Trade and Human Capital as Determinants of Growth

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Abstract

Do openness to trade and higher levels of human capital growth promote faster growth? To answer that question we use a panel of countries to investigate the role of human capital and two measures of openness in determining both the level of income and its growth rate. We argue that focusing on the levels of income by estimating a production function will give misleading estimates if there are unobserved differences in the underlying growth of technical efficiency across countries that are correlated with the explanatory variables. Using a growth rate equation, where we allow for country fixed effects and for possible endogeneity of explanatory variables, we show that both measures of openness, one the Sachs-Warner measure which reflects policy, and one from the PENN World Tables, the share of trade in GDP, give similar results. We argue that openness has a highly significant and large effect on the underlying rate of growth of productivity, while human capital does not.

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1 Introduction

There has been much dispute as to whether economies that are open and those with more human capital grow faster. The economic success stories of the post-war period, the East Asian NICs, had both higher levels of human capital and, by some measures, a more outward orientation than their less successful contemporaries. Such a congruence of policies makes it difficult disentangling which, if either, of the two elements - openness or human capital - was the source of higher growth rates. Recent papers have questioned the evidence that human capital does affect growth. Bils and Klenow (2000) ask if the observed correlation between school enrolments in 1960 and growth over the period from 1960 to 1990 can be interpreted as causal. They argue that it cannot. Krugman (1994), Rodrik (1995) and Rodriguez and Rodrik (1999) all question whether there is any convincing empirical evidence of a link from trade liberalisation, or openness, to growth.

In modelling differences in per capita income, rather than growth, the importance of both human and physical capital has been disputed. Hall and Jones (1999) argue that "differences in physical capital and educational attainment explain only a modest amount of the difference in output per worker across countries" (p.92). They argue that output per worker is fundamentally related to differences in social infrastructure across countries. By social infrastructure they mean "the institutions and government policies that determine the economic environment within which individuals accumulate skills, and firms accumulate capital and produce output" (p.84). Their measure of social infrastructure is formed from two indices. The first is an index of government anti-diversion policies. The second is the Sachs and Warner (1995) index of the openness of the economy. Poorly performing economies are those with poor social infrastructure. Low rates of human capital formation are one of the consequences of poor social infrastructure, not a cause of poor performance. In a recent contribution Easterly and Levine (2000) argue, along similar lines, that factor accumulation is not the key to growth.[1]

These new views on growth run counter to a long empirical investigation of the links between human capital, openness and growth. The large literature on growth stemming from the work of Barro (1991, 1997) has consistently found some measure of human capital significant in determining growth. Gemmel (1996) finds both the levels of human capital and their growth rates to be important. Benhabib and Spiegel (1994) present evidence that education influences rates of technological progress.[2] These results are all based on cross-section analysis. Similarly nearly all the analysis which links trade policy to growth is based on cross-section data, Dollar (1992), Sachs and Warner (1995), Edwards (1998). The problem with establishing any causal link from education or openness to growth is that cross-section data, while informative of the correlations that can be established from the data, is uninformative as to determinants unless convincing instruments can be found. One of the criticisms of the Edwards (1998) paper advanced by Rodriguez and Rodrik (1999) is that the instruments used are not valid ones.

The use of panel data in principle allows some of these issues to be advanced. A recent paper uses panel data to investigate the role of both openness and human capital in determining differences in productivity, Miller and Upadhyay (2000). They argue that an interaction term between human capital and openness has a significant effect on total factor productivity. As they recognise their study, while controlling for fixed effects, does not allow for the possible endogeneity of these variables and so the results cannot be given a causal interpretation. The value of panel data methods in growth equations has also been questioned. Temple (1999b, p. 132) summarises the problems posed by the use of such methods. There is much empirical evidence that the use of differencing can take away by the increase in measurement error what is gained in terms of eliminating fixed effects, a

[1] Other papers that argue for the importance of including some measure of social capital or capability in determining growth include Knack and Keefer (1997) and Temple and Johnson (1998).

[2] Temple (1999a) shows that the inability to produce a significant coefficient on human capital in the growth regressions reported in Benhabib and Spiegel (1994) may be due to the influence of outliers. Once these are excluded from the data set the coefficient estimate on human capital is 0.165 which is much closer to that reported in their levels equation.

point made by Barro (1997, pp 41-42) in the context of cross-country regressions. Lee, Pesaran and Smith (1998) point out that panel methods applied to production functions do not control for heterogeneity in countries' rates of growth of technology. The failure to allow for such heterogeneity can lead to seriously misleading inferences regarding convergence.

If panel data methods, which allow for problems of endogeneity, measurement error and the attenuating effects of differencing, can be applied to a specification which allows for heterogeneity in rates of technological progress then it would seem possible to take the next step and ask if either human capital or openness *causes* growth. That is our objective in this paper. In the next section we set out the sources of data that we will use to carry out this test. In section 3 we discuss whether a production function or a growth equation should be estimated. Section 4 presents the results for a growth equation, which are linked to cross-country growth evidence in section 5, and a production function in section 6. A final section concludes.

2 The data

We follow Benhabib and Spiegel (1994) and Miller and Upadhyay (2000) in combining the PENN World Table (PWT) data, Summers and Heston (1991), which covers income and trade, with data on the educational component of human capital from Barro and Lee (1993). From the PWT and Barro-Lee data sets it is possible to obtain a set of 54 countries for which there is complete information on output and human and physical capital inputs every five years from 1965 to 1990, giving us six observations on each of the 54 countries.[3] (The countries included are given in the Appendix). Table 1 shows the key variables on which we will focus averaged across regions.

Two measures of openness are presented. The one from the PWT data set measures openness by the share of imports and exports in GDP. The second measure (SW) is from Sachs and Warner (1995), it is one component of the Hall and Jones index of social capital. The Sachs and Warner (SW) measure of openness is a zero-one dummy which takes the value 0 if the economy was closed according to any one of a set of criteria related to tariffs, non-tariff barriers to trade, the treatment of exports, the type of economy and the size of a black market premium, Sachs and Warner (1995). We have chosen these two measures of openness as the literature has drawn a distinction between measures of openness which represent policy outcomes, like the trade ratio measured by PWT, and the attempt to obtain a measure of trade policy of which the Sachs-Warner index is probably the best known example. Both measures have been widely criticised.

We believe that the central criticism of the PWT type of measure is that it is endogenous to the other variables being modelled. Both output and the trade share could be driven by some common factor, the most obvious candidates being either human capital investment or a better policy environment. Possibly the most comprehensive criticism of the SW measure can be found in the Rodriguez and Rodrik (1999) paper reviewing the empirical evidence linking openness to higher rates of growth. They argue that this measure is dominated by two components – the black market premium and the variable on state monopoly of exports – which are either so correlated with region, or with general macro policies, or poor institutions, as to make the variable unhelpful as a measure of trade policy. The identification of countries as open has been challenged, the case of Korea in the 1960s being a particularly contentious example.

We propose to investigate if openness affects the growth rate, specifically the growth rate of technical progress. Figure 1 shows the relationship between the PWT measure of openness and the rate of growth of productivity which is measured as the residuals from a function relating the growth rate of income per worker to the growth rate of capital per worker (see figure notes for details). There is a positive relationship but it is clear from the figure that Hong Kong dominates the high openness, high growth rate, part of the figure and both Iran and Syria are outliers. The importance of allowing for fixed effects and the possible importance of the NICs in generating any results is apparent from the figure.

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[3] We have chosen not to include countries with fewer than six observations as the econometric approach we use is not suitable for too short time series. As we shall see in Section 5, however, we can nevertheless with this restricted sample reproduce results that have been widely found in the literature.

Figure 2a shows for the SW openness measure the rates of technological progress for three classes of countries, those that, by the SW measure, were always closed, those that were always open and those that switched during the period from being one to the other. The figure shows that open economies have higher rates of technical progress, a growth of 2 per cent (per five year period) as compared with a fall of 3 per cent. As we propose to use differenced measures of the data to remove the fixed effects it is the countries that switched that are of primary interests. Figure 2b shows for this set of countries that, when they were open, they had a growth rate of underlying productivity of 5 per cent and, while they were closed, their underlying productivity fell by 3 per cent. For this class of switching countries the raw data suggests a rise in underlying productivity growth of 9 percentage points in moving from being closed to being open. This difference is statistically significant from zero at the 1 per cent level.

Figures 1 and 2 show the rates of technical progress based on a simple growth rate equation. Figure 3 shows a plot of the growth rate of income per worker against that growth rate of physical capital per worker. As with the earlier figures Iran and Syria are outliers, as now is one of the observations for Malawi. It is clear from the figure that there is a relatively good fit (the line shown is the predicted value of the OLS regression). Figure 4 shows a similar plot for the growth rates of income per worker and human capital defined as the average years of education of the population aged over 15 years. Here the relationship between growth of income and the growth of human capital is much less clear. The fitted line slopes up but human capital in the underlying regression is not significant. Sierra Leone (SL) is now an outlier. Figures 3 and 4 suggest that in any regression of growth rates for income per worker, the growth of physical capital will be by far the most important determinant. However such a finding, which is one found in the macro literature on modelling growth, throws no light on the role of the variables in *levels* in determining the *growth* rate of productivity. To model that we need to allow both the human capital and the openness measures to influence both the level of income per worker and the growth rate of technical progress.

The data that underlie the figures are given by region in Table 1. The growth rate of education ranged from 24.2 per cent (the figures are averages over a five year period) to 2.2 per cent. The range in growth rates for income and capital per worker is equally large, from 3 to 29 per cent for income and from 7 to 33 for capital (both figures are per worker). As is well known for both income and physical capital Africa is by far the poorest performing region while East Asia has the highest rates of growth. In 1965 East Asia has twice the physical and human capital stock of Africa and is much more open by the SW measure. It is easy to see why distinguishing between the roles of human capital and openness in the growth process has proved so difficult.

In seeking to distinguish between the part played by openness and that by human capital we note that some of the criticisms that have been advanced of both the PWT type of measure and that due to Sachs and Warner are testable. If the SW measure is in fact so collinear with regions then controls for fixed effects should eliminate its significance. If its treatment of the NICs is the reason for it significance then dropping East Asia from the regression should eliminate its significance. In the tests we conduct below we control for fixed effects that are potentially correlated with the explanatory variables, and we report runs which exclude the East Asian economies. We also allow both measures to be endogenous in the regressions we report. In summary we would argue that allowing for the endogeneity of the policy measure of openness combined with controls for fixed effects addresses the most important criticisms that have been advanced of both these measures.

Our macro data is short on countries as we have confined the sample to those countries for which there is data on physical capital per worker over a sufficiently long time period to create a panel. Even so the panel dimension of the data is short, it covers the six five year periods from 1965 to 1990. The reason for these restrictions is that we wish to ask how much both openness and human capital, controlling for physical capital, contribute to both the level of output and its growth rate. In the next section we specify the production functions we will use to answer this question.

3 Modelling Growth

We begin by specifying a production function,

$$[1] \qquad Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} H_{it}^{\gamma},$$

where Y_{it} is real income, K_{it} is physical capital, L_{it} is the number of workers, H_{it} is the total amount of human capital, defined as $h_{it}L_{it}$ where h_{it} is the average level of education of the workers in years, i and t are country and time indices, respectively, and α, β and γ are parameters to be estimated. A_{it} is the technology parameter, reflecting how well the country does at transforming inputs into outputs. We specify this as

$$[2] \qquad \ln A_{it} = \omega \cdot X_{it} + \mu_i + \eta_i t + \varepsilon_{it},$$

where ω is a parameter vector to be estimated, X_{it} is a vector of variables determining total factor productivity (TFP), μ_i is an unobserved country specific effect affecting the level of TFP but not its growth, η_i is another country specific effect affecting both the level and the growth of TFP and ε_{it} is a shock to TFP.[4] Notice that the growth effects of the country specific term η_i operate through the interaction with the time variable. The vector X_{it} contains the log-level of education, ln h_{it}, and the degree of openness of the economy, O_{it}. It is likely that the explanatory variables in [1] and [2] are affected by the country specific effects (e.g. countries with high η_i would have a high marginal product of capital, and thence presumably more investment in physical capital than countries with low η_i), and we will therefore in the empirical analysis allow μ_i and η_i to be correlated with the explanatory variables. This is important issue given that we want to investigate how human capital and openness impact on growth.

Given the data to hand it is possible to estimate the production function [1] directly. A very influential paper in this area has chosen to proceed by modelling the determinants of steady state income per capita, Mankiw et al (1992). An alternative approach is to proceed directly to estimating a growth rate equation as discussed in Temple (1999b, p.124). Using [2] in the logarithm of [1] and taking first differences, we can rewrite the equation in per capita terms as

$$[3] \qquad \Delta \ln(Y/L)_{it} = \alpha \cdot \Delta \ln(K/L)_{it} + \gamma \cdot \Delta \ln h_{it} + \lambda \cdot \Delta \ln L_{it} + \omega \cdot \Delta X_{it} + \eta_i + v_{it},$$

where v_{it} is the differenced residual in [2], and where $\lambda = \alpha + \beta + \gamma - 1$ implying that $\lambda > 0$ indicates increasing returns to scale, $\lambda = 0$ constant returns to scale, and $\lambda < 0$ decreasing returns to scale. Notice that while first differencing eliminates the fixed effect μ_i, the fixed effect η_i still appears on the right-hand side. To the extent that η_i is correlated with the explanatory variables in [3], failure to control for variation in η across countries will yield misleading results.[5]

Although the dependent variable in [3] is the growth of income, the coefficients on the regressors in differences represent effects on the *level* of income. For our purposes it is of interest to see if we can find effects of changes in openness and human capital on the *growth* of income.[6] We shall therefore add to the set of regressors in [3] the levels of openness and growth, yielding our most general specification:

[4] See e.g. Miller and Upadhyay (2000) for a discussion of the possibility that human capital and openness affect the level of total factor productivity .

[5] As has already been noted Lee, Pesaran and Smith (1998) have stressed that allowing for fixed effects in specifications such as [1] does not solve the problems posed in growth analysis where there are differences in technological progress across countries.

[6] See Benhabib and Spiegel (1994) for a discussion of the effect of human capital on the growth of total factor productivity.

$$[4] \qquad \Delta \ln(Y/L)_{it} = \alpha \cdot \Delta \ln(K/L)_{it} + \gamma \cdot \Delta \ln h_{it} + \lambda \cdot \Delta \ln L_{it} + \omega \cdot \Delta X_{it} + \theta \cdot X_{it} + \eta_i + v_{it},$$

where θ is a vector of parameters linking changes in the levels of openness and human capital to changes in the growth of income. Notice that [4] nests [1], and can therefore serve as a basis for testing if the levels equation is an appropriate specification. In particular, if we obtain significantly different estimates of α, β and γ in [1] and [4], and/or θ is significantly different from zero, we have reasons to question the validity of the levels specification. The problems of moving from [4] to [1] are of importance as many papers modelling the determinants of technical change obtain the data from either an estimated or calibrated production function in levels. If these estimates under-state the contribution of either physical or human capital they will be attributing to the residual part of what is due to the inputs.

4 Estimating a Growth Rate Equation

To estimate the growth rate equation [4] we must deal with the fact that the country specific effect may be correlated with the explanatory variables, and with the fact that the explanatory variables may not be predetermined. With panel data to hand it is common, particularly in the microeconometric literature, to address such issues by taking first differences to eliminate the country effect, and then formulate a generalised method of moments (GMM) estimator (Hansen, 1982), which uses lags of the explanatory variables as instruments for contemporaneous values. However, in practice this approach is unlikely to give satisfactory results if the regressors are highly persistent, as in this case lagged levels will be weak instruments for contemporaneous differences (Blundell and Bond, 1998).[7] In contrast, lagged differences may be good instruments for contemporaneous levels even if variables are highly persistent: for instance, large investments (i.e. changes in capital stock) will imply a larger capital stock. Blundell and Bond show how to utilise such additional information to formulate a system GMM estimator, which uses lagged levels as instruments for contemporaneous differences and lagged differences as instruments for contemporaneous levels. The authors present results from a Monte Carlo experiment indicating that the system GMM estimator performs substantially better than the standard GMM when the data are highly persistent. We will present both differenced and system estimators drawing on the experience with these estimators with micro data to suggest reasons for conflicts in the findings. Both the differenced and the system GMM estimators provide information that allows us to check for the validity of our estimates.

Table 2 presents our basic results using the PWT measure of openness. We estimate equation [4] by OLS, by differencing to allow for fixed effects but with no allowance for endogeneity, by differenced GMM which allows for both fixed effects and endogeneity and by system GMM which allows for fixed effects, endogeneity and uses differenced lags of the right-hand side variables as instruments for the "levels" equation.[8] By estimating the growth rate equation we directly address the concern of Lee, Pesaran and Smith (1998) that differences in the rates of growth of technological progress across countries will bias the estimation of a production function such as equation [1] above, unless such differences are uncorrelated with the regressors. If these fixed effects in the growth rate equation are important then our estimates of the production function will be biased. We argue below that such biases can explain the results when a production function is estimated. Given that we estimate a growth rate equation we can test directly for the role of human capital and openness as both determinants of the level of efficiency, by the differenced term in the regression, and for an effect on technological progress by the levels term in the regression. The procedure is similar to that adopted by Nickell (1996) in testing for competitiveness as a determinant of firm performance.

The results in Table 2 suggest that fixed effects are indeed important. In moving from the OLS result reported in Column [1] to the differenced estimates in Column [2] the coefficient on

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[7] For instance, if W follows a random walk, $W_t = W_{t-1} + e_t$, then W_{t-1} will be uncorrelated with ΔW_t, and therefore be of no use as an instrument.

[8] Of course, "levels" here means the variables in the form they enter [4], i.e. prior to the differencing of the growth equation.

capital declines from 0.41 to 0.28. The reduction in the coefficient on capital and the evidence for decreasing returns to scale for this macro data are consistent with the findings for micro data, Griliches and Mairesse (1997), Blundell and Bond (2000). The increased measurement error in the differenced series (and in this case these are second differences) ensures that such error is biasing down the coefficient. The net effect of the bias from measurement error and endogeneity cannot of course be established. To assess the effects of both endogeneity and measurement error we move in Column [3] to a GMM difference estimator. The result is to increase the coefficient on capital and to substantially increase the point estimate on the openness variable. In Column [4] of the table we ask if using differences as instruments for levels assists our ability to identify the size of the openness variable. It does as the *t* statistic doubles. In Columns [1] –[4] we retain the most general specification that allows both human capital and openness to affect both levels and rates of growth of output. There is no evidence from any of these results that the level of openness affect the level of output or that the level of human capital affects the growth of output. In the final column of Table 2 we drop the terms for these variables. The result is a significant coefficient on the openness measure. The coefficient implies that a 40 percentage point rise in the share of exports and imports to GDP would increase the rate of technical progress by 4.4 percentage points per five year period. It needs to be noted that this is an effect on the growth of underlying productivity, not on the level of income per worker and that the openness measure, as with all the other regressors, is treated as endogenous. All the tests for the validity of the instruments are passed. We have experimented with lagging the human capital variable for up to two periods and in no run did the variable have a t statistic over 1.0 and when positive the point estimate was very low. The point estimate on capital in Table 2 equation (5) is 0.52, which is substantially above the 0.3 used is standard growth accounting exercises, King and Levine (1994).

In Table 3 we repeat the same set of estimations as for Table 2 but now using the Sachs and Warner index of openness. Again there is no evidence for an effect from openness onto the level of output or for human capital on the growth of output. The point estimate for the coefficient on openness in the system GMM estimator is not significant at conventional levels. One reason for our inability to obtain a more precise estimate of the effect may be due to the limited variance of this measure of openness. We may also be asking too much of the data in assuming, as we do in Table 3 Columns [3]-[5], that all the regresssors are endogenous.

In Table 4 we report estimates for both our equations in which we allow the openness measure to be exogenous, an assumption which we test for by means of a difference Sargan test.[9] We can easily accept exogeneity at conventional levels of significance. Table 4 Column [1] and [3] repeat the restricted specification from Tables 2 and 3 but now assuming that openness is exogenous (it is still allowed to be correlated with the country-fixed effect). We now find for both measures of openness a highly significant effect from openness onto growth. In fact for the SW measure the result in Table 4 is almost exactly the same as that obtained from the OLS result reported in Table 3, Column [1]. The result is not only reasonably well identified but large. Moving your economy from closed to open increases the rate of growth of output by 9 percentage points per five year period. The result is not due to the inclusion of East Asian countries in the sample; they are excluded in columns [2] and [4]. Both the point estimates and the *t* statistics are largely unaffected.

5 Comparative Growth Performance

In this section we take up two issues. First, it seems useful to confirm that our data when treated as a cross-section sample can reproduce results which have been widely found in the literature. Second, we ask how much of productivity growth is left unexplained by the growth rates of capital and the openness measure. In particular do either Africa or East Asia have unexplained determinants of the growth rate of their productivity?

As our country sample is small, only 54 countries, it is not possible to assess how similar the results would be for the larger samples that have been widely used. However Table 5 provides evidence that these 54 countries do behave in a very similar manner to these larger samples. Table 5

[9] See notes under Table 4 for details of how we carried out this test.

Column [1] shows that when the rate of growth of GDP per worker from 1965 to 1990 is regressed on the level and growth of human capital, both terms are positive and the level term is significant. If the average rate of investment and a term in initial income are added these are also found to be significant. The finding that the coefficient on initial income is negative has been interpreted as evidence for what is termed β convergence and here it is negative as expected. Table 5 Column [3] shows that the effect in the cross section for the openness measure can be identified but it is much smaller than that found by the use of the panel. Finally Column [4] introduces regional dummies which are highly significant and in effect eliminate the significance of all the explanatory variables apart from the initial income.

The result in Column [4] is open to two interpretations. It is possible to argue that the introduction of regional dummies, which act as fixed effects, eliminate the cross-section dimension of the data and therefore that their inclusion is unhelpful. The second interpretation is that the significance of the regional dummies is indicative that fixed effects may well be important and the cross-section evidence must be regarded as unreliable. We would argue that it is much preferable to use the panel dimensions of the data so that the effects of time varying variables can be estimated while allowing for fixed effects as was done in the last section. We note however that whichever methodology is used an effect from openness onto growth can be identified but, we would argue, the cross-section approach greatly understates its magnitude.

The second issue we consider is whether there are regional effects in our growth rate equation. Specifically what do the results imply about the sources of African and East Asian growth? Hong Kong, Korea and Taiwan are the three East Asian countries included in this data set. Detailed macro evidence for these is included in the analysis of their sources of growth by Young (1995, Table 13) who finds an average rate of total productivity growth of 2 per cent per annum for these three countries. Young argues that these countries were not exceptional in the growth of their productivity but they were exceptional in the growth of their inputs. Young's argument has not gone unchallenged. Klenow and Rodriguez-Clare (1997) argue that, except in Singapore, factor accumulation has not played the dominant role in growth. Easterly and Levine (2000, p.9) cite Hsieh (1998) as showing that there is no evidence for high returns in the East Asian economies which is implied by the Young analysis. To investigate this issue for our data set we take the residuals from our growth equation, Table 2 Column [5], as a measure of technical progress and regress them on country dummies. We then ask if the coefficients on these country dummies differ significantly by region. The result, shown in the final column of Table 5, is that East Asian productivity growth is 7.1 percentage points (per five year period) higher than the other regions. This suggests that there was growth in technical progress for these economies which cannot be explained by openness. However, as explained in the tables notes, only the regional dummy for East Asia was significant. There is no evidence for any other regional effect, specifically there is no African dummy. We note that these results may reflect our relatively small sample of countries.

6 Modelling the Production Function

It is an implication of the importance of fixed effects in the growth rate function that a production function will produce biased estimates of the coefficients even if we control for fixed effects. It is common to base estimates of efficiency on residuals from a production function, either calibrated or estimated. We now investigate whether the biases introduced by estimating a production, rather than a growth rate, function are likely to be serious.

In Table 6 we use the PWT measure of openness to test if it is possible to obtain a levels production function which captures the effects of openness on the growth rate of productivity. In order to ensure that the level production function can be compared as closely as possible with the growth rate equation we set up the specification so that both openness and human capital can affect the level and growth rate of productivity. To allow for the latter possibility we interact averages of these variables over the sample period with the time variable, see Nickell (1996).[10]

[10] If we had interacted the time varying measure of openness or human capital with the time variable in the production function then the differential of this term does not simply give a levels effect of openness on growth. We have experimented with this approach and the final results are similar to those reported in the text.

In Table 6 Column [1] we report the OLS estimates of the most general levels specification. It is clearly a most unsatisfactory production function. It appears to be important to allow for the interaction of time with the human capital measure. However there is a significant, at the 10 per cent level, negative effect from openness onto the level of productivity; and, most striking of all, the time dummies in the equation imply significant technical regress. Column [2] differences this equation thus removing the fixed effects. The capital coefficient decreases in size but remains highly significant. The other variables that are now significant are the openness measures. Thus this equation reproduces the most important finding of the growth rate equation that there is an impact of openness is on the rate of growth of underlying productivity, but there remain significant negative coefficients on the time dummies. Further the point estimate on openness interacted with the time variable is very low compared to that obtained in Table 2 Column [5] where we use the system GMM estimator to allow for both endogeneity and measurement error in the variable.

In Table 6, Columns [3] and [4] we report the differenced and system GMM estimates. The result in Column [3] is to reduce both the size and significance of the coefficient on capital and to suggest that there is a levels effect from openness onto productivity. The system GMM estimator is reported in Column [4]. While this equation reproduces what we believe to be the correct result that openness affects the rate of growth of productivity it is also clear the equation has some of the problems posed by the OLS estimates in Column [1]. In particular the estimates on the time dummies still imply technical regress. Column [5] of the table confirms that these problems cannot be removed by a more parsimonious specification.

We would argue that the failure of the production function to provide a coherent explanation of changes in output is an indirect confirmation of the result of Tables 2 to 4 which showed that both fixed effects and endogeneity were important in a growth rate equation. It is not possible to obtain consistent estimates of the technology by estimating a levels production function when there are unobserved differences across the countries in the growth rates of technical progress which are correlated with the explanatory variables.

7 Summary and Conclusions

The contribution of this paper is to ask if either human capital or openness can be given a causal interpretation in the growth process. To advance such an interpretation the use of instruments is essential. We have used a panel to create the possibility of using past values of the variables as instruments for both physical and human capital and two measures of openness. One of these measures from the PWT data measures openness by the share of trade in GDP, the second is the Sachs-Warner measure of trade policy. If we have valid instruments we can test if our measures of human capital and openness are exogenous and whether they cause growth.

The use of panel data estimation techniques has proved problematic in previous studies. If differencing is used to remove fixed effects, and endogeneity is allowed for by instruments, a common finding has been that the resulting parameter estimates have large standard errors. The reasons for this are well understood. The importance of measurement error increases with differencing so there is no assurance that estimates that allow for fixed effects are an improvement on those that do not. We have used an estimator developed by Blundell and Bond (1998) which addresses this issue by allowing information on differences instrumented with levels to be combined with a levels equation instrumented with differences. In the context of this paper, where we wish to distinguish between the roles of human capital and openness on both the growth and the level of income, this estimator has great appeal.

Proceeding by estimating a growth rate equation and allowing for both fixed effects and the endogeneity of the variables we find, for both measures of openness, that greater openness causes faster rates of productivity growth. We find no evidence, using these estimators, that human capital has any effect on productivity growth. Human capital has a small, and not statistically significant effect, on the level of output. There is no evidence that openness affects productivity in levels once we control for its effects on the growth rate.

We have shown that these results are not due to our choice of countries. It is possible to estimate cross-country growth regressions on this data set which reproduce results identical to those found in the larger cross-country data sets that have been very widely used to investigate these questions. We have also shown that attempts to estimate a production function will give rise to very misleading inferences. Even if such an equation includes factors which do influence the underlying rate of technical progress the presence of unobserved country fixed effects influencing the growth of technical progress may make it impossible to obtain consistent estimates of the parameters. Such is the case in our data. We have shown that by proceeding with a growth rate equation these problems can be circumvented.

Clearly the results leave open the question as to what determines the growth of physical capital. While we have allowed for its endogeneity in the growth process we may well be understating the role of either human capital or openness in so far as these variables affect investment in physical capital.

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TABLE 1
DESCRIPTIVE STATISTICS (MEANS): OPENNESS, HUMAN CAPITAL, INCOME AND CAPITAL

	PWT		SW		Years of Education		
	1965	1990	1965	1990	1965	1990	Growth Rate
Africa	72.8	71.9	0.17	0.17	2.1	3.7	11.9
South Asia	43.6	43.1	0.0	0.0	3.0	5.1	10.9
East Asia	72.4	138.4	0.67	1.0	5.3	9.0	11.9
Middle-East	32.9	44.2	0.50	0.0	1.6	4.5	24.2
Industrial	48.3	64.9	0.90	1.0	6.6	8.5	5.1
East Europe	28.9	45.5	0.0	0.5	3.8	5.4	10.1
Australasia	38.7	44.9	0.5	1.0	9.5	10.8	2.2
South East Asia	36.6	68.7	0.5	1.0	4.1	6.3	6.3
Latin America	39.7	55.9	0.36	0.64	3.5	5.5	8.5
All	47.9	64.5	0.56	0.72	4.8	6.8	8.2

INCOME AND CAPITAL

	Income per Worker		Capital per Worker		Rates of Growth (%)	
	1965	1990	1965	1990	Income	Capital
Africa	2,777	3,377	1,861	1,763	2.9	7.3
South Asia	2,565	4,489	2,477	5,441	9.2	16.7
East Asia	4,650	19,086	3,929	18,826	28.8	33.0
Middle-East	9,620	13,636	6,211	15,271	9.6	21.8
Industrial	15,856	27,484	13,601	34,453	13.8	20.3
East Europe	4,543	9,320	2,409	8,076	15.5	24.2
Australasia	22,452	27,863	19,249	35,467	5.3	12.2
South East Asia	2,809	5,769	1,776	4,305	14.6	19.7
Latin America	7,996	9,238	4,979	9,157	6.2	13.7
All	10,361	16,781	8,194	19,554	10.9	17.6

Table notes on the next page.

Definitions: The PWT measure of Openness is taken from the PENN World Table (Mark 5.6) data, Summers and Heston (1991). It is the share of exports+imports in nominal GDP. The figures given in the table are percentages.

The SW measure of Openness is that derived by Sachs and Warner (1995). It is a zero-one dummy which takes the value 0 if the economy was closed according to any one of a set of criteria related to tariffs, non-tariff barriers to trade, the treatment of exports, the type of economy and the size of a black market premium. There were some observations for which it was not available. We interpolated the following values: ICELAND open=1 for all years, MALAWI in 1965open=0; MAURITIUS in 1965 open=0; PANAMA open=1 for all years**.**

The years of education figures are taken from the Barro and Lee data and are a measure of the average schooling yeas in the population aged over 15.

The figures for Income per worker and Capital per worker are also from the PENN World Tables. Both figures are expressed in 1985 international prices. The capital stock figures is for non-residential capital stock.

The growth rates for income and capital given in the table are the means of the differences in the logs of these variables for the five years period used in the regression analysis. The means are thus for five year periods.

TABLE 2
GROWTH RATE EQUATION WITH PWT OPENNESS MEASURE

	[1] OLS	[2] DIFF	[3] DIFF GMM$	[4] SYS GMM$$	[5] SYS GMM$$
PARAMETER					
Δ Ln (Capital per Worker)	0.41 (4.33)**	0.28 (1.96)+	0.37 (2.09)*	0.42 (3.84)**	0.52 (3.19)**
Δ Ln (Education in years)	0.01 (0.07)	0.04 (0.37)	0.02 (0.15)	-0.01 (0.05)	0.03 (0.40)
Δ Ln (Workers)	-0.25 (1.31)	-0.54 (1.81)+	0.02 (0.03)	-0.14 (0.59)	-0.12 (0.52)
Δ Open/1000	1.28 (1.34)	1.50 (0.77)	-0.03 (0.02)	0.87 (1.02)	
Open/1000	0.65 (2.66)*	0.61 (0.30)	3.4 (0.79)	0.95 (1.59)	1.1 (2.37)*
Ln (Education in years)/100	0.18 (0.08)	-19.9 (1.86)+	0.28 (0.01)	0.55 (0.09)	
Period 1975/70	-0.027 (1.19)			-0.038 (1.35)	-0.026 (1.09)
Period 1980/75	-0.036 (1.33)	0.018 (0.47)	0.054 (1.32)	-0.042 (1.34)	-0.03 (0.96)
Period 1985/80	-0.084 (3.0)**	-0.041 (1.26)	-0.001 (0.03)	-0.091 (2.59)**	-0.07 (1.78)
Period 1990/85	-0.021 (0.62)	0.084 (2.55)*	0.132 (2.44)*	-0.026 (0.69)	0.001 (0.03)
Inputs Endogenous	No	No	Yes	Yes	Yes
Fixed Effects	No	Yes	Yes	Yes	Yes
Number of Observations	270	216	216	270	270
Number of Countries	54	54	54	54	54
	SPECIFICATION TESTS (p-VALUES)				
M1(1)			0.02	0.02	0.02
M2(2)			0.39	0.29	0.20
SARGAN(3)			0.13	0.18	0.32
DIFFERENCE SARGAN(4)				0.39	0.42

Note: The dependent variable is the difference of the log of income per worker. t-statistics based on standard errors robust to heteroskedasticity (White, 1980) are reported in parenthesis. Significance at the 1%, 5% and 10% level is indicated by * , ** and + respectively.

Table notes continue on the next page.

Table notes, continued.

[$] The difference GMM estimator is due to Arellano and Bond (1991). The reported coefficients are two-step estimates, and the associated *t*-statistics are based on robust, finite sample corrected standard errors (see Windmeijer, 2000). The instrument set consists of capital per worker, education, number of workers and openness, in differences, in period t-1, openness and education, in levels, in period t-2, a constant and year dummies.

[$$] The system GMM (SYS) estimator is a combination of the differenced GMM estimator and a GMM levels estimator (see Blundell and Bond, 1998). The reported coefficients are two-step estimates, and the associated *t*-statistics are based on robust, finite sample corrected standard errors (see Windmeijer, 2000). In [4], the instrument set for the differenced equation consists of capital per worker, education, number of workers and openness, in differences, in period t-1, and openness and education, in levels, in period t-2, while the instrument set for the levels equation consists of capital per worker, education, number of workers and openness, in second differences, in period t-1, the difference of openness in t-1, a constant and year dummies. In [5], the instrument set for the differenced equation consists of capital per worker, education, number of workers and openness, in differences, in period t-1, while the instrument set for the levels equation consists of capital per worker, education, number of workers and openness, in second differences, in period t-1, a constant and year dummies.

(1) Tests the null hypothesis that the differenced residuals in periods *t* and *t*-1 are uncorrelated.

(2) Tests the null hypothesis that the differenced residuals in periods *t* and *t*-2 are uncorrelated.

(3) Tests for the validity of the instruments.

(4) Tests for the validity of the instruments in the levels equation.

TABLE 3
GROWTH RATE EQUATIONS WITH SACHS-WARNER OPENNESS MEASURE

	[1] OLS	[2] DIFF	[3] DIFF GMM	[4] SYS$	[5] SYS$
PARAMETER					
Δ Ln (Capital per Worker)	0.36 (4.15)**	0.27 (1.68)+	0.43 (2.45)*	0.43 (2.85)**	0.60 (4.06)**
Δ Ln (Education in years)	0.02 (0.24)	0.04 (0.35)	0.10 (0.83)	0.09 (0.96)	0.06 (0.47)
Δ Ln (Workers)	-0.08 (0.4)	-0.46 (1.63)	0.06 (0.12)	-0.21 (0.57)	0.19 (0.47)
Δ Open	-0.02 (0.56)	-0.001 (0.01)	-0.03 (0.31)	-0.001 (0.02)	
Open	0.078 (4.08)**	0.116 (1.30)	0.064 (0.36)	0.018 (0.22)	0.04 (0.64)
Ln (Education in years)/100	-2.59 (1.13)	-20.88 (1.83)+	-6.16 (0.33)	-3.41 (1.44)	
Period 1975/70	-0.02 (0.87)			-0.014 (0.57)	-0.024 (1.13)
Period 1980/75	-0.03 (1.01)	0.004 (0.11)	0.028 (0.57)	-0.014 (0.43)	-0.012 (0.38)
Period 1985/80	-0.09 (2.77)**	-0.056 (1.75)+	-0.018 (0.63)	-0.056 (1.19)	-0.037 (1.00)
Period 1990/85	-0.026 (0.69)	0.058 (1.89)+	0.075 (1.49)	-0.001 (0.02)	0.017 (0.48)
Inputs Endogenous	No	No	Yes	Yes	Yes
Fixed Effects	No	Yes	Yes	Yes	Yes
Number of Observations	270	216	216	270	270
Number of Countries	54	54	54	54	54
Adjusted R^2	0.38	0.20			
	SPECIFICATION TESTS (*p*-VALUES)				
M1(1)			0.01	0.01	0.01
M2(1)			0.13	0.16	0.08
SARGAN(1)			0.071	0.13	0.11
DIFFERENCE SARGAN(1)				0.47	0.22

Note: The dependent variable is the difference of the log of income per worker. *t*-statistics based on standard errors robust to heteroskedasticity (White, 1980) are reported in parenthesis. Significance at the 1%, 5% and 10% level is indicated by * , ** and + respectively.

Table notes continue on the next page.

Table notes, continued.

[$] The difference GMM estimator is due to Arellano and Bond (1991). The reported coefficients are two-step estimates, and the associated *t*-statistics are based on robust, finite sample corrected standard errors (see Windmeijer, 2000). The instrument set consists of capital per worker, education, number of workers and openness, in differences, in period t-1, openness and education, in levels, in period t-2, a constant and year dummies.

[$$] The system GMM (SYS) estimator is a combination of the differenced GMM estimator and a GMM levels estimator (see Blundell and Bond, 1998). The reported coefficients are two-step estimates, and the associated *t*-statistics are based on robust, finite sample corrected standard errors (see Windmeijer, 2000). In [4], the instrument set for the differenced equation consists of capital per worker, education, number of workers and openness, in differences, in period t-1, and openness and education, in levels, in period t-1, while the instrument set for the levels equation consists of capital per worker, education, number of workers and openness, in second differences, in period t-1, a constant and year dummies. In [5], the instrument set for the differenced equation consists of capital per worker, education, number of workers, in differences, and openness in levels, all in period t-1, while the instrument set for the levels equation consists of capital per worker, education, number of workers, in second differences, in period t-1, openness in first differences in period t-1, a constant and year dummies.

[(1)] See notes to Table 2.

TABLE 4
GROWTH RATE EQUATIONS SYS GMM: OPENNESS EXOGENOUS

	[1]	[2]	[3]	[4]
PARAMETER				
Δ Ln (Capital per Worker)	0.45 (2.53)*	0.43 (2.03)*	0.51 (2.72)**	0.45 (1.91)
Δ Ln (Education in years)	0.06 (0.67)	0.04 (0.40)	0.06 (0.56)	0.06 (0.49)
Δ Ln (Workers)	-0.22 (0.77)	-0.26 (0.74)	0.22 (0.66)	0.09 (0.25)
PWT Open/1000	1.99 (3.17)**	2.4 (2.35)*		
SW Openness Measure			0.092 (2.55)*	0.088 (2.56)*
Period 1975/70	-0.033 (1.48)	-0.04 (1.62)	-0.02 (0.84)	-0.022 (0.80)
Period 1980/75	-0.04 (1.18)	-0.043 (0.97)	-0.02 (0.44)	-0.028 (0.60)
Period 1985/80	-0.08 (1.69)	-0.09 (1.56)	-0.04 (0.86)	-0.022 (0.39)
Period 1990/85	-0.02 (0.46)	-0.03 (0.55)	-0.004 (0.09)	-0.022 (0.23)
Inputs Endogenous	No	No	Yes	Yes
Fixed Effects	No	Yes	Yes	Yes
East Asia Excluded	No	Yes	No	Yes
Number of Observations	270	255	270	255
Number of Countries	54	51	54	51
	SPECIFICATION TESTS (*p*-VALUES)			
OPENNESS EXOGENOUS(1)	0.48		0.25	
M1(2)	0.02	0.02	0.01	0.01
M2(2)	0.28	0.26	0.11	0.15
SARGAN(2)	0.42	0.54	0.12	0.18
DIFFERENCE SARGAN(2)	0.91	0.92	0.36	0.51

Note: The dependent variable is the difference of the log of income per worker. The reported coefficients are two-step system GMM estimates, and the associated *t*-statistics are based on robust, finite sample corrected standard errors (see Windmeijer, 2000). For all specifications the instrument

Table notes continue on the next page.

Table notes, continued.

set for the differenced equation consists of capital per worker, education, number of workers, in differences, in period t-1, while the openness variable (differenced) serves as its own instrument. The instrument set for the levels equation consists of capital per worker, education and number of workers, in second differences, in period t-1, a constant and year dummies.

(1) Tests the validity of including the openness variable differenced as its own instrument in the differenced equation. The consistent (unrestricted) models are those reported in Table 2, Column [5] for PWT, and Table 3, Column [5] for SW. These tests were based on the criterion-based statistic $D_{RU} = N(J(\beta_2^R) - J(\beta_2^U))$, where β_2^U is the two-step GMM estimator in the unrestricted model, β_2^R is the two-step GMM estimator in the restricted model, and $J(\ )$ denotes the Sargan statistic. Under the null hypothesis, D_{RU} follows a Chi-squared distribution with the degrees of freedom being equal to the number of restrictions (see Bond et al, 2000).

(2) See notes to Table 2.

TABLE 5
GROWTH RATE EQUATIONS: CROSS SECTION

	[1]	[2]	[3]	[4]	[5]
	Growth rate of income per worker				Growth of productivity
PARAMETER					
Ln (Education in years) in 1965	0.01 (2.79)**	0.01 (2.40)*	0.01 (2.47)*	-0.001 (0.21)	
Growth Rate of Education 1960-65	0.002 (1.23)	0.002 (1.88)+	0.003 (2.69)*	-0.001 (1.45)	
Average Investment Rate 1965-90/1000		0.85 (2.46)*	0.38 (1.0)	0.01 (0.04)	
Ln (Real GDP per worker) in 1965		-0.012 (3.69)**	-0.014 (4.61)**	-0.014 (4.06)**	
Average of SW Openness Measure 1965-1990			0.019 (2.61)*	0.006 (0.91)	
East Asia (a)					0.071 (3.18)*
Regional dummies	No	No	No	Yes	Yes
Number of observations	54	54	54	54	54
Adjusted R^2	0.09	0.32	0.43	0.72	0.031

Note: The dependent variable for Columns [1]-[4] is the growth rate of Real GDP per Worker from 1965 to 1990. The dependent variable in Column [5] is obtained as follows: the residuals from the growth rate equation reported in Table 2, Column [5] are regressed on country dummies; the coefficients on these country dummies are then used as the measure of a country fixed effect measure of technical change. *t*-statistics based on standard errors robust to heteroskedasticity (White, 1982) are reported in parenthesis. Significance at the 1%, 5% and 10% level is indicated by *, ** and + respectively. In Column [5] none of the other regional dummies, which are not reported, were significant at the 10 per cent level or lower.

(a) The regional dummies included in the regression were for East Asia, Africa, South Asia, the Middle-East, the Industrial countries, Australasia and South-East Asia, see Appendix Table for the countries included in each region. For Column [5] none of the other regional dummies were significant at the 10 per cent level and a joint test of the null that they were jointly zero had a *p*-value of 0.48. The coefficient on East Asia implies that growth in East Asia is higher by 7.1 percentage points per five year period than can be explained either by factor accumulation or the openness of the economy.

TABLE 6
PRODUCTION FUNCTION WITH PWT OPENNESS MEASURE

	[1] OLS	[2] DIFF	[3] $ DIFF GMM	[4] $$ SYS GMM	[5] $$ SYS GMM
PARAMETER					
Ln (Capital per Worker)	0.51 (5.55)**	0.40 (4.47)**	0.23 (1.08)	0.58 (2.56)*	0.69 (5.15)**
Ln (Education in years)	0.14 (0.77)	0.03 (0.32)	-0.14 (0.46)	0.03 (0.09)	-0.06 (0.19)
Ln (Workers)	-0.04 (1.17)	-0.21 (1.14)	-1.39 (1.85)	0.19 (1.48)	0.20 (1.18)
Open/1000	-3.36 (1.98)+	1.57 (1.75)+	3.27 (3.26)**	0.19 (0.11)	
Average Open/1000 * WAVE	0.41 (0.91)	0.15 (2.59)*	0.41 (1.01)	0.79 (3.09)**	0.95 (2.19)*
Average Ln (Education in years)/100*WAVE	5.79 (2.43)*	0.40 (0.80)	-6.51 (1.38)	3.56 (0.86)	
Period 1970/65	-0.098 (2.34)*			-0.128 (2.77)**	-0.096 (2.55)*
Period 1975/70	-0.199 (2.52)*	-0.040 (1.50)	-0.027 (0.88)	-0.273 (2.72)**	-0.205 (2.88)**
Period 1980/75	-0.317 (2.63)*	-0.062 (1.73)+	-0.027 (0.57)	-0.405 (2.48)*	-0.297 (2.84)**
Period 1985/80	-0.481 (3.03)*	-0.122 (2.96)**	-0.106 (1.63)	-0.572 (2.57)*	-0.423 (3.19)**
Period 1990/85	-0.566 (2.78)**	-0.075 (1.38)	-0.040 (0.63)	-0.675 (2.33)*	-0.477 (2.76)**
CONTROL VARIABLES					
Inputs Endogenous	No	No			
Fixed Effects	No	Yes			
Number of Observations	324	270	324	324	324
Number of Countries	54	54	54	54	54
Adjusted R^2	0.79	0.40			
M1(1)			0.29	0.89	0.91
M2(1)			0.21	0.16	0.23
SARGAN (1)			0.36	0.32	0.28
DIFFERENCED SARGAN(1)				0.35	0.86

Note: The dependent variable is the difference of the log of income per worker. *t*-statistics based on standard errors robust to heteroskedasticity (White, 1980) are reported in parenthesis. Significance at the 1%, 5% and 10% level is indicated by * , ** and + respectively.

$ See notes to Table 2. The instrument set consists of capital per worker, and education lagged from 2 to 5 periods and openness lagged 2 periods, a constant and year dummies.

$$ See notes to Table 2. In [4] the instrument set for the differenced equation consists of capital per worker, and education lagged from 2 to 5 periods and openness lagged 2 periods, while the instrument set for the levels equation consists of capital per worker, education, number of workers and openness, in period t-1, a constant and year dummies. In [5] the instrument set for the differenced equation consists of capital per worker, and education lagged from 2 to 5 periods, while the instrument set for the levels equation consists of capital per worker, education, number of workers and openness, in period t-1, a constant and year dummies.

(1) See notes to Table 2.

APPENDIX TABLE
REGIONS AND COUNTRIES INCLUDED IN THE SAMPLE

AFRICA

Kenya
Malawi
Mauritius
Sierra Leone
Zambia
Zimbabwe

AUSTRALASIA

Australia
New Zealand

EAST ASIA

Hong Kong
Republic of Korea
Taiwan

INDUSTRIAL

Austria
Belgium
Canada
Denmark
Finland
France
West Germany
Greece
Iceland
Ireland
Israel
Italy
Japan
Netherlands
Norway
Portugal
Spain
Sweden
Swtizerland
U.K.
U.S.A.

LATIN AMERICA

Argentina
Bolivia
Chile
Colombia
Dominican Republic
Ecuador
Guatemala
Honduras
Jamaica
Mexico
Panama
Paraguay
Peru
Venezuela

MIDDLE-EAST

Iran
Syria

MIDDLE-EUROPE

Turkey
Yugoslavia

SOUTH ASIA

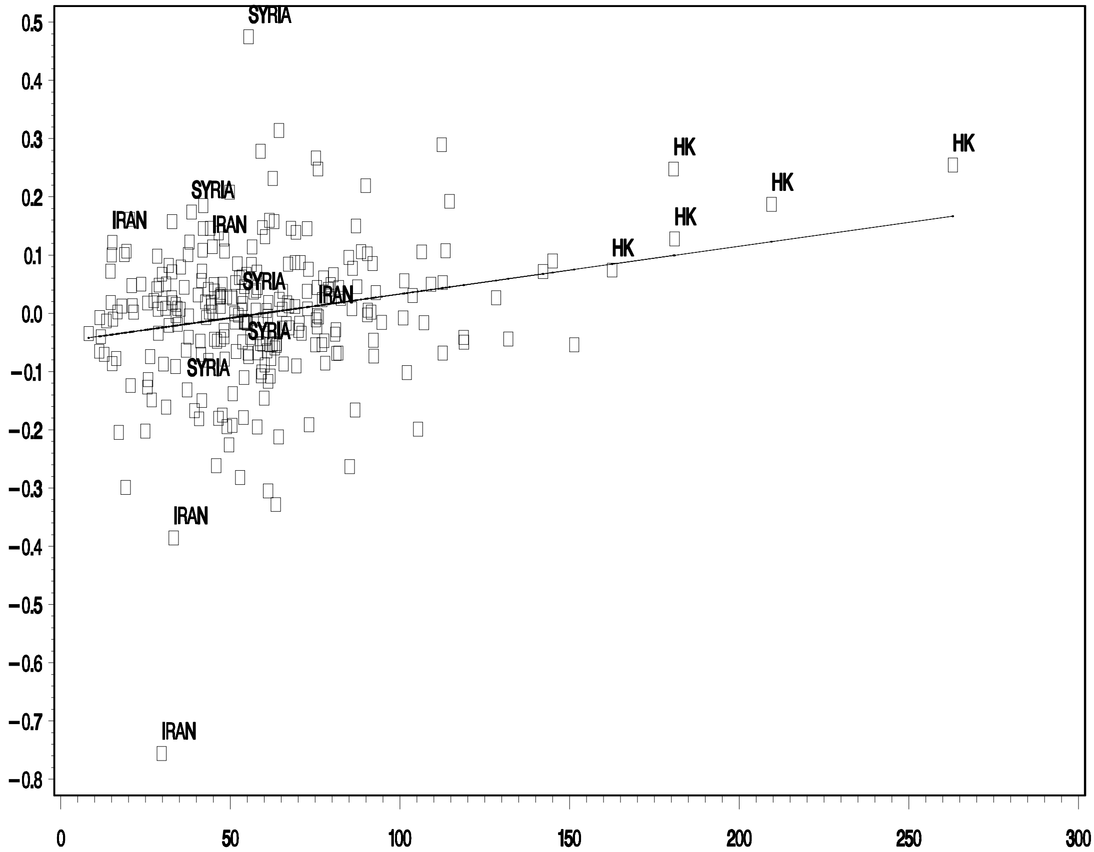
India
Sri Lanka

SOUTH EAST ASIA

Philippines
Thailand

FIGURE 1

TECHNICAL PROGRESS AND THE PWT MEASURE OF OPENNESS



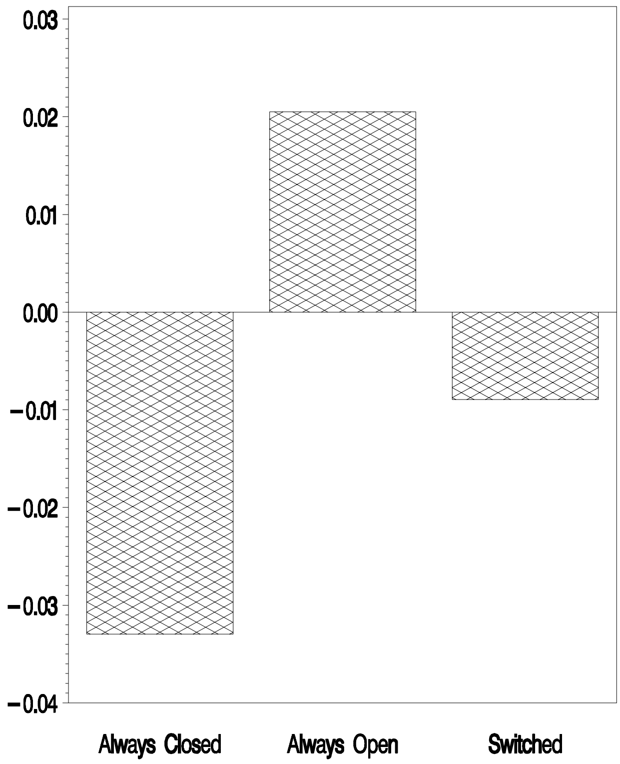
Note: Technical progress is measured as the residual from the estimated OLS regression

$$\Delta \ln [\text{ Income per capita}]_{it} = \underset{[1.12]}{0.01} + \underset{[11.7]}{0.48}\, \Delta \ln [\text{ Physical capital per capita}]_{it} + \varepsilon_{it}$$

where Δ is the difference operator and numbers in [ ] are *t*-statistics. The adjusted R-squared from this regression is 0.33.

FIGURE 2A

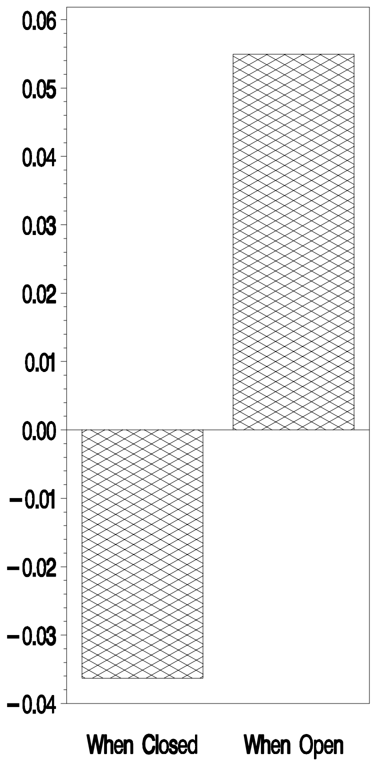
TECHNICAL PROGRESS AND THE SW MEASURE OF OPENNESS: ALL COUNTRIES



Note: 13 countries were always closed, 27 countries always open and 14 countries switched.

FIGURE 2B

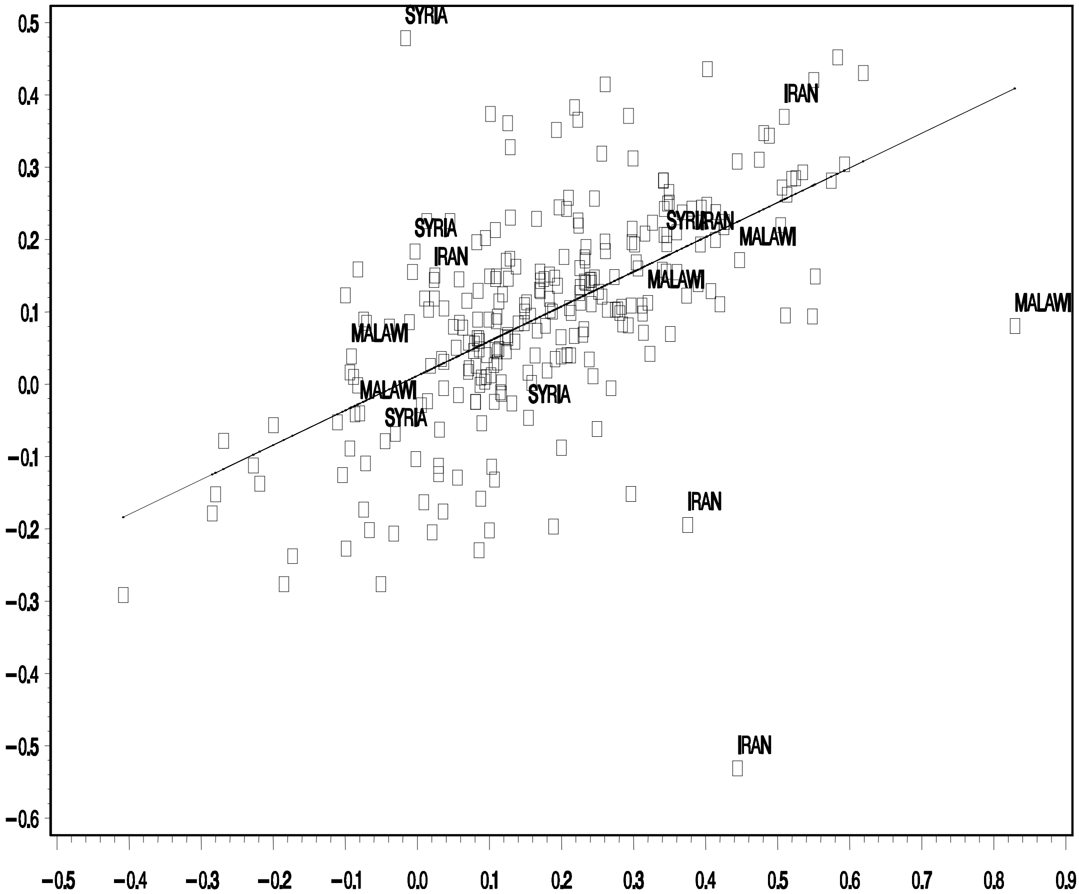
TECHNICAL PROGRESS AND THE SW MEASURE OF OPENNESS: COUNTRIES WHICH SWITCHED



Note: The calculations are based on a total of 70 observations on the 14 countries that switched. Of these, 21 observations were open and 49 were closed.

FIGURE 3

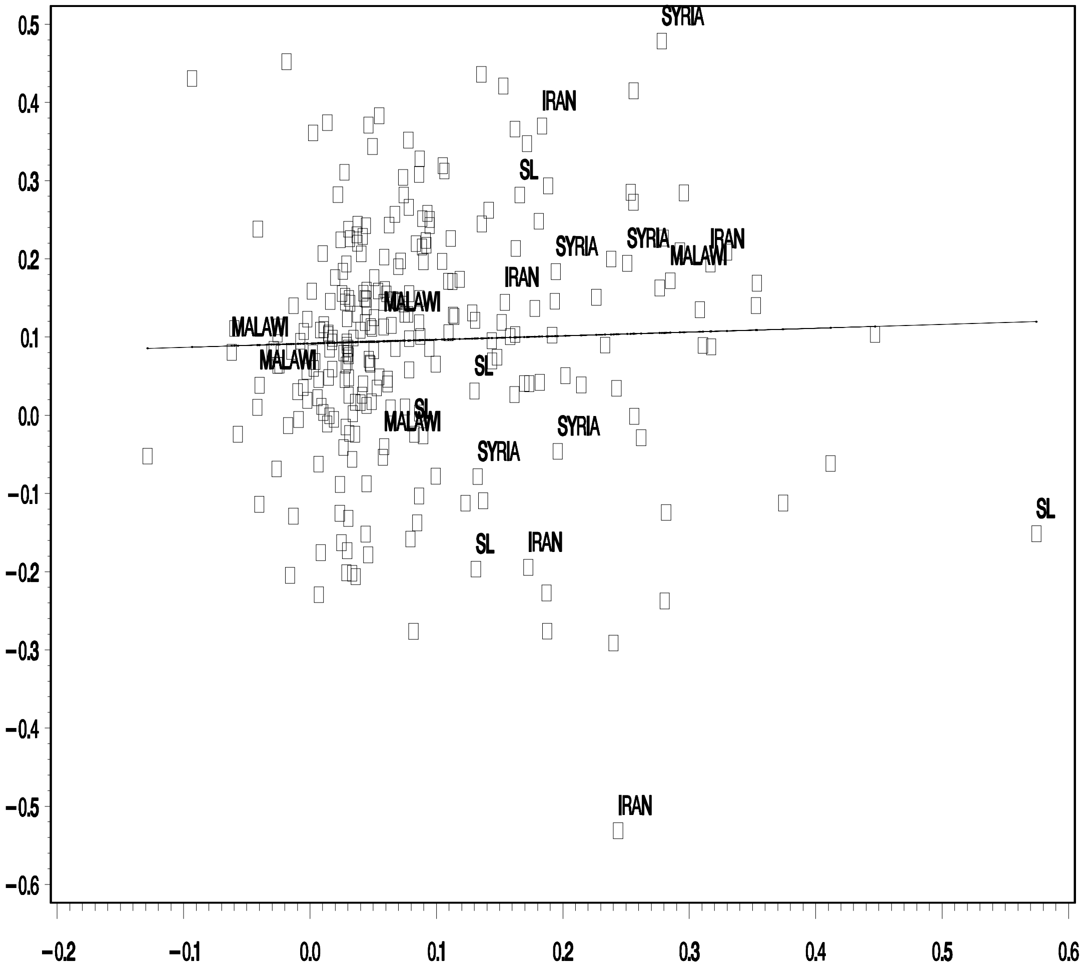
GROWTH RATE OF INCOME PER WORKER AND GROWTH RATE OF PHYSICAL CAPITAL PER WORKER



Note: See notes in Figure 1 for details about the regression results.

FIGURE 4

GROWTH RATE OF INCOME PER WORKER AND GROWTH RATE OF HUMAN CAPITAL



Note: The OLS results are

$$\Delta \ln [\text{ Income per capita}]_{it} = \underset{[7.61]}{0.09} + \underset{[0.53]}{0.05}\ \Delta \ln [\text{ Average years of education }]_{it}$$

where Δ is the difference operator and numbers in [ ] are *t*-statistics. The adjusted R-squared from this regression is 0.00.