Revista de Análisis Económico, Vol. 20, Nº 2, pp. 3-21 (Diciembre 2005)

AN INVESTIGATION OF CROSS-COUNTRY INCOME DIFFERENCES*

PEDRO CAVALCANTI FERREIRA**
Fundação Getulio Vargas

JOÃO VICTOR ISSLER**
Fundação Getulio Vargas

SAMUEL DE ABREU PESSÔA**
Fundação Getulio Vargas

Abstract

This paper investigates the nature of income inequality across nations. Several exercises, such as variance decompositions, simulations and counter-factual analyses are performed. We find that, although total factor productivity has a leading role in explaining the dispersion of output per worker, countries grew in the past –and, consequently, are poor in the present– for different reasons. Even after correcting for productivity differences, some nations remain poor mostly because of low schooling of the labor force and other because they impose too many distortions to capital accumulation. Policy recommendations have to take country differences into account, or else they have a high chance of being either wrong or ineffective.

Keywords: *Cross-Country Income inequality, Development, Total Factor Productivity, Aggregate Production Function.*

JEL Classification: *O11, O47, O57.*

* We gratefully acknowledge the comments and suggestions of two anonymous referees and several seminar participants around the world. All remaining errors are ours. The authors also acknowledge the financial support of CNPq-Brazil and PRONEX.

** Graduate School of Economics-EPGE. Email addresses of the authors are, respectively, ferreira@fgv.br, jissler@fgv.br, pessoa@fgv.br.

I. Introduction

It is a well known fact that differences of output per worker across countries are very high. For example, in 1990 the average worker in the U.S. produced 34 times more than a worker in Mali, 12 times more than one in Guyana or India, and twice as much as one in Portugal.

Understanding the nature of output-per-worker differences across countries should be one of the main objectives of the literature of economic growth, since the level of output per worker of a given country can be thought of as its cumulative growth experience. Several authors have decomposed output per worker into the contribution of inputs and productivity, using different methods, and obtaining different results.

Studies that have tried to explain these differences can be roughly divided into two groups. The first finds that differences in factors of production alone (e.g., physical and human capital) can explain most of the observed differences in output per worker; see for example, Mankiw, Romer, and Weil (1992), and Mankiw (1995). The second group finds that, even controlling for physical and human capital, there is still a large portion of output per worker disparity left unexplained. Hence, total factor productivity (TFP) disparity can be an important factor in explaining the differences of output per worker across countries; see, for example, Hall and Jones (1999), Prescott (1998), and Klenow and Rodriguez-Clare (1997).

The conclusions in these articles are somewhat influenced by their methodological choices, particularly by the choice of the functional form of the aggregate production function, by the choice of the estimation method and/or by the parameter-calibration employed. Ferreira, Issler and Pessôa (2003) estimate and test alternative functional forms, which have been used in this literature, representing the aggregate production function for a panel of countries. The tests conducted in this article show unequivocally that the mincerian formulation of schooling-returns to skills, traditionally used in the labor-economics literature, e.g., Mincer (1974) and Wills (1986), but recently incorporated into the growth literature as well, e.g., Bills and Klenow (2000), and Hall and Jones (1999) is the more appropriated among all models tested. Moreover, the estimated coefficients are consistent with previous microeconomics evidence and testing whether productivity is the same for all countries strongly rejects this hypothesis.

The present paper starts from the estimation results in Ferreira, Issler and Pessôa (2003) to study the relative contribution of factors of production –human capital and capital– and productivity in explaining the variation of output per worker. In certain exercises tax-distortions affecting the return on physical capital (calculated following Chari, Kehoe, and McGrattan, 1997) are used.

We perform several exercises, such as variance decompositions, simulations and counterfactual analyses. The variance decomposition exercise shows that productivity is the most important factor in explaining the variation in output per worker across countries: while productivity explains almost two thirds of output difference, capital intensity explains less than one quarter. We also divided the set of 83 countries we have data into 8 sub-sets, according to their relative position with respect to the average of the three determinant factors of output per worker. As expected, the set of countries with above-average productivity and education, and below-average distortions to capital accumulation, contains almost all of the rich countries. In the other extreme, the set of countries with below-average productivity and education and above-average tax distortions contains only poor nations, with average output per worker of about one tenth that of the rich-country group.

Despite the importance of productivity in explaining the dispersion of output per worker in our sample of countries, it may be unimportant as a factor hampering long-run growth for some specific countries. For example, Brazil and Uruguay had in 1985 almost the same output per worker (1/4 of the U.S. level) and productivity, but the labor force in Brazil had about half the schooling of that in Uruguay, and Uruguay's distortion to capital accumulation is more than 20% higher than that in Brazil. This shows that these countries should pursue different development policies to reduce the gap between them and the group of rich nations. Likewise, some middle income countries such as Chile and some relatively rich ones such as Taiwan and Ireland, in 1996 were found to be relatively educated and productive, but distortions to capital accumulation were above average.

This paper has four additional sections. In Section II we review the main results in Ferreira, Issler and Pessôa (2003), and perform some additional estimations, and present the production function and data used throughout the paper. In Section III we present variance decomposition exercises, in Section IV we perform counter factual exercises while in Section V countries are divided according to their relative level of productivity, tax-distortion, and human-capital. Section VI concludes.

II. Model Specification, Data and Estimation

This session review results in Ferreira, Issler and Pessôa (2003) that are relevant for the exercises in Sections III to V. The specification there uses a mincerian (e.g., Mincer, 1974 and Wills, 1986) formulation of schooling returns to skills to model human capital, H. There is only one type of labor in the economy with skill level determined by educational attainment. It is assumed that the skill level of a worker with h years of schooling is exp (ϕh) greater than that of a worker with no education at all, leading to the following homogenous-of-degree-one production function:

$$Y_{it} = A_{it} K_{it}^{\alpha} \left(e^{gt} H_{it} \right)^{1-\alpha} = A_{it} K_{it}^{\alpha} \left(e^{gt} L_1 e^{\phi h_{it}} \right)^{1-\alpha} \tag{1}$$

The parameter ϕ in exp (ϕh_{it}) gives the skill return of one extra year of education, i.e., ϕ can be interpreted as a measure of the percentage increase in income of an additional year of schooling. In per-worker terms, after applying logarithm in both sides, the equation above reduces to:

$$\ln y_{it} = \ln A_i + \alpha \ln k_{it} + (1 - \alpha)(\phi h_{it} + gt) + \eta_{it}, \tag{2}$$

where in (2) A_{it} is decomposed into a time-invariant component A_i and a component that varies across i and t, η_{it}.

The assumption of a common exogenous growth rate of technology g followed, among many, Jones (1997) and Barro and Sala-i-Martin (1997). One logical justification is that it implies that countries will not diverge permanently in the long run. If we believe that technology is the ultimate cause of growth and that in the long run there are no barriers to technology adoption and transfer, in the very long run growth rate have to be the same. Moreover, it makes not much sense to think of a given country or group of countries to grow forever above the rest of the economies, otherwise fast growers with permanent higher g would end up being infinitely larger than slow growers. Differences in the growth rate in this interpretation are transitory, represented by fluctuactions of A_{it}.

However, the fact is that the dataset is not too long, so that so that we could alternatively interpret g as involving not only technological progress but also catch-up. In fact, the formulation in (2) does not allow for productivity growth to explain income differentials over time. However, in neoclassical formulations (e.g., Parente and Prescott, 1999) temporary increases in the rate of technological growth due to exogenous factors (e.g., institutional changes) may be the engine behind growth miracles. In this sense we also tested the alternative formulation below:

$$\ln y_{it} = \ln A_i + \alpha \ln k_{it} + (1 - \alpha)g_{it} + (1 - \alpha)\phi h_{it} + \eta_{it}, \tag{3}$$

so that the model allows for a different growth rate for each economy.

The panel data set used ranged from 1960 to 1985, and combined macroeconomic data for 95 countries in the mark 5.6 of the Summers and Heston (SH, from now on) data set with human-capital measures extracted from Barro and Lee (1996). The specific series used are the following: y_{it} is the ratio of real GDP (at 1985 international prices) and the number of workers in the labor force, extracted from SH; k_{it} is the physical capital series per worker. The physical capital series is constructed with real investment data from SH (at 1985 international prices) using the Perpetual Inventory Method;[1] h_{it} is Barro and Lee's (1996) series of average years of completed education of the labor force, interpolated (in levels) to fit annual frequency.

The model was estimated, after testing by means of a Hausman test, using fixed effects. The estimation method weights data in each equation by the reciprocals of the standard deviation of country-specific errors, similar to the procedure in weighted two-stage least squares.[2] Instruments used were rest-of-the-continent average lagged (log of the) capital stock, and rest-of-the-continent average lagged level of the human capital stock. Hence, instruments are country specific. Finally, a Wald test for $\ln(A_i) = \ln(A)$, $\forall i$, when estimating (2) was performed and results overwhelmingly rejected these restrictions (a p-value of 0.000), showing that productivity indeed varies across countries.

In Table 1 we reproduce the estimates of the parameters of equations (2) and (3).

TABLE 1

ESTIMATES OF THE MODELS WITH CONSTANT AND VARYING G

Model	Independent Variable			
	α	ø	g	mean g
(2)	0.42 (0.0058)	0.075 (0.0062)	0.014 (0.0006)	
(3)	0.44 (0.056)	0.057 (0.016)		0.010

Note: standard errors in parentheses.

The reported estimates for α, ϕ, and g in of model (2) in Table 1 are close to what could be expected a *priori*: several calibrated studies use a capital elasticity $\alpha = 1/3$ (see Cooley and Prescott, 1995). Estimates in Gollin (2002) are also close to 0.40 for a variety of countries. As discussed above, ϕ can be interpreted as a measure of the percentage increase in income of an additional year of schooling. Mincerian regressions usually find $\hat{\theta} \cong 10\%$ (Mincer, 1974). Moreover, Psacharopolos (1994), who surveys schooling-return evidence using a large set of countries, finds an average of 6.8% for OECD countries and 10.1% for the world as a whole. An average growth rate of productivity of about 1.5% a year is not unlikely, being in line with the evidence on long-run growth presented by Maddison (1995).

With respect to (3), the reported estimates for α and ϕ, and the mean of the g_i estimates, are very close to those of the previous model. Moreover, the estimated $A_i's$ (not reported) are also similar: the mean difference between them is less than 3% and in no case the estimated values differ from each other by more than 9%. Their variances are similar too, so that using either group of values to perform the exercises in the next sections will not make any difference. This is so because they are cross-section exercises that do not use g, but only the estimated values of A_i, α and ϕ that regressions found not to vary much from model to model. In what follow we will use the estimates of (2).

III. Variance Decomposition of Output per Worker

To understand the relative contribution of inputs and productivity to the variance of output per-worker, two variance-decomposition exercises were performed. Initially, we take 1996 variables and disregard the uncertainty in parameter estimates, using α = 0.420, ϕ = 0.075, and g = 0.014. The first exercise is a naive decomposition, because in it we disregard the fact that part of the variation of the capital-labor ratio is due to productivity variation across countries. The second exercise follows Hall and Jones (1999), among others, rewriting the production function per-worker in terms of the capital-output ratio. We show that the decomposition performed by Hall and Jones have a natural interpretation in terms of distortions to capital accumulation.

In the "naive" decomposition, given the structural model in 1996 with its error term η_i replaced by its unconditional expectation (zero), we have:

$$\ln y_i = \ln A_i + \alpha \ln k_i + (1 - \alpha)(\phi h_i + g1996) \tag{4}$$

We decompose the variance of (the log of) output per worker in 1996 (ln y_i) in terms of (the log of) productivity (ln A_i), (the log of) capital per worker (ln k_i), and (the level of) human-capital per-worker (h_i).

This exercise is naive because it treats each factor as exogenous in calculating the variance decomposition. This is particularly troublesome for physical capital, since, for example, part of its variation may be induced by productivity variation; see the discussion in Hall and Jones (1999, p. 88). Indeed, for a given investment rate, an exogenous increase in productivity will increase the incentive to accumulate capital in the long run, raising the capital per-worker ratio. Hence, part of the impact of physical capital on output is induced by productivity, and this is not taken into account in performing the first exercise.

To cope with this problem, Hall and Jones proposed performing the decomposition in terms of the capital-output ratio. The production function is rewritten as:

$$\frac{Y_i}{L_i} = A_i^{\frac{1}{1-\alpha}} \frac{H_i}{L_i} \left(\frac{K_i}{Y_i}\right)^{\frac{\alpha}{(1-\alpha)}}, \tag{5}$$

where, in this case, $H_i = L_i \exp(\phi h_i)$. Taking logs of (5):

$$\ln y_i = \frac{1}{1-\alpha} \ln A_i + \phi\left(h_i + g1985\right) + \frac{\alpha}{1-\alpha} \ln\left(\frac{K_i}{Y_i}\right). \tag{6}$$

This formulation allows decomposing the variation of output per-worker into variations of productivity, human capital, and the capital-output ratio. Moreover, the effect of productivity on capital cancels out with that on output. Hence, variations in the capital-output ratio are free from the effect of productivity on the capital measure, answering the endogeneity problem raised above.[3]

Hall and Jones argue that in the balanced-growth path the capital-output ratio is proportional to the investment rate, which suggests a natural interpretation for the decomposition based on (6). It turns out that we can also interpret it in terms of the distortions to capital accumulation present in each country. First, assume that the net return to capital is the same across countries (r). Implicitly, this relies solely on free capital mobility. We can find, for each country, its (dynamic) distortion to capital accumulation (τ_i) by solving the following equation:

$$\alpha(1-\tau_i)A_i k_i^{\alpha-1}\left(e^{\phi h_i}\right)^{1-\alpha} = \delta + r,\ or, \tag{7}$$

$$1-\tau_i = \frac{K_i}{Y_i}\frac{\delta + r}{\alpha}, \tag{8}$$

where δ is the depreciation rate of physical capital.

Equation (8) implies that:

$$\ln(1-\tau_i) = \ln\left(\frac{K_i}{Y_i}\right) + \ln\left(\frac{\delta + r}{\alpha}\right). \tag{9}$$

Therefore, any cross moments involving $\ln\left(\frac{K_i}{Y_i}\right)$ will be identical to their respective counterparts using ln $(1 - \tau_i)$, and the results of the variance decomposition for $\ln\left(\frac{K_i}{Y_i}\right)$ based on (6) will be numerically identical to those based on ln $(1 - \tau_i)$. Indeed, because of (9), variance decomposition for $\ln\left(\frac{K_i}{Y_i}\right)$ based on (6) can be interpreted as the relative importance of distortions to capital accumulation.[4]

As in the case of the decomposition based on (6), performing it using ln $(1 - \tau_i)$ solves the exogeneity problem of physical capital. *Ceteris paribus,* the higher τ_i is, the smaller is the incentive for capital accumulation, and hence, the smaller is the capital per-worker ratio in the long run. Therefore, there is part of the variation of ln k_i that is induced by ln $(1 - \tau_i)$, and performing the analysis based on ln $(1 - \tau_i)$ isolates the effects of distortions. In other words, it is postulated here that there is no (negative) relationship between capital per worker and market returns, as in the standard neoclassical model, because τ_i equates returns across economies.

The approach based on ln $(1 - \tau_i)$ is interesting in its own right, since one rarely sees in the growth literature accounting exercises in terms of distortions.

Computation of τ_i for different countries allows: (i) measuring which of those implicitly “tax” capital accumulation, (ii) classifying countries according to distortions, and, (iii) performing counter-factual exercises in long-run growth, such as the ones discussed below.

Since in Ferreira, Issler and Pessôa (2003) it was used panel-data techniques to estimate structural parameters, one can argue that performing the variance decomposition exercise using data on 1985 alone may “throw away” relevant information on other years. One way of taking all possible years into account is to time aggregate the basic equations used in variance decompositions, performing the latter in terms of time averages. Taking equation (6), for example, if we disregard irrelevant constants, a variance decomposition exercise can be based on:

$$\frac{1}{T}\sum_{t=1}^{T}\ln y_{it} = \frac{1}{1-\alpha}\ln A_i + \phi\frac{1}{T}\sum_{t=1}^{T}h_{it} + \frac{1}{1-\alpha}\frac{1}{T}\sum_{t=1}^{T}\ln\left(\frac{K_{it}}{Y_{it}}\right), \tag{10}$$

with a corresponding counterpart using (4). Notice that these decomposition exercises take all years into account, being immune to cyclical fluctuations and other effects that may change the cross-sectional distribution of relevant variables.

3.1 Variance decomposition results

Before proceeding to the results, it may be helpful to give the reader some indication of what the paper is trying to explain and examine the relative levels of GDP per worker of some selected countries and its evolution since 1960. This is done in Table 2.

Variables are presented as proportion to the American GDP per capita in the corresponding year. Note that output differences were and remained large in many cases (e.g., India, Tanzania and Mozambique), but we also observed growth miracles (e.g., Japan, Spain, Ireland and Korea). As for growth disasters, three noteworthy cases occurred in South America: Argentina, Peru and, more dramatically, Venezuela.

Table 3 presents the results of the variance-decomposition exercises using 1996 data. In the “naive” decomposition, the variance of productivity, physical capital, and human capital account respectively for 21%, 49% and 2% of the variance of output per-worker. The remaining 28% is accounted for by the covariances between these factors. With all caveats in mind, physical capital variation can be an important factor explaining output-per-worker variation. Also, the relative importance of productivity is undeniable.

Quantitative results change considerably once physical capital is treated endogenously as in the decomposition used by Hall and Jones (1999), i.e., equation (6). The second line of Table 3 shows that productivity alone explains 62% of the variance of ln y_i. Human capital explains 6%, and the capital-output ratio explains 19%. These numbers are very different from those of the previous exercise, showing

TABLE 2

EVOLUTION OF OUTPUT RELATIVE TO US OF SELECTED COUNTRIES

Country	Y_i / Y_{US}	Y_i / Y_{US}	Y_i / Y_{US}
	1960	1980	1996
Argentina	61.8	65.9	44.9
Brazil	24.3	39.5	32.8
Mozambique	8.6	4.5	3.1
Niger	9.1	4.7	2.9
India	6.4	6.8	9.5
Japan	25.4	57.1	66.3
Spain	40.1	75.5	68.2
Netherlands	85.9	95.0	80.2
Korea	14.8	28.0	60.0
Venezuela	83.5	54.7	34.8
Tanzania	2.3	2.7	1.7
Peru	33.3	35.7	17.9
Chile	38.6	36.2	40.6
Ireland	43.0	60.9	83.8

TABLE 3

VARIANCE DECOMPOSITION OF OUTPUT PER WORKER (1985) IN TERMS OF DIFFERENT FACTORS

Variance Decomposition of ln y_i (in 1996)	% of variance due to factor				
	ln A_i	$\ln\left(\frac{K_i}{Y_i}\right)$ or $\ln(1-\tau_i)$	ln k_i	h_i	$\sum Cov.$
"Naive," Eq. (4)	19		51	2	28
Equation (6)	62	19		6	13
Extreme 10 Countries (Eq. (6))	67	11		6	16

that, when the indirect effect of productivity on capital is accounted for, the first explains not about one-fifth but about one-half of the variance of ln y_i. The last row of Table 3 presents the results of the variance-decomposition exercise, based on equation (6), when we restricted the number of countries to include only the 5 richest and 5 poorest in our sample. Productivity differences are still the main reason for income dispersion across countries.

We perform robustness checks on the results in Table 3, first by running variance decompositions of output per worker for all years we have actual data on human capital (five year intervals, starting in 1965). Results based on 1996 did not change qualitatively. For instance, using 1985 data productivity would explain 54% of the variance, while human and physical capitals 27%. Next, we decomposed the variance of $\frac{1}{T}\sum_{t=1}^{T} \ln y_{it}$ using equation (10). Again, $\ln A_i$ accounts for most of the variation of $\frac{1}{T}\sum_{t=1}^{T} \ln y_{it}$ – 56%, followed by $\frac{1}{T}\sum_{t=1}^{T} \ln (K/Y)_{it}$ – 24% and then $\frac{1}{T}\sum_{t=1}^{T} h_{ti}$ – 5%. The naive decomposition had its results virtually unchanged and so did the decomposition based on the 5 poorest and richest nations. Therefore, we conclude that, once the endogeneity of the capital measure is taken into account, productivity is the most important factor in explaining the variation of output per worker across nations.

Results here are very close to those in the literature and particularly those in Bosworth and Collins (2003). When these authors perform variance decomposition using capital-labor ratios as in our "naive" decomposition, the contribution of physical capital is almost the same as that of TFP. However, when using capital-output labor as in (6), the contribution of TFP jumps to 83%.

Our results are also similar to those in Hall and Jones (1999) and Klenow and Rodriguez-Clare (1997). This could be expected a priori for two reasons. First, these authors use a mincerian specification for the production function, as we do. Second, our estimated parameter values are very close to those used by these authors in their calibrated exercises. Again, the econometric results show that their choice of parameter values in calibration is sensible. Comparing our results to their shows the following: the variance decomposition of model BK4 in Table 2 of Klenow and Rodriguez-Clare –their preferred model– found productivity explaining 66% of output per worker variation and inputs only 34%. Given the zero covariance restriction in their exercise, if we impose it in ours we find almost the same values when using 1985 data as they did: 67.5% and 32.5%, for productivity and inputs respectively. Hall and Jones, compare the 5 richest to the 5 poorest countries. They find that productivity alone explains 67% of income variation. Again ignoring covariances, and using 1985 data, we find that productivity explains 62.3% of the income difference of these two groups.

IV. Counter-Factual Exercises on Long-Run Growth

In Table 4 we present basic statistics for a select group of countries on estimated total factor productivity – $\widehat{\ln A_i}$, distortions to capital accumulation – τ_i and human capital measures – hi, relative to their U.S. counterparts.

TABLE 4

RELATIVE PRODUCTIVITY ESTIMATE FOR SELECTED COUNTRIES (U.S.=1.00)
FACTORS AND PRODUCTIVITY RELATIVE TO THE U.S

Country	$\frac{A_i}{A_{US}}$	$\frac{\tau_i}{\tau_{US}}$	$\frac{h_i}{h_{US}}$
Iran	0.78	1.88	0.40
Netherlands	0.93	-0.96	0.75
Canada	0.82	-0.60	0.94
Spain	0.96	-1.06	0.57
Argentina	0.74	1.21	0.70
Brazil	0.79	1.30	0.37
Chile	0.87	3.22	0.60
Japan	0.77	-2.57	0.76
Korea	0.75	0.44	0.87
Indonesia	0.70	3.93	0.38
Ghana	0.50	4.82	0.31
India	0.60	4.64	0.38
Kenya	0.74	3.30	0.53
Malawi	0.38	4.00	0.23

Productivity levels of rich countries –particularly those in Europe– are above average. In contrast, productivity of the poor countries is below average. Only eight economies in the sample were more productive than the U.S. economy in 1996, and 5 in 2000. Ireland, Taiwan, Honk Kong, Mauritius and Italy belong to both groups.

Rich nations (and more educated nations) distort capital accumulation less than poor (and under-educated) nations do. For instance, while the average per capita income of the group of 20 countries with the higher estimated distortion is only 13.1% of the USA, that of the 20 less distortive countries is 68.5% of the U.S. income. However, since the correlation between ln $(1 - \tau_i)$ and ln A_i is virtually zero (actually 0.04), economies that are very good at combining inputs (i.e., are highly productive) do not necessarily have the right incentives to boost capital accumulation. Ex-communist countries (using 1985 data) and some Asian countries have little distortions and are relatively unproductive; e.g., Indonesia, Korea, and Japan. The case of the latter is very interesting: its estimated distortion is the second lowest amongst all nations (it is negative - a subsidy - as a matter of fact) but it is the median country in terms of productivity. Ireland also has a similar pattern.

Table 5 displays a counter-factual exercise on long-run growth, which might help in understanding the nature of income inequality across nations. The second column displays 1996 output per worker (relative to the U.S.) – Y_i / Y_{US}. The third column shows relative income corrected for τ_i, i.e., where country i is given the same τ as the U.S. economy. The fourth column corrects for human capi-

TABLE 5

RELATIVE OUTPUT OF SELECTED COUNTRIES IN COUNTER-FACTUAL ANALYSIS

Country/Statistics	Y_i/Y_{US} (Uncorrected)	Y_i/Y_{US} ($\tau_i = \tau_{US}$)	Y_i/Y_{US} ($h_i = h_{US}$, and $\tau_i = \tau_{US}$)
Argentina	0.45	0.45	0.59
Belgium	0.88	0.78	0.98
Brazil	0.33	0.38	0.67
Canada	0.79	0.68	0.72
Chile	0.41	0.54	0.78
Congo	0.01	0.05	0.10
France	0.79	0.71	1.00
India	0.09	0.24	0.42
Ireland	0.84	0.99	1.25
Jamaica	0.13	0.13	0.22
Japan	0.66	0.51	0.64
Korea	0.60	0.55	0.62
Mozambique	0.03	0.37	0.86
Niger	0.03	0.12	0.28
Norway	0.88	0.68	0.70
Peru	0.18	0.17	0.25
Spain	0.68	0.63	0.94
Switzerland	0.77	0.55	0.63
Tanzania	0.02	0.02	0.05
United Kingdom	0.71	0.69	0.86
Venezuela	0.35	0.35	0.54

tal and τ, i.e., where country i is given the same τ and human capital as the U.S. economy.[5]

In the second column we estimated GDP per worker of each country with the American τ in place of their own. Results would be identical if instead we had replaced the corresponding capital-output ratio. On average income per capita in the world would be 3 times larger if all the countries had the same distortions (or, equivalently, the same capital-output ratio) of the U.S. In certain cases, output gain would be large (e.g., India, Mozambique and many African economies) and is an indication that barriers to capital accumulation are an important factor hampering growth. In contrast, had Japan and Norway that same incentives as the U. S. they would be 20% poorer. These economies are very good in accumulating physical capital.

Almost in all cases relative output increases considerably when we allow a country to have the τ and h corresponding to the U.S.; see, for instals, Chile, Spain, and particularly Mozambique, where output per worker gets very close to that of the U.S. However, there are exceptions: in Norway, Japan and Switzerland, for instance (and the ex-communist countries when using 1985 data) output decreases. This is so because the incentives for capital accumulation in these economies are better than those in the U.S and human capital do not differ much to compensate the loss when we replace variables for those of the American economy. In other words, if it were not for capital accumulation, relative output per worker would be way below the observed level.

There are groups of countries, such as Tanzania, Congo and Jamaica (same is true for Zambia, Lesotho and Malawi, for instance), where the increase in relative income brought about by the reduction of τ and improvement in education is small. In this case, most of the difference between them and the U.S. is due to productivity differences. Similarly, but less dramatic, in India, Korea, Venezuela and Japan a sizeable difference in income stills remains due to their relatively small productivity.

Most OECD countries which have output per worker close to that of the U.S., such as the Belgium, United Kingdom and Denmark, would not change much either, but for different reasons: their τ_i, h_i and A_i are already very close to those of the U.S. economy. However, this pattern is not uniform across Europe: if Spain had the same incentives to capital accumulation and educational level as the U.S., its relative output would have jumped from 68% to 99% of the latter, while France GDP per worker would match that of the U.S. Ireland, similarly to other very productivity economies, would be richer than the U.S.

It deserves note that even after correcting for factor differences across countries, there still remains a large income disparity left unexplained. On average, output per worker of the 83 nations in our data set is 38% of that of the U.S. After substituting their τ_i, and h_i with the corresponding values of the American economy, the average output per worker increases to only 65% of the U.S. output; the rest corresponds to total factor productivity differences.[6]

In summary, some countries would reach the U.S. if they were given the same factors - capital intensity and human capital. Some few rich economies would become poorer, as they are better at accumulation capital, although those are the exceptions, countries in fact get richer. Finally, in most economies, even after compensating for schooling and distortions, large differences in GDP per worker would remain due to productivity.

V. Classifying Countries According to Productivity, Dynamic Distortion, and Human-Capital Figures

As a final exercise, the sample of countries is divided according to their relative position (i.e., above or below the median) for the three factors explaining (the log of) income per-worker: productivity ln (A_i), the dynamic distortion τ_i, and human-capital h_i. Hence, we divided these nations into $2^3 = 8$ sub-groups, according to their relative position for each of these factors. Table 6 summarizes the results (see Table 7 in the appendix for the complete list of countries in each group).

The first group of countries –high productivity and human capital and low dynamic distortion– is composed almost exclusively of rich countries, essentially

TABLE 6

COUNTRY CLASSIFICATION ACCORDING TO DIFFERENT FACTORS

Group	Features	# of Countries	"Bad" Features	Mean Income
1	Productive, Non-distortive and Educated	21	0	44763
2	Unproductive, Non-distortive and Educated	10	1	24868
3	Productive, distortive and Educated	7	1	29704
4	Productive, Non-distortive and Under-educated	3	1	22269
5	Productive, distortive and Under-educated	11	2	13904
6	Unproductive, distortive and Educated	4	2	13995
7	Unproductive, Non-distortive and Under-educated	8	2	5847
8	Unproductive, distortive and Under-educated	19	3	5820

the OECD countries plus Hong-Kong and Singapore. Their average income per worker is twice as large as that of the second group. They are richer than the rest because they are more educated, very productive and have few distortions affecting capital accumulation. On the other hand, the group of nations that have the wrong incentives for long-run growth (unproductive, undereducated and dynamically distortive) is composed of 19 poor or very poor nations (with few exceptions). Their average output per worker is 1/10 of the average of the first group. Typical nations are the Sub-Saharan countries, Pakistan, India, Honduras and Bolivia.

The second group is composed of 13 nations with well educated labor forces, relatively few dynamic distortions but below-average productivity. This group is very diverse, as it includes rich economies such as Korea, New Zealand and Sweden and a large group of middle income and poor Latin American economies such as Argentina, Mexico and Panama.[7] The third group is composed of seven countries, four Latin American and Caribbean countries, such as Barbados and Chile. Those are well educated countries, which are relatively productive, but have relatively poor incentives for capital accumulation. Taiwan and Ireland, fast grower countries, are part of this group. In the case of the latter, its capital intensity is only a bit below the median.

The fourth group is composed of only three nations, Brazil, Portugal, and Iran. These countries are relatively productive and have few dynamic distortions, but the schooling level of their labor force is below average. The result for Brazil is expected: its good postwar growth record was mostly based on physical-capital accumulation. Contrasting to this favorable incentive to grow, schooling of its labor force was only 3.39 years in 1985 and 4.56 in 1996,[8] and there has been no serious governmental policy to improve these figures. It is interesting to have Portugal in the same group as Brazil, showing that the effects of a particular type of colonization may be long lasting. The fifth group has only one above average factor (productivity), and it is composed mostly of countries that are rich in natural resources.

One interesting characteristic of this way of dividing nations is that the average income per worker for groups declines monotonically with the number of "bad" features (factors hampering long-run growth); see Table 6. Hence, the long-term gain for a country to "fix" one bad feature is always positive, and in some cases it can be significantly high. For instance, a country that jumps from the group with exactly one bad feature to the group with no bad features may double its long-run output per worker.

VI. Conclusion

In this article we have investigated the main characteristics of output-per-worker differences across countries. Similarly to Prescott (1998) and Klenow and Rodriguez-Clare (1997), we found that after endogenizing capital accumulation, the variation of productivity explains more than half of the variation of output per worker. Thus, the conclusion that inputs alone can explain the variation of output per worker can be called into question.

Productivity, however, cannot explain all the variation of output per worker. There are groups of countries that are rich, but their productivity is relatively low (e.g., Korea and Sweden). They are rich mostly because of high levels of education and because they have high incentives for physical-capital accumulation. On the other hand, some countries where productivity was above average do not belong to the group of rich nations: either because their labor force is under-educated (e.g. Brazil), or because the incentives for capital accumulation are relatively low (e.g. Uruguay) or both (e.g., Mexico and Jordan). Results did not change much when different data were used.

Hence, the main conclusion of this exercise is that there is no single factor explaining long-run growth. Hence, trying to find a single culprit for lack of growth can be a futile exercise: there may be a single factor for a given country, but not for the group of countries analyzed here. Examples are abundant, even within the same continent in some cases: Senegal and Zimbabwe had almost the same output per worker in 1985 - around 7% of the U.S. level. However, productivity in Senegal was 50% higher than that in Zimbabwe, while dynamic distortions in Senegal are 80% higher; New Zealand and Belgium had around 70% of U.S. output per worker in 1985, and about the same productivity. However, the average schooling of the labor force in New Zealand was 40% higher than that in Belgium, while its dynamic distortion was 24% higher. Of course, policy recommendations have to take country differences into account, or else they have a high chance of being either wrong or ineffective.

These results have an interpretation in terms of convergence and why the large observed income per head differentials have not narrowed. If, following Pritchet (1997), among many, we assume that income gaps were small in the distant past (say, two centuries ago) the relative income differentials we observe in the data today are evidence of divergence as stressed by this author. Hence, our exercises point to factors hampering TFP growth as the main culprit for divergence, as many had found in the past. However, in some countries the reduction of distortions to capital accumulation would certainly affect growth, even if only temporarily, and reduce the gap with respect to the leading economies. In others, investing in education would generate the best results. In the case of very poor countries, the correction of these three factors would be necessary to the effective reduction of relative poverty.

The questions of why productivity differs across countries and why income gaps have not narrowed in the past are no doubt important and although related to the present work it is certainly beyond its objective. However, there is a vast literature dedicated to these topics. For instance, Parente and Prescott (1999) suggest that barriers to technology adoption and monopoly power of local groups are the main reason for TFP differences. Acemoglu, Johnson and Robison (2001) and Hall and Jones (1999), on the other hand, stress differences in institutions –respect to property rights, for instance– as the ultimate cause for productivity differences. The latter also consider barriers to trade an important reason for TFP and income divergence. In the same fashion, in Ferreira and Trejos (2005) and Herrendorf and Teixeira (2005) obstacles to international trade are the ultimate cause for income and productivity differences. Another possible causes studied in the literature are geographic factors (e.g., Sachs, 2001), tax distortions and barriers to capital accumulation (Restucia and Urrutia, 2001), financial repression and capital market imperfections (e.g., Hidalgo and Erosa, 2004).

The present paper is concerned with the “proximate causes,” using the nomenclature created by Maddison, for the divergence and relative poverty, while the literature cited above goes one step beyond and studies their “ultimate causes.” While we posit a standard neoclassical production function with exogenous TFP and technology growth, these articles endogenize the causes for productivity differences. Our main contribution, as said before, is to show that although productivity has a leading role in explaining the dispersion of output per worker across countries, grew in the past (and consequently, are poor in the present) for different reasons.

Notes

1 As for the initial capital stock, it was followed Young (1995) and Hall and Jones (1999) and approximated it by $K_0 = I_0 / (g_I + \delta)$, where K_0 is the initial capital stock, I_0 is the initial investment expenditure, g_I is the sample growth rate of investment, and δ is the depreciation rate of the capital stock. Various depreciation rates were tested and results did not change significantly. In the present paper we report results with $\delta = 9\%$.

2 The only difference to weighted two-stage least squares is that equation-specific instruments were used and not the whole set of instruments.

3 Not all agree with this interpretation, as one could expect. Bosworth and Collins (2003) argue that this formulation overstates the importance of TFP as, for instance, both TFP and capital may vary together due to a third factor. According to them “an ideal representation would be somewhere between the two extremes of changes in the capital-labor ratio and changes in the capital-output ratio”.

4 A caveat to this approach is that we could think of distortions as simply how much the implied marginal product of capital in each country deviates from the world interest rate. In a world with

limited capital mobility (see Feldstein and Horioka, 1990) this could reflect differences in savings rates and population growth rates due to demographics, preferences, among other factors, and not only taxation or distortions to capital accumulation.

5 A different way to look at the fourth column of Table 4 is to regard it as the relative output of a country which is identical to the U.S. in everything but productivity. A Table with the entire set of countries is available upon request.

6 We redid the same exercise with 1985 data. The main reason is that the sample in this case is larger (99 countries now) and most additions were poor economies, which are somewhat under represented in the 1996 sample. Results remain close, but now after substituing in τ_i and h_i, the average residual left unexplained is larger: output per worker now goes from 29% (the observed mean) to only 48%, the counterfactual mean. The exclusion of poor unproductive countries from the 1996 sample is rendering TFP less important than most probably it is.

7 When we replicated this exercise using 1985 data, we found that all the ex-communist countries belong to this group.

8 Brazil is the 39th richest country in our data set (in income per worker terms) but ranks 65th in educational attainment.

References

ACEMOGLU, D., S. JOHNSON and J. ROBINSON (2001) "The Colonial Origins of Comparative Development: An Empirical Investigation," *American Economic Review*, 91 (5), pp. 1369-1401.

BARRO, R. and J. W. LEE (1996). "International Measures of Schooling Years and Schooling Quality," *American Economic Review,* 86 (2), pp. 218-223.

BARRO, R. and X. SALA-I-MARTIN (1997). "Technological Diffusion, Convergence, and Growth", *Journal of Economic Growth,* 2 (1), pp. 1-26.

BOSWORTH, B. and S. COLLINS (2003). "The Empirics of Growth: An Update", *Brookings Panel on Economic Activity,* September.

CHARI, V. V., P. J. KEHOE and E. MCGRATTAN (1997). "The Poverty of Nations: A Quantitative Investigation", *Research Department Staff Report 204,* Federal Reserve Bank of Minneapolis (Revised October 1997).

BILLS, M. and P. KLENOW (2000). "Does Schooling Causes Growth?", *American Economic Review,* 90 (5), pp. 1160-1183.

COOLEY, T. and E. PRESCOTT (1995). "Economic Growth and Business Cycles", in T. Cooley and E. Prescott (eds.), *Frontiers of Business Cycle Research,* Princeton, Princeton University Press.

FELDSTEIN, M. and C. HORIOKA (1980). "Domestic Saving and International Capital Flows", *The Economic Journal,* 90 (358), pp. 314-329.

FERREIRA, P.C., J.V. ISSLER AND S. PESSÔA (2003). "Testing Production Functions Used in Empirical Growth Studies", *Economics Letters,* 83 (1), pp. 29-35.

FERREIRA, P.C. and A. TREJOS (2005). "On the Output Effects of Barriers to Trade", Forthcoming, *International Economic Review.*

GOLLIN, D. (2002). "Getting Income Shares Right: Self Employment, Unincorporated Enterprise, and the Cobb-Douglas Hypothesis", *Journal of Political Economy,* 110 (2), pp. 458-472.

HALL, R. E. and C. JONES (1999). "Why do Some Countries Produce So Much More Output Per Worker Than Others?", *Quarterly Journal of Economics,* 114 (1), pp. 83-116.

HERRENDORF, B. and A. TEIXEIRA (2005). "How Barriers to International Trade Affect TFP", forthcoming, *Journal of Economic Dynamics and Control.*

HIDALGO, A. and A. EROSA (2005). "On Capital Market Imperfections as an Origin of Low TFP and Economic Rents", *manuscript,* University of Toronto.

JONES, C. (1997). "Convergence Revisited", *Journal of Economic Growth,* 2 (2), pp. 131-153.

KLENOW, P. J. and A. RODRÍGUEZ-CLARE (1997). "The Neoclassical Revival in Growth Economics: Has it Gone Too Far?", in B. S. Bernanke and J. J. Rotemberg (eds.), *NBER Macroeconomics Annual 1997,* Cambridge MA: The MIT Press, pp. 73-103.

MADDISON, A. (1995). *Monitoring the World Economy: 1820-1992,* Paris: OECD.

MANKIW, N. G. (1995). "The Growth of Nations", *Brookings Papers on Economic Activity,* 1, pp. 275-326.

MANKIW, N. G., D. ROMER and D. WEIL (1992). "A Contribution to the Empirics of Economic Growth", *The Quarterly Journal of Economics* 107 (May), pp. 407-437.

MINCER, J. (1974). *Schooling, Experience, and Earning,* National Bureau of Economic Research, distributed by Columbia University Press.

PARENTE, S. AND E.C. PRESCOTT (1999), "Monopoly Rights: A Barrier to Riches", *American Economic Review,* 89 (5), pp. 1216-1233.

PRESCOTT, E. (1998). "Needed: a Theory of Total Factor Productivity", *International Economic Review,* 39 (3), pp. 525-551.

PRICHETT, L. (1997). "Divergence, Big Time", *Journal of Economic Perspectives,* 11 (3), pp. 3-17.

PSACHAROPOULOS, G. (1994). "Returns to Investment in Education: A Global Update", *World Development,* 22 (9), pp. 1325-1343.

SACHS, J. (2001). "Tropical Underdevelopment", *NBER working paper* 8119.

RESTUCCIA, D. and C. URRUTIA (2001). "Relative Prices and Investment Rates", *Journal of Monetary Economics,* 47 (1), pp. 93-121.

SUMMERS, R. and A. HESTON (1991). "The Penn World Table (Mark 5): An Expanded Set of International Comparisons 1950-1988", *Quarterly Journal of Economics,* 106 (2), pp. 327-368.

WILLIS, R. J. (1986). "Wage Determinants: A Survey and Reinterpretation of Human Capital Earnings Functions", in O. Ashenfelter and R. Layard (eds.), *Handbook of Labor Economics,* volume 1, North-Holland. Chapter 10, pp. 525-602.

APPENDIX

TABLE 7

GROUPS OF COUNTRIES ACCORDING TO RELATIVE POSITION WITH RESPECT TO AVERAGE PRODUCTIVITY, DISTORTION AND EDUCATION

Group 1: Productive, Non-distortive and Educated:
Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Hong Kong, Iceland, Israel, Italy, Japan, Netherlands, Norway, Singapore, Spain, Switzerland,United Kingdom, USA

Group 2: Unproductive, Non-distortive and Educated:
Argentina, Ecuador, Greece, Korea, New Zealand, Panama, Peru, Venezuela, Mexico, Sweden,

Group 3: Productive, Distortive and Educated:
Barbados, Chile, Ireland, Malaysia, Taiwan, Trinidad & Tobago, Uruguay

Group 4: Productive, Non-distortive and Under-educated:
Brazil, Iran, Portugal

Group 5: Productive, Distortive and Under-educated:
Botswana, Colombia, Dominican Republic, El Salvador, Guatemala, Mozambique, Mauritius, South Africa, Syria, Tunisia, Uganda

Group 6: Unproductive, Distortive and Educated:
Fiji, Kenya, Jordan, Philippines

Group 7: Unproductive, Non-distortive and Under-educated:
Guyana, Jamaica, Lesotho, Nicaragua,Tanzania, Thailand, Zambia, Zimbabwe

Group 8: Unproductive, Distortive and Under-educated:
Bangladesh, Bolivia, Cameroon, Central African Republic, Congo, Costa Rica, Ghana, Honduras, India, Indonesia, Malawi, Nepal, Niger, Pakistan, Papua New Guinea, Paraguay, Senegal, Togo, Turkey