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The role of the elasticity of substitution in economic growth: A cross-country investigation ☆

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ABSTRACT

Although the importance of the elasticity of substitution between capital and labor (σ) has long been recognized in several branches of economics, it has not received enough attention in the growth literature. de La Grandville (1989) showed theoretically that at any stage 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 set in very slowly. To the best of our knowledge, this is the first paper that tests the hypothesis that growth rate is increasing with the value of σ 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, and a set of policy variables. After accounting for endogeneity and the fact that σ is a "generated" regressor, we find strong support for the hypothesis. The result is robust to both Leamer's (1983) extreme value analysis and Bayesian model averaging. About a fifth to a quarter of the growth rate differential between East Asia and Sub-Saharan Africa can be explained by σ alone.

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 very little attention in the growth literature. de La Grandville (1989) was the first to systematically explore the relationship between σ and economic growth. He showed theoretically that at any stage of an economy's development, the growth rate of income per capita is an increasing function of σ.[1] Intuitively, the mechanism for this hypothesis is the following: for an increase in σ, the incremental capital is more easily substituted for labor, thus leading to a more equiproportionate increase in both factors; consequently, diminishing returns to capital set in very slowly. In short, a larger σ allows an economy to rapidly accumulate capital without substantially lowering its marginal product. This hypothesis readily extends to understanding the differential growth performances among countries. If two countries have different values of σ but otherwise share the same initial conditions, such as the capital–labor ratio, and the population growth and savings rates, then the country with the larger value of σ will experience a higher growth rate. To the best of our knowledge, ours is the first paper that tests the hypothesis of the positive effect of σ on the growth rate at the cross-country level.[2]

The hypothesis is tested in a Barro-type cross-country growth regression framework that regresses the growth rate of per capita real GDP on σ and a set of variables related to growth. In the first step, σ is obtained for 90 countries by estimating the normalized CES production function for each country separately using respective country time series. These estimated values of σ are then included in a cross-country growth regression in the second step, and the sign and significance of the coefficient of σ are investigated 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 second-step cross-country regression is inconsistent, and the asymptotic t-statistic overstates the true value. For correct inference, the standard error of the coefficient of σ is adjusted by the correction proposed by Murphy and Topel (1985). However, it is not known that the Murphy–Topel (M–T) correction is appropriate in the presence of endogenous regressors; therefore, the second-step equation is also estimated by 2SLS, an alternative to the

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[1] Solow (1956) and Pitchford (1960) mentioned the importance of σ for perpetual growth, but this has largely been ignored.

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

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M–T correction, by instrumenting both σ and other endogenous variables. The instruments for σ are the percentage of union workers and the share of general government consumption in GDP, which is a proxy for inclination to socialist ideas. The relevance and validity of the instruments are discussed in detail in Section 3.2. We also employ an alternation identification strategy proposed by Lewbel (2012) that does not rely on exclusion restrictions but exploits the heteroskedasticity for identification.

After controlling for country characteristics, initial conditions, and a set of policy variables, we find a positive and significant coefficient of σ that indicates strong support for the hypothesis. The result is robust in a variety of ways including both Leamer's (1983) extreme value analysis and Bayesian model averaging. Finally, σ can explain about a fifth to a quarter of the growth rate differential between East Asia and Sub-Saharan Africa.

The rest of the paper proceeds as follows. Section 2 discusses the importance of σ in economic growth. Section 3 discusses the analytical framework and econometric issues associated with testing the hypothesis. The data set is discussed in Section 4. Section 5 discusses estimation and summary statistics of the estimated values of σ. The results are presented in Section 6. Finally, Section 7 concludes.

2. σ and economic growth

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. Turnovsky's (2002) calibration of the neoclassical growth model indicates that for a given productivity shock, the rate of convergence of per capita output to its steady state level is 45.3% (per year) when σ equals 0.1, but drops markedly to 12.2% when σ equals 0.8. The rate of convergence falls further to 8.9%, 6.4%, and 3.5% as σ increases to 1.0, 1.2, and 1.5, respectively.[3] However, the influence of σ on the speed of convergence interacts with other parameters in the model. For example, Ramanathan (1975) demonstrated that the speed of convergence is negatively related to the share of capital. The larger the capital share, the less rapidly the average product of capital declines and, since the latter is positively related to σ, larger values of σ slow convergence. Mankiw (1995) reports that an increase in the capital share from one-third to two-thirds reduces the speed of convergence by one-half. King and Rebelo (1993) show that, in a Cass–Koopmans model with consumer optimization, the rate of return on capital is sensitive to σ and is implausibly high when some part of growth is due to transitional dynamics.

Development accounting by Caselli (2005), that assesses how much of cross-country differences in per capita income are attributable to productive factors and technical efficiency, shows the sensitivity of the cross-country income differences to the value of σ. When σ is close to 0.5, variation in productive factors accounts for almost all variations in per capita income across countries. The percentage variation is decreasing in σ and drops to 40% for the Cobb–Douglas value of σ equals 1. He concludes that "the most important outstanding question in development accounting" may well be the precise value of σ. Notwithstanding such importance, the relationship between σ and economic growth has not been investigated empirically.

de La Grandville (1989) showed theoretically that at any stage of economic development the growth rate of income per capita is an increasing function of σ.[4] He also 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 their higher savings rate. His argument is based on Hicks' (1932) idea that a larger value of σ also entails higher 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.[5] An alternative intuitive explanation of the relationship is as follows. The higher is σ, the greater the similarity between capital and labor; thus the incremental capital is easily substituted for labor. Consequently, the capital–labor does not substantially increase, which in turn resists the pull of diminishing returns to capital (Brown, 1968; p. 50). Rapid capital accumulation without substantially lowering the marginal product of capital is the mechanism for higher economic growth (an analytical proof is provided in Appendix A).[6] Therefore, a higher value of σ not only alters the production possibilities, it also expands them in a manner similar to technical progress.[7]

The σ is in principle a technology parameter of the production function. Therefore, if σ varies across countries, the production possibility frontier can also vary. However, σ at the aggregate level is also influenced by the institutional framework such as, among others, the strength of the labor union or inclination to socialist ideas (Solow, 2005; Easterly and Fischer, 1995) (discussed in detail in Section 3.2). Therefore, differences in technology and production possibility frontiers cannot be eliminated by free flow of ideas or technology.

3. Analytical framework

The analytical framework is built on Barro (1991) that regresses the growth rate of per capita GDP on a number of variables related to growth:

$$g_i^y = \alpha + \beta\sigma_i + \eta C_i + \gamma X_i + \varepsilon_i, \quad (1)$$

where g_i^y is the average growth rate 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 factors), and X_i is a vector of other variables. Our focus is on the sign and significance of the β coefficient.

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 can be included. The total number of variables in any growth regression has exceeded 65, but there is no consensus on the statistical significance of these variables. Most of these variables are not robust to inclusion or exclusion of other variables in the regression. For example, variable

[3] These figures are based on an intra-temporal elasticity of substitution between consumption and leisure of 1.0 and the inter-temporal elasticity of substitution of composite consumption good of 0.4. The pattern of results is robust to variations in the latter parameter.

[4] Miyagiwa and Papageorgiou (2003) demonstrate that the monotonic relationship between σ and growth may not exist in the Diamond overlapping-generations model. If σ is sufficiently high, a further increase in σ lowers output and income per worker both in the transition and in the steady state. In the Solow model, a higher σ implies not only an increase in total income but also a fall in labor income share. In the Diamond model, agents save out of wage income, which makes it ambiguous how savings will be affected by an increase in σ. Papageorgiou and Sam (2008) show that the inverse relationship between σ and growth can also persist in the three-factor nested CES case in which the inputs are capital, skilled and unskilled labor. Irmen (2011) mutes the negative effect of σ on the savings rate by assuming a constant aggregate consumption growth rate equal to the growth rate of the economy. Xue and Yip (forthcoming) develop a unified approach to reconcile the contradictory results of the effect of σ on growth.

[5] 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 (2011b).

[6] The proof is based on one of the fundamental properties of general means, which can be generalized in the case of more than two inputs if the elasticity of substitution between any two inputs is the same.

[7] de La Grandville (1989) and Klump and de La Grandville (2000), among others, emphasize the role of normalization of the CES production function. However, Temple (forthcoming) criticizes the arbitrary normalization to establish the positive effect of σ on labor productivity.