IS GROWTH EXOGENOUS? TAKING MANKIW, ROMER, AND WEIL SERIOUSLY*

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ABSTRACT

Is long-run economic growth exogenous? To address this question, we show that the empirical framework of Mankiw, Romer, and Weil (1992) can be extended to test any growth model that admits a balanced growth path; and we use that framework both to revisit variants of the Solow growth model and to evaluate simple alternative models of endogenous growth. To allow for the possibility that economies in our sample are not on their balanced growth paths, we also study the cross-sectional behavior of TFP growth, which we estimate using alternative measures of labor's share. Our broad conclusion, based on both model estimation and growth accounting, is that long-run growth is significantly correlated with behavioral variables such as the savings rate, and that this correlation is not easily explained by models in which growth is treated as the exogenous variable. Hence, future empirical studies should focus on models that exhibit endogenous growth.

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I. Introduction

"This paper takes Robert Solow seriously." Thus begins one of the most influential and widely cited pieces in the empirical growth literature, a 1992 article by N. Gregory Mankiw, David Romer, and David Weil. In brief, Mankiw, Romer, and Weil (1992), henceforth MRW, performed an empirical evaluation of a "textbook" Solow (1956) growth model using the Penn World Tables, a multi-country data set constructed by Summers and Heston (1988) for the years 1960-1985. MRW found support for the Solow model's predictions that, in the long-run steady state, the level of real output per worker by country should be positively correlated with the saving rate and negatively correlated with the rate of labor-force growth. However, their estimates of the textbook Solow model also implied a capital share of factor income of about 0.60, high compared to the conventional value (based on U.S. data) of about one-third.

To address this possible inconsistency, MRW considered an "augmented" version of the Solow model, in which human capital enters as a factor of production in symmetrical fashion with physical capital and raw labor. They found that the augmented Solow model fits the data relatively better and yields an estimated capital share more in line with conventional wisdom. They concluded (abstract, p. 407) that "an augmented Solow model that includes accumulation of human as well as physical capital provides an excellent description of the cross-country data." Numerous authors have since used the MRW framework to study the significance of additional factors to growth (see Durlauf and Quah, 1999, for references). Islam (1995) and others have extended the MRW analysis to panel data.

That MRW's augmented Solow model fits the cross-country data well is an interesting finding (and, as they point out, the results could have been otherwise). However, as we will discuss in some detail below, it is not entirely clear to what degree the good fit of the MRW specification may be attributed to elements that are common to many models of economic growth (such as the Cobb-Douglas production structure), and how much of the fit is due to elements that are specific to the Solow formulation (such as the exogeneity of steady-state growth rates). Indeed, as we will show, MRW's basic estimation framework is broadly consistent with *any* growth model that admits a balanced growth path – a category that includes virtually all the growth models in the literature.[1] Hence, one might argue that MRW do not actually test the Solow model, in the sense of distinguishing it from possible alternative models of economic growth.

On the other hand, the fact that the MRW framework is for the most part not specific to the Solow model is also a potential strength, as it implies that their approach can in principle be used to evaluate not only that model but other candidate growth models as well. Because the policy implications of the Solow model and other growth models (especially "endogenous growth" models) differ markedly, assessing the empirical relevance of alternative models is an important task.

In this paper we modestly extend the empirical framework introduced by MRW and use it to re-evaluate both the Solow model and some alternatives. In particular, we re-examine the crucial prediction of the Solow model, that long-run economic growth is determined solely by exogenous technical change and is independent of variables such as the aggregate saving rate, schooling rates, and the growth rate of the labor force. To anticipate our conclusion, we find strong statistical evidence against the basic Solow prediction. In particular, we find that a country's rate of investment in physical capital is strongly correlated with its long-run growth rate of output per worker, and that rates of human capital accumulation and population growth are also correlated, though somewhat less strongly, with the rate of economic growth.

The rest of the paper is organized as follows. Section II reconsiders the MRW empirical framework. We show that the assumptions underlying their specification can be broken into two parts: those that apply to any growth model admitting a balanced growth path, or BGP, and those that are specific to the Solow model. This discussion paves the way for subsequent re-analysis of both the Solow model and some simple alternatives.

The empirics of the Solow model, under the maintained assumption of steady states, are revisited in Section III. We first replicate and extend the MRW results, using more recent data and a longer sample period. We find that both the textbook and augmented Solow models perform slightly less well with updated data, and that parameter restrictions of the model that MRW found to be consistent with the data are now typically rejected. However, we do not consider these results to be particularly informative about the applicability of the Solow model, particularly its strong implication that long-run growth is exogenous.

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[1] Durlauf and Quah (1999) derive a general framework that nests a variety of alternative growth models,

Instead, we propose a more powerful test of the Solow model, based on its prediction that in the steady state national growth rates should be independent of variables such as the saving rate and the rate of human capital formation. We find a strong rejection of the joint hypothesis that the Solow model is correct and that the economies in our sample are in steady states.

Section IV uses our version of the MRW framework to consider some simple alternative growth models, the Uzawa (1965)-Lucas (1988) two-sector model with human capital formation and the so-called AK model. Both models have some explanatory power, in the sense that rates of human capital formation (Uzawa-Lucas) and of physical capital accumulation (the AK model) both appear to be strongly related to output growth in the long run. However, neither model is a complete description of the cross-country data; in particular, the over-identifying restrictions imposed by each model are decisively rejected.

All the analysis through Section IV is based on the assumption that the economies in the sample are on balanced growth paths. If all or some of the economies were in fact in transition to a balanced growth path during the sample period, our tests are invalid. MRW study the issue of non-steady-state behavior by estimating rates of convergence and relating these to the parameters of the model. We take a more direct approach: According to the Solow model, TFP growth rates should be independent of behavioral variables such as the saving rate whether the economy is in a steady state or not. In Section V we construct estimates of factor shares for more than 50 countries, which allows us to infer long-run TFP growth rates. We also consider TFP growth rates for the full sample, based on a plausible assumption about factor shares. Finally, in Section VI, we verify that long-run TFP growth rates are not statistically independent of national rates of saving and other behavioral variables. We do not here take a strong position on the direction of causation between TFP growth and other country characteristics, as either suggests that a richer model than the Solow model is needed to explain long-run growth.

II. A Generalized Mankiw-Romer-Weil Framework

MRW (1992) provide an appealing framework for comparing the implications of the Solow model with the cross-country data. In this section we show that their framework is potentially even more fruitful than they claim, in that it can be used to evaluate essentially any growth model that admits a balanced

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including alternative versions of the Solow model.

growth path (BGP). Indeed, as we will show, the MRW framework can be thought of as consisting of two parts: a general structure that is applicable to any model admitting a BGP, and a set of restrictions imposed on this structure by the specific growth model (such as the Solow model) being studied. Here we develop the point in some generality; in subsequent sections we apply the generalized MRW approach to study both the Solow model and some alternative models of economic growth.

Assume that in a given country at time *t*, output Y_t depends on inputs of raw labor L_t and three types of accumulated factors: K_t, H_t, and Z_t. The factors K_t and H_t are accumulated through the sacrifice of current output (think of physical capital and human capital, or structures and equipment). The factor Z_t, which could be an index of technology, or of human capital acquired through learning-by-doing, is assumed to be accumulated as a byproduct of economic activity and does not require the sacrifice of current output.

The four factors of production combine to produce output according to the following standard, constant-returns-to-scale Cobb-Douglas form (note that Z_t multiplies raw labor L_t and thus may also be thought of as an index of labor productivity):

$$(2.1) \qquad Y_t = K_t^a H_t^b (Z_t L_t)^{1-a-b}$$

Output may either be consumed or transformed into K-type or H-type capital:

$$(2.2) \qquad Y_t = C_t + \dot{K}_t + d_K K_t + \dot{H}_t + d_H H_t$$

where C_t is consumption and the overdot indicates a time derivative. K-type and H-type capital depreciate at rates d_K and d_H respectively. Z-type capital does not use up output but is accumulated according to some yet-unspecified relationship that links changes in Z to the current state of the economy:

(2.3) $\dot{Z}_t = z(Z_t, K_t, \dot{K}_t, H_t, \dot{H}_t, L_t, \dot{L}_t)$

Behavioral or technological parameters (such as the parameter that links the rate of learning-by-doing to the level of production) may be implicit in $z(...)$. Finally, the labor force grows at exogenous rate n:

(2.4) $L_t = L_0 e^{nt}$

We consider a balanced growth path of this economy in which constant shares of output, denoted by s_K and s_H, respectively, are devoted to gross investment in the two capital goods. For now we take these shares to be strictly exogenous. This assumption is harmless for the analysis of the Solow model, which also assumes exogenous saving rates. We examine the case of endogenous saving rates at various points below.

Using lower-case letters to denote per-worker quantities, e.g., $y_t = Y_t / L_t$, we can re-write the production function and the capital accumulation equations in a standard way as

(2.5) $y_t = Z_t^{1-a-b} k_t^a h_t^b$

(2.6) $\dot{k}_t = s_K y_t - (d_K + n)k_t$

(2.7) $\dot{h}_t = s_H y_t - (d_H + n)h_t$

The growth rates of k and h, which are constant along the balanced growth path, are given by

(2.8) $g_k \equiv \dot{k}_t / k_t = s_K Z_t^{1-a-b} k_t^{a-1} h_t^b - (d_K + n)$

(2.9) $$g_h \equiv \dot{h}_t / h_t = s_H Z_t^{1-a-b} k_t^a h_t^{b-1} - (d_H + n)$$

The growth rate of output per worker is

(2.10) $$g_y \equiv \dot{y}_t / y_t = (1-a-b) g_Z + a g_k + b g_h$$

where $g_Z = \dot{Z}_t / Z_t$.

The first term on the right-hand side of the expression for g_k, eq. (2.8), equals $s_K Y_t / K_t$. Since both g_k and $(d_K + n)$ are constant along the balanced growth path, Y_t / K_t must also be constant. Hence Y and K grow at the same rate on the BGP (cf. Barro and Sala-i-Martin, 1999, p. 54). By similar argument, the expression for g_h, eq. (2.9), implies that Y and H grow at the same rate. Hence, Y, K, and H share a common growth rate, call it g, where $g = g_K = g_H = g_Y$. Finally, from the expression for g_y, eq. (2.10), we see that Z must also grow at the same constant rate, or $g_Z = g$. The requirement that Z grow at a constant rate on the balanced growth path rules out scale effects in the determination of Z, hence the equation for Z reduces to

(2.11) $$\dot{Z}_t / Z_t = g(s_K, s_H, n, Z_0, K_0, H_0, L_0)$$

We can now solve explicitly for the balanced growth path of output per worker. Using the equations for g_k and g_h above, and the fact that these two quantities are equal in the steady state, we find

(2.12) $$\frac{h_t}{k_t} = \frac{s_H (n + g + d_K)}{s_K (n + g + d_H)} \equiv w$$

To simplify the algebra a bit, and for comparability to MRW, suppose that $d_K = d_H = d$, so that that $w = \frac{s_H}{s_K}$. Solving eqs. (2.8) and (2.9) to find the BGP values of k_t and h_t, call them k_t^* and h_t^*, we get

$$k_t^* = Z_t \left(\frac{s_K^{1-b} s_H^{b}}{n+g+d}\right)^{\frac{1}{1-a-b}} \tag{2.13}$$

$$h_t^* = Z_t \left(\frac{s_H^{1-a} s_K^{a}}{n+g+d}\right)^{\frac{1}{1-a-b}} \tag{2.14}$$

Output per worker along the balanced growth path, y_t^*, is given (in logs) by

$$\ln(y_t^*) = \ln Z_t + \frac{a}{1-a-b}\ln(s_K) + \frac{b}{1-a-b}\ln(s_H) - \frac{a+b}{1-a-b}\ln(n+g+d) \tag{2.15}$$

Further, the t-period difference in output per worker along the BGP is

$$\ln(y_t^*) - \ln(y_0^*) = \ln(Z_t) - \ln(Z_0) = tg(s_K, s_H, n, Z_0, K_0, H_0, L_0) \tag{2.16}$$

To this point we have considered the BGP of a single country. Suppose now that we have a panel of countries, indexed by i. Further, suppose that $\ln(Z_{it}) = \bar{z}_t + e_{it}$[2], and that $\ln(y_{it}) = \ln(y_{it}^*) + h_{it}$, where h_{it} is stationary and represents cyclical deviations of output from the BGP. Then equations (2.15) and (2.16) may be written in estimation form as:

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[2] MRW assume (in our notation) that $\ln(Z_{i0}) = \bar{z}_0 + e_{i0}$. Their assumption implies that $\bar{z}_t = \bar{z}_0 + \bar{g}t$ and $e_{it} = e_{i0} + (g_i - \bar{g})t$, where $\bar{g}$ is the mean country growth rate. Under the MRW assumption that $g_i = \bar{g}$, we have simply $e_{it} = e_{i0}$. We discuss the implications of this error structure further below.

(2.17)

$$\ln(y_{it}) = \bar{z}_t + \frac{a_i}{1-a_i-b_i}\ln(s_{Ki}) + \frac{b_i}{1-a_i-b_i}\ln(s_{Hi}) - \frac{a_i+b_i}{1-a_i-b_i}\ln(n_i+g_i+d) + e_{it} + h_{it}$$

(2.18) $$\ln(y_{it}) - \ln(y_{i0}) = \ln(Z_{it}) - \ln(Z_{i0}) = tg(s_{Ki}, s_{Hi}, n_i, Z_{i0}, K_{i0}, H_{i0}, L_{i0}) + h_{it} - h_{i0}$$

As we have stressed, our analysis thus far assumes *only* that the economy is in a BGP and does not rule out endogenous determination of total factor productivity (identified here with Z_t). To go from this generalized MRW framework to a specific growth model, additional restrictions are required. For example, in their estimation of the augmented Solow model, MRW specialize further by assuming that a_i, b_i, and (most importantly) g_i are the same for all countries, and that actual output equals BGP output ($h_{it} = 0$). (MRW do not write down eq. (2.18) explicitly, but it is implicit in their calculations as they use average output growth to determine the value of the common growth rate g.) Their estimation of the textbook Solow model further assumes that $b = 0$, that is, human capital H does not enter as a separate factor of production. In Section IV we show how this framework can accommodate other models of economic growth. First, though, we revisit the MRW estimates, using updated data.

III. Replication and Extension of the MRW Results

The original MRW article used cross-national data for the period 1960-1985. In this section we replicate the MRW results for 1960-1985 and extend them through 1995. We find that the MRW conclusions about the fit of the textbook Solow model and the augmented Solow model seem slightly weaker when we use revised and/or extended data, though their main results survive. We also propose a new test of the Solow model based on joint estimation of equations in the form of (2.17) and (2.18).

Following MRW we draw our basic data from the Summers-Heston Penn World Tables (PWT), which contain information on real output, investment, and population (among many other variables) for a large number of countries. The data set used in the original MRW study was PWT version 4.0. The PWT data have been revised twice since publication of the MRW article; as of this writing, PWT version 5.6

(which extends coverage of most variables through 1992) is the latest publicly available version. Alan Heston and Robert Summers have also kindly supplied us with a preliminary version of PWT version 6.0, which extends the data through 1998 for most variables.[3] In what follows we compare results using all three PWT data sets (4.0, 5.6, and preliminary 6.0).

MRW measure n as the average growth of the working-age population (ages 15 to 64). They obtained these data from the World Bank's *World Tables* and the 1988 *World Development Report*. We use the original MRW data on working-age population in conjunction with the PWT 4.0 data set. For analyses using PWT 5.6 and PWT 6.0, we use analogous data taken from the World Bank's *World Development Indicators* 2000 CD-ROM.

The saving rate relevant to physical capital, s_K, is measured as the average share of gross investment in GDP, as in MRW. In open economies, of course, investment and saving need not be equal. However, if the capacity of countries to borrow abroad is limited (for reasons well-known from the literature on sovereign debt), MRW's identification of the ratio of investment to GDP with s_K seems defensible, even though technically investment is not fully financed by domestic saving. Reconciling closed-economy growth models with the existence of international capital flows is a general problem in this literature, and we do not have much to add on the issue here.[4]

MRW's estimates of the augmented Solow model (with human capital accumulation) include a variable they call *SCHOOL*, analogous to our s_H, which is the average percentage of a country's working-age population in secondary school. More specifically, MRW define *SCHOOL* as the percentage of school-age population (12-17) attending secondary school times the percentage of the working-age population that is of secondary school age (15-19). The age ranges in the two components of *SCHOOL* are incommensurate but we are inclined to agree with MRW that the imperfect matchup is not likely to create major biases and we use the same construct. Data on enrollment rates, and working-age population and its components are from the sources noted two paragraphs above and from the UN *World Population Prospects*.

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[3] Of course, Heston and Summers are not responsible for results obtained using these preliminary data.

[4] For an open-economy extension of the augmented Solow model of MRW, see Barro, Mankiw, and Sala-i-Martin (1995).

With these data we perform the following exercises. First, we replicate the MRW results for the textbook Solow model for their sample period, 1960-1985, for each of their three country samples and using all three vintages of the PWT data. Next, we use the data sets PWT 5.6 and PWT 6.0 to repeat the estimation for the periods 1960–1990 and 1960-1995, respectively. Finally, we repeat these exercises for MRW's augmented Solow model.

The replication of MRW's results for the textbook Solow model and for their 1960-1985 sample period are contained in Table I (compare to MRW's Table I, p. 414 of their article). As in MRW, the three country samples we examine are 1) the "non-oil" sample, the set of all countries for which complete data are available, excluding oil producers (98 countries); 2) the "intermediate" sample, which is the non-oil sample excluding countries whose data receive a grade of "D" from Summers and Heston or whose population is less than one million (75 countries);[5] and 3) the OECD sample, OECD countries with populations greater than one million (22 countries).[6] Note that, because of missing data, the sample sizes are in some cases slightly smaller when PWT 5.6 and PWT 6.0 are used for the replication.

When we repeat the MRW estimations using PWT 4.0 (see the three leftmost columns of Table I), our results are essentially identical to theirs, as expected. In particular, in the restricted regression (that imposes cross-parameter restrictions on the regression coefficients) we find an $\overline{R}^2$ of 0.59 for both the non-oil and intermediate samples, suggesting that the model explains a significant part of the variation in real output per worker among these countries. For the OECD sample, the $\overline{R}^2$ is a much more modest 0.06, as in MRW. The single restriction imposed by the model is not rejected in any of the three samples. The primary shortcoming of the results, as identified by MRW, is that the estimated capital share a is about 0.60 in both the non-oil and intermediate samples, a value that seems too high. The estimated a for the OECD sample is a more reasonable 0.36.

We also obtained estimates for the MRW sample period, 1960-1985, using revised PWT data (see Table I). The results are again similar to those found by MRW, with two exceptions worth noting: First, when the revised data are used, the over-identifying restriction of the model is rejected for the non-OECD country samples (the p-values are 0.02 and 0.04 respectively for both the PWT 5.6 data and the PWT 6.0

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[5] More recent versions of the PWT data no longer include these grades.

data). This rejection contrasts with the original MRW finding for the same sample period. Second, we find somewhat lower estimates of the capital share, closer to 0.5 than 0.6.

As the MRW results go only through 1985, it is interesting to see whether their findings hold for updated data. Table II shows the results of estimating the MRW specification using more recent data and hence longer sample periods. The leftmost three columns of the table show estimates for the 1960-1990 sample period (using PWT 5.6) and the rightmost three columns show the results for 1960-1995 (using PWT 6.0). The end dates were chosen to minimize the effect of missing data at the end of the sample. Qualitatively the results are similar to those in Table I; indeed, relative to the results for 1960-1985, $\overline{R}^2$ is somewhat higher for both sample periods and each group of countries. However, the over-identifying restriction proposed by MRW is now strongly rejected outside of the OECD (the p-values for the non-oil and intermediate samples are 0.00 and 0.00 respectively for 1960-1990, 0.00 and 0.01 for 1960-1995). The estimated capital shares remain between 0.5 and 0.6 for the large samples, and they rise to about 0.4 for the OECD sample.

As we have noted, the high estimated values of the capital share obtained by MRW for the textbook Solow model led them to consider a variant of the Solow model in which human capital as well as physical capital is accumulated. In terms of our exposition of Section II, this model allows for a non-zero coefficient b on the second form of accumulated capital, while retaining the assumption that technology growth rates are the same for all countries. We also replicated and extended this set of MRW estimates. Our estimates of the augmented Solow model for the 1960-1985 sample period are reported in Table III, and Table IV gives the estimates for the 1960-1990 and 1960-1995 sample periods.

As MRW found, the performance of the augmented Solow model, with human capital, is generally better than that of the textbook version. The augmented model explains considerably more of the cross-country variation in output per worker; for example, for the 1960-1995 sample (using PWT 6.0), $\overline{R}^2$ equals 0.75 for the large non-oil sample, 0.77 for the intermediate sample, and 0.45 for the OECD sample. The coefficient on human capital, b, takes on reasonable values (generally between 0.3 and 0.4), and the estimates of the coefficient on physical capital, a, are correspondingly reduced. There are also some

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[6] Our OECD sample coincides with that of MRW throughout, that is, we do not include countries joining

problems, however. First, the over-identifying restriction on the OLS coefficients is rejected at the 1% level for the broadest sample for the 1960-1990 and 1960-1995 sample periods, and at the 5% level the 1960-1985 sample using the most recent vintage of the data (PWT 6.0). Second, the estimated capital share a is now unreasonably low in some cases: For 1960-1985, a is estimated to be 0.00 for the OECD sample when PWT 5.6 is used and –0.03 when PWT 6.0 is used. For 1960-1990 and 1960-1995 respectively, the OECD capital share is estimated to be 0.09 and 0.04.

A more powerful test of the Solow model

Based on the results so far, one might follow MRW and draw broadly positive conclusions about the fit of the Solow model, especially when augmented with human capital. Notably, a simple regression using only three variates (the saving rate, the schooling rate, and the population growth rate) seems to explain a remarkable share of cross-country variation in the level of output per worker. It is true that the estimates of the production function coefficients are not always reasonable, and we have found that the over-identifying restriction implied by the Cobb-Douglas structure is often rejected, but problems with estimation of production relationships are not uncommon. Very possibly, these statistical rejections are not of great economic significance.

However, as our exposition in Section II suggests, the results shown so far do not constitute the strongest test of the Solow model within this framework. In our view, the better test of the Solow model involves testing the restrictions on the analogue of equation (2.18), the equation explaining long-run growth. In particular, if the hypothesis that the steady state of the Solow model describes the cross-sectional distribution of output per worker is true, then we should not be able to reject the hypothesis that factors such as the saving rate or the rate of human capital accumulation do not enter into the determination of the long-run growth rate. Formally, equations (2.17) and (2.18), together with the assumptions that all countries share the same production function parameters and long-run growth rate, imply that

$$\ln(y_t) = \bar{z}_t + \frac{a}{1-a-b}\ln(s_{Ki}) + \frac{b}{1-a-b}\ln(s_{Hi}) - \frac{a+b}{1-a-b}\ln(n_i + g + d) + e_i + h_{it} \tag{3.1}$$

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since 1990.

(3.2) $$\ln(y_{it}) - \ln(y_{i0}) = \ln(Z_t) - \ln(Z_0) = tg + h_{it} - h_{i0}$$

where the growth rate g is constant across countries. A straightforward statistical implication of the model, easily tested in this framework, is that the coefficients on variables such as the saving rate, the schooling rate, and the growth rate of the workforce rate should be zero, when they are entered on the right side of eq. (3.2). (More precisely, we divide both sides of eq. (3.2) by the number of periods *t*, so that the annual growth rate is on the right-hand side).)

Table V reports the results of this test. Equations (3.1) and (3.2) are estimated jointly by seemingly unrelated regression (SUR), with equation (3.2) being augmented by the variables *I/GDP*, *SCHOOL*, and the labor-force growth rate n.[7] The prediction of the Solow model (under the auxiliary assumption of steady states) is that the estimated coefficients of the last three variables should all be zero. Table V shows the parameter estimates and standard errors for the augmented equation (3.2). The chi-squared test and the associated p-value in the final two rows test the exclusion restriction implied by the model. In brief, the Solow model's implication that growth is exogenous is strongly rejected for the non-oil and intermediate samples. When equation (3.1) takes the form implied by the textbook Solow model, that is, we impose $b = 0$, exogeneity of growth is rejected for the OECD sample at the 10% level. When equation (3.1) allows $b \neq 0$, the restriction is rejected at the 5% level for the OECD. Inspection of the coefficients and standard errors in Table V shows that the principal reason for the rejections is the strong relationship of the saving rate (I/GDP) to the long-run growth rate.

There are at least two possible reasons for the statistical rejections found in Table V: First, growth may not be truly exogenous, in the sense of the Solow model. Second, the maintained hypothesis that the countries in the sample are in the steady state may be wrong, i.e., we may be picking up transition dynamics.

One simple test of the second possibility is to consider only the 22 countries in our sample that are located in the Western hemisphere. Arguably, the assumption of steady states makes more sense for

Western hemisphere countries than for the rest of the world, as the Americas have not been the scene of major wartime destruction, post-colonial transitions, or (except for Cuba, which is not in our sample) sustained non-market experiments during the past century. Interestingly, as Table V shows, the restrictions of the Solow model cannot be rejected for the countries of the Western hemisphere as a group. Thus, it remains possible that the results of this section arise because of transition dynamics, not because the Solow model is fundamentally wrong about long-run growth. In the latter part of the paper we address this issue directly by considering the determinants of TFP growth rather than output.

Endogenous savings rates? The Ramsey model

Our rejection of the Solow model is based on the finding that variables such as saving rates are correlated with growth rates. One possible reason for this correlation is that saving rates are endogenous and depend on rates of growth, rather than the other way around, as in the classic formulation due to Ramsey (1928), Cass (1965), and Koopmans (1965); see, e.g., Barro and Sala-i-Martin (1999, chapter 2), for an exposition. In the remainder of this section we briefly consider the fit of the "Ramsey model" to the data.

Before doing so, however, we should emphasize that the possibility that saving rates are endogenous to growth does not (in our view) invalidate our rejection of the Solow model in the previous section. In brief, there are two possibilities: Either the long-run growth rate is the same for all countries (that is, $g_i = g$ for all i), as maintained by MRW, or it is not. If the long-run growth rate is invariant, then differences in growth rates cannot account for differences in savings rates. In any case, the null that the growth rate is the same for all countries is rejected by our test reported above, under the plausible assumption that the long-run average values of *I/GDP*, *SCHOOL*, and *n* are not strongly correlated with the cyclical error term, $(h_{it} - h_{i0})/t$. Suppose then that the long-run growth rates differ (exogenously) across countries. This alternative assumption raises both econometric and substantive problems for the MRW analysis of the Solow model. Econometrically, if the growth rate is stochastic, the MRW equation (2.17) is no longer a valid regression, as the error term is correlated with the regressors (see footnote 2).

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[7] Our focus is not on equation (3.1) but the SUR approach brings efficiency gains in the estimation of this equation too.

Hence the interpretation of MRW’s results favoring the Solow model is problematic. More substantively, “explaining” growth by assuming that growth rates differ exogenously across countries is not particularly helpful. Once it is allowed that long-run growth rates differ across countries, we are naturally pushed to consider explanations for these differences, as offered (for example) by endogenous growth models.

We consider the version of the Ramsey model without human capital, that is, with $b = 0$. The relevant equations are

$$\text{(3.3)} \qquad \ln(y_{it}) = \bar{z}_t + (\frac{a}{1-a})\ln(s_{Ki}) - (\frac{a}{1-a})\ln(n_i + g_i + d) + e_i + h_{it}$$

$$\text{(3.4)} \qquad \ln(y_{it}) - \ln(y_{i0}) = tg_i + h_{it} - h_{i0}$$

$$\text{(3.5)} \qquad s_{Ki} = \frac{a(n_i + g_i + d)}{(r + sg_i + d)} + n_{1i}$$

where r is the discount rate (of the representative agent), s is the coefficient of relative risk aversion, and n_{1i} is a country-specific (but time-independent) error term. Equations (3.3) and (3.4) are the appropriately modified versions of eqs. (2.17) and (2.18), and eq. (3.5) is the standard expression for the Ramsey steady-state saving rate.[8] To estimate this system, it is convenient to rewrite eq. (3.4) as

$$\text{(3.6)} \qquad g_i = (1/t)(\ln(y_{it}) - \ln(y_{i0}) + (1/t)(h_{i0} - h_{it})$$

Using (3.6), we substitute for g_i in eqs. (3.3) and (3.5). This substitution introduces a measurement error term, $(1/t)(h_{i0} - h_{it})$; however, this measurement error is probably small for our sample length (35

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[8] This savings rate comes from the solution of the consumer optimization problem, $\max \int_0^\infty e^{-rt} \frac{c_t^{1-s} - 1}{1-s} L_t dt$, where c_t is per capita consumption. The same maximization problem also applies to the Uzawa-Lucas model introduced in the next section.

years) and is zero asymptotically. After making this substitution, we estimate the system (3.3) and (3.5) jointly by nonlinear seemingly unrelated regression (SUR), to take advantage of possible efficiency gains if the error terms are correlated. As noted above (see also footnote 2), when growth rates vary across countries equation (3.3) is no longer a valid regression, as the error term, $e_{it} = e_{i0} + (g_i - \overline{g})t$, is likely to be correlated with the regressors; hence, we impose $a = 0.35$ (a value justified later in the paper) and estimate only the constant term in (3.3). (Estimation of equation (3.5) alone produced similar results to those reported here.) Table VI shows the results for the period 1960-1995 for four samples (the three MRW samples plus the Western hemisphere).

The results provide at best weak support for the view that saving rates are endogenous to growth rates. The link between the growth rate and the saving rate operates most directly through the risk aversion parameter (the inverse of the intertemporal elasticity of substitution), s. As Table VI shows, the estimated value of s is much too low (negative, for the largest sample), relative to typical findings, and is poorly identified. (However, estimates of the discount rate r are well-identified and reasonable in magnitude.) As a measure of fit, the table also reports for each sample the simple correlation of the actual saving rate and the fitted saving rate. This correlation is 0.49 for the largest (non-oil) sample (recall, though, that here the estimated s is negative) and 0.33 for the intermediate sample. For the OECD and Western hemisphere samples respectively, the correlations of actual and fitted saving are only 0.14 and 0.15. Further, much of the explanation for saving appears to be due to variation in the growth rate of the labor force rather than variation in the growth rate. In short, it appears that one cannot reasonably account for the observed correlation of saving and growth as reflecting the endogenous response of the former to the latter.[9] [10] More evidence on this point is provided below. In the next section we consider the fit of some alternatives to the Solow model which permit growth as well as saving to be endogenous.

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[9] Independent evidence is provided by King and Rebelo (1993), who show that a neoclassical growth model with endogenous savings rates has strong counterfactual implications, such as real interest rates above 100% in early stages of development.

[10] Preliminary estimation of the out-of-steady-state dynamics of the savings rate in the Ramsey model also resulted in unreasonable estimates of the coefficient of relative risk aversion and the discount rate.

IV. Alternative growth models

The extended MRW framework provides a means of assessing alternative growth models. In this section we consider the application of the framework to the Uzawa (1965) – Lucas (1988) two-sector growth model with human capital and to a version of the *AK* model with learning-by-doing. At this point these exercises are meant to be largely illustrative, as the models considered are quite simple.

The Uzawa-Lucas model

In our version of the Uzawa-Lucas model, we assume that production is given by

$$(4.1)\qquad Y_t = K_t^a (Ah_t L_t)^{1-a} (1-s_H)^{1-a}$$

In equation (4.1), h_t is human capital per worker at time t and $(1-s_H)$ is the share of worker time devoted to market production. The term A is a constant (i.e., it may vary by country but not over time). Long-run growth occurs in this model only through the accumulation of human capital. The human capital accumulation equation is

$$(4.2)\qquad \dot{h}_t = Bs_H h_t$$

where B measures the productivity of educational technology and s_H (as previously defined) is the share of time devoted to education by people of working age (the *SCHOOL* variable of MRW). Equation (4.1) reduces to equation (2.1) when $Z_t = A(1-s_H)h_t$ and $b = 0$. Since $\dot{Z}_t / Z_t = \dot{h}_t / h_t$, equation (4.2) is equivalent to equation (2.11) with $g(s_K, s_H ...) = Bs_H$.

Following the steps of the analysis of Section II, we obtain the pair of empirical equations for this model corresponding to equations (2.17) and (2.18) respectively:

(4.3) $$\ln(y_{it}) = \bar{z}_t + \frac{a}{1-a}\ln(s_{Ki}) - \frac{a}{1-a}\ln(n_i + g_i + d) + e_{it} + h_{it}$$

(4.4) $$\ln(y_{it}) - \ln(y_{i0}) = tBs_{Hi} + h_{it} - h_{i0}$$

where $e_{it} = e_{i0} + (g_i - \bar{g})t = e_{i0} + B(s_{Hi} - \bar{s}_H)t$. Thus, as expected, the term Bs_{Hi} appears in the expression for $\ln(y_{it})$. Note that (4.4) has no constant term. Both equations also appear likely to exhibit heteroscedasticity; that will be taken care of by our estimation procedure.

In principle, the Uzawa-Lucas model allows the rate of human capital formation and the saving rate in the steady state to be endogenous. To accommodate this endogeneity, we append the following two equations:

(4.5) $$s_{Ki} = \frac{a(n_i + g_i + d)}{(r + sg_i + d)} + n_{1i}$$

(4.6) $$s_{Hi} = \frac{1}{sB}(B + n_i - r) + n_{2i}$$

where v_{1i} and v_{2i} are error terms. Equation (4.5) is the same as the Ramsey expression for the optimal saving rate, eq. (3.5), and eq. (4.6) gives the optimal steady-state rate of human capital formation. We estimate this variant of the Uzawa-Lucas model in two ways: First, we estimate only equations (4.3) and (4.4.), effectively treating s_{Ki} and s_{Hi} as exogenous. Second, to allow for endogenous rates of saving and human capital formation, we estimate the system (4.3) – (4.6) simultaneously, making the substitution for the growth rate, eq. (3.6), in eqs. (4.3), (4.5), and (4.6). Again we have the problem that the error term is correlated with the regressors in eq. (4.3), and hence, for both exercises, we simply impose $a = 0.35$.[11]

Table VII shows the results of estimation for four samples of countries for the years 1960-1995. The top part of Table VII shows the results when the savings rates for physical and human capital are treated as exogenous and given, the bottom part allows these variable to be endogenously determined by the utility maximization problem of a representative agent. We find that the parameters $\bar{z}$ and B are tightly estimated, with similar values independent of whether savings rates are treated as exogenous or endogenous. However the estimated values of s and r, shown in the bottom part of Table VII, are found to be inadmissible (s is always estimated to be negative) or implausible. The negative estimates for s result from the fact that human capital investment rates and population growth rates are negatively correlated in the data, which is inconsistent with equation (4.6) unless $s < 0$. Again, the representative agent model does not seem to do very well in explaining cross-country variations in saving; future work should consider alternative models of saving, such as the life-cycle model (which focuses on demographics).

In order to assess goodness of fit, Table VII also shows the cross-sectional correlations of the endogenous variables of the model and their fitted values. In the top half of the table, the correlations of actual and fitted growth rates treat the saving rate and the rate of human capital formation as exogenous and given. More precisely, this correlation is just the correlation of the actual growth rate and $\hat{B}s_{Hi}$. In the bottom part of the table all three variables are treated as endogenous (the rate of population growth is thus the only exogenous source of cross-country variation). With saving rates exogenous, the correlation of actual and fitted growth under the Uzawa-Lucas model is 0.54 for the large non-oil sample and 0.43 for the

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[11] One is tempted to put Bs_{Hi} explicitly in the expression (4.3) and assume that that term is uncorrelated with e_{i0}, rendering the regression valid. A little reflection shows that this is unreasonable however. If the term $g_i = Bs_{Hi}$ were uncorrelated with e_{i0}, it would perforce by definition be correlated with every error term e_{ij}, $j = -\infty,...,-1,1,...,\infty$. But the start date of the sample is arbitrary; there is no reason to assume that the error term corresponding to the start date happens to have the unique property of being uncorrelated with the growth rate.

intermediate sample.[12] The correlations of actual and fitted growth are much lower for the other two country samples (-0.10 for the OECD sample and 0.19 for the Western hemisphere sample). For the OECD sample at least, there is probably not enough meaningful variation in measured schooling rates to explain differences in growth.

When saving and human capital formation are allowed to be endogenous (bottom part of Table VII), the results deteriorate markedly, as expected. Conditional on fitted rather than actual schooling rates, the correlation of fitted and actual growth rates are much lower for the two bigger samples (though higher for the OECD and Western hemisphere). The last two rows, which show the correlations of fitted and actual saving and schooling rates, make the point that (given the broad patterns in the data) the representative agent model appears unable to fit both variables simultaneously. In particular, the correlations of fitted and actual savings rates are negative, reflecting the poor fit of $\hat{g}$ and the negative estimates of s (see equation 4.5).

We conclude that, conditional on rates of human capital formation, the Uzawa-Lucas model does a reasonably good job of explaining growth for the non-oil and intermediate samples. However, an optimizing model that assumes that behavioral parameters are the same across countries does not do a good job of explaining cross-country differences in savings rates and rates of human capital formation. This latter finding is consistent with the relatively weak explanatory power of the Ramsey model, above, though at least in that case the correlations of actual and fitted values of saving rates were positive.

The AK model

Another standard growth model in the literature is the so-called *AK* model. One common rationalization of this model is Arrow's (1962) idea of learning-by-doing. Suppose that the production function of the economy is given by eq. (4.1), but that worker skills are proportional to the capital-labor ratio, i.e., $h_t = k_t$. Then the per-worker production function is simply

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[12] Note that these correlations are not comparable to the $\overline{R}^2$'s obtained in the MRW regressions, which take the level of output per capita rather than its growth rate as the dependent variable. By definition, the steady-state Solow model explains none of the cross-country growth variation examined here.

(4.7) $$y_t = \tilde{A}k_t$$

where $\tilde{A} = A^{1-a}$ is a country-specific constant. Along the BGP the growth rate of the capital-labor ratio and hence of output per worker is $s_K\tilde{A} - (n + d)$. Assume that $\tilde{A}_i = \overline{A}(1 + e_i)$ and $\ln(\overline{A}) = \overline{a}$, so that $\ln(\tilde{A}_i) = \overline{a} + e_i$, approximately. Then the two equations describing the BGP of this model are

(4.8) $$\ln(y_{it}) - \ln(k_{it}) = \overline{a} + e_i + h_{it}$$

(4.9) $$\begin{aligned}\ln(y_{it}) - \ln(y_{i0}) &= t(s_{Ki}\tilde{A}_i - (n_i + d)) + h_{it} - h_{i0} \\ &= t(s_{Ki}\overline{A} - (n_i + d)) + ts_{Ki}\overline{A}e_i + h_{it} - h_{i0}\end{aligned}$$

We estimated (4.8) and (4.9) simultaneously by SUR and then tested the restriction that $\ln(\overline{A}) = \overline{a}$. Here we treat the saving rate as exogenous.

The results are shown in Table VIII. As shown by the p-values in the penultimate row of the table, the over-identifying restriction of the model is strongly rejected.

As above, an alternative way to evaluate the *AK* model is to see how the growth rates it implies are correlated with observed growth rates. For each country we estimated $\tilde{A}_i$ as the output-capital ratio in 1995, then calculated the forecasted growth rate for that country as $\hat{g}_i = s_{Ki}\tilde{A}_i - (n_i + d)$. The correlations of this forecasted growth rate with the actual growth rate for the four country samples are shown in the last row of Table VIII. Reflecting the positive relationship of saving rates and growth rates, these correlations are rather high, ranging from 0.32 for the Western hemisphere sample to 0.67 for the large non-oil sample. We thus come to mixed conclusions about the *AK* model. On the one hand, the cross-equation restriction imposed by the model, relating the output-capital ratio and the sensitivity of growth to the saving rate, is strongly rejected by the data. On the other, the key prediction of the model that the saving rate (rate of capital accumulation) is important for explaining the *growth* as well as the *level* of per capita output seems to hold considerable validity. We find a similar result linking the saving rate and TFP growth below.

V. Estimates of labor's share

To this point we have assumed that all the economies in the sample lie on a balanced growth path. At best this can only be an approximation. First, economies are buffeted by a variety of major and minor shocks, as well as changes in institutions and policies; hence, even if our models are precisely correct, some component of observed economic growth must be accounted for by transition dynamics.[13] Second, we cannot take literally the prediction of many endogenous growth models that country growth rates may differ permanently, as that would imply counterfactually that the cross-sectional variance of real GDP per worker grows without bound. Although government policies and private-sector decisions may have highly persistent effects on growth (the prediction of endogenous growth models that we take most seriously), ultimately there must be forces (such as technology transfer from leaders to followers) that dampen the tendency toward divergence.

In the second part of their paper, MRW attempt to estimate directly the speed of convergence to the steady state and to relate their findings to the predictions of the Solow model. Although this exercise is an interesting one, measuring the speed of convergence is a difficult econometric problem, especially in the face of possible parameter heterogeneity and ongoing economic shocks. A more direct way to study the determinants of long-run growth, without having to take a stand on whether the world's economies are currently on a balanced growth path (or whether some are and some aren't), is to obtain country-by-country estimates of the growth of TFP. As is well known, if production is Cobb-Douglas[14] and factor markets are competitive[15], then TFP growth rates can be found by standard growth accounting methods, using factor shares to estimate the elasticities of output with respect to capital and labor. In this section we build on the

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[13] Much of macroeconomics is devoted to the study of these short-run dynamics around a steady state, otherwise known as business cycles.

[14] The Cobb-Douglas production function may also be viewed as a first-order approximation to more complicated production functions. Below we provide some evidence in favor of the Cobb-Douglas assumption.

[15] Some endogenous growth models assume monopolistic competition and payments to factors other than capital and labor. In practice, we expect that the empirical labor share will be a reasonable measure of the Cobb-Douglas coefficients applying to an agglomerate of raw labor and human capital.

work of Gollin (1998) to calculate labor shares for a sample of countries. Section VI reports the results of the associated growth accounting exercises.

Studies of labor's share have often found lower values in developing countries than in industrial countries (see, e.g., Elias, 1992). Taken at face value, this result suggests either that less developed countries operate different technologies than industrialized countries, or, perhaps that the constant-elasticity-of-substitution (CES) or other production function form is preferable to Cobb-Douglas. In an important paper, Douglas Gollin (1998) presents evidence against the conventional finding. Gollin's key insight is that published series on "employee compensation" may significantly understate total labor compensation, particularly in developing economies, because of the large share of income flowing to workers who are self-employed or employed outside the corporate sector.[16]

To try to capture the income of the latter group of workers, Gollin employs data from the United Nations System of National Accounts (see United Nations, *National Accounts Statistics*). Our Table IX shows the UN's method of breaking down the cost components of GDP. Income received by the self-employed and non-corporate employees is a component of the category Operating Surplus, Private Unincorporated Enterprises (OSPUE). Gollin considers two measures of labor's share which use data on OSPUE. For the first measure, he attributes all of OSPUE to labor earnings, so that labor's share becomes (corporate) employee compensation plus OSPUE, divided by GDP net of indirect taxes. For his second measure, he assumes that the share of labor income in OSPUE is the same as its share in the corporate sector. Specifically, this measure of the share of labor income can be written

$$(5.1) \qquad Labor\ \ share = \frac{Corporate\ employee\ compensation}{GDP - indirect\ \ taxes - OSPUE}$$

We view this second measure, which allows for the existence of non-corporate capital income, as more reasonable; we will refer to it as the *OSPUE measure*.

Gollin also considers a third measure of labor's share, which uses data on the ratio of corporate employees to the total labor force less unemployed, available in various issues of the International Labor

Organization's *Yearbook of Labor Statistics*. Specifically, he assumes that corporate and non-corporate workers receive the same average compensation, so that aggregate labor income can be calculated by scaling up corporate employee compensation by the ratio of the total labor force to the number of corporate employees. This measure, which we will refer to as the *labor force correction*, is defined by

$$\text{(5.2)} \qquad Labor\ share = \frac{Corporate\ employee\ compensation}{Corp.\ share\ of\ \ labor\ \ force * (GDP - indirect\ \ taxes)}$$

We have replicated and updated Gollin's calculations for the OSPUE measure and the labor force correction for our sample of countries. One problem that we noted in doing so is that OSPUE is reported for only about 20 countries; the majority of countries report only the total operating surplus of corporate enterprises and private unincorporated enterprises, that is, we have only the sum of OSPUE and corporate capital income.[17] To expand the number of countries for which labor shares could be calculated, we constructed an alternative measure of labor share that combines information about the corporate share of the labor force and the aggregate operating surplus. To do so, we assume that the corporate share of total private-sector income (both capital income and labor income) is the same as the share of the labor force employed in the corporate sector. Total private-sector income is calculated as the sum of the operating surplus and corporate employee compensation. We then compute "imputed OSPUE" as the share of non-corporate employees in the labor force times private-sector income. Using the imputed value of OSPUE we then estimate labor's share using equation (5.1), with imputed OSPUE in place of actual OSPUE.

Table X reports a variety of data for the 53 countries in our sample for which either 1) OSPUE is available or 2) the share of corporate employees in the labor force is at least half, or both. We impose the second requirement because we found that, for countries with very low corporate employment shares (for some, this share is below 0.10), the calculated labor shares are often unreasonable (e.g., they may exceed

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[16] Gollin also examines the possibility that differences in sectoral composition might explain cross-country differences in labor share. However, he does not find this factor to be important.

[17] The operating surplus of government enterprises is also included in Operating Surplus. As our data set does not include economies in which the government controls a large share of enterprises, this component can safely be ignored.

one). This result is not unexpected, for two reasons: First, countries with large informal sectors are likely to have relatively poor economic statistics, all else equal. Second, our estimates which use the labor force correction scale up corporate employee compensation by the inverse of the corporate employee share of the labor force. When the corporate employee share is both small and measured with error, estimates based on the inverse of the share will be highly unreliable. We found, on the other hand, that when the corporate employee share exceeds 0.5 or 0.6, the estimated labor shares that result are both reasonable in magnitude and tend to agree closely with alternative measures. All of the analyses reported below use both 0.5 as the cutoff for the corporate employee share of the labor force; results for samples based on a 0.6 cutoff are essentially identical.

In Table X the second column gives the share of the country's labor force employed in the corporate sector. Columns 3 through 6 give four alternative measures of labor's share for each country. Column 3, the "naïve" calculation, is corporate employee compensation divided by GDP net of indirect taxes. As emphasized by Gollin, this estimate is likely to be too low, because it ignores the income of non-corporate employees. We include it for reference and comparison to other measures.

Columns 4-6 give our three primary measures of labor's share. Column 4 shows Gollin's *OSPUE measure*, Column 5 our *imputed OSPUE measure*, and Column 6 the measure based solely on the *labor force correction*. Columns 2-6 are based on averaged data for the period 1980-1995, or for a period as close to 1980-1995 as possible. We also calculated country-by-country time series for the labor share (not shown). For comparison, Columns 7-10 show estimates from previous studies, as reported in Barro and Sala-i-Martin (1999, Table 10.8, pp. 380-81). The year ranges at the head of columns 7-10 correspond to the timing of the data used by the previous studies.

We find the results of this exercise encouraging. As Table X shows, when alternative measures of labor's share exist, they tend to agree closely, especially when the corporate employee share is greater than 0.6 or so. Two additional findings tend to support Gollin's (1998) conclusion that the Cobb-Douglas assumption of stable income shares is a good one: First, we find no systematic tendency for country labor shares to vary with real GDP per capita or the capital-labor ratio. Indeed, most estimated labor shares lie between 0.6 and 0.8, and the average value of the labor share is 0.65, similar to that observed in the United

States and other industrialized countries.[18] Second, the time series of labor shares by country tend to be quite stable, with no systematic tendency to rise or fall over time.

The comparison of our calculated labor shares to previous studies suggests that the earlier studies took insufficient account of non-corporate employee income (note how close the results of several of the earlier studies are to the "naïve" calculation of labor share, column 3). The exception is the careful work of Young (1995), who obtains numbers similar to ours for Hong Kong and Korea, though a smaller value for Singapore.

VI. The determinants of TFP growth

In this section we describe our calculations of TFP growth for our sample of countries and report results of regressions of TFP growth on country characteristics. Again, the advantage of looking directly at TFP growth is that it avoids the need to take a stand on whether countries are on a balanced growth path or in transition to a BGP.

The labor shares (and by implication, the capital shares) shown in Table VI are an important input to the calculation of TFP growth. We have output growth from the PWT 6.0 data. The two remaining required inputs to a growth accounting exercise are measures of capital stock growth and labor force growth.

PWT version 5.6 provides data on capital stocks for a subset of countries, but our pre-release version of PWT 6.0 does not yet have capital stock data. We estimate capital stocks from available PWT 6.0 data by a perpetual inventory calculation. Here (in contrast to our replication of the MRW results) we assume a depreciation rate of 6%, following Hall and Jones (1999).[19] Initial capital stocks are found by the assumption that capital and output grow at the same rate. Specifically, for countries with investment data beginning in 1950 we set the initial capital stock $K_{1949} = I_{1950}/(g+d)$ where g is the ten-year growth rate of output (e.g., from 1950 to 1960) and d (= 0.06) is the assumed rate of depreciation. We have

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[18] In the next section, we set the labor share for each country equal to the OSPUE measure, if available; to the imputed OSPUE measure, if OSPUE is unavailable; and finally to the labor force correction measure if neither OSPUE measure is available. The average labor share derived from this procedure is precisely 0.65.

[19] We get similar results if we assume 3% depreciation or if we use PWT version 5.6 instead.

investment data starting from 1950 for 50 countries, from 1955 for 14 countries, and from 1960 for 26 countries.

The calculated capital stocks include both residential and nonresidential capital. PWT 5.6 provides data on residential capital per worker as a fraction of non-residential capital per worker for 63 countries. For these countries we use the average ratio of non-residential capital to total capital to impute non-residential capital stocks in the PWT 6.0 data set. For other countries we assume that residential capital is one-third of the total, about the average value for the countries on which we have data.

Labor force growth unadjusted for quality (that is, assuming a zero return to schooling) is calculated as the rate of growth of the working-age population, as in Section III. We also compute alternative quality-adjusted measures, as follows: We use the most recent Barro-Lee (2000) data on educational achievement to give higher weight to more educated workers, assuming social returns to education of 7% per year (results are not sensitive to alternative assumptions). A similar method was employed by Collins and Bosworth (1996) and by Klenow and Rodriguez-Clare (1997). TFP growth rates (reported in the Appendix) are then found by the standard growth accounting calculation. The Appendix to the working paper version of this paper gives our estimated TFP growth rates under alternative assumptions and for different subsamples.

With average TFP growth rates by country in hand, we can ask whether these growth rates are independent of variables such as the saving rate, schooling rate, or labor force growth rate, as the Solow model would predict. As Table XI shows, the answer is a strong “no”. The top portion of Table XI shows regression results for the sample of about 50 countries for which we have calculated labor shares (see footnote 10). The bottom half of Table XI uses calculated TFP growth rates under the assumption that labor’s share is a fixed 0.65 in each country, an assumption which we believe to be reasonable in light of our labor share estimates above. The advantage of this assumption is that it allows us to expand the sample to 80 countries or more. Note that in either case we are focusing on long-run averages, so that cyclical influences should be minimal.

Table XI shows that, whether we include a human capital correction or not, and independent of the combination of variates included in the regression, TFP growth is cross-sectionally strongly related (in both the economic and statistical senses) to the saving rate and, in most cases, to the growth rate of the labor force. TFP growth rates also tend to be related to schooling rates, but when both the saving rate and the schooling rate are included in the regression the coefficient on the schooling rate tends to become statistically insignificant. Further, as might be expected, when the labor force is adjusted for human capital accumulation, the effect of the schooling variable is reduced.

Table XII repeats the analysis of Table XI for the 1980-1995 sub-period. The data for this sub-period are probably more reliable (we don't need to worry about whether our estimated initial capital stocks are reasonable, for example), it agrees more closely with the period for which we estimated labor shares, and in any case it is interesting to know if the results hold in shorter periods. If anything, the rejection of the Solow prediction seems stronger in the second half of the sample, with saving rates and workforce growth entering with high economic and statistical significance.

Visual inspection of the data is useful to reassure ourselves self that the results are not being driven by a few outliers. Figures 1-6 show scatter plots of the bivariate relationships between TFP growth and each of the three variates: s_K, s_H, and n. To conserve space, we show results only for the larger sample in which we have imposed a fixed labor share of 0.65; the results for the smaller sample with directly estimated labor shares are quite similar, as the reader can verify from the regression results reported in Tables XI and XII. Figures 1-3 show the results without a quality adjustment for the labor force, Figures 4-6 adjust labor force quality by assuming a 7% return to a year of schooling. As suggested by the regression results, the weakest relationship is between TFP growth and schooling, especially when the human capital correction is used (as expected). However, the relationship of TFP growth to both saving rates and workforce growth rates seems to be quite robust. It is difficult to account for these results by appealing to measurement error: For example, if saving rates are mismeasured, the resulting mis-estimation of the capital stock should tend to induce a negative relationship between TFP growth and the saving rate, rather than the positive relationship we observe.

VII. Conclusion

We have re-visited Mankiw, Romer, and Weil's classic empirical study of the Solow model of economic growth. We showed that the MRW framework applies broadly to almost any economic growth model that admits a balanced growth path, and that the restrictions specifically imposed by the Solow model tend to be rejected. In particular, we find that variables such as the saving rate seem to be strongly correlated with long-run growth rates. The correlation of variables like the saving rate with long-run output growth rates is inconsistent with the joint hypothesis that the Solow model is true and the economies being studied are in their respective steady states. The finding that the saving rate and the growth rate of the labor force are correlated with estimated TFP growth is inconsistent with the standard Solow model, even if we do not assume steady states.

We also use the MRW framework to consider some alternative models of economic growth, such as the Uzawa-Lucas model and the *AK* model. These models are rejected as literal descriptions of the data. However, the implications of these models, that country growth rates depend on behavioral variables such as the rate of human capital formation and the saving rate, seem more consistent with the data than the Solow model's assumption that growth is exogenous. Future research should consider variants of endogenous growth models to see which if any provide a more complete and consistent description of the cross-country data. We believe that the generalized MRW-type framework we have developed here could prove very helpful in assessing the alternative possibilities.

TABLE I: Estimation of the textbook Solow model for 3 alternative vintages of the PWT data set

Dependent variable: Log GDP per working-age person in 1985

Data set:	PWT 4.0			PWT 5.6			PWT 6.0		
Sample	Non Oil	Intermediate	OECD	Non Oil	Intermediate	OECD	Non Oil	Intermediate	OECD
Observations	98	75	22	96	75	22	90	72	21
Constant	5.62	5.47	7.99	4.44	4.74	8.66	5.06	5.23	9.10
	(1.56)	(1.52)	(2.46)	(1.35)	(1.39)	(2.49)	(1.35)	(1.46)	(2.48)
ln (*I/GDP*)	1.43	1.32	0.50	0.97	1.02	0.61	0.88	0.93	0.36
	(0.14)	(0.17)	(0.43)	(0.09)	(0.13)	(0.53)	(0.09)	(0.14)	(0.37)
ln $(n+g+d)$	-1.92	-1.97	-0.75	-2.25	-2.19	-0.66	-2.14	-2.13	-0.53
	(0.55)	(0.53)	(0.83)	(0.49)	(0.49)	(0.82)	(0.49)	(0.51)	(0.79)
$\overline{R}^2$	0.59	0.59	0.02	0.64	0.62	0.00	0.62	0.56	0.01
Restricted regression									
Constant	6.87	7.10	8.61	7.74	7.71	8.76	8.31	8.25	9.52
	(0.12)	(0.15)	(0.53)	(0.08)	(0.11)	(0.60)	(0.08)	(0.12)	(0.37)
ln (*I/GDP*)- ln $(n+g+d)$	1.49	1.43	0.56	1.07	1.16	0.63	0.98	1.09	0.40
	(0.12)	(0.14)	(0.36)	(0.08)	(0.11)	(0.41)	(0.09)	(0.12)	(0.26)
$\overline{R}^2$	0.59	0.59	0.06	0.63	0.60	0.06	0.60	0.54	0.06
Test of restriction									
p value	0.42	0.29	0.80	0.02	0.04	0.97	0.02	0.04	0.86
Implied a	0.60	0.59	0.36	0.52	0.54	0.39	0.49	0.52	0.29
	(0.02)	(0.02)	(0.15)	(0.02)	(0.02)	(0.15)	(0.02)	(0.03)	(0.14)

Notes: Standard errors are reported immediately below parameter estimates. The investment and population growth rates are averaged over the period 1960-1985. $(g + d)$ is assumed to be 0.05.

TABLE II: Estimation of the textbook Solow model for more recent sample periods

Dependent variable: Log GDP per working-age person in:

	1990			1995		
Data set:	PWT 5.6			PWT 6.0		
Sample	Non Oil	Intermediate	OECD	Non Oil	Intermediate	OECD
Observations	85	70	22	90	72	21
Constant	3.59	3.62	7.96	4.16	4.58	7.79
	(1.37)	(1.36)	(2.20)	(1.38)	(1.44)	(2.37)
ln (I/GDP)	0.94	0.95	0.65	1.07	1.11	0.38
	(0.10)	(0.13)	(0.47)	(0.10)	(0.14)	(0.37)
ln ($n+g+d$)	-2.59	-2.60	-0.97	-2.66	-2.54	-1.07
	(0.49)	(0.47)	(0.73)	(0.49)	(0.50)	(0.75)
$\overline{R}^2$	0.67	0.66	0.09	0.68	0.65	0.12
Restricted regression						
Constant	7.84	7.79	8.72	8.24	8.19	9.48
	(0.09)	(0.12)	(0.55)	(0.08)	(0.12)	(0.37)
ln(I/GDP)-ln($n+g+d$)	1.09	1.19	0.74	1.22	1.32	0.57
	(0.09)	(0.11)	(0.37)	(0.09)	(0.12)	(0.27)
$\overline{R}^2$	0.63	0.62	0.13	0.66	0.63	0.14
Test of restriction						
p value	0.00	0.00	0.72	0.00	0.01	0.48
Implied a	0.52	0.54	0.43	0.55	0.57	0.36
	(0.02)	(0.02)	(0.12)	(0.02)	(0.02)	(0.11)

Notes: Standard errors are reported immediately below parameter estimates. The investment and population growth rates are averaged over the periods 1960-1990 or 1960-1995, depending on the sample. ($g + d$) is assumed to be 0.05.

TABLE III: Estimation of the augmented Solow model for 3 alternative vintages of the PWT data set

Dependent variable: Log GDP per working-age person in 1985

Data set:	PWT 4.0			PWT 5.6			PWT 6.0		
Sample	Non Oil	Intermediate	OECD	Non Oil	Intermediate	OECD	Non Oil	Intermediate	OECD
Observations	98	75	22	96	75	22	90	72	21
Constant	6.98	7.87	8.67	6.80	7.94	10.84	6.71	8.38	10.29
	(1.15)	(1.17)	(2.17)	(1.06)	(1.15)	(1.91)	(1.09)	(1.12)	(1.93)
ln (*I/GDP*)	0.70	0.71	0.28	0.45	0.51	0.19	0.42	0.51	-0.01
	(0.13)	(0.15)	(0.39)	(0.09)	(0.12)	(0.41)	(0.10)	(0.11)	(0.30)
ln ($n+g+d$)	-1.71	-1.48	-1.06	-1.69	-1.43	-0.67	-1.82	-1.42	-0.78
	(0.41)	(0.40)	(0.74)	(0.38)	(0.39)	(0.60)	(0.39)	(0.38)	(0.61)
ln (*SCHOOL*)	0.66	0.73	0.75	0.61	0.72	1.17	0.56	0.71	1.01
	(0.07)	(0.10)	(0.29)	(0.07)	(0.10)	(0.28)	(0.08)	(0.09)	(0.27)
$\bar{R}^2$	0.78	0.77	0.24	0.80	0.78	0.46	0.76	0.77	0.42
Restricted regression Constant	7.86	7.97	8.71	8.45	8.44	9.20	8.91	8.89	9.73
	(0.14)	(0.15)	(0.47)	(0.10)	(0.13)	(0.47)	(0.10)	(0.11)	(0.29)
ln (*I/GDP*) – ln($n+g+d$)	0.74	0.71	0.29	0.48	0.52	0.00	0.46	0.53	-0.06
	0.12	0.14	0.33	0.09	0.12	0.34	(0.10)	(0.11)	(0.24)
Ln (*SCHOOL*) – ln ($n+g+d$)	0.66	0.73	0.76	0.63	0.73	1.11	0.58	0.72	1.00
	0.07	0.09	0.28	0.07	0.09	0.28	(0.08)	(0.08)	(0.26)
$\bar{R}^2$	0.78	0.77	0.28	0.79	0.78	0.47	0.75	0.77	0.45
Test of restriction p value	0.45	0.93	0.98	0.12	0.66	0.39	0.05	0.65	0.77
Implied a	0.31	0.29	0.14	0.23	0.23	0.00	0.23	0.24	-0.03
	(0.04)	(0.05)	(0.15)	(0.04)	(0.05)	(0.16)	(0.04)	(0.04)	(0.12)
Implied b	0.28	0.30	0.37	0.30	0.32	0.53	0.28	0.32	0.52
	(0.03)	(0.04)	(0.12)	(0.03)	(0.04)	(0.13)	(0.04)	(0.04)	(0.11)

Notes: Standard errors are reported immediately below parameter estimates. The investment and population growth rates are averaged over the period 1960-1985. ($g + d$) is assumed to be 0.05. *SCHOOL* is the average percentage of the working-age population in secondary school for the period 1960-1985.

TABLE IV: Estimation of the augmented Solow model for more recent sample periods

Dependent variable: Log GDP per working-age person in:

Data set:	1990 PWT 5.6			1995 PWT 6.0		
Sample	Non Oil	Intermediate	OECD	Non Oil	Intermediate	OECD
Observations	85	70	22	90	72	21
Constant	5.42	6.50	10.03	5.81	7.92	9.48
	(1.09)	(1.23)	(1.89)	(1.12)	(1.07)	(1.98)
ln (*I/GDP*)	0.41	0.52	0.30	0.54	0.60	0.08
	(0.10)	(0.13)	(0.39)	(0.11)	(0.12)	(0.31)
$\ln(n+g+d)$	-2.24	-1.97	-0.90	-2.35	-1.81	-1.19
	(0.38)	(0.40)	(0.59)	(0.39)	(0.36)	(0.60)
ln (*SCHOOL*)	0.65	0.72	1.00	0.65	0.85	1.06
	(0.09)	(0.13)	(0.30)	(0.09)	(0.10)	(0.32)
$\bar{R}^2$	0.80	0.77	0.40	0.80	0.83	0.43
Restricted regression						
Constant	8.50	8.42	9.08	8.84	8.85	9.61
	(0.11)	(0.13)	(0.46)	(0.10)	(0.10)	(0.30)
ln (I/*GDP*) – $\ln(n+g+d)$	0.48	0.57	0.20	0.62	0.64	0.09
	(0.11)	(0.13)	(0.34)	(0.11)	(0.11)	(0.25)
ln(*SCHOOL*) – $\ln(n+g+d)$	0.69	0.79	0.96	0.68	0.88	1.06
	(0.09)	(0.12)	(0.28)	(0.09)	(0.09)	(0.30)
$\bar{R}^2$	0.78	0.76	0.42	0.79	0.83	0.46
Test of restriction p value	0.01	0.12	0.61	0.01	0.39	0.95
Implied a	0.22	0.24	0.09	0.27	0.25	0.04
	(0.05)	(0.05)	(0.15)	(0.04)	(0.04)	(0.12)
Implied b	0.32	0.33	0.44	0.30	0.35	0.49
	(0.04)	(0.05)	(0.12)	(0.04)	(0.04)	(0.11)

Notes: Standard errors are reported immediately below parameter estimates. The investment and population growth rates are averaged over the periods 1960-1990 or 1960-1995, depending on the sample. $(g + d)$ is assumed to be 0.05. *SCHOOL* is the average percentage of the working-age population in secondary school for the relevant sample period.

TABLE V: Test of exogeneity of growth in the Solow model

Dependent variable: Change in log GDP per working-age person, 1960-1995

	Textbook Solow model				Augmented Solow model			
Sample	Non Oil	Intermediate	OECD	Western	Non Oil	Intermediate	OECD	Western
Observations	90	72	21	22	90	72	21	22
Constant	-0.01	0.00	0.02	0.02	-0.01	-0.01	0.02	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
I/GDP	0.14	0.14	0.06	0.06	0.12	0.12	0.07	0.05
	(0.02)	(0.02)	(0.04)	(0.04)	(0.02)	(0.02)	(0.04)	(0.04)
SCHOOL	-0.01	-0.04	-0.02	-0.08	0.07	0.05	-0.12	-0.05
	(0.05)	(0.05)	(0.10)	(0.10)	(0.05)	(0.05)	(0.10)	(0.11)
n	0.00	-0.03	-0.40	-0.36	0.03	0.03	-0.38	-0.31
	(0.15)	(0.15)	(0.28)	(0.26)	(0.15)	(0.15)	(0.28)	(0.27)
$\chi^2(3)$	80.41	54.57	6.84	3.48	79.68	53.13	8.03	2.90
p	0.00	0.00	0.08	0.32	0.00	0.00	0.05	0.41

Notes: SUR estimation of two-equation system of the form of equations (3.1) and (3.2), with coefficients of (3.1) unconstrained. The table shows the results of the estimation of equation (3.2). The final two rows report a test of the prediction of the model that variables other than the constant should be excluded from (3.2). A small value of p implies rejection of the joint hypothesis that the economies are in a steady state and growth is exogenous.

TABLE VI: Estimates of the Ramsey model

Sample	Non Oil	Intermediate	OECD	Western
Observations	90	72	21	22
$\bar{z}$	8.54	8.73	9.56	8.81
	(0.09)	(0.10)	(0.06)	(0.11)
s	-0.17	0.16	0.08	0.75
	(0.41)	(0.40)	(0.51)	(1.35)
r	0.13	0.11	0.07	0.12
	(0.01)	(0.01)	(0.01)	(0.02)
corr(s_k , $\hat{s}_k$)	0.49	0.33	0.14	0.15

Notes: SUR estimation of two-equation system (3.3) and (3.5), with $a = 0.35$ assumed in both equations. The last row shows the simple correlation of actual and fitted saving rates across countries.

TABLE VII: Estimates of the Uzawa-Lucas model

Sample	Non Oil	Intermediate	OECD	Western
Observations	90	72	21	22
s_k, s_h *exogenous*				
$\bar{z}$	8.53	8.73	9.57	8.79
	(0.09)	(0.10)	(0.06)	(0.11)
B	0.21	0.23	0.25	0.15
	(0.02)	(0.02)	(0.02)	(0.02)
corr($g, \hat{g}$)	0.54	0.43	-0.10	0.19
s_k, s_h *endogenous*				
$\bar{z}$	8.27	8.39	9.61	8.75
	(0.07)	(0.08)	(0.06)	(0.10)
B	0.23	0.24	0.26	0.14
	(0.01)	(0.02)	(0.02)	(0.01)
s	-4.16	-4.57	-13.89	-5.71
	(0.40)	(0.48)	(2.60)	(1.16)
r	0.31	0.33	0.64	0.23
	(0.02)	(0.03)	(0.11)	(0.03)
corr($g, \hat{g}$)	0.25	0.27	0.39	0.22
corr($s_K, \hat{s}_K$)	-0.38	-0.42	-0.34	-0.04
corr($s_H, \hat{s}_H$)	0.36	0.43	0.03	0.53

Notes: Results are derived from SUR estimation of equations (4.3) and (4.4) in the top panel, and (4.3)-(4.6) in the bottom panel, imposing a value of 0.35 for a in all equations.

TABLE VIII: Estimates of the *AK* model

Sample	Non Oil	Intermediate	OECD	Western
Observations	90	72	21	22
$\overline{a}$	-0.08	-0.20	-0.55	-0.08
	(0.06)	(0.06)	(0.06)	(0.10)
$\overline{A}$	0.40	0.37	0.27	0.42
	(0.02)	(0.02)	(0.01)	(0.03)
$c^2(1)$	376.68	341.13	393.42	115.85
p	0.00	0.00	0.00	0.00
corr($g, \hat{g}$)	0.67	0.63	0.47	0.32

Notes: Results are derived from SUR estimation of equations (4.8) and (4.9). The tested restriction is that $\ln(\overline{A}) = \overline{a}$.

TABLE IX. Cost components of GDP

Indirect taxes, net
- Indirect taxes
- Less: Subsidies

Consumption of fixed capital

Compensation of employees by resident producers
- Resident households
- Nonresidents

Operating surplus
- Corporate and quasi-corporate enterprises
- Private unincorporated enterprises
- General government

Statistical discrepancy

Equals **Gross Domestic Product**

Source: UN *National Accounts Statistics*

TABLE X: Alternative measures of labor’s share

COUNTRY		---EST.	LABOR	SHARES	------				
			Actual	Imputed		1947-73	1960-90	1940-80	1966-90
	Employee/LF	Naïve	OSPUE	OSPUE	LF	CCJ	Dough’y	Elias	Young
Algeria	0.74	0.47		0.61	0.63				
Australia	0.84	0.57	0.68	0.66	0.68				
Austria	0.86	0.61		0.70	0.71				
Belgium	0.82	0.60	0.74	0.71	0.73				
Bolivia	0.55	0.37			0.67				
Botswana	0.45	0.39	0.45						
Burundi	0.06	0.22	0.75						
Canada	0.91	0.62		0.68	0.69	0.56	0.55		
Chile	0.68	0.42		0.59	0.62			0.48	
Colombia	0.68	0.45			0.65			0.37	
Congo	NA	0.38	0.47						
Costa Rica	0.72	0.54		0.73	0.74				
Denmark	0.89	0.64		0.71	0.72				
Ecuador	0.56	0.25			0.45				
Egypt	0.56	0.43			0.77				
El Salvador	0.60	0.35			0.58				
Finland	0.85	0.62	0.71	0.71	0.73				
France	0.85	0.61	0.74	0.71	0.73	0.60	0.58		
Germany, W	0.89	0.63		0.69	0.71	0.61	0.60		
Greece	0.52	0.45		0.79	0.86				
Hong Kong	0.88	0.51			0.57				0.63
Ireland	0.77	0.58		0.73	0.75				
Israel	0.80	0.59		0.70	0.73				
Italy	0.72	0.49	0.71	0.65	0.69	0.61	0.62		
Ivory Coast	0.11	0.43	0.68						
Jamaica	0.60	0.53	0.60						
Japan	0.76	0.59	0.68	0.73	0.77	0.61	0.58		
Jordan	0.67	0.45		0.64	0.67				
Korea, Rep	0.56	0.48	0.65						0.68
Malaysia	0.64	0.43			0.66				
Mauritius	0.85	0.48			0.57				
Mexico	0.59	0.34		0.55	0.59			0.31	
Morocco	0.63	0.36			0.58				
Netherlands	0.88	0.59	0.67	0.66	0.67	0.55			
New Zealand	0.80	0.55		0.67	0.69				
Norway	0.89	0.55		0.61	0.63				
Panama	0.65	0.50		0.73	0.76				
Paraguay	0.62	0.32		0.49	0.52				
Peru	0.53	0.31		0.56	0.59			0.34	
Philippines	0.44	0.27	0.59						
Portugal	0.71	0.52	0.72	0.71	0.73				
Singapore	0.85	0.47		0.53	0.55				0.47
S. Africa	0.94	0.59		0.62	0.63				

Spain	0.73	0.52		0.67	0.70			
Sri Lanka	0.62	0.50		0.78	0.81			
Sweden	0.91	0.68	0.77	0.74	0.75			
Switzerland	0.85	0.66		0.76	0.78			
Trin & Tobago	0.77	0.55		0.69	0.71			
Tunisia	0.66	0.41			0.62			
UK	0.89	0.65	0.75	0.72	0.74	0.62	0.61	
USA	0.91	0.65	0.74	0.71	0.71	0.60	0.59	
Uruguay	0.74	0.43		0.58	0.59			
Venezuela	0.68	0.38		0.53	0.55			0.45
Zambia	0.62	0.48		0.72	0.78			

Sources: Authors' calculations. Studies corresponding to the final four columns are Christensen, Cummings, and Jorgenson (1980); Elias (1992); Dougherty (1991); and Young (1995).

TABLE XI. Determinants of TFP growth, 1965-1995

	No returns to education							7% returns to education						
Dependent variable: Average growth rate of TFP, 1965-1995														
Actual labor shares *53 countries*								*50 countries*						
Constant	0.00	0.00	0.02	-0.01	0.00	0.01	0.00	-0.01	-0.01	0.02	-0.01	0.00	0.01	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
s_K	0.08			0.06	0.06		0.05	0.07			0.07	0.05		0.05
	(0.01)			(0.02)	(0.02)		(0.02)	(0.02)			(0.02)	(0.02)		(0.02)
s_H		0.15		0.07		0.10	0.05		0.14		0.06		0.08	0.03
		(0.05)		(0.05)		(0.04)	(0.04)		(0.06)		(0.06)		(0.06)	(0.05)
n			-0.44		-0.29	-0.36	-0.27			-0.45		-0.32	-0.41	-0.31
			(0.10)		(0.10)	(0.11)	(0.10)			(0.11)		(0.10)	(0.11)	(0.11)
$\bar{R}^2$	0.33	0.16	0.25	0.34	0.41	0.31	0.41	0.28	0.08	0.26	0.28	0.39	0.27	0.38
Labor share=0.65 *90 countries*								*81 countries*						
Constant	-0.01	-0.01	0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	-0.02	-0.01	0.00	-0.01
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
s_K	0.11			0.09	0.11		0.09	0.10			0.09	0.10		0.09
	(0.01)			(0.02)	(0.01)		(0.02)	(0.01)			(0.02)	(0.01)		(0.02)
s_H		0.21		0.07		0.20	0.07		0.17		0.05		0.15	0.04
		(0.03)		(0.04)		(0.03)	(0.04)		(0.03)		(0.04)		(0.04)	(0.04)
n			-0.37		-0.03	-0.10	0.01			-0.38		-0.10	-0.19	-0.08
			(0.14)		(0.11)	(0.13)	(0.11)			(0.13)		(0.11)	(0.13)	(0.11)
$\bar{R}^2$	0.49	0.32	0.06	0.50	0.48	0.32	0.50	0.43	0.22	0.09	0.44	0.43	0.23	0.43

TABLE XII. Determinants of TFP growth, 1980-1995

	No returns to education							**7% returns to education**						
Dependent variable: Average growth rate of TFP, 1980-1995														
Actual labor shares														
53 countries								*50 countries*						
Constant	-0.01	-0.01	0.02	-0.02	0.00	0.01	0.00	-0.02	0.00	0.02	-0.02	0.00	0.01	0.00
	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
s_K	0.10			0.10	0.07		0.07	0.10			0.10	0.07		0.06
	(0.02)			(0.02)	(0.02)		(0.02)	(0.02)			(0.02)	(0.02)		(0.02)
s_H		0.14		0.05		0.10	0.05		0.06		0.01		0.05	0.02
		(0.06)		(0.06)		(0.05)	(0.05)		(0.08)		(0.07)		(0.06)	(0.06)
n			-0.69		-0.50	-0.65	-0.50			-0.69		-0.55	-0.69	-0.55
			(0.13)		(0.13)	(0.13)	(0.13)			(0.13)		(0.13)	(0.13)	(0.13)
$\overline{R}^2$	0.32	0.07	0.35	0.32	0.48	0.38	0.48	0.25	-0.01	0.35	0.24	0.45	0.35	0.44
Labor share=0.65														
90 countries								*81 countries*						
Constant	-0.02	-0.01	0.01	-0.02	-0.01	0.00	-0.01	-0.02	-0.01	0.01	-0.02	-0.01	0.00	-0.01
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
s_K	0.13			0.12	0.11		0.10	0.11			0.11	0.10		0.10
	(0.02)			(0.02)	(0.02)		(0.02)	(0.02)			(0.02)	(0.02)		(0.02)
s_H		0.17		0.04		0.14	0.03		0.13		0.01		0.09	0.00
		(0.04)		(0.04)		(0.04)	(0.04)		(0.05)		(0.05)		(0.04)	(0.05)
n			-0.59		-0.24	-0.45	-0.24			-0.59		-0.32	-0.51	-0.32
			(0.16)		(0.15)	(0.15)	(0.15)			(0.15)		(0.15)	(0.15)	(0.15)
$\overline{R}^2$	0.36	0.16	0.13	0.36	0.37	0.22	0.37	0.30	0.08	0.15	0.29	0.33	0.18	0.32

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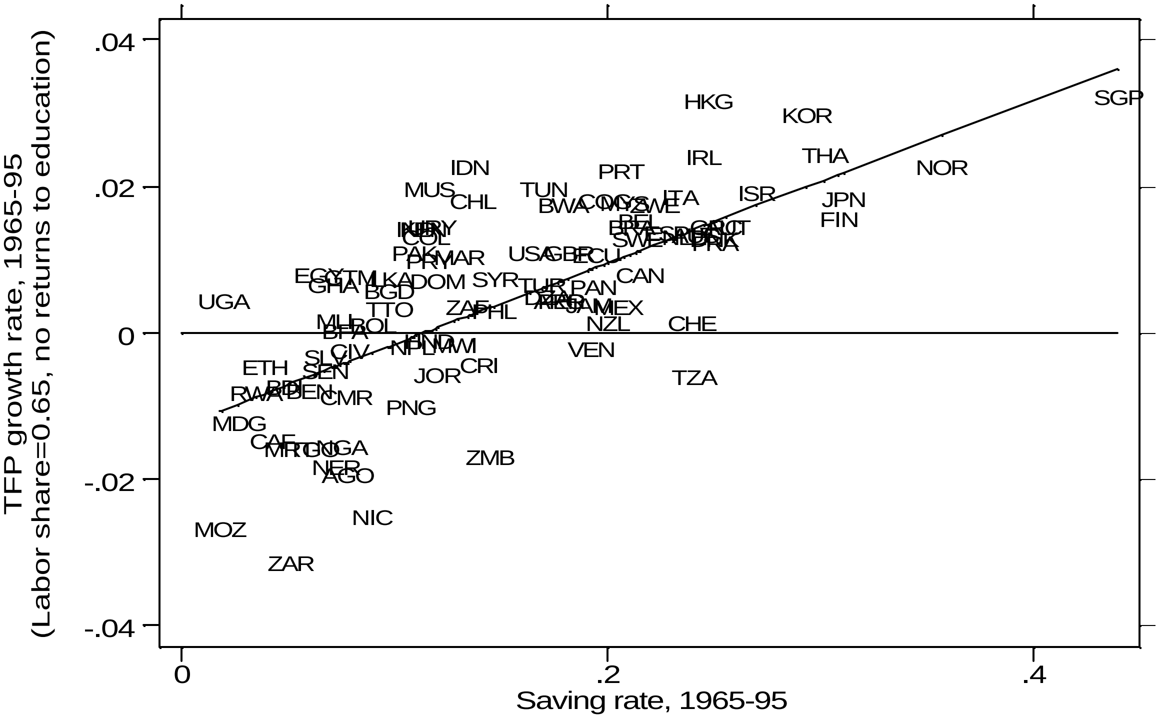

Figure 1: Relation of TFP growth to saving rate

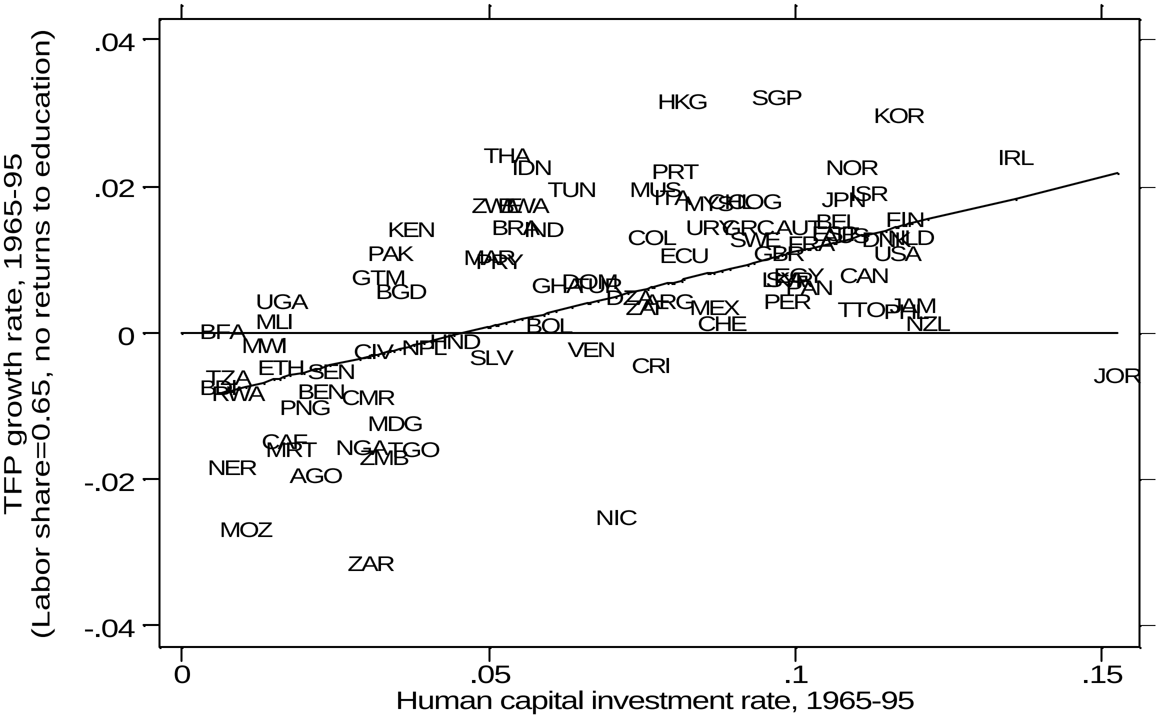

Figure 2: Relation of TFP growth to schooling rate

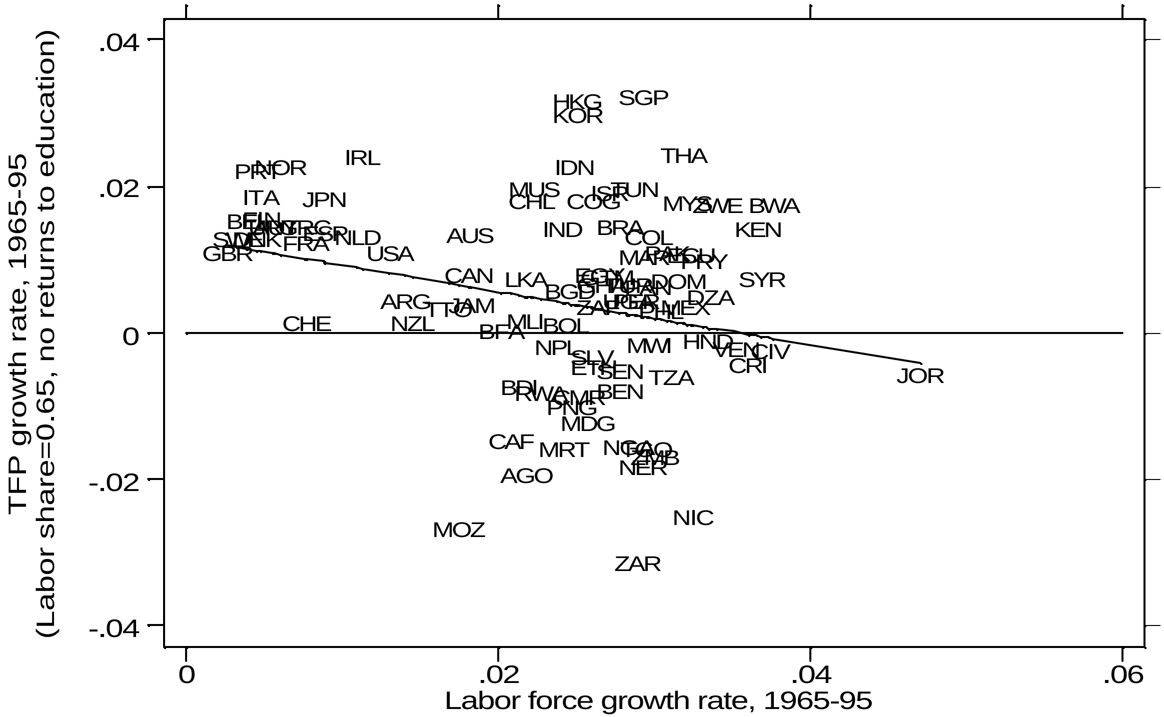

Figure 3: Relation of TFP growth to labor force growth rate

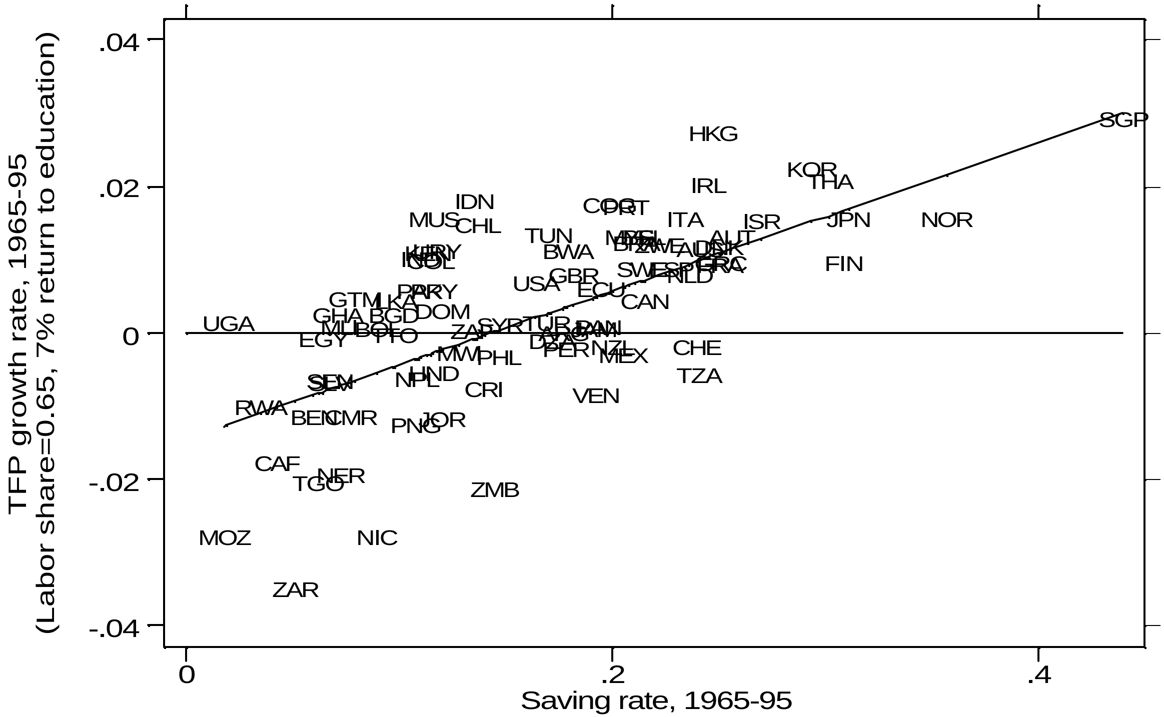

Figure 4: Relation of TFP growth to saving rate

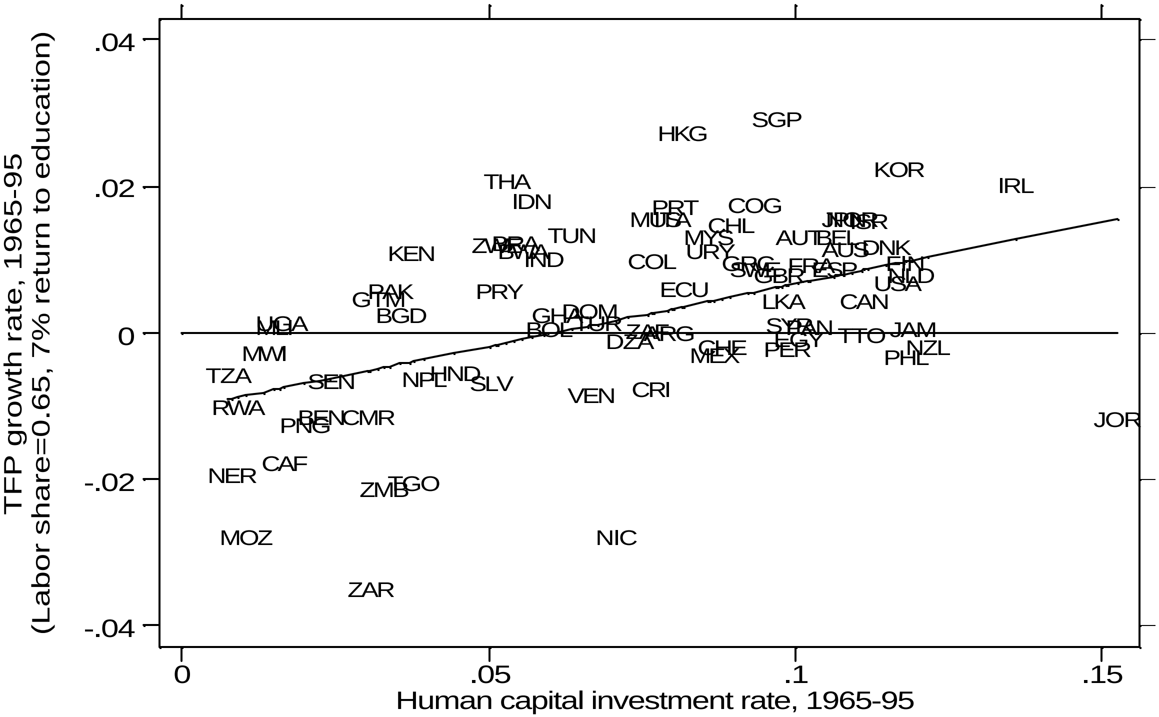

Figure 5: Relation of TFP growth to schooling rate

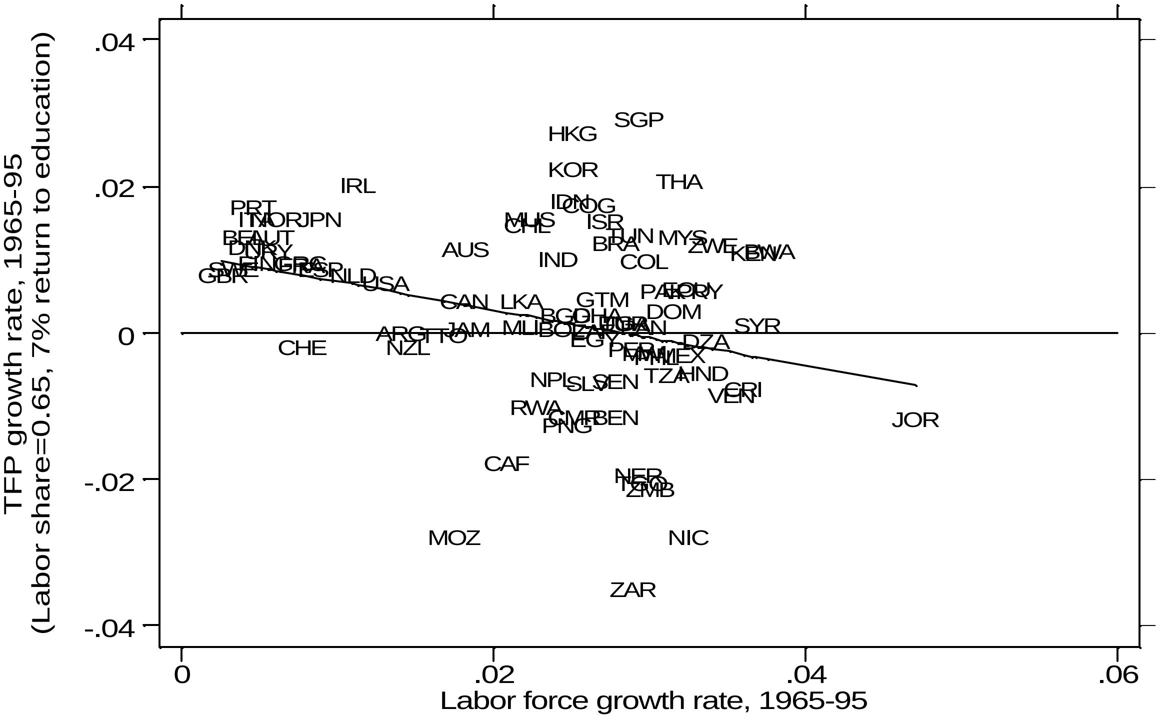

Figure 6: Relation of TFP growth to labor force growth rate

APPENDIX. Additional country data

Table A.1 Estimated TFP growth rates, 1965-95

Country	Actual labor shares		Labor share=0.65	
	No returns to education	7% return to education	No returns to education	7% return to education
ALGERIA	0.35	-0.23	0.39	-0.22
ANGOLA	..	..	-2.05	..
ARGENTINA	..	..	0.34	-0.11
AUSTRALIA	1.30	1.10	1.24	1.06
AUSTRIA	1.52	1.41	1.33	1.22
BANGLADESH	..	..	0.47	0.14
BELGIUM	1.67	1.41	1.43	1.20
BENIN	..	..	-0.90	-1.24
BOLIVIA	-0.02	-0.06	0.00	-0.04
BOTSWANA	-0.47	-0.92	1.66	1.01
BRAZIL	..	..	1.33	1.13
BURKINA FASO	..	..	-0.07	..
BURUNDI	-0.37	..	-0.83	..
CAMEROON	..	..	-0.98	-1.24
CANADA	0.78	0.40	0.71	0.34
CENTRAL AFR. R.	..	..	-1.57	-1.88
CHILE	1.66	1.37	1.70	1.39
COLOMBIA	1.22	0.87	1.22	0.87
CONGO	1.72	1.68	1.71	1.65
COSTA RICA	-0.34	-0.70	-0.54	-0.87
DENMARK	1.31	1.21	1.17	1.08
DOMINICAN REP.	..	..	0.61	0.19
ECUADOR	0.81	0.48	0.97	0.49
EGYPT	1.10	0.06	0.70	-0.18
EL SALVADOR	-0.53	-0.85	-0.43	-0.79
ETHIOPIA	..	..	-0.56	..
FINLAND	1.63	0.97	1.46	0.86
FRANCE	1.41	1.09	1.12	0.84
GHANA	..	..	0.56	0.15
GREECE	1.93	1.33	1.35	0.86
GUATEMALA	..	..	0.67	0.36
HONDURAS	..	..	-0.22	-0.65
HONG KONG	2.63	2.25	3.06	2.62
INDIA	..	..	1.31	0.91
INDONESIA	..	..	2.17	1.71
IRELAND	2.56	2.12	2.31	1.92
ISRAEL	1.93	1.51	1.81	1.42
ITALY	1.91	1.60	1.74	1.46
IVORY COAST	-0.34	..	-0.35	..
JAMAICA	0.30	-0.03	0.29	-0.06
JAPAN	1.92	1.65	1.71	1.46
JORDAN	-0.72	-1.33	-0.67	-1.29

KENYA	..	..	1.32	1.00
KOREA, REP.	2.87	2.13	2.87	2.13
MADAGASCAR	..	..	-1.32	..
MALAWI	..	..	-0.27	-0.37
MALAYSIA	1.73	1.27	1.66	1.21
MALI	..	..	0.07	-0.03
MAURITANIA	..	..	-1.69	..
MAURITIUS	1.73	1.36	1.87	1.46
MEXICO	0.09	-0.45	0.25	-0.39
MOROCCO	0.80	..	0.93	..
MOZAMBIQUE	..	..	-2.78	-2.89
NEPAL	..	..	-0.30	-0.73
NETHERLANDS	1.26	0.70	1.22	0.68
NEW ZEALAND	0.05	-0.29	0.02	-0.30
NICARAGUA	..	..	-2.62	-2.89
NIGER	..	..	-1.93	-2.04
NIGERIA	..	..	-1.66	..
NORWAY	2.08	1.41	2.18	1.47
PAKISTAN	..	..	0.99	0.47
PANAMA	0.76	0.13	0.54	-0.02
PAPUA N. GUINEA	..	..	-1.11	-1.35
PARAGUAY	0.13	-0.17	0.87	0.47
PERU	0.44	-0.12	0.34	-0.32
PHILIPPINES	0.06	-0.49	0.19	-0.42
PORTUGAL	2.44	1.91	2.10	1.62
RWANDA	..	..	-0.91	-1.12
S.AFRICA	0.24	-0.07	0.25	-0.07
SENEGAL	..	..	-0.62	-0.75
SINGAPORE	2.09	1.85	3.12	2.82
SPAIN	1.34	0.83	1.25	0.76
SRI LANKA	1.27	0.91	0.64	0.34
SWEDEN	1.44	0.97	1.18	0.78
SWITZERLAND	0.33	-0.08	0.05	-0.30
SYRIA	..	..	0.62	0.00
TANZANIA	..	..	-0.70	-0.69
THAILAND	..	..	2.32	1.97
TOGO	..	..	-1.69	-2.15
TRINIDAD&TOBAGO	0.33	-0.03	0.22	-0.12
TUNISIA	1.82	1.23	1.85	1.24
TURKEY	..	..	0.55	0.03
UGANDA	..	..	0.34	0.04
UNITEDKINGDOM	1.28	0.93	1.00	0.70
UNITEDSTATES	1.22	0.76	0.99	0.59
URUGUAY	1.29	1.00	1.34	1.02
VENEZUELA	-0.22	-0.72	-0.33	-0.94
ZAIRE	..	..	-3.23	-3.61
ZAMBIA	-1.97	-2.44	-1.79	-2.22
ZIMBABWE	..	..	1.64	1.09