-*k* estimation accounts for the measurement errors in σ, to further test the robustness of our results we retain only those countries with A and B types data, which are mostly OECD countries. This also eliminates from our sample all Sub-Sahara African countries and some East Asian countries. Now we reproduce some of the previous regressions for the reduced sample of only 26 countries. The results are reported in columns 1-3 of Table 6. In column 1, we report the results after conditioning only the country characteristics. In column 2, we condition on the full set of variables other than institutions. The reason for excluding institutions is that the countries in this reduced sample do not vary much in terms of institutional development. In column 3, we add the East Asia dummy. In all cases, we account for the measurement errors in σ, and endogeneity of investment-output ratio. The positive coefficients of σ and low standard errors in all columns further confirm the robustness of our earlier results from the full sample.

Insert Table 6 here

5.2 <u>Alternative specification</u>

Our previous analysis is based on the assumption of a linear relationship between σ and growth rate. In the following equation, we extend the analysis to allow for a nonlinear relationship by specifying a quadratic equation in σ.

$$g_i^y = \alpha + \beta\sigma_i + \delta\sigma_i^2 + \eta C_i + \gamma X_i + \varepsilon_i \qquad \text{---(7)}$$

Now β, the coefficient of σ, does not refer to the marginal effect of σ on growth rate because of the quadratic specification. It is now given by $\beta + 2\delta\bar{\sigma}$, where, $\bar{\sigma}$ is the mean value of σ. Results are reported in Table 7. Column 1 reports the results for the full sample of 70 countries. The coefficients of σ and σ-squared are both positive but not statistically significant. With the mean value of σ of 0.357, the marginal effect is 3.01 with a standard error of 1.90, which is larger than the maximum value of β obtained from the EVA. In columns 2 and 3, results for 44 countries for which the σ estimators are significant at least at 5% level are reported. Column 3 adds East Asia and Sub-Sahara Africa dummies as additional regressors. In both regressions, the coefficient of σ is positive and that of σ-squared is negative, but not statistically significant. The marginal effect is 1.412 when East Asia and Sub-Sahara Africa dummies are excluded, and is 1.651 when the dummies are included. We also replicate the above exercise for 26 countries with better quality data types A and B. Results are reported in columns 4 and 5. In Column 5, we include East Asia dummy as an additional regressor. In both regressions, the coefficients of σ are positive and significant, but the coefficients of σ-squared are now negative and significant thus rejecting a linear relationship in favor of a concave relationship between σ and growth rate. The mean of value of σ is 0.387, and the marginal effects are 1.109 and 1.283, respectively.

Insert Table 7 here

It is important to mention that the measurement errors in σ are compounded in its square. The value of the F-statistics from the first-stage regression of σ-squared on its instruments is lower than that from the regression of σ indicating that the instruments are weaker in the nonlinear regressions. Unable to find additional instruments for σ (and its square), we have used the second and third powers of both percentage of union workers and share of general government consumption as additional instruments. The F-statistics although increase with new additional instruments but still remain below the critical value proposed by Stock et al. (2002). Therefore, we have employed Fuller-*k* estimation to correct the bias for the estimated coefficients.

In the above, we found that the coefficient of σ in the cross-country growth regression is always positive and significant. The results are also robust to Leamer's (1983) extreme value analysis. The results are not driven by outliers, and also hold in a small sample of countries with better quality data. However, we are unable to infer on the exact form of relationship between σ and growth rate.

6 Conclusion

The conclusion is fairly evident. We have found strong support for the de La Grandville (1989) hypothesis that growth rate of income per capita is increasing with σ.[16] Our results are robust in a variety of ways including Leamer's (1983) extreme value analysis. This finding has important policy implications. The aggregate σ is not a purely technological parameter, as Hicks realized, but it depends on many other institutional and financial factors. It can be a choice variable for the policy makers, who can increase the aggregate σ through intervention in the factor markets, and emphasizing the institutional and financial development to accelerate growth of a country.

[16] Miyagiwa and Papageorgiou (2003) contrasted the hypothesis by demonstrating that no such monotonic relationship between σ and growth exists in the Diamond overlapping-generations model. They showed that, if capital and labor are relatively substitutable, an economy with a higher σ exhibits lower per capital income growth in transition and in the steady state. They conclude that the role of σ for the economic growth depends on choice of particular model (Solow vs. Diamond).

Reference:

Acemoglu, D., J. A. Robinson and S. Johnson (2001), “The Colonial Origins of Comparative Development: An Empirical Investigation,” *American Economic Review*, 91 (December), 1369-1401.

Acemoglu, D. (2003), “Labor- and Capital-Augmenting Technical Change,” *Journal of European Economic Association*, 1 (March), 1-37.

Andronov, A. A., A. A. Vitt and S. E. Khaikin (1966), “Theory of Oscillators,” London, Pergamon Press.

Antras, P. (2004), “Is the US Aggregate Production Function Cobb-Douglas? New Estimates of the Elasticity of Substitution,” *Contributions to Macroeconomics*, 4 (1, April), 1-34.

Arrow, K. J., H. B. Chenery, M., B. S. Minhas and R. M. Solow (1961), "Capital-Labor Substitution and Economic Efficiency,” *Review of Economics and Statistics* 43, 225-250; reprinted in *Production and Capital: Collected Papers of Kenneth J. Arrow* Vol. 5 (Cambridge: Harvard University Press, 1985), 50-103

Bairam, E. (1990), “Capital-Labour Substitution and Slowdown in Soviet Economic Growth: A Re-examination,” *Bulletin of Economic Research*, 42 (1), 63-72.

Bairam, E. (1991), “Elasticity of Substitution, Technical Progress and Returns to Scale in Branches of Soviet Industry: A New Production Function Approach,” *Journal of Applied Econometrics*, 6 (1), 91-96.

Barro, R. J. (1990), “Government Spending in a Simple Model of Endogenous Growth,” *Journal of Political Economy*, 98 (2), 103-125.

Barro, R. J. (1998), “Determinants of Economic Growth: A Cross-Country Empirical Study,” Cambridge, MA, MIT Press.

Barro, R. J. and X. Sala-i-Martin (1995), “Economic Growth,” Cambridge, MA, MIT Press.

Baxter, M. and R. G. King (1999), “Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series,” *Review of Economics and Statistics*, 81 (November), 575-593.

Berndt, E. R. (1976), “Reconciling Alternative Estimates of the Elasticity of Substitution,” *Review of Economics and Statistics*, 58 (February), 59-68.

Blanchard, O. J. (1980), "The Solution of Linear Difference Models under Rational Expectation," *Econometrica*, 48 (5, March), 1305-1313.

Blitzer, C. (1991), "Elasticity of Substitution and the Retardation of Soviet Growth Rates," Review *of Economics and Statistics*, 52 (1, February), 104-108.

Brown, M. (1968), "On the Theory and Measurement of Technological Change," Cambridge University Press, UK.

Caselli, F. (2005), "Accounting for Cross-Country Income Differences," in *Handbook of Economic Growth*, Vol. 1A, edited by P. Aghion and Steven N. Durlauf, Elsevier Science.

Chirinko, R. S. and J. A. Elston (2006), "Finance, Control and Profitability: The Influence of German Banks," *Journal of Economic Behavior & Organization*, 56, 69-88.

Chirinko, R. S. and D. Mallick (2006a), "A Low-Pass Filter Panel Model for Estimating Production Function Parameters: The Substitution Elasticity and Growth Theory," Emory University, Atlanta.

Chirinko, R. S. and D. Mallick (2006b), "The Elasticity of Derived Demand, Factor Substitution, and Product Demand: Corrections to Hicks' Formula and Marshall's Four Rules", Emory University, Atlanta.

de La Grandville, O. (1989), "In Quest of the Slutsky Diamond," *American Economic Review*, 79 (June), 468-481.

de La Grandville, O. and R. M. Solow (2004), "Determinants of Economic Growth: Is Something Missing?" MIT.

de La Grandville, O. and R. M. Solow (2006), "A Conjecture on General Means," *Journal of Inequalities in Pure and Applied Mathematics*, 7 (1), 1-3.

DeLong, B. (1988), "Productivity Growth, Convergence and Welfare: Comment," *American Economic Review*, 78, 1138-1154.

Devrajan, S., W. R. Easterly and H. Pack (2003), "Low Investment is not the Constraint on African Growth," *Economic Development and Cultural Change*, 51 (3), 547-571.

Domar, E. D. (1946), "Capital Expansion, Rate of Growth, and Employment," *Econometrica*, 14, 137-147.

Duffy, J. and C. E. Papageorgiou (2000), "A Cross Country Empirical Investigation of the Aggregate Production Function Specification", *Journal of Economic Growth*, 5 (March), 87-120.

Dufour, J-M and J. Jasiak (2001), “Finite Sample Inference Methods for Simultaneous Equations and Models with Unobserved and Generated Regressors,” *International Economic Review*, 42 (3, August), 815-843.

Easterly, W. and R. Levine (2001), “It's Not Factor Accumulation: Stylized Facts and Growth Models,” *World Bank Development Review*, 15 (2), 177-219.

Easterly, W. and S. Fisher (1994), “The Soviet Economic Decline: Historical and Republican Data,” *NBER Working Paper No. 4735*, Cambridge, Massachusetts.

Freeman, R. B. and J. L. Medoff (1982), “Substitution Between Labor and Other Production Inputs in Unionized and Nonunionized Manufacturing,” *Review of Economics and Statistics*, 64 (2, May), 220-233.

Fuller, W. A. (1977), “Some Properties of a Modification of the Limited Information Estimator,” *Econometrica*, 45 (4, May), 939-953.

Hahn, J., J. Hausman and G. Kuersteiner (2004) “Estimation with weak instruments: Accuracy of higher-order bias and MSE approximations,” *Econometrics Journal* 7 (1, Jun), 272-306.

Hardy, G., J. E. Littlewood and G. Pólya (1952), “Inequalities,” Second Edition, Cambridge Mathematical Library, Cambridge.

Greene, W. H. (2003), “Econometric Analysis,” Fifth Edition, Prentice Hall, New Jersey.

Gurr, T. R. (1997), “Polity II: Political Structures and Regime Change. 1800-1986,” Unpublished Paper (Limited Revised Edition), University of Colorado, Boulder.

Harrod, R. F. (1939), “An Essay in Dynamic Theory,” *Economic Journal*, 49, 14-33.

Heston, A., R. Summers and B. Atten (2002), “Penn World Tables Version 6.1. Download Database,” Center for International Comparisons at the University of Pennsylvania.

Hicks, J. R. (1963), “The Theory of Wages,” Second Edition, London: MacMillan & Co., First edition published in 1932.

Kmenta, J. (1967), “On Estimation of the CES Production Function,” *International Economic Review*, 8 (June), 180-189.

Krain, M. (1997), “State-Sponsored Mass Murder: The Onset and Severity of Genocides and Politicides,” *Journal of Conflict Resolution*, 41 (3), 331-360.

Kim, J. I. and L. J. Lau (1994), "The Sources of Economic Growth of East Asian Newly Industrialized Countries," *Journal of the Japanese and International Economics*, 8 (3), 235-271.

Klump, R. and O. de La Grandville (2000), "Economic Growth and the Elasticity of Substitution: Two Theorems and Some Suggestions," *American Economic Review*, 90 (March), 282-291.

Leamer, E. E. (1983), "Let's Take the Con Out of Econometrics," *American Economic Review*, 73 (1, March), 31-43.

Leamer, E. E. (1991), "Sensitivity Analyses Would Help," *American Economic Review*, 57 (3, June), 308-313.

Levine, R. and D. Renelt (1992), "A Sensitivity Analysis of Cross-Country Growth Regressions," *American Economic Review*, 82 (4, September), 942-963.

Maddison, A. (1987), "Growth and Slowdown in Advanced Capitalist Economics: Techniques of Quantitative Assessment," *Journal of Economic Literature*, 25 (2), 649-698.

Maki, D. R. and L. N. Meredith (1987), "A Note on Unionization and the Elasticity of Substitution," *Canadian Journal of Economics*, 20 (4, November), 792-801.

Mallick, D. (2005), "Growth and Slowdown of Nations: What Role for the Elasticity of Substitution?," Emory University, Atlanta.

Mallick, D. (2006), "Reconciling Different Estimates of the Elasticity of Substitution," Emory University, Atlanta.

Mankiw, G. N., D. Romer and D. Weil (1992), "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics*, 107, 407-438.

Masanjala, W. H. and C. E. Papageorgiou (2003), "The Solow Model with CES Technology: Nonlinearities and Parameter Heterogeneity," *Journal of Applied Econometrics*, 18, 1-31.

McMohan, G. and L. Squire (2003), "Explaining Growth--A Global Research Project," New York, Palgrave MacMillan.

Miyagiwa, K. and C. E. Papageorgiou (2003), "Elasticity of Substitution and Growth: Normalized CES in the Diamond Model," *Economic Theory*, 21 (January), 155-165.

Miyagiwa, K. and C. E. Papageorgiou (2006), "Endogenous Aggregate Elasticity of Substitution," forthcoming in *Journal of Economic Dynamics and Control*.

Murphy, K. M. and R. H. Topel (1985), "Estimation and Inference in Two-Step Econometric Models," *Journal of Business and Economic Statistics* 3 (4), 370-379.

Musgrave, R. A. (1969), "Fiscal Systems," Yale University Press, New Haven.

Nehru, V. and A. Dhareshwar (1993), "A New Database on Physical Capital Stock: Sources, Methodology and Results," *Revista De Analisis Economico*, 8 (1), 37-59.

Nelson, C. R. and R. Startz (1990), "Some Further Results on the Exact Small Sample Properties of the Instrumental Variables Estimator," *Econometrica*, 58 (July), 967-976.

OECD (1991), "Flows and Stocks of Fixed Capital (1964-89)," *OECD Department of Economics and Statistics*.

Oxley, L. and M. McAleer (1993), "Econometric Issues in Macroeconomic Models with Generated Regressors," *Journal of Economic Surveys*, 7(1), 1-40.

Pagan, A. (1984), "Econometric Issues in the Analysis of Regressions with Generated Regressors," *International Economic Review*, 23 (1, February), 221-247.

Parente, S. L. and E. C. Prescott (1993), "Changes in the Wealth of Nations," *Federal Bank of Minneapolis Quarterly Review*, 17, 3-16.

Pitchford, J. D. (1960), "Growth and the Elasticity of Factor Substitution," *Economic Record* 36 (December), 491-504.

Pritchett, L. (2000), "The Tyranny of Concepts: CUDIE (Cumulated, Depreciated, Investment Efforts)," *Journal of Economic Growth* 5 (4), 361-384.

Ram, R. (1986), "Government Size and Economic Growth: A New Framework and Some Evidence from Cross-Section and Time-Series Data," *American Economic Review*, 76 (1, March), 191-203.

Rama, M. and R. Artecona (2002), "A Database of Labor Market Indicators across Countries," unpublished manuscript, Washington, DC, The World Bank.

Rotemberg, T. J. (1984), "Approximating the Distribution of Econometric Estimators and Test Statistics," in *Handbook of Econometrics*, Vo. 2, edited by Z. Griliches and M. D. Intriligator, Amsterdam, North-Holland.

Rutherford, T. (2003), "Lecture Notes on Constant Elasticity Functions," University of Colorado, November, 2003.

Saam, M. (2005), "Trade Liberalization as a Determinants of the Elasticity of Substitution between Capital and Labor," University of Frankfurt, Germany.

Sala-i-Martin, X. (1997), "I Just Ran Two Million Regressions," *American Economic Review*, 87 (2, May), 178-83.

Sala-i-Martin, X., G. Doppelhofer, and R. I. Miler (2004), "Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach," *American Economic Review*, 94 (4, September), 813-35.

Senhadji, A. (1999), "Sources of Economic Growth: An Extensive Growth Accounting Exercise," *IMF Working Paper No. 99/77*, Washington D.C.

Solow, R. M. (1956), "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70 (February), 65-94.

Solow, R. M. (1999), "Neoclassical Growth Theory" in *Handbook of Macroeconomics*, Vol. 1, edited by J. B. Taylor and M. Woodford, Elsevier Science.

Solow, R. M. (2005), "Reflections on Growth Theory" in *Handbook of Economic Growth*, Vol. 1A, edited by P. Aghion and S. N. Durlauf, Elsevier Science.

Srinivasan, T. N. (1995), "Long-Run Growth Theories and Empirics: Anything New?" in *Growth Theories in Light of the East Asian Experience*, edited by T. Ito and A. O. Krueger, The University of Chicago Press.

Stock, J. H., J. H. Wright, and M. Yogo (2002), "A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments," *Journal of Business & Economic Statistics*, 20 (October), 518-529.

Stock, J. H. and M. Yogo (2003), "Testing for Weak Instruments in Linear IV Regression," Harvard University, Mimeo.

Tanzi, V. and L. Schuknecht (2000), "Public Spending in the 20Th Century," Cambridge University Press, Cambridge, UK.

Thursby, J. G. and C. A. K. Lovell (1978), "An Investigation of the Kmenta Approximation to the CES Function," *International Economic Review*, 19 (2, June), 363-377.

Weitzman, M. L. (1970), "Soviet Postwar Economic Growth and Capital-Labor Substitution," *American Economic Review*, 60 (5, December), 676-692.

Young, A. (1995), "The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience," *Quarterly Journal of Economics*, 110 (3), 641-680.

Yuhn, K. (1991), "Economic Growth, Technical Change Biases, and the Elasticity of Substitution: A Test of the de La Grandville Hypothesis," *Review of Economics and Statistics*, 73 (May), 340-346.

Zarembka, P. (1970), "On the Empirical Relevance of the CES Production Function," *Review of Economics and Statistics*, 52 (February), 47-53.

Appendix

A.1. Calculation of capital stock

We use the perpetual inventory method to construct capital stock series. Suppose, I_t is the gross investment at time period *t*, and δ is the constant rate of depreciation, then the capital stock at *t*, K_t is given by

$$K_t = I_t + (1-\delta)K_{t-1} \qquad \text{--- (A.1.1)}$$

Initial capital stock, K_0, is constructed using the following method. We first rearrange equation-A.1.1 to get an expression for investment.

$$I_t = \left[\frac{K_t}{K_{t-1}} - (1-\delta)\right]K_{t-1} = (g+\delta)K_{t-1} \qquad \text{--- (A.1.2)}$$

where, g is the constant growth rate of capital stock.

Substituting equation-A.1.2 into equation-A.1.1, we obtain $K_t = (1+g)K_{t-1}$. Working backward recursively we can express capital stock in period *t-1* in terms of initial capital stock as K_0, $K_{t-1} = (1+g)^{t-1}K_0$. Next, we substitute this equation into the investment equation-A.1.2 to express investment in period *t* in terms of initial capital stock, K_0 as $I_t = \frac{g+\delta}{1+g}(1+g)^t K_0$. Finally, take logarithms to both sides to obtain

$$\ln I_t = \ln\left(\frac{g+\delta}{1+g}K_0\right) + t\ln(1+g) = \alpha_1 + t\beta \qquad \text{--- (A.1.3)}$$

where, $\alpha_1 = \ln\left(\frac{g+\delta}{1+g}K_0\right)$, and $\beta = \ln(1+g) \approx g$. We estimate equation-A.1.3 to obtain $\hat{\alpha}_1$ and $\hat{\beta}$, and given the depreciation rate we can recover K_0 as

$$K_0 = \exp(\hat{\alpha}_1)\frac{1+\hat{\beta}}{\hat{\beta}+\delta}.$$

Advantage of this method is that it uses all available information to estimate the initial capital stock.

The choice of the depreciation rate is no less important than the initial capital stock. Even if the initial capital stock is measured erroneously, the errors in the subsequent stocks are dampened over time by the depreciation rate. On the contrary, if the choice of the depreciation rate is higher (lower) than the actual, not only the initial capital stock estimate would be lower (higher), but also the capital stocks in the subsequent years would also be lower (higher) by greater amounts, because the errors are compounded in the subsequent stocks (Nehru and Dhareswar, 1993). Data on depreciation rate is not available for most of the countries. This has led the cross-country growth accounting studies to use a common depreciation rate for all countries. Following the growth accounting literature (Mankiw, Romer and Weil, 1992; Nehru and Dhareswar, 1993; Easterly and Levine, 2001) we use a common 4% depreciation rate for all countries.

A.2. List of variables and data sources.

Variable	Source
Real GDP	Penn World Table 6.1
Investment-output ratio	Penn World Table 6.1
Labor	Penn World Table 6.1
Latitude	Global Development Finance (GDF) Growth Database, World Bank
Landlocked	GDF
Ethnic fractionalization	Matthew Krain
British Legal origin	GDF
French Legal origin	GDF
Infant mortality rate	GDF
Primary school enrollment	GDF
Openness (Export and import as % of GDP)	GDF
Black market premium	GDF
Constraint on executives	Polity-II (Ted Gurr and Associates)
General government consumption (% of GDP)	World Development Indicator, World Bank
Fraction of union workers	Martin Rama (The World Bank in Vietnam) and Raquel Artecona

A.3. Estimation method of σ from the normalized CES production function by NLS

We reproduce equation 5 here.

$$\log \overline{Y}_t = \log(A_0) + \lambda t + \rho \log\left[\alpha \overline{K}_t^{-\frac{1}{\rho}} + (1-\alpha)\overline{L}_t^{-\frac{1}{\rho}}\right] \qquad \text{--- (5)}$$

For simplicity rewrite equation 5 as $y = f[X:\Phi]$, where $\Phi = [\alpha, \lambda, \sigma]$ is the parameter vector and *X* is the vector of variables entering equation 5 (For detail, see Greene (2003, p. 165-70). We preset the value of Φ at Φ^0, and take a Taylor approximation to $y = f[X:\Phi]$ around Φ^0.

$$f[X:\Phi] \approx f[X:\Phi^0] + \sum_{k=1}^{3} \frac{\partial f[X:\Phi^0]}{\partial \Phi_k^0}(\Phi_k - \Phi_k^0). \qquad \text{--- (A.3.1)}$$

By collecting terms we obtain,

$$f[X:\Phi] \approx \left[f^0 - \sum_{k=1}^{3} x_k^0 \Phi_k^0\right] + \sum_{k=1}^{3} x_k^0 \Phi_k \text{, where } f^0 = f[X:\Phi^0] \text{ and } x_k^0 = \frac{\partial f[X:\Phi^0]}{\partial \Phi_k^0}.$$

Using matrix notation $y = f[X:\Phi]$ can be expressed as $y \approx f^0 - X^{0'}\Phi^0 + X^{0'}\Phi + \varepsilon$.

Here, the only unknown to be estimated is Φ, so we rewrite the above equation

as $y^0 \approx X^{0'}\Phi + \varepsilon$, --- (A.3.2)

where $y^0 = y - f^0 - X^{0'}\Phi^0$. Equation A.3.2 is linear, and is estimated by OLS to obtain $\hat{\Phi}^1$. We repeat the entire procedure using the estimated parameter vector $\hat{\Phi}^1$, as we did using Φ^0, to obtain a new parameter vector $\hat{\Phi}^2$. This procedure is iterated until the parameter vector converges, so that $\hat{\Phi}^j = \hat{\Phi}^{j+1}$.

A.4: Value of σ by region and GDP growth rate

Region/ GDP growth rate	σ		Number of countries
	Mean	Standard Deviation	
All	0.338	0.380	90
East Asia	0.737	0.657	14
Sub-Saharan Africa	0.275	0.264	28
OECD	0.340	0.312	24
OECD (excluding East Asian countries)	0.299	0.223	20
GDP growth rate <1%	0.203	0.192	22
GDP growth rate >=1% but <2%	0.257	0.315	17
GDP growth rate >=2% but <3%	0.336	0.241	22
GDP growth rate >=3%	0.491	0.537	29

Table 1: Value of σ (and standard error) by country

Country	σ	Standard error	Country	σ	Standard error
Argentina	0.112125	0.119246	Japan	0.330502	0.018359
Australia	0.230056	0.064782	Kenya	0.094002	0.085541
Austria	0.231658	0.018088	Korea, South	1.440629	0.133021
Burundi	0.031128	0.118136	Sri Lanka	0.428039	0.045442
Belgium	0.238228	0.016259	Lesotho	0.833528	0.076187
Benin	0.332678	0.106454	Luxembourg	0.332951	0.281706
Bangladesh	0.152298	1.98311	Morocco	0.10223	0.102193
Brazil	0.126055	0.027758	Madagascar	0.564631	0.238793
Barbados	0.133728	0.151819	Mexico	0.087222	0.021677
Central African Republic	0.093348	0.036106	Mozambique	0.082835	4.879769
Canada	0.236155	0.026096	Mauritania	0.098026	0.069101
Switzerland	0.154932	0.042077	Mauritius	0.687388	0.169961
Chile	0.099882	0.08532	Malawi	0.714232	1.645645
China	0.548428	0.223212	Malaysia	1.52205	0.204276
Cote d'Ivoire	0.144398	0.090111	Namibia	0.200169	0.121008
Cameroon	0.088743	0.089997	Niger	0.171831	0.095679
Congo, Republic of	0.164589	0.195408	Nigeria	0.177224	0.051825
Colombia	0.146666	0.027822	Nicaragua	0.084334	0.248448
Comoros	0.144026	0.45805	Netherlands	0.164692	0.034891
Cape Verde	0.31098	0.521797	Norway	0.76199	0.119417
Costa Rica	0.114007	0.033344	Nepal	0.563015	0.080016
Denmark	1.321511	0.348453	New Zealand	0.175233	0.392015
Dominican Republic	0.503423	0.179549	Panama	0.264794	0.051536
Ecuador	0.126152	0.074637	Philippines	0.07539	0.037409
Spain	0.126667	0.026001	Papua New Guinea	0.518458	3.492253
Ethiopia	0.082016	0.047478	Portugal	0.488343	0.072907
Finland	0.196602	0.029357	Paraguay	1.279504	0.318853
Fiji	0.137551	0.629335	Romania	0.085242	0.203029
France	0.216632	0.012479	Singapore	0.538795	0.135964
Gabon	0.119191	0.254436	Sierra Leone	0.030915	0.087541
United Kingdom	0.195042	0.128566	El Salvador	0.191256	0.120343
Ghana	0.140967	0.156114	Sweden	1.197656	0.051194
Gambia	0.278348	0.038403	Seychelles	0.872653	0.219188
Guatemala	0.088517	0.029357	Syria	0.170084	0.125793
Guyana	0.083337	0.678061	Chad	0.783858	0.059549
Hong Kong	2.184898	0.976902	Togo	0.06811	0.102317
Honduras	0.112279	0.035493	Thailand	0.196835	0.025899
Indonesia	1.138845	0.106714	Trinidad &Tobago	0.053797	0.076715
India	0.515283	0.353573	Tunisia	0.133854	0.129543
Ireland	0.684165	0.221576	Turkey	0.685593	0.104076
Iran	0.070374	0.079274	Taiwan	1.282201	0.059961
Iceland	0.23863	0.053815	USA	0.643052	0.086263
Israel	0.135631	0.051943	Venezuela	0.261887	0.145368
Italy	0.115633	0.014464	Zambia	0.133313	0.044274
Jordan	0.331228	0.158966	Zimbabwe	0.258562	0.165507

Table 2: OLS estimation of equation 3: Per capita real GDP growth rate is the dependent variable

$$g_i^y = \alpha + \beta\sigma_i + \eta C_i + \gamma X_i + \varepsilon_i \qquad \text{---(3)}$$

Explanatory variables	(1)	(2)	(3)	(4)
σ	**1.491 (0.262)*** **	**0.983 (0.230)*** **	**0.831 (0.219)*** **	**0.825 (0.221)*** **
Fixed factors (C)				
Latitude	0.014 (0.005)	0.017 (0.004)	0.011 (0.003)	0.011 (0.003)
Landlocked	-0.740 (0.441)	-0.485 (0.259)	-0.870 (0.211)	-0.862 (0.211)
Ethnic fractionalization	-1.246 (0.508)	-0.715 (0.409)	-0.675 (0.358)	-0.689 (0.362)
British Legal origin	-0.160 (0.441)	0.344 (0.316)	-0.186 (0.271)	-0.190 (0.273)
French Legal origin	-0.702 (0.396)	-0.040 (0.281)	-0.222 (0.256)	-0.230 (0.254)
Initial conditions (X_1)				
Initial per capita real GDP (log)		-1.185 (0.193)	-1.012 (0.156)	-1.032 (0.163)
Initial infant mortality rate		-0.008 (0.004)	-0.002 (0.004)	-0.001 (0.004)
Initial primary school enrollment		0.028 (0.005)	0.017 (0.005)	0.017 (0.005)
Institutions (X_2)				
Constraint on executives in 1950-1994				0.022 (0.051)
Other controls (X_3)				
Investment-output ratio (log)			1.209 (0.255)	1.201 (0.256)
Openness (X+M as % of GDP)			0.007 (0.003)	0.007 (0.003)
Black market premium			-0.0003 (0.0003)	-0.0003 (0.0003)
Constant	2.526 (0.442)	9.606 (1.789)	5.299 (1.834)	5.338 (1.870)
R-square	0.414	0.717	0.818	0.818
N	88	88	88	88

Column 1: Only the country-characteristics are the conditioning variables.
Column 2: Initial per capita real GDP, initial infant mortality rate, and initial primary school enrollment rate are included in column 1.
Column 3: Investment-output ratio, openness and black market premium are added to the conditioning variables in column 2.
Column 4: Constraint on executives in 1950-1994 is added to the conditioning variables in column-3.

Figures in the parentheses are the White (1982) corrected robust standard errors.

*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level (The significance of only the coefficient of σ is mentioned)

Table 3: Fuller-*k* estimation of equation 3: Per capita real GDP growth rate is the dependent variable

$$g_i^y = \alpha + \beta\sigma_i + \eta C_i + \gamma X_i + \varepsilon_i \qquad \text{---(3)}$$

Explanatory variables	(1)	(2)	(3)	(4)	(5)
σ	**1.871 (0.821)****	**1.307 (0.520)****	**1.360 (0.513)*****	**1.587 (0.509)*****	**1.831 (0.587)*****
Fixed factors (C)					
Latitude	0.012 (0.005)	0.016 (0.004)	0.014 (0.004)	0.013 (0.003)	0.011 (0.004)
Landlocked	-0.937 (0.443)	-0.708 (0.299)	-0.879 (0.293)	-1.094 (0.292)	-1.146 (0.305)
Ethnic fractionalization	-1.055 (0.442)	-0.609 (0.421)	-0.571 (0.417)	-0.437 (0.373)	-0.556 (0.416)
British Legal origin	-0.241 (0.439)	0.244 (0.329)	-0.123 (0.333)	-0.110 (0.294)	-0.069 (0.311)
French Legal origin	-0.626 (0.443)	-0.151 (0.290)	-0.423 (0.326)	-0.205 (0.289)	-0.191 (0.295)
Initial conditions (X_1)					
Initial per capita real GDP (log)		-0.941 (0.190)	-0.829 (0.190)	-0.768 (0.168)	-0.844 (0.176)
Initial infant mortality rate		-0.007 (0.004)	-0.002 (0.004)	-0.000 (0.004)	0.001 (0.004)
Initial primary school enrollment		0.024 (0.005)	0.025 (0.005)	0.015 (0.006)	0.008 (0.009)
Institutions (X_2)					
Constraint on executives in 1950-1994					0.140 (0.156)
Other controls (X_3)					
Investment-output ratio (log)				1.190 (0.387)	1.385 (0.450)
Openness (X+M as % of GDP)			0.007 (0.004)	0.005 (0.003)	0.006 (0.004)
Black market premium			-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
Constant	2.434 (0.642)	7.921 (1.925)	6.393 (1.924)	3.242 (2.287)	2.893 (2.391)
Chi-sq (1) *p*-value[#]	0.253	0.801	0.686	0.315	0.203
N	70	70	70	70	70

\# Chi-sq(1) *p*-value of Anderson-Rubin statistic (over-identification test of all instruments)

Column 1: Only the country-characteristics are the conditioning variables. Percentage of union workers, and share of general government consumption in GDP are the instruments for σ.

Column 2: Initial per capita real GDP, initial infant mortality rate, and initial primary school enrollment rate are included in column 1.

Column 3: Openness and black market premium are added to the conditioning variables in column 2.

Column 4: Investment-output ratio is added to the conditioning variables in column 3. Initial investment-output ratio is the instrument for average investment-output ratio.

Column 5: Constraint on executives in 1950-1994 is added to the conditioning variables in column 4. Constraint on executives in 1900 is the instrument for constraint on executives in 1950-1994.
Figures in the parentheses are the White (1982) corrected robust standard errors.

*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level (The significance of only the coefficient of σ is mentioned)

Table 4: Extreme value analysis for the coefficient of σ using the Fuller-*k* estimation

	Coefficient	*t*-statistics
	(1)	(2)
Mean [S.D.]	1.533 [0.424]	2.494 [0.618]
Minimum	0.511	0.844
Maximum	2.253	3.683

Extreme-value analysis using all possible combinations of the 7 conditioning variables in equation 8 (in all cases σ and country-characteristics are held fixed). There are $2^7 = 128$ possible combinations.

Column 1: Contains the mean and standard deviation, minimum and maximum values of the distribution of the coefficient of σ.

Column 2: Contains the same statistics for the distribution of the associated t-statistics.

All standard errors White (1982) corrected.

Table 5: Fuller-*k* estimation of equation 3: Per capita real GDP growth rate is the dependent variable

$$g_i^y = \alpha + \beta\sigma_i + \eta C_i + \gamma X_i + \varepsilon_i \qquad \text{---(3)}$$

Explanatory variables	(1)	(2)	(3)	(4)
σ	**1.591 (0.749)****	**2.740 (01.316)****	**2.230 (0.576)*****	**1.960 (0.971)****
Fixed factors (C)				
Latitude	0.010 (0.004)	0.010 (0.004)	0.008 (0.005)	0.007 (0.006)
Landlocked	-1.065 (0.402)	-1.376 (0.377)	-0.985 (0.403)	-0.953 (0.559)
Ethnic fractionalization	-0.531 (0.400)	-0.556 (0.426)	-0.021 (0.588)	-0.073 (0.520)
British Legal origin	-0.141 (0.288)	-0.140 (0.378)	-0.313 (0.380)	-0.334 (0.416)
French Legal origin	-0.287 (0.285)	-0.041 (0.453)	-0.103 (0.372)	-0.170 (0.377)
East Asia dummy	-0.026 (0.453)			0.003 (0.758)
Sub-Saharan Africa dummy	-0.279 (0.350)			-0.364 (0.507)
Initial conditions (X_1)				
Initial per capita real GDP (log)	-0.871 (0.168)	-0.894 (0.200)	-0.987 (0.241)	-0.882 (0.277)
Initial infant mortality rate	0.001 (0.004)	-0.000 (0.004)	-0.004 (0.004)	-0.003 (0.004)
Initial primary school enrollment	0.009 (0.007)	0.000 (0.012)	0.008 (0.008)	0.010 (0.007)
Institutions (X_2)				
Constraint on executives in 1950-1994	0.110 (0.127)	0.159 (0.150)	0.188 (0.156)	0.084 (0.156)
Other controls (X_3)				
Investment-output ratio (log)	1.264 (0.461)	1.979 (0.802)	1.540 (0.521)	1.473 (0.849)
Openness (X+M as % of GDP)	0.007 (0.003)	0.007 (0.003)	0.005 (0.006)	0.005 (0.005)
Black market premium	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.001)	-0.000 (0.001)
Constant	3.768 (2.413)	2.036 (3.485)	3.371 (2.631)	3.300 (2.394)
Chi-sq (1) *p*-value[#]	0.689	0.349	0.179	0.19561
N	70	64	44	44

Chi-sq(1) *p*-value of Anderson-Rubin statistic (over-identification test of all instruments)

Column 1: East Asia and Sub-Sahara Africa dummies are added to column 5 in table 3.
Column 2: Six extreme σ data points, three from each tail of the distribution of σ, have been deleted from the sample. Estimation is based on a sample of 64 countries.

Column 3-4: Values of σ with at least 5% level of significance have been retained. Sample size is 44.

Figures in the parentheses are the White (1982) corrected robust standard errors.

*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level (The significance of only the coefficient of σ is mentioned)

Table 6: Fuller-*k* estimation of equation 3: Per capita real GDP growth rate is the dependent variable

$$g_i^y = \alpha + \beta\sigma_i + \eta C_i + \gamma X_i + \varepsilon_i \qquad \text{---(3)}$$

Explanatory variables	(1)	(2)	(3)
σ	**2.581 (0.928)*** **	**0.441 (0.158)*** **	**0.451 (0.185)** **
Fixed factors (C)			
Latitude	0.006 (0.006)	-0.006 (0.003)	-0.008 (0.005)
Landlocked	0.012 (0.494)	-0.003 (0.149)	-0.000 (0.156)
Ethnic fractionalization	-0.087 (1.23)	0.556 (0.482)	0.606 (0.500)
British Legal origin	0.195 (0.561)	-0.548 (0.186)	-0.591 (0.204)
French Legal origin	0.425 (0.440)	-0.373 (0.147)	-0.411 (0.165)
East Asia dummy			-0.144 (0.329)
Initial conditions (X_1)			
Initial per capita real GDP (log)		-2.237 (0.232)	-2.327 (0.306)
Initial infant mortality rate		-0.015 (0.007)	-0.017 (0.008)
Initial primary school enrollment		0.009 (0.005)	0.009 (0.005)
Other controls (X_3)			
Investment-output ratio (log)		-0.848 (0.380)	-0.890 (0.406)
Openness (X+M as % of GDP)		0.009 (0.001)	0.009 (0.001)
Black market premium		-0.027 (0.008)	-0.030 (0.008)
Constant	1.800 (0.528)	24.206 (3.393)	25.323 (4.187)
Chi-sq (1) *p*-value#	0.800	0.767	0.654
N	26	26	26

Chi-sq(1) *p*-value of Anderson-Rubin statistic (over-identification test of all instruments)

Columns 1-3: Countries with better quality (A and B) categorized by PWT are included. Sample size is 26.

Column 1: Only the country-characteristics are the conditioning variables. Percentage of union workers, and share of general government consumption in GDP are the instruments for σ.

Column 2: Initial per capita real GDP, initial infant mortality rate, initial primary school enrollment rate, investment output ratio, openness and black market premium are included to the conditioning variables in column 1. Initial investment-output ratio is the instrument for average investment-output ratio.

Column 3: East Asia dummy is added to the conditioning variables in column 2.

Figures in the parentheses are the White (1982) corrected robust standard errors.

*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level (The significance of only the coefficient of σ is mentioned)

Table 7: Fuller-*k* estimation of equation 7: Per capita real GDP growth rate is the dependent variable

$$g_i^y = \alpha + \beta\sigma_i + \delta\sigma_i^2 + \eta C_i + \gamma X_i + \varepsilon_i \qquad \text{---(7)}$$

Explanatory variables	(1)	(2)	(3)	(4)	(5)
σ	**3.528 (2.849)**	**0.701 (2.696)**	**1.108 (2.248)**	**1.485 (0.591)****	**1.694 (0.690)****
σ-squared	**-0.725 (1.393)**	**0.759 (1.421)**	**0.579 (1.218)**	**-0.486 (0.223)****	**-0.531 (0.242)****
Mean value of σ	0.357	0.469	0.469	0.387	0.387
Marginal effect	3.010 (1.900)	1.412 (1.451)	1.651 (1.352)	1.109 (0.423)***	1.283 (0.511)**
Fixed factors (C)					
Latitude	0.009 (0.004)	0.007 (0.005)	0.006 (0.006)	-0.006 (0.004)	-0.010 (0.005)
Landlocked	-1.352 (0.498)	-0.874 (0.442)	-0.961 (0.536)	0.067 (0.165)	0.090 (0.190)
Ethnic fractionalization	-0.633 (0.536)	-0.319 (0.899)	-0.173 (0.809)	0.576 (0.564)	0.705 (0.571)
British Legal origin	0.045 (0.468)	-0.375 (0.410)	-0.397 (0.448)	-0.438 (0.215)	-0.502 (0.206)
French Legal origin	-0.047 (0.448)	-0.335 (0.408)	-0.322 (0.410)	-0.191 (0.176)	-0.208 (0.192)
East Asia dummy			-0.149 (0.790)		-0.265 (0.393)
Sub-Sahara Africa dummy			-0.158 (0.476)		
Initial conditions (X_1)					
Initial per capita real GDP (log)	-0.898 (0.214)	-1.061 (0.243)	-1.033 (0.285)	-2.160 (0.319)	-2.305 (0.357)
Initial infant mortality rate	0.002 (0.005)	-0.002 (0.006)	-0.002 (0.005)	-0.017 (0 .009)	-0.021 (0.010)
Initial primary school enrollment	-0.006 (0.016)	0.014 (0.010)	0.013 (0.009)	0.005 (0.005)	0.004 (0.006)
Institutions (X_2)					
Constraint on executives in 1950-1994	0.328 (0.154)	0.245 (0.123)	0.191 (0.135)		
Other controls (X_3)					
Investment-output ratio (log)	1.920 (0.785)	1.054 (0.839)	1.294 (0.970)	-0.533 (0.606)	-0.550 (0.616)
Openness (X+M as % of GDP)	0.007 (0.004)	0.007 (0.007)	0.006 (0.007)	0.008 (0.001)	0.008 (0.001)
Black market premium	0.000 (0.000)	0.001 (0.001)	0.000 (0.002)	-0.023 (0.009)	-0.027 (0.008)
Constant	1.484 (3.357)	4.874 (3.261)	4.367 (3.014)	22.782 (4.937)	24.469 (5.150)
Chi-sq (1) *p*-value#	0.857	0.394	0.441	0.180	0.260
N	70	44	44	26	26

Chi-sq(1) *p*-value of Anderson-Rubin statistic (over-identification test of all instruments)
Column 1: Estimation based on a sample of 70 countries.
Column 2: Values of σ with at least 5% level of significance have been retained. Sample size is 44.
Column 3: East Asia and Sub-Sahara dummies have been added in column 2.
Column 4: For countries with A and B quality data. Sample size is 26.
Column 5: East Asia dummy has been added in column 4.

Percentage of union workers, general share of government consumption in GDP, and their second and third powers are the instruments for σ and its square.
Figures in the parentheses are the White (1982) corrected robust standard errors.

Marginal effect is calculated by $\beta + 2\delta\bar{\sigma}$, where, $\bar{\sigma}$ = mean value of σ.

*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level (The significance of only the coefficient of σ, and the marginal effect are mentioned)