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Why Do Some Countries Produce So Much More Output per Worker than Others?

Some Further Results

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INSTITUTE FOR SOCIAL AND ECONOMIC RESEARCH AND POLICY
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Abstract

To explain differences in output per worker across countries, we test for the workings of a learning-by-doing hypothesis and the hypothesis that the effectiveness of human capital depends on the laws and institutions that promote workplace practices that allow skills to develop. The quality of laws and institutions in the workplace is measured by an index of economic security (ESI). We find that ESI is a good proxy for human capital whilst educational attainment is not. We also find that countries with high ESI use more effectively the skills of the workforce and are better at exploiting profitable opportunities in capital markets.

Keywords: economic growth, learning-by-doing, economic security

JEL Classifications: O11, O47, J24

| 1 | INTRODUCTION

A version of the neoclassical production function expresses output per worker as the product of effective human capital and the capital-output ratio, the latter raised to a power measured by the ratio of income from capital to income from labor. If externalities are assumed away, differences in capital-output ratios can be shown to contribute to a factor of 2 in explaining cross-country differences in output per worker. Moreover, if one assigns—as a rule of thumb—a 10 percent return to schooling, one finds that cross-country differences in schooling can account for a factor of a little more than 2 in explaining cross-country differences in output per worker. This suggests that if schooling were the only variable to determine human capital, the "effectiveness" of human capital would have to account for a factor of about 8 in explaining the 32-fold difference in output per worker between the richest and the poorest economies. This prompted Prescott (1998) to write: "Needed: A Theory of Total Factor Productivity." In this paper we explore the determinants of the effectiveness of human capital and the way in which effective human capital and physical capital interact to account for the observed differences in living standards.

Like Lucas (1988), we believe that there is an externality attached to human capital. However, whilst Lucas' *external effect* derives from a measure of the average level of accumulated human capital, the externality associated with human capital in our model derives from a measure of the social infrastructure specific to the labor market. That social infrastructure plays a crucial role in determining cross-country differences in labor productivity is well documented in Hall and Jones (1999). However, the authors' measure of social infrastructure seems too broad for our purposes. What is needed, in our view, is a measure of institutions and policies that encourage and promote the accumulation of skills at the work place or out of the work place. We believe that the economic security index (henceforth, 'ESI') compiled by the International Labor Organization (henceforth, 'ILO') can serve to proxy the *external effects* of human capital.[1]

In summary, there are two key hypotheses put forth in this paper. Firstly, differences in capital-output ratios play a far more important role in explaining cross-country differences in standards of living than neoclassical models of growth would account for since the latter neglect the effects of learning-by-doing. Secondly, the effectiveness of human capital crucially depends on the laws and institutions that protect skills and promote workplace practices that enable skills to develop. What both hypotheses share in common is some degree of externality.

The remainder of the paper is organized as follows. Section II revisits the neoclassical

[1] In their very thorough and important study, Black and Lynch (2001) employ cross-section as well as panel data estimation methods to test the importance of a number of workplace practices and information technology on the productivity of a large sample of U.S. businesses. They find, among other things, that unionized establishments that have practices that promote joint decision making and incentive based compensation have higher productivity than unionized businesses with more traditional management relations. Whilst there is some similarity in terms of aims and methodology between Black and Lynch (2001) and our study, the differences are significant. Firstly, our main aim is to explain the sources of cross-country differences in productivity and this calls for a significant amount of aggregation. Secondly, we wish to investigate the role of spillovers in physical and human capital accumulation on productivity at the national level. The finding that once we control for economic security educational, attainment becomes statistically insignificant, suggests that—to some extent—the productivity recorded at the firm or industry level derives from an *external effect*.

model to rehearse, in some detail, its behavior and its ability to fit the data. In Section III we outline a learning-by-doing model to explain away the major challenges posed by the neoclassical model. In section IV we present one representative specification of the model we propose to estimate. Section V presents the specifications of the model we explore empirically cast in a cross-sectional and panel data setting, and describes the variables and the methods of estimation employed. The empirical findings are discussed in section VI and conclusions are drawn in section VII.

| 2 | The Challenge Posed by the Neoclassical Model

A typical production function in the neoclassical model assumes that output exhibits constant returns to scale in physical capital and in effective human capital so that:

$$Y_i = (A_i H_i)^{1-\alpha}(K_i)^{\alpha} = (A_i H_i)(K_i / A_i H_i)^{\alpha} \tag{1}$$

where Y measures output, A measures the effectiveness of human capital, H measures the stock of human capital, K measures the stock of physical capital, α is a parameter that measures the share of income attributed to physical capital, and i is used to subscript variables pertaining to the i^{th} country in a world economy comprising N such countries.

It is convenient to define H as the product of the human capital embodied in the representative worker h and the number of workers currently employed L:

$$H_i \equiv h_i L_i \tag{2}$$

Combining (1) with (2) we arrive at the expression for output per worker, y, given in (3) below:

$$y_i = (A_i h_i)(K_i / A_i H_i)^{\alpha} = (A_i h_i)(k_i / A_i h_i)^{\alpha} \tag{3}$$

where: $k_i \equiv \left(K_i / L_i\right)$

In what follows, it will prove convenient to express the ratio of physical to human capital in terms of the ratio of physical capital to income. For this purpose, notice that (1), above, implies (4) below:

$$\left(Y_i / K_i\right) = \left(K_i / A_i H_i\right)^{\alpha-1} \tag{4}$$

From (4) and (3) we arrive at an expression for y given in (5) below:

$$y_i = (A_i h_i)(Y_i / K_i)^{\alpha/\alpha-1} \tag{5}$$

Using r to subscript variables belonging to a rich economy and p to subscript variables belonging to a poor economy we can use (6a)-(6c), below, to account for cross-country differences in y:

$$(y_r / y_p) = (A_r / A_p)(h_r / h_p)\{(Y_r / K_r)/(Y_p / K_p)\}^{\alpha/a-1} \tag{6a}$$

$$(y_r / y_p) = (A_r / A_p)(h_r / h_p)\{(K_r / Y_r)/(K_p / Y_p)\}^{\alpha/1-a} \tag{6b}$$

$$\ln(y_r / y_p) = \ln(A_r / A_p) + \ln(h_r / h_p) + (\alpha/1-\alpha)\ln\{(K_r / Y_r)/(K_p / Y_p)\} \tag{6c}$$

To assess the importance of human capital in explaining cross-country differences in per capita incomes, it is convenient to follow Jones (2001) and assume that,

$$h = e^{r_e Sch_i} \tag{7}$$

where r_e measures the average return to schooling and where Sch_i measures the number of years of schooling for those over 25. Using the Barro and Lee (2001) data on educational attainment, Jones (2001) reports that workers in the richest economies have, on average, 11 years of schooling while workers in the poorest economies have, on average, 3 years of schooling. The author then applies an average return to schooling of 10 percent to establish that differences in human capital account for a factor of

$$e^{0.1(11-3)} = e^{0.8} \approx 2.2 .$$

To assess the importance of capital-to-output ratios in explaining differences in living standards, a frequently used practice is to use data on the gross investment to income ratio and argue that (K/Y) is proportional to (I/Y) along the balanced growth path. To illustrate, consider the balanced growth path identity that links (I/Y), (I/K) and (K/Y):

$$(I/K)_i \equiv (I/Y)_i (Y/K)_i = n + x + \delta \tag{8a}$$

where n measures the rate of population growth taken to be exogenous, x measures the growth rate of output per person along the balanced growth path, and δ measures the rate of depreciation of capital. Using (8a) to solve for the capital-output ratio, we obtain:

$$(K/Y)_i = \frac{(I/Y)_i}{x + n + \delta} \tag{8b}$$

If we assume away cross-country differences in $x + n + \delta$, we need only use data for the share of gross investment to GDP to compare capital-output ratios internationally. According to Jones (2001) and Hall and Jones (1999), the wealthiest economies have investment shares up to 5 times the investment shares found in the poorest of economies. Setting $\alpha = 1/3$, the authors conclude that differences in capital-output ratios (or in investment shares) account for a factor between 1.8 and 2.2 in explaining cross-country differences in income. To account for a more than 32-fold difference in output per worker between the richest and the poorest economies, it must be the case that differences in *A* account for a factor between 7 and 8. The major challenge, therefore, is to explain *A*.

| 3 | EXPLAINING AWAY THE CHALLENGE POSED BY THE NEOCLASSICAL MODEL

Probably the earliest line of inquiry into issues of endogenous growth goes by the name of learning-by-doing associated with Kenneth Arrow (1962). In this section, we consider a version of a model of learning-by-doing to better explain the vast differences in output per worker observed across countries. To anticipate our empirical findings, suffice to say that features of the model we consider are shown to be supported by the data.

A Model of Learning-by-Doing: Modeling Effective Human Capital

To introduce learning-by-doing, we hypothesize that effective human capital depends on the product of two factors specific to each country: technological know-how T_i, and social infrastructure $(Is)_i$, so that,

$$A_i H_i = (Is)_i T_i \tag{9}$$

Suppose, further, that $(Is)_i$ is exogenous and time-invariant, and that T_i is a by-product of accumulating physical and human capital determined by a function which exhibits constant returns to scale in the stock of human capital and the stock of physical capital, so that,

$$T_i = H_i^{1-\gamma} K_i^{\gamma} \quad , \quad 1 \leq \gamma \geq 0 \tag{10}$$

Combining (9) with (10) to substitute *AH* out of equation (1) and dividing by *L*, we arrive at,

$$y_i = (Is)_i^{1-\alpha} (h_i)(k_i / h_i)^{\varphi} \tag{11}$$

where $\varphi = a + \gamma(1-\alpha)$

Equation (11) encompasses two interesting polar cases: (a) When $\gamma = 1$ we obtain a version of the *AK* model of endogenous growth where the growth rate of output per worker is driven by the saving rate; (b) When $\gamma = 0$, we revert to the model of equation (1) where the growth rate of output per worker is exogenously determined. What is of interest in both cases is that *A* is seen to be synonymous with social infrastructure.

To narrow the concept of social infrastructure relevant to our analysis, observe that equation (9) hypothesizes a link between social infrastructure and human capital. To highlight further this link, we re-write equation (11) as follows:

$$y_i = (Is)_i^{1-\alpha} (h_i)(k_i / h_i)^{\phi} = (Is)_i^{1-\alpha} (h_i)(K_i / Y_i)^{\phi/1-\phi} \tag{12}$$

Since our notion of social infrastructure is linked with the effectiveness of human capital and human capital is linked with skills, it is natural to want to link $(Is)^{1-\alpha}$ to an index constructed to take the value between 0 and 1, call it *E*, and designed to measure the degree that labor market institutions protect and promote workers' skills. To this effect we can write,

$$y_i = (Is)_i^{1-\alpha}(h_i)(K_i / Y_i)^{\phi/1-\phi} = (E_i h_i)(K_i / Y_i)^{\phi/1-\phi} \tag{13}$$

At the moment we leave aside the important issue of how to measure E until section V. Assuming that such a measure exists, it would seem natural to model effective human capital in a way that allows E to interact with schooling. To this effect, consider a specification that proved successful empirically:

$$(Eh)_i = e^{\beta\sqrt{E_i}(\ln Sch_i)} \tag{14}$$

In (14) above, the return to schooling is measured by $\beta\sqrt{E_i} / Sch_i$, a term that allows for heterogeneity amongst countries' returns and captures the aspect of diminishing returns to schooling reported in the literature.

A Model of Learning-by-Doing: Modeling the Capital-Output Ratio in the Long Run

It would be tempting to assume that differences in capital output ratios or in investment shares reflect differences in saving rates and assume saving rates to be exogenously determined to close the model. This, however, would ignore the role of the relative price of capital, q, in determining the capital-output ratio, an omission likely to lead to erroneous conclusions. To illustrate, consider revisiting equation (8b) to multiply both sides with the (relative) price of capital to obtain:

$$(qI / Y) = (qK / Y)(n + x + \delta) \tag{15a}$$

Consider, next, the long-run relation between the interest rate, r, the marginal product of capital, MPK and the price of capital, q, to write:

$$(aY / qK) = (MPK / q) = (r + \delta) \tag{15b}$$

Letting ρ denote the rate of time preference and θx denote the product of the coefficient of relative risk aversion with the growth rate of consumption per capita, the equilibrium interest rate is defined by:

$$r = \rho + \theta x \tag{15c}$$

Combining (15a) with (15c), and rearranging, we obtain:

$$(qK / Y)(n + x + \delta) = (n + x + \delta)(\alpha /(r + \delta)) = [(n + x + \delta)a]/[\rho + \delta + \theta x] \tag{15d}$$

One can instantly identify the middle and the right hand-side of (15d) with the equilibrium saving rate. Thus, by (15d) and (15a) we come to identify the long-run equilibrium saving rate, s, with the ratio of gross investment (*valued in units of output*) to GDP. This is what equation (15e) below records:

$$(qI / Y) = s \tag{15e}$$

One important conclusion is that unless one can safely ignore cross-country differences in q one cannot use data on (I / Y) to impute the value for the saving rate. For though it is true that (I / Y) is much higher for the richer economies, it is also true that q is much higher for the poorer economies. This suggests that there is little—if any—cross-country variation in the 'true' measure of the saving rate. To explain that rich economies are endowed with a capital-output ratio which is higher by a factor of almost 5 than that of poorer economies, we may assume—as a working hypothesis—that perfect capital mobility rules in the long-run such that (MPK / q) equalizes across countries in the long-run. This suggests that the economies with high (low) capital-output ratios are the economies with low (high) cost of capital. The data supports that view.

| 4 | THE MODEL THAT EMBODIES OUR KEY HYPOTHESES

When we come to estimate our model, we explore several distinct specifications. At the moment, though, it would suffice to describe a simple specification to capture the key elements of the main hypotheses advanced in this paper. To this effect, we combine (15b) with (13) above to arrive at:

$$y_i = (E_i h_i)(K_i / Y_i)^{\phi/1-\phi} = b(E_i h_i)(q_i)^{-(\phi/1-\phi)} \tag{16}$$

where: $b \equiv \left[(\varphi/(r+\delta))\right]^{\varphi/1-\varphi}$

Using equation (14) to substitute out $(Eh)_i$, we obtain:

$$y_i = be^{\beta(\sqrt{E_i}(\ln Sch_i)}(q)^{-(\varphi/1-\varphi)} \tag{17}$$

Taking logarithms and ignoring the constant term, we write:

$$\ln y_i = \beta\sqrt{E_i}(\ln Sch_i) - (\varphi/1-\varphi)\ln q \qquad (18)^2$$

If we are to be successful empirically, we ought to arrive at an estimator of β which, given the data, yields a sensible return to schooling, a return which can be corroborated by other sources. Similarly, our estimator for φ must be considerably bigger than 1/3 if we are to claim evidence in favor of learning-by-doing.

[2] In an earlier study, Jones (1994) documents a negative relationship between the relative price of machinery and economic growth. He argues that there is a negative relation between investment and the relative price of capital on the one hand, and a positive relation between investment and the growth rate on the other, and that this explains the negative association between the relative price of machinery and the growth rate. He attributes variations in the relative price of capital to distortions (through taxes, tariffs and/or subsidies). In our paper, we favor an approach that focuses on the long-run relation between the relative price of capital and the average product of labor. Whilst we also believe that there are distortions in the relative price of capital, we prefer to build our analysis on the existence of installation costs in capital formation and use this to derive a relation between the relative price of capital and the capital-output ratio in the long-run on the one hand, and the capital-output ratio and labor productivity on the other.

| 5 | Estimating our Model

In the empirical section we will be reporting results obtained by applying cross-section as well as panel data methods of estimation to models cast in dynamic form.

Empirical Specifications

<u>Cross-section Regressions</u>
The cross-section, dynamic, regressions to be estimated are given in equations (CS1) to (CS3) below:

$$\overline{y}_i = \rho \overline{y_{i,-1}} + \beta_1 \overline{q}_i + \beta_2 \overline{Sch_i} + \beta_3 \ln E_i + \varepsilon_i \quad \text{(CS1)}$$
$$\overline{y}_i = \rho \overline{y_{i,-1}} + \beta_1 \left(E_i \times \overline{q_i}\right) + \beta_2 \overline{Sch_i} + \beta_3 \ln E_i + \varepsilon_i \quad \text{(CS2)}$$
$$\overline{y}_i = \rho \overline{y_{i,-1}} + \beta_1 \overline{q}_i + \beta_2 \left(E_i \times \overline{Sch_i}\right) + \varepsilon_i \quad \text{(CS3)}$$

where: $\overline{y_i} = \frac{1}{T}\sum_{t=1}^{T} \ln y_{it}$, $\overline{y_{i,-1}} = \frac{1}{T}\sum_{t=1}^{T} \ln y_{i,t-1}$, $\overline{q_i} = \frac{1}{T}\sum_{t=1}^{T} \ln q_{it}$, and $\overline{Sch_i} = \frac{1}{T}\sum_{t=1}^{T} \ln Sch_{it}$
and where the (ε_i) terms are the structural errors.

To implement these regressions, we averaged each variable listed in (CS1) to (CS3) over the *N* cross-sectional units and then expressed each equation in terms of deviations from cross-sectional averages. This was done for the purpose of minimizing cross-sectional dependence. A convenient way to estimate these equations is to apply a Bewley (1979) type transformation. The advantage of this transformation is that it readily yields estimates of the long-run average coefficients and of the mean lag, together with the standard errors attached to these estimates. To effect this transformation we multiply each of the right-hand side terms of (CS1)-(CS3) by $(1/1-\rho)$ and we replace $\overline{y_{i,-1}}$ by $\Delta \tau y_i$, where $\Delta \tau y_i = (y_{iT} - y_{i0})/T$. Since $\Delta \tau y_i$ is correlated with the error term, we apply an instrumental variables estimation method to ensure consistency of the estimators.

<u>Panel Regressions</u>
The panel data regressions to be estimated are given in equations (PD1)-(PD3) below:

$$\ln y_{it} = \rho \ln y_{i,t-1} + \beta_1 \ln q_{it} + \beta_2 \left(\sqrt{E_i} \times \ln Sch\right)_{it} + \gamma_t + c_i + \varepsilon_{it} \quad \text{(PD1)}$$
$$\ln y_{it} = \rho \ln y_{i,t-1} + \beta_1 \left(\sqrt{E_i} \times \ln q_{it}\right) + \beta_2 \left(\sqrt{E_i} \times \ln Sch\right)_{it} + \gamma_t + c_i + \varepsilon_{it} \quad \text{(PD2)}$$
$$\ln y_{it} = \rho \ln y_{i,t-1} + \beta_1 \left(\sqrt{E_i} \times \ln q_{it}\right) + \beta_2 \ln Sch_{it} + \gamma_t + c_i + \varepsilon_{it} \quad \text{(PD3)}$$

where γ_t is a year-specific intercept designed to control for year-specific shocks that affect all cross-sectional units at *t*, where c_i is an unobserved, time-invariant, and country-specific fixed effect, and where ε_{it} is an idiosyncratic error term.

Definitions, Measurement, and Data Sources

Quality of Social Infrastructure in the Labor Market

Our proxy for the quality of social infrastructure is the Economic Security Index (ESI) developed by the ILO (2004). Its authors make the general point that, "... each time the risk environment is increased, the modal citizen has to devote proportionately more of his or her time to risk control activity and proportionately less to developmental or freedom enhancing activity". They then focus on the labor market to describe and quantify activities that reduce risk or, rather, enhance security in that market. They distinguish between the following seven types of security: (1) Labor Market Security; (2) Employment Security; (3) Job Security; (4) Work Security; (5) Skill Reproduction Security; (6) Income Security; and (7) Representation Security. An index is developed for each of the seven types of security and for as large a group of countries as data permits. Finally, the authors construct a weighted average of the seven constituent indexes which they label ESI. In what follows, we assume that the index thus far called E_i is simply the ESI for the i^{th} country.

Educational Attainment, Output per Worker and the Price of Capital

Our measure for schooling is taken from Barro and Lee (2001). In particular, $(Sch)_i$ measures the average number of years of schooling attained by the representative agent in country i who is over 25 years of age. Our measure for the output per worker and the price of capital are based on data published in the Penn World Tables Version 6.1 (PWT6.1). In particular our measure for q is the ratio (PI/P), where PI is the PPP value of the price index for investment goods and P is the PPP value of the price index for output.

Our Sample

It was decided at the outset to include only those economies in PWT6.1 which, under the period of investigation, possessed a full set of data with quality not below C and were managed on market principles. The sample of countries in PWT6.1 that met these criteria was 83. Of these, only 68 economies possessed a full data set on educational attainment and only 60 possessed data on the ESI. This narrowed the size of countries for the purpose of our analysis to 49. These are the countries which meet the criteria of (a) operating a market economy under the period of investigation, (b) possessing a full data set on output per worker, and the relative price of capital of quality not below C, and (c) possessing data on the ESI and a full data set on educational attainment. However, and for the reasons we explain in the next section, our empirical results are based on a group of 35 countries.

Our sample spans the period 1960-2000. Data on output per worker and the relative price of capital are measured annually, schooling years are measured quinquennially, and the ESI is based on a single observation taken on 1999 or the year closest to 1999. To employ panel data methods of estimation, we express output per worker and the relative price of capital as 5-year averages starting with 1960-1964 and ending with 1995-2000 (altogether 8 observations) and we also utilize 8 observations on schooling starting with the 1960 observation and ending with the 1995 observation.

Some Issues of Estimation

Estimating Panel Data Regressions with Integrated Variables

To employ panel data methods of estimation where the size of the time dimension of the panel, *T*, is small relative to the size of the cross-section dimension, *N*, it is customary to apply methods of estimation appropriate to dealing with stationary data (Wooldridge, 2002, p. 175). This is because, it is argued, with small *T* but large *N* the appropriate procedure is to conduct an asymptotic analysis on the basis that *T* remains fixed as $N \to \infty$. When *T* is large relative to *N* or when both *T* and *N* are large, asymptotic analysis can be conducted on the basis that *T* can grow to infinity or that both *T* and *N* grow to infinity, as the case may be. In those circumstances, it may seem natural to pretest the data for unit roots to avoid the problems one usually associates with spurious regressions.

However, problems can arise even if the panel consists of co-integrating relationships for, as Pesaran and Smith (1995) argue, pooled estimators are inconsistent when parameters differ randomly across groups. In the case where the independent variables are I(1) but form a single co-integrating vector with the dependent variable and coefficients differ randomly, "the pooled regression will not constitute a co-integrating regression and the parameter estimates will not be consistent" (Pesaran and Smith, 1995, p. 91). Hall et al. (1999) show that there is an important case—albeit rather special case—where the findings of Pesaran and Smith do not apply. This is the case where the regressors in each co-integrating unit are driven by common stochastic trends. Phillips and Moon (1999) go even further to argue that one can consistently estimate the average long-run coefficient in a panel of spurious regressions where no co-integrating vectors are to be found between the I(1) regressors and the I(1) regressand. This departure from the Pesaran and Smith findings is based on a definition of the long-run average coefficients which, in the case of Phillips and Moon, can exist even in the absence of co-integration.[3]

Estimating Cross-Section Regressions with Integrated Variables

Even if coefficients are allowed to vary randomly across units and variables are I(1), consistent estimates of the long-run average coefficients can still be obtained in a setting of cross-section regressions (Pesaran and Smith, 1995). What is required is that in each such regression there is a single co-integrating vector linking the regressors with the regressand and that the regressors are strictly exogenous.

Panel Data and Cross-Section Regressions with Integrated Variables: Pretesting for Unit Roots

With a sample size of *N=49* and a time dimension *T=8*, we may have been justified to ignore the time series properties of the data. However, since the hypotheses advanced in this paper are meant to apply to countries which exhibit conditional convergence, we felt that if our panels were to contain integrated series, these series must co-integrate. To test for unit roots, we first applied a variety of panel unit root tests to the PWT6.1 series to arrive at inconclusive results. However, Augmented Dickey Fuller tests applied to each country's series individually were conclusive; not surprisingly, in almost all the series tested, we could not reject the unit root hypothesis. Panel unit root tests applied

[3] For a review of recent developments in panel data models with integrated variables and dynamic panel data models with and without integrated variables, see Phillips and Moon (2000), Baltagi and Kao (2000) and Banerjee (1999).

to the Barro and Lee (2001) educational attainment data were nearly unanimous in rejecting the unit root hypothesis. To avoid having unbalanced regressions, we applied the Johansen test for co-integration to the series for output per worker and the relative price of capital to arrive at a set of 35 countries for which, by at least one criterion, we rejected the null of no co-integration at the 95% level of confidence. The empirical analysis that follows is based on this sample of 35 countries.[4]

[4] We do not report here the results of our stationarity and co-integration tests for reasons of space, but they are available from the authors upon request. Our sample contains the following 35 countries: Argentina, Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Denmark, Ecuador, Finland, France, Greece, Honduras, India, Indonesia, Ireland, Israel, Japan, Republic of Korea, Mauritius, Nepal, Netherlands, New Zealand, Norway, Panama, Portugal, Senegal, Spain, Sri Lanka, Sweden, Tunisia, USA, United Kingdom, and Venezuela.

| 6 | Empirical Results

Estimates from Cross-Section Regressions

Table 1 below presents Two Stage Least Squares estimates of (CS1) to (CS3) outlined above. We describe the manner in which we obtain in-sample predictions estimates in the Appendix.

Table 1. Cross-sectional regressions (Sample: 35 countries). Regressand: $\overline{y}_i$

CS1		CS2		CS3	
Regressors:		**Regressors:**		**Regressors:**	
$\Delta \tau y_i$	-5.2810	$\Delta \tau y_i$	-5.7010	$\Delta \tau y_i$	-6.6467
	[1.2882]		[1.4960]		[2.0221]
$\overline{q}_i$	-1.2004	$ESI_i \times \overline{q}_i$	-2.4990	$\overline{q}_i$	-1.0221
	[0.2891]		[0.7674]		[0.6328]
$\overline{Sch}_i$	-0.0507	$\overline{Sch}_i$	-0.1072	$ESI_i \times \overline{Sch}_i$	0.8630
	[0.1835]		[0.2066]		[0.3263]
$\ln ESI_i$	1.0476	$\ln ESI_i$	1.2132		
	[0.2407]		[0.2581]		
Shea partial R-squared for each instrument	0.5949 0.9701 0.9472		0.5780 0.8641 0.9311		0.4838 0.9086 0.9377
F-stat for the null that the excluded instruments are irrelevant	12.72 156.02 614.43		12.72 33.79 614.43		8.47 221.66 5253.62
p-value for the null hypothesis that the instruments are valid	0.7939		0.4229		0.2041
Observations	35		35		35

Notes: Robust standard errors in brackets. The instruments for equations (CS1) and (CS2) are: lagged $\overline{q}_i$, lagged, $\overline{Sch}_i$, lagged $\left(ESI_i \times \overline{Sch}_i\right)$ and y_{i0}. The instruments for equation (CS3) are lagged $\overline{q}_i$, lagged $\left(ESI_i \times \overline{Sch}_i\right)$ and y_{i0}. In all specifications, the estimated constant is zero due to our data being demeaned. The lagged variables are averages over the entire time period other than the final observation. The non-lagged variables are averages over the entire time period other than the first observation.

Our choice of instruments is intuitive: First, we use lagged values of the endogenous regressors as instruments. Second, we use initial income (y_{i0}) as an instrument for the change in income ($\Delta \tau y_i$) and we expect this to be a highly relevant instrument based on the convergence hypothesis from the growth literature. To evaluate the appropriateness of our instruments, we report the Shea partial R-squared (Shea, 1996) and the F-statistic corresponding to a test of the null hypothesis that the instruments are irrelevant. These two statistics are obtained after the first-stage regressions and address the issue of instrument relevance. In all cases, we find that the null hypothesis of instrument irrelevance is rejected. The Shea partial R-squared statistics are no lower than 40 percent, while the F-statistic is (with one exception) in excess of the rule-of-thumb value of 10 (Staiger and Stock, 1997). We also report the p-value of a test of the null hypothesis of instrument validity. Again, for all three cross-sectional regressions, we fail to reject the hypothesis that our instruments are exogenous.[5]

Glancing at Table 1, one cannot fail to observe that once one controls for ESI, schooling years no longer play an independent role in explaining output per worker: economic security is seen to be a good proxy for human capital whilst educational attainment is not. This suggests that to measure the effect of educational attainment statistically, it would be necessary to let schooling years interact with economic security. It may also suggest that decisions about how much schooling to acquire are based on—among other factors—the social infrastructure in the market for labor summarized by economic security.

In (CS2), the elasticity of output with respect to the relative price of capital is equal to $\left(2.5ESI\right)$, which, for a given return to capital, it is also the elasticity of output with respect to the capital output ratio. Countries with a highly developed social infrastructure in their market for labor are seen to be more responsive to changes it the profitability of capital compared to countries with a less developed infrastructure. As it turns out the average value for ESI_i for the richest five countries in the sample is 0.757 whilst the average value for the poorest five countries is 0.216. This means that the elasticity of output with respect to the capital—output ratio is $(2.5 \times 0.757) = 1.892$ for the rich countries and $(2.5 \times 0.216) = 0.54$ for the poor countries. This, in turn, implies that the elasticity of output with respect to capital is about $1.892/2.892 \cong 0.65$ for the rich countries and about $0.54/1.54 \cong 0.35$ for the poor countries. Thus the model implies that rich countries are able to benefit from learning-by-doing whilst poor countries seem unable to benefit. Notice, also, that the size of the absolute value of β_1 in (CS1) and (CS3) is not far from the average of 1.892 and 0.54, as it should be.[6] Notice, next, that the three estimates for the mean lag imply an average value for the coefficient of the lagged dependent variable equal to about 0.85. Given that the data are constructed to be 5-year averages, economies seem to adjust to their balanced growth path, at the rate of, around, 3 percent per annum.

In (CS3), the elasticity of output with respect to schooling is $\left(0.863ESI\right)$, whilst the

[5] We recognize there may be issues of endogeneity in the economic security index (caused by feedback from the dependent variable). We do not address this issue in the cross-sectional regressions, but we relax the assumption of exogeneity of the ESI (and in particular, of interaction terms involving the ESI) in our panel specifications (See Section VI.B). As we shall see, cross-sectional and panel coefficient estimates are consistent with each other, which suggest that endogeneity is not a cause of serious concern in cross-sectional specifications.

[6] In a model with installation costs but with a constant savings rate, the formula for the speed of convergence reported by Barro and Sala-i-Martin (1999) is given by

$$\beta = (1-\alpha)(x+n+\delta)\frac{1+0.5b(x+n+\delta)}{1+b(x+n+\delta)}$$

where b is the installation cost parameter. Our data on *q* suggest that an appropriate value for *b* for the poor countries in our sample is about 20 whilst for the rich countries of about 0.5 may be sufficient. Noting that our cross-section estimates suggest that = 0.65 for the rich countries and that = 0.35 for the poor countries, and following Barro and Sala-i-Martin (1999) to set $x+n+\delta$ = 0.08, we find that β = 0.0275 for the rich and β = 0.036 for the poor which suggests an arithmetic (unweighted) yearly average speed of a little over 3.175 percent. This is only marginally above the upper bound for the speed of convergence considered by Barro and Sala-i-Martin (1999).

return to schooling is measured by $\frac{(0.863 ESI)}{1/T \sum_{t=1}^{T} Sch_{it}}$. Utilizing sample averages for the period under observation, we find that the five richest countries in the sample have an average return to schooling equal to about 6.93 percent whilst the poorest five countries have an average return equal to about 9.46 percent.

Finally, the richest five economies in the sample of 35 are, on average, about 10.8 times wealthier than the poorest five economies. The estimates presented in Table 1 can account for about a 7-fold of this difference leaving a residual factor of about 1.5. Overall, the estimates in Table 1 accord well with the estimates that would be compatible with a world where some countries can reap the benefits from learning-by-doing and where the social infrastructure that prevails in the market for labor plays a critical role in explaining labor's productivity.

Empirical Results From Panel Data Regressions

Tables 2 presents estimates of (PD1)-(PD3) obtained using the system GMM estimator (Blundell and Bond, 1998). The long-run estimates with associated standard errors (labeled LPD1 to LPD3) are presented in Table 3. For each specification, we report the Chi-squared statistic for a Wald test of overall significance of the model, as well as the p-value for the Hansen test of over-identifying restrictions. We also report the p-values of the Arellano-Bond tests for autocorrelation applied to the first difference equation residuals. If our estimation strategy is appropriate, we expect not to reject the null hypothesis of a first order autoregressive model but to reject that of second order autocorrelation in the first difference equation residuals. We would then conclude that

Table 2. System GMM panel regressions (Sample: 35 countries). Regressand: $\ln y_{it}$

PD1		PD2		PD3	
Regressors:		**Regressors:**		**Regressors:**	
$\ln y_{i,t-1}$	0.8755	$\ln y_{i,t-1}$	0.8573	$\ln y_{i,t-1}$	0.9229
	[0.0518]		[0.0794]		[0.0504]
$\ln q_{it}$	-0.1492	$\left(\sqrt{ESI}_i \times \ln q_{it}\right)$	-0.2129	$\left(\sqrt{ESI}_i \times \ln q_{it}\right)$	-0.2456
	[0.0854]		[0.1558]		[0.1995]
$\left(\sqrt{ESI_i} \times \ln Sch_{it}\right)$	0.1455	$\left(\sqrt{ESI_i} \times \ln Sch_{it}\right)$	0.1880	$\ln Sch_{it}$	0.0579
	[0.0703]		[0.1259]		[0.0350]
Constant	1.1411	Constant	1.2529	Constant	0.7717
	[0.4404]		[0.6218]		[0.4454]
Wald Chi-squared	3183.81		3453.17		6333.00
p-value Arellano-Bond tests of AR(1) and AR(2) in first differences	0.006 0.718		0.008 0.693		0.005 0.618
p-value Hansen test	1.000		1.000		1.000
Observations	245		245		245

Notes: Robust standard errors in brackets. All specifications include time-dummies, but the coefficient estimates are not reported. All three regressors are treated as endogenous in specifications (PD1)-(PD3).

lagged values of the endogenous variables are valid instruments. Given the reported p-values in the table below, it is clear that we cannot reject the null hypothesis that the instruments used by the GMM estimator—*as a group*—are exogenous. This finding is strengthened by the Arellano-Bond test results. We therefore have evidence to conclude that the estimation procedure is appropriate and proceed to employ the coefficient estimates to compute the long-run coefficients and their standard errors.

Table 3. Long-run estimates (Sample: 35 countries).

LPD1		LPD2		LPD3	
$\ln q_{it}$	-1.198	$\left(\sqrt{ESI}_i \times \ln q_{it}\right)$	-1.492	$\left(\sqrt{ESI}_i \times \ln q_{it}\right)$	-3.185
	[0.52]		[0.751]		[1.347]
$\left(\sqrt{ESI_i} \times \ln Sch_{it}\right)$	1.169	$\left(\sqrt{ESI_i} \times \ln Sch_{it}\right)$	1.317	$\ln Sch_{it}$	0.751
	[0.32]		[0.292]		[0.207]
Constant	9.165	Constant	8.780	Constant	10.009

A first key hypothesis put forth in this paper is that differences in capital-output ratios play a far more important role in explaining cross-country differences in standards of living than neoclassical models of growth would account for because these models neglect the effects of learning-by-doing. The second key hypothesis advanced in this paper is that the effectiveness of skills crucially depends on the laws and institutions that protect skills and promote practices that allow skills to develop in the workplace. As we shall argue immediately below, the long-run solutions to (PD1)-(PD3) strongly support both these hypotheses.

To begin with, let us recall that the numerical value of the elasticity of output per worker with respect to the price of capital is also the numerical value of the elasticity of output per worker with respect to the capital-output ratio. If we were to follow Hall and Jones (1999) and take capital-output ratios in rich countries to be five times the capital-output ratios in poor countries then the recorded elasticity of 1.198 in (LPD1) would imply that differences in capital-output ratios contribute a factor of about 6.8-fold in explaining the more than 32-fold difference in standards of living. Differences in effective skills between rich and poor captured by the term $1.169\left(\sqrt{ESI_i} \times \ln Sch_{it}\right)$ give rise to a factor of 5.9-fold in explaining cross-country differences in living standards if, like Hall and Jones (1999), we let rich countries have 11 years of schooling compared to 3 years for the poor countries and if we let the economic security index for the rich stands at 0.7 and for the poor at 0.2. Therefore, (LPD1) is more than capable to explain the vast difference in living standards between the rich and the poor without the need to resort to unobserved differences in multi-factor productivities.

The model's parameters accord well with theory in general and the hypotheses put forth in this paper in particular. For instance, an elasticity of output per worker with respect to the price of capital equal to 1.198 suggests that the elasticity of output with respect to capital is (1.198/2.198) = 0.55, a number which would accord well with some mechanism of learning-by-doing at play. Using sample averages for the five richest and the five poorest countries in the sample the model implies that the (marginal) return to a year of schooling to an agent who has 9.471 years of schooling and enjoys an economic security index of 0.757 is 10.74 percent whilst the marginal return to an agent who has 2.274 years of schooling and enjoys an economic security index of 0.216

is 23.86 percent.[7] Whilst these figures suggest sharply diminishing returns to schooling, these returns are well in line with results reported in Bils and Klenow (2000). The model "predicts" that the richest five countries in the sample are about 12.83 times richer than the poorest five compared with an observed difference of 10.8.

In (PD2) we test the hypothesis that all other things equal countries with high (low) economic security index are better (worse) placed to respond to variations in the profitability of capital. The long run solution to (PD2) supports this hypothesis. The implication of (LPD2) is that the richest five countries in the sample have an elasticity of output with respect to capital equal to 0.57 compared with an elasticity of 0.41 for the poorest five. Regarding returns to schooling the model implies that the richest five countries in the sample enjoy, on average, a 12.01 percent return whilst the poorest five enjoy, on average, a 26.89 percent return. The model "predicts" that the richest five countries in the sample are 13-fold richer than the poorest five.

In (PD3) we continue to assume that, other things equal, countries with a high (low) economic security index are better (worse) placed to respond to variations in the profitability of capital. However, and rather counter-intuitively, we do not allow for a direct interaction between economic security and skills. As a result, the contrast between (LPD3) on the one hand, and (LPD1)-(LPD2) on the other is quite noticeable: (LPD3) calls for a more pronounced difference between returns to education in the rich and the poor countries and it also calls for very strong learning-by-doing effects, especially for the rich. What is at play in (LPD1)-(LPD2), but not in (LPD3), is the direct interaction of economic security with skills. Therefore what the contrast between (LPD3) with (LPD1)-(LPD2) seems to suggest is that the effect of the interaction between economic security and skills is to reduce the gap in returns between rich and poor. Finally, it would come as no surprise to say that (LPD3) fits the data less well than (LPD1) or (LPD2).

[7] One reason that agents in poor countries acquire less schooling than agents in rich countries may well be related to the fact that agents may be facing a borrowing constraint that puts a limit to the amount they can borrow against future earnings and that this constraint is more severe in poor countries.

| 7 | Discussion and Conclusions

In Lucas' (1988) model, aggregate production depends not only on the aggregate capital stock and the effective workforce but also on an *external effect* measured by the average level of human capital. In our model we assume that much of the external effect hypothesized by Lucas is captured by a social infrastructure that promotes the acquisition of skills and protects these skills in the workplace. To test this hypothesis, we propose to measure the quality of this social infrastructure using the economic security index, ESI, compiled by the ILO. Our results lead us to conclude that once economic security is controlled for, educational attainment plays no role in explaining differences in output per worker across countries: economic security is seen to be a good proxy for human capital whilst educational attainment is not. This suggests that a useful way to model human capital is to let ESI interact with educational attainment. We also put forth the hypothesis that there is a mechanism of learning-by-doing at work. Our empirical results suggest that countries with high economic security are better placed to use efficiently the skills accumulated through formal education and are better placed in exploiting profitable opportunities to expand physical capital than countries with low economic security. To put it differently, countries with high ESI are better placed to exploit the mechanism of learning-by-doing than countries with low ESI.

The fact that labor can move freely from firm to firm makes it rather costly for each firm acting in isolation to provide the right environment for maintaining and improving skills. Clearly, there is considerable scope for government intervention to take advantage of the externality afforded by human capital and to provide incentives to firms to offer opportunities for training on the job and/or other schemes that enhance skills. Not surprisingly, what is also important empirically is for firms to enjoy a low rental price for their capital. What recommends these conclusions is the fact that the hypotheses advanced in this paper are supported rather well by the empirical evidence. We have been able to explain, to a large extent, the reasons for cross-country differences in output per worker and the magnitude for these differences together with other puzzles.

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APPENDIX. OBTAINING *IN-SAMPLE* PREDICTIONS

Since the empirical specifications are (essentially) log-linear in the variables, to obtain "predictions" about the average level of the dependent variable we need to calculate the antilogarithm of the average "predicted" level for the logarithm of each of the dependent variables in the sample. However problems arise when there are outliers in the dependent variables. To illustrate a procedure that can mitigate the problem in the presence of outliers, consider a simple estimated log-linear relationship without a constant: $\ln y_i = \alpha \ln x_i + e_i$

where e_i is the estimated residual associated with the i^{th} cross-section, and where by assumption, there are one or more outliers in the $\ln x_i$ in the sample(s) of interest. Suppose, next, that the samples of interest are the group of the five richest and the five poorest countries. To assess the explanatory power of *x* in "predicting" the average level of *y* in, say, the five poorest countries, we assembled the $(\ln x_i, x_i)$ of the poorest five countries to compute $\alpha \left\{ \left(\frac{\sum \ln x_i}{5} + \ln \frac{\sum x_i}{5} \right) / 2 \right\} = \alpha \overline{\ln x}_p$ and $e^{\alpha \overline{\ln x}_p}$. To assess the explanatory power of *x* in "predicting" the average level of *y* in, say, the five richest countries, we proceeded in a fashion similar to that used to compute the average level of y in the five poorest countries. That means first obtaining $\overline{\ln x}_r$ and then proceeding to obtain $e^{\alpha \overline{\ln x}_r}$. Accordingly, the "predicted" ratio of the average y in the five richest countries relative to the average *y* in the five poorest is $e^{\alpha\left(\overline{\ln x}_r - \overline{\ln x}_p\right)}$.

For the sake of consistency and as a measure of precaution, we applied a similar procedure to calculate the average of the "observed" *y*. For instance, to calculate the average of the observed *y* for the five richest countries, we assembled the $(\ln y_i, y_i)$ for these countries to calculate $e^{\left\{\left(\frac{\sum \ln y_i}{5} + \ln \frac{\sum y_i}{5}\right)/2\right\}} = \overline{(y)}_r$ and similarly $\overline{(y)}_p$. Hence, the "observed" ratio of the average *y* in the five richest countries relative to the average *y* in the five poorest countries is given by $e^{\overline{(y)}_r - \overline{(y)}_p}$.

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