The Effects of Openness, Trade Orientation, and Human Capital on Total Factor Productivity

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and

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Abstract

We study the effects of openness, trade orientation, and human capital on total factor productivity for a pooled cross-section, time-series sample of developed and developing countries. We first estimate total factor productivity from a parsimonious specification of the aggregate production function involving output per worker, capital per worker, and the labor force, both with and without the stock of human capital. Then we consider a number of potential determinants of total factor productivity including measures of openness, trade orientation, and human capital. Several findings emerge. A higher openness benefits total factor productivity. An outward-oriented country experiences higher total factor productivity, over and above the positive effect of openness. Finally, human capital generally contributes positively to total factor productivity. For poor countries, however, human capital interacts with openness to achieve a positive effect.

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1. Introduction

Students of trade theory and policy have since the time of Adam Smith debated whether openness and trade liberalization provide the necessary ingredients for economic growth. Edwards (1993) describes the ebb and flow of this debate during the latter half of the twentieth century. Various protectionist theories captured the major attention of trade policy makers after World War II. During the last two decades, however, a growing body of empirical evidence has legitimized the role of market-oriented reforms and trade liberalization. Now, the International Monetary Fund and the World Bank make market-oriented reforms and trade liberalization a condition for financial aid.

The effects of openness and trade liberalization on economic growth remains a highly contentious issue, however.[1] Trade and exchange rate regimes interact with other economic and non-economic factors to affect changes in real per capita income.[2] Larger trade implies greater openness that facilitates the economy's adoption of more efficient techniques of production, leading to faster growth of total factor productivity and, hence, real per capita income.[3] The expansion of exports relaxes the foreign exchange constraint and allows for larger imports of key inputs in the production process. Finally, improvements in the terms of trade can exogenously increase output.

The empirical tests of the effects of openness and trade orientation on economic growth (e.g., Dollar 1992, Sachs and Warner 1995, and Edwards 1998) typically employ cross-section analysis. Edwards (1993) argues that "A more precise answer to this general question (how openness and trade orientation affect output growth) would require more

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[1] Theoretical support for a positive linkage between trade liberalization and growth appears in the newer theories of endogenous growth such as Romer (1986) and Lucas (1988). Other authors such as Krugman (1994) and Rodrik (1995) are skeptical of the trade liberalization-growth nexus. Numerous empirical studies attempt to establish that nexus (e.g., Dollar 1992, Sachs and Warner 1995, Harrison 1996, and Edwards 1998). Rodriguez and Rodrik (1999) argue that the empirical evidence to date does not provide convincing evidence.

[2] Mankiw (1995) and Ventura (1997) argue that the process of equalization of factor prices internationally improves the substitutability of capital and labor, thus, improving growth prospects.

[3] Romer (1992) and Barro and Sala-i-Martin (1995), for example, make this argument.

detailed analysis relying, at least in part, on time series data, …" (p. 1385), parentheses added) and to examining, among other things, "… the robustness of specific results …" (p. 1390). We employ pooled cross-section, time-series data with robustness analysis to improve the likelihood of uncovering important links between openness and trade orientation and total factor productivity.[4]

The reemergence of the importance of growth theory has also refocused much of the debate toward how public policy can affect economic growth. The standard neo-classical growth models [i.e., the Solow (1956) model, Ramsey's (1928) optimal growth model, or Samuelson's (1958) overlapping generations model, and their descendants] have been challenged by the literature on endogenous growth. The neo-classical paradigm considers technological change as an exogenous process whereas the endogenous growth literature makes this process endogenous, looking for possible driving forces.

Mankiw (1995) recently discusses three practical empirical problems associated with the neo-classical approach along with a proposed solution -- the model cannot explain the observed differences in real income per capita across countries, the observed rate of convergence across countries, or the observed differences in real rates of return across countries. He modifies one parameter, the returns to capital, by defining capital to include both physical and human capital, and argues that this one change goes a long way toward allowing the neo-classical model to explain these three empirical regularities.[5,6]

[4] Harrison (1996), for example, argues that developing countries exhibit significant adjustments in trade regimes over time. Cross-section analysis misses those important policy changes. Moreover, she finds stronger results for her pooled cross-section, time series findings than her pure cross-section findings, supporting her observation.

[5] Romer (1995), a leading proponent of endogenous growth theory, disagrees strongly with Mankiw's conclusion that changing the capital share rescues the neo-classical model.

[6] An alternative view of the production process might argue that physical capital contains mixes of different vintages and that human capital contains mixes of different skills. Measures of human capital attempt to reflect the skill mix within a country, recognizing that such measures are typically crude indices of the average level of education or training. To our knowledge, no comparable measure of the technology base that reflects the mix of capital vintages exists. Moreover, we can argue that the vintage mix of capital and the skill mix of labor reflect the existing stock of technological advantage extant within a given country's economy. As such, we should logically look for the effect of human capital on total factor productivity growth rather than include it

Economists, at least since Solow (1957), explain output growth by the accumulation of factor inputs and of the growth of total factor productivity. The growth accounting regressions commonly search for additional determinants of growth beyond the basic factors of production. In effect, these studies treat all determinants of output growth as inputs. That approach may be conceptually inaccurate, since many included determinants may only indirectly affect output. Rather, these determinants affect the efficiency of the real inputs, physical capital, labor, and possibly human capital. Consequently, these additional determinants of output growth directly affect total factor productivity.

Our analysis involves two steps. First, we calculate two total factor productivity measures from production function specifications that exclude and include human capital as an input. Second, we search for significant determinants of total factor productivity, especially measures of openness and trade orientation.[7] While the existing literature has identified total factor productivity to be large and significant, much less work searches for the determinants of total factor productivity. We add some depth to this latter discussion.

We can state our basic findings simply. First, a country's openness, as measured by the ratio of exports to gross domestic product (GDP), has a significant and robust positive effect on total factor productivity.[8] Second, outward orientation, as measured by deviations from purchasing power parity (PPP), lead to a significant and robust negative effect on total

directly into the production function. An agnostic approach, which we adopt, examines both possibilities for the effect of human capital on the growth process.

[7] Our analysis complements Edwards (1998). He adds richness to the existing literature by considering 9 different measures of openness and trade orientation within a cross-section framework. We add richness to the existing literature by introducing the time dimension to the cross-section work. Harrison (1996) considers 6 openness measures and introduces time in a panel setting. She examines each measure of openness and trade orientation individually, rather than simultaneously, because her panels do not overlap sufficiently. We confine our analysis to an identical panel that allows consideration of variables simultaneously. As a result, data availability constrains us to a much smaller set of openness and trade-orientation measures. We do, however, compile openness and other external variables for our larger cross-section, time-series panel of 83 countries. Given the well-known data problems for measuring total factor productivity, openness, and trade orientation, the richer the mix of studies and findings, the more confidence that can be placed on those consistent results.

[8] Robustness check uses Leamer's (1983) extreme bounds analysis.

factor productivity.[9] Finally, human capital has a significant effect on output when it is included as a factor of production. The inclusion of human capital in the production function lowers the elasticity of output with respect to labor when compared to the production function without human capital. The elasticity of output with respect to physical capital remains essentially unaltered by the introduction of human capital as an input. Further, human capital positively affects total factor productivity in many, but not all, specifications. Finally, for low-income countries, human capital possesses a negative effect on total factor productivity until openness exceeds a threshold, where the effect turns positive.

Our paper progresses as follows. In the next section, we estimate parsimonious production functions and determine the levels of total factor productivity under two specifications -- one with and one without the stock of human capital as an input. We consider the importance and robustness of various determinants of total factor productivity in section 3. Finally, we conclude in section 4.

2. Estimates of the Production Function and Total Factor Productivity

Our total factor productivity measures emerge from the estimation of a production function. To keep the analysis simple, we adopt, as a first approximation, the Cobb-Douglas production function. Thus, our two production functions, one excluding and one including the stock of human capital, are expressed as follows:

(1) $Y = A\,K^{\alpha} L^{\beta}, \qquad 0 < \alpha < 1$ and $0 < \beta < 1,$ and

(2) $Y = A\,K^{\alpha} H^{\gamma} L^{\beta}, \qquad 0 < \alpha < 1, 0 < \gamma < 1,$ and $0 < \beta < 1,$

where Y equals real GDP, K equals the total physical capital stock, L equals the number of workers (labor force), H equals our measure of human capital, and A equals an index of total factor productivity. We allow for the possibility of non-constant returns to scale by not restricting $(\alpha + \beta)$ or $(\alpha + \beta + \gamma)$ to equal one.

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[9] Rodriguez and Rodrik (1999) question the validity of deviations from PPP as a trade distortion. We find, nonetheless, that if trade distortions produce deviations from PPP, this affects total factor productivity.

Dividing equations (1) and (2) by the labor force *(L)* expresses output, the physical capital stock, and the human capital stock on a per worker basis. That is,

(3) $$y = A\, k^{\alpha}\, L^{\alpha+\beta-1}, \text{ and}$$

(4) $$y = A\, k^{\alpha}\, h^{\gamma}\, L^{\alpha+\beta+\gamma-1},$$

where y equals real GDP per worker, k equals the per worker stock of physical capital, and h equals the per worker stock of human capital. These production functions display increasing, constant, or decreasing returns to scale as $(\alpha + \beta)$ or $(\alpha + \beta + \gamma)$ are greater than, equal to, or less than one, respectively.

Rewriting equations (3) and (4) in natural logarithms yields the following:

(5) $$lny = lnA + \alpha\, lnk + (\alpha + \beta - 1)\, lnL, \text{ and}$$

(6) $$lny = lnA + \alpha\, lnk + \gamma\, lnh + (\alpha + \beta + \gamma - 1)\, lnL.$$

Thus, constant returns to scale implies that the coefficient of lnL equals zero.

Using human capital as an input in the production function is controversial. Mankiw, Romer, and Weil (1992) theoretically and empirically advocate that approach and generate a better fit with human capital in their cross-section regressions. Islam (1995), using panel regressions, finds that human capital does not contribute significantly to explaining output. Rather, human capital should significantly affect total factor productivity.

Benhabib and Spiegel (1994) also incorporate human capital into a growth-rate estimation of the production function. They discover insignificant or negative coefficients for the human capital variable (i.e., the growth rate of human capital). This finding leads them to consider more complex paths (i.e., through interaction terms) whereby human capital affects growth. They conclude that human capital does not enter the production function as an input, but rather influences growth through its effect on total factor productivity.

We use, as does Islam (1995), panel data to estimate the production function. Our data cover 1960 to 1989 (1959 to 1989 for any growth rate) for 83 countries. The following regions appear in our data set : Africa (19 countries), Caribbean, Central America, and North America (11), South America (11), Asia (16), Europe (20), and Oceania (4). The Data

Appendix, Table A, lists the countries included in our sample and reports our two measures of total factor productivity. Data availability limited the country sample. Our panel combines data in five-year blocks as follows: 1960-64, 1965-69, 1970-74, 1975-79, 1980-84, and 1985-89. Usually, the data are averages of the five years in each block.

The data for estimating the production function come largely from the Summers and Heston (1991) Penn World Table 5.6 (PWT5.6). The output measure is real GDP per worker (1985 international prices) averaged over five-year blocks. The labor force is derived from the reported data on real GDP per capita, real GDP per worker, and population. The labor force is also averaged over five-year blocks. The physical capital stock per worker was not available for all years in all countries. Thus, to keep from losing too many countries in the panel, we estimated the capital stock from investment flow data and some benchmark stocks of physical capital. (See the Data Appendix for details.) Finally, the stock of human capital is based on the average years of schooling per adult reported by NBER/Barro and Lee (1994). (See the Appendix for details.) Due to data availability, we measure the stock of human capital at the beginning of each five-year period rather than an average over the period (i.e., 1960 for the 1960-64 time period).

Our data encompasses 498 observations (83 countries and 6 time blocks). Our estimating equations emerge by adding random errors to equations (5) and (6). These error terms incorporate the effects of omitted variables. Classical regression analysis assumes that the omitted variables are independent of the included right-hand-side variables and are independently, identically distributed. When using panel data, however, we can further classify the omitted variables into three groups -- country-varying time-invariant, time-varying country-invariant, and country- and time-varying variables.[10]

The estimation of equations (5) and (6) without consideration of possible country-specific or time-specific effects can generate misleading results for ordinary-least-squares

[10] For more details about panel estimation, consult Hsiao (1986) and Greene (1990).

regressions. We restrict our attention to fixed-effect estimation since the random-effects estimation requires that the omitted variables are uncorrelated with the included right-hand-side variables -- an unrealistic assumption in the context of our model.

Our problem, however, has few elements in the time dimension. Thus, rather than adjusting the data as deviations from the mean across countries, we include time-specific dummy variables (i.e., six dummy variables for the six time periods). We still adjust the data as deviations from the means over time within each country rather than include country-specific dummy variables, which would necessitate 83 additional variables.

The estimated equations are as follows:[11]

(7) $$\ln y = \ln A + \alpha \ln k + (\alpha + \beta - 1) \ln L + \sum_{i=1}^{6} \theta_i \, time_i + \varepsilon$$ and

(8) $$\ln y = \ln A + \alpha \ln k + \gamma \ln h + (\alpha + \beta + \gamma - 1) \ln L \, , + \sum_{i=1}^{6} \theta_i \, time_i + \varepsilon,$$

where $time_i$ (i = 1, ..., 6) represent the time dummy variables and the variables for each country measure deviations from their country means over time. We then calculate the country-specific fixed effects of intercepts ($cint_j$) as follows:

(9) $$cint_j = \overline{\ln y}_j - \hat{\alpha} \, \overline{\ln k}_j - \hat{\delta}_1 \, \overline{\ln L}_j$$ and

(10) $$cint_j = \overline{\ln y}_j - \hat{\alpha} \, \overline{\ln k}_j - \hat{\gamma} \, \overline{\ln h}_j - \hat{\delta}_2 \, \overline{\ln L}_j \, ,$$

where a bar over a variable indicates the mean of that variable, a caret over a parameter indicates the estimate of that parameter, $\delta_1 = (\alpha + \beta - 1)$, $\delta_2 = (\alpha + \beta + \gamma - 1)$, and j = {1,2,3,...,83} is the index across countries. Note that the time-specific fixed effects appear directly as the respective coefficients of the time dummy variables.

Table 1 reports the estimates of equations (7) and (8) as well as two modifications of equation (7). Column one gives the estimate of equation (7). The coefficient of *ln L* (i.e., -0.0988), although only significant at the 20-percent level, indicates that the production

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[11] The estimation of an aggregate production function confronts the researcher with numerous problems. One major concern is the possible endogeneity of physical and human capital, since these factors are accumulated over time. Benhabib and Spiegel (1994) examine this issue and conclude that the coefficients of physical and human capital probably over-estimate their effects while the coefficient of labor probably under-estimates its effect. The reader needs to keep these potential biases in mind when interpreting our findings.

function exhibits slightly decreasing returns to scale. The coefficient of *ln k* assigns a value of 0.4756 to the elasticity of output with respect to the physical capital stock. These two coefficients combine to generate the implied elasticity of output with respect to the labor force of 0.4256. Thus, after accounting for country- and time-specific effects, the output elasticities with respect to labor and physical capital sum to a value of 0.9012.

Column 2 in Table 1 reports the estimates of equation (8), where the stock of human capital per worker enters the production function.[12] Now, the output elasticity with respect to human capital equals 0.1136, which is significantly different from zero at the 10-percent level. The output elasticity with respect to physical capital remains essentially unchanged from the specification without human capital at 0.4712. The combined elasticity of output with respect to physical and human capital totals 0.5848, not too far from the findings of Mankiw, Romer, and Weil (1992). The implied elasticity of output with respect to the labor force falls to 0.2769, suggesting that the coefficient of labor in the specification without human capital captures much of the influence of human capital. In sum, our human capital results support the findings of Mankiw, Romer, and Weil (1992) and differ from those of Islam (1995) and Benhabib and Spiegel (1994).

An alternative method of incorporating human capital into estimates of the production function allows for the interaction of human capital with either physical capital or the labor force.[13] That is, changes in human capital affect either the elasticity of output with respect to physical capital or the labor force. Column three of Table 1 reports the results of interacting the stock of human capital with the stock of physical capital per worker while column four, human capital and the labor force. The elasticity of output with respect to physical capital is significantly affected by the stock of human capital; the elasticity of output with respect to

[12]In fact, we measure the stock of human capital as the average years of schooling per adult. We assume that the variable provides a good proxy for the average years of schooling per worker.

[13] To calculate the total stock of human capital, we multiply our measure of human capital (i.e., average years of schooling per worker) times the number of workers to get the average years of schooling in the labor force.

labor is not. So, once again, we find evidence suggesting a link between human and physical capital rather than human capital and the labor force.

The time-specific dummy variables tell a consistent story. Total factor productivity increases over each five-year time span from 1960-64 to 1975-79. The last two time spans -- 1980-84 and 1985-89 -- suggest a stagnation in total factor productivity growth.

We employ the estimates of equations (7) and (8) (i.e., columns 1 and 2 in Table 1) to produce total factor productivity estimates for each country over time. Table A in the Appendix ranks the 83 countries for our two different estimates of total factor productivity averaged over time. These two rankings possess a rank correlation of 0.9761, indicating a consistent pattern across the two different estimates of total factor productivity. Moreover, the correlation between our two total factor productivity measures and real GDP per worker equal 0.68 and 0.60, excluding and including human capital in the production function.[14]

3. Determinants of Total Factor Productivity

This section studies the role of trade-related variables and other factors in influencing total factor productivity. We derived two different measures of total factor productivity in section 2 based on estimated production functions that exclude and include the stock of human capital. Our estimating equation takes the following form:

$$\begin{aligned}(11)\qquad \ln tfp = {} & a_1 + a_2 \ln H + a_3 \ln x + a_4 \ln tot + a_5 \ln pd + a_6 \ln (1+\pi) \\ & + a_7 \ln \sigma_x + a_8 \ln \sigma_{tot} + a_9 \ln \sigma_{pd} + a_{10} \ln \sigma_\pi \\ & + \sum_{i=1}^{6} a_{10+i}\, time_i + \varepsilon,\end{aligned}$$

where x equals the ratio of exports to GDP,[15] *tot* equals the terms of trade, *pd* equals local price deviation from purchasing power parity, π equals the inflation rate, and σ_i equals the

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[14] As with any cross-country calculation of total factor productivity, a cursory examination of the data may suggest anomalous results. We offer a word of caution. An "old chestnut" among development economists argues that the productivity growth in agriculture falls below that in manufacturing. Martin and Mitra (1999) report that "… technical progress appears to have been faster in agriculture than in manufacturing. Moreover, there is strong evidence of convergence in levels and growth rates of TFP in agriculture, suggesting relatively rapid international dissemination of innovations." (p. 20)

[15] We also examined regression results where we used imports plus exports to GDP rather than just exports to GDP. The export-to-GDP ratio performed somewhat better.

standard deviation of i (= x, tot, pd, and π) over the five-year sub-periods. Details on the variables are contained in the Data Appendix.

We estimate equation (11) using the fixed-effect method where each variable in each country is measured as a deviation from its mean over time.[16] In addition, we include time dummy variables to capture fixed effects over time. Table 2 reports the results of our estimates of equation (11). Columns 1 and 5 report the estimates of equation (11) where the dependent variable is the total factor productivity variable that excludes and includes the stock of human capital in the first-stage production function regressions, respectively.

Taken together, the trade variables tell a consistent story. The export-to-GDP ratio has a significant positive effect at the 1-percent level. A more open economy, other things equal, associates with higher total factor productivity. The local price deviation from purchasing power parity has a significant negative effect at the 5-percent level. What does this imply? An increase in deviations from purchasing power parity means that the countries currency becomes less undervalued (more overvalued). Trade policies that lower (raise) the real exchange rate toward or below (above) its purchasing power parity value associate with higher total factor productivity. In sum, real exchange rate changes that stimulate exports (and limit imports) associate with a higher total factor productivity. Moreover, to the extent that trade-orientation effects cause the movement in the real exchange rate, those effects on total factor productivity exist even though the regression holds the openness variable constant – the effect is over and above the openness effect. The terms of trade variable has a positive effect, but it is only significant at the 20-percent level.[17]

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[16] Table 2 reports results based on ordinary least squares regressions. In an attempt to address issues of endogeneity, we also estimated the equations using once-lagged values of the independent variables, except for the time dummy variables. By construction, once-lagged values represent essentially a five-year lag. The findings are essentially unchanged, although the levels of significance generally fall using the lagged values. Introducing lagged values does reduce degrees of freedom by 83. Footnotes report when the results using once-lagged values differ from the ordinary least squares findings.

[17] Moreover, the terms of trade is insignificant when once-lagged values replace independent variables.

The inflation rate negatively affects total factor productivity at the 1-percent level. That higher inflation associates with lower total factor productivity may explain the observed empirical regularity between higher inflation and lower economic growth.[18] That is, higher inflation lowers economic growth through its effect on total factor productivity.

The volatility variables have, on average, much less significance in explaining total factor productivity. The one exception, the volatility of exports to GDP, has a significant negative effect at the 1-percent level. That is, the less variable and more stable the openness variable, the higher is total factor productivity.

In sum, a higher and more stable export-to-GDP ratio, a lower inflation rate, and lower-valued currency associate with higher total factor productivity.

We also note that the specification in equation (11) leads to a stock of human capital variable that is insignificant in column 1, but negative and significant at the 20-percent level in column 3. These results are consistent with the findings of many researchers. These researchers, however, generally examine the effect of human capital on growth rather than on total factor productivity. Islam (1995) and Benhabib and Spiegel (1994) suggest that human capital may affect growth indirectly through total factor productivity.

Finally, consistent with production function estimates, a significant pattern emerges in the time fixed effects. Total factor productivity grows monotonically, other things equal, from 1960-64 through 1975-79, leveling off and/or falling somewhat in the 1980s.

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[18] While Levine and Renelt (1992) find that the effect of inflation on economic growth is fragile, they do find that it is consistently negative. Kormendi and Meguire (1985), Grier and Tullock (1989), and Miller and Russek (1997) report evidence of a negative effect of inflation on economic growth. Bruno and Easterly (1998) argue that the negative effect becomes stronger the higher the frequency of the data (e.g., correlation improves when moving from a 30-year cross section to 10-year averages to 5-year averages to annual data). Bruno and Easterly (1998) also find a threshold effect, discovering a significant negative effect on economic growth when inflation is restricted to levels above 40 percent per year.

Human Capital-Trade Openness Interaction

Another possible way that human capital affects total factor productivity is its interaction with trade orientation.[19] Greater openness fosters competition, encourages modern technology, increases the demand for high-skilled labor, and promotes learning by doing.[20]

Columns 2 and 6 in Table 2 add the interaction term of human capital and the export-to-GDP ratio. The coefficient of the interaction term is positive and significant at the 5- and 10-percent levels for the total factor productivity measure that excludes and includes the stock of human capital in the first-stage production function regressions, respectively. The effect of the ratio of exports to GDP on total factor productivity remain significant and positive [i.e., both coefficients of (*ln x*) and (*ln H ln x*) are positive]. Now, however, the effect of openness is leveraged by the stock of human capital -- more human capital implies a larger effect of openness on total factor productivity.

The effect of the stock of human capital on total factor productivity becomes conditioned on the level of exports to GDP. For low levels of openness, the coefficient on the stock of human capital, which is negative, dominates the positive coefficient on the interaction between openness and human capital. For large levels of openness, this effect of human capital on total factor productivity reverses and becomes positive, since the interaction term dominates the isolated effect of human capital.

We can calculate the level of exports to GDP when the total effect of the stock of human capital on total factor productivity reverses sign. For the results in column 2 of Table 2, this reversal occurs based on point estimates when exports to GDP reaches about 11 percent. The level rises to about 50 percent for the results in column 6. We note that the results in column 6 already incorporate the effect of the stock of human capital on total

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[19] Grossman and Helpman (1991) suggest that increased trade orientation may interact with human capital to produce higher output growth. Benhabib and Spiegel (1994) interact human capital with other variables including technological progress.

[20] Leamer (1995), among others, claims that increased U. S. foreign trade has led to an increase in the real wage of skilled workers and a corresponding reduction in the real wage of unskilled workers.

factor productivity through the inclusion of human capital in the first-stage production function estimation. Thus, the level of openness when human capital begins to have a positive effect on total factor productivity rises from 11 to 50 percent.

This finding possesses intuitive appeal. To wit, as noted previously, greater openness fosters competition, encourages modern technology, increases the demand for high-skilled labor, and promotes learning by doing. Too little openness, therefore, does not allow a country to leverage its stock of human capital. Human capital investment absent liberalization of the external sector may lead to the under-utilization of human capital.[21]

Finally, we also note that the inclusion of the human capital and openness interaction term does not have significant effects on the magnitudes, signs, and significance of the other variables in the total factor productivity regressions.[22]

Robustness of the Openness and Trade Orientation Effects

Numerous empirical studies attempt to link trade liberalization and faster economic growth (e.g., Dollar 1992, Sachs and Warner 1995, and Edwards 1998). Rodriguez and Rodrik (1999) provide an exhaustive examination of the more prominent empirical papers that establish this link, concluding that the evidence is not convincing. Given the existing controversy about tests of trade liberalization, we provide evidence on the robustness of the coefficient estimate for deviations from purchasing power parity (and openness).

We apply the extreme bounds analysis of Leamer (1983), using the approach of Breusch (1990).[23] We divide the independent variables into "free" and "doubtful" categories.

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[21] Upadhyay (1994, 1997) provides a theoretical discussion of (1) large education subsidies that cause a rapid human capital expansion at the cost of expanding physical capital, and (2) the effect of public-sector schemes to employ human capital, frequently for reasons of political economy rather than public goods, that we observe in many countries in Africa or Asia.

[22] We also interacted human capital with, in turn, the terms of trade and local price deviation from PPP. The coefficient of the interaction of human capital and the terms of trade is significantly positive while the coefficient of the terms of trade becomes insignificant. The coefficient of the interaction of human capital and local price deviation from PPP is not significant. Moreover, the inclusion of these differing interaction terms also has no significant effects on the magnitudes, signs, and significance of the other variables in the total factor productivity regressions. Complete results are available from the authors.

[23] Miller and Russek (1996) provide an illustration of implementing Bruesch's (1990) method.

Free variables, usually containing the inferences of interest, appear in all sub-family models tested. Doubtful variables may or may not appear in any given sub-family model. Sensitivity analysis determines how much the coefficient of interest varies as we impose different restrictions on the doubtful variables. Extreme bounds analysis calculates the bounds on the coefficient of interest over all possible linear combinations of the doubtful variables. Breusch (1990) provides a simple procedure for calculating the extreme bounds using the regression output from restricted and unrestricted regressions.

We adopt columns 2 and 6 from Table 2 as our unrestricted model. We define the free variables to include the time dummy variables, the inflation rate, and the two variables of interest – openness and deviations from purchasing power parity. The remaining variables are classified as doubtful.[24] The restricted model sets the coefficients of the doubtful variables to zero (see Breusch 1990, p. 78, equation 17). The extreme bounds are 0.0645 lower bound and 0.1365 upper bound for the coefficient of openness and –0.1016 lower and –0.0166 upper for the coefficient of deviations from purchasing power parity.

McAleer, Pagan, and Volker (1985) define Type A and Type B coefficient fragility based on the extreme bounds. Type B fragility occurs when the extreme bounds encompass zero. In this case, we conclude that neither of our variables possesses Type B fragility. Type A fragility occurs when the extreme bounds exceed k times the standard deviation of the focus coefficient (i.e., the coefficient of the deficit). McAleer, Pagan, and Volker (1985, p. 296) argue that the literature is unclear about the choice of k. Miller and Russek (1996) note that a necessary condition for Type A fragility is that the chi-squared statistic for the doubtful variable coefficients equal their prior means exceeds k^2 (McAleer, Pagan, and Volker, 1985, p. 296 and Breusch, 1990, p. 76). Thus, we follow Miller and Russek (1996) and set k equal to the square-root of the chi-squared statistics with 7 degrees of freedom for the 1-, 5-, 10-, and 20-

[24] We also experiment with a few other classifications of free and doubtful variables, but always include openness and deviations from purchasing power parity as free. Breusch (1990) suggests not including variables of interest in the doubtful category to "… avoid cases in which there appear to be obvious anomalies." (p. 79). Those results produce findings consistent with those reported in the text.

percent levels of significance, producing k values of 4.30, 3.75, 3.46, and 3.13, respectively. Based on these values for k, Type A fragility does not exist for the coefficients of either openness or deviations from purchasing power parity, at even the 20-percent level. That is, k times the standard deviation of the focus coefficient in the unrestricted regression exceeds the difference between the upper and lower bounds on the focus coefficient.

In sum, we find that both the coefficients of the export to GDP ratio and the deviations from purchasing power parity are robust in the sense of Leamer (1983).

Structural Shifts due to the Exchange Rate Regime

Some authors (e.g., Edwards 1993 and his citations) suspect that openness and trade orientation may affect economic growth differently depending on the exchange rate regime. As a crude test, we rerun the total factor productivity regressions where each independent variable except for the time dummy variables are interacted with an exchange rate regime dummy variable that equals zero in 1960-64, 1965-69, and 1970-74 and equals one in 1975-79, 1980-84, and 1985-89. The exchange rate dummy variables distinguished roughly between the Bretton Woods and post-Bretton Woods exchange rates.[25]

We first run regressions with all exchange rate interaction variables included and then rerun the regressions where we drop interaction variables that are insignificant at the 20 percent level. Table 2 columns 3 and 4 report the results for the total factor productivity measure calculated from the production function that excludes human capital.[26]

Several points deserve mention. First, most variables do not experience shifts in their coefficients between Bretton Woods and post-Bretton Woods. Only the coefficient of the standard deviation of the terms of trade shifts in both specifications while the coefficients of human capital and human capital times openness shift in the specifications with only human capital and with human capital times openness, respectively.

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[25] While many countries stayed with a fixed exchange rate regime after the Bretton Woods collapse, a world trend toward a flexible exchange rate regime evolved clearly by 1976.

[26] Similar results emerge for the measure of human capital calculated from the production function that includes the human capital measure. Results are available from the authors.

Second, the story of the effect of human capital on total factor productivity changes. Now, human capital and its interaction with openness significantly and positively affect total factor productivity. No openness threshold causes the effect of human capital to change sign. The significant, positive effect appears, however, only post-Bretton Woods.

Finally, both the openness (exports to GDP) and trade orientation (deviations from purchasing power parity) variables remain highly significant during both Bretton Woods and post-Bretton Woods, continuing the robustness that we see in our prior analysis.

In sum, little evidence exists of structural change in our total factor productivity regressions between Bretton Woods and post-Bretton Woods. A positive effect of human capital on total factor productivity exists, but only during post-Bretton Woods.

Differences due to the Level of Development

Rodriguez and Rodrik (1999) suggest that a fruitful area for cross-sectional research could consider whether "… trade restrictions operate differently in low- versus high-income countries." (p. ??). Other authors (e.g., Miller and Russek 1997) suggest that analysis such as ours needs disaggregation into sub-samples of countries of similar levels of development. We divide our sample into three sub-samples – low-, middle-, and high-income countries based on World Bank data on real per capita income.[27] We run the total factor productivity regressions across each group. Table 3 reports the results with total factor productivity calculated from the production function that excludes human capital.[28]

Several points deserve mention. First, the time fixed effects shown in Table 2 imply that total factor productivity rose during the 1960s and 1970s and leveled off during the 1980s. Table 3 provides an interesting (distressing) twist. To wit, the low-income countries did not

[27] We divided our sample into low-, middle-, and high-income countries based on real GDP per worker in the 1960-64 period. The World Bank divides countries into low-, middle-, and high-income countries based on real GDP per capita. Using a number in the range of 2 to 2.5 to measure the ratio of population to the number of workers, we convert these ranges into ranges based on real GDP per worker. Low-income countries had an average income for 1960-64 below $3,000 per worker; middle-income countries, between $3,000 and $10,000 per worker; and high-income countries, above $10,000 per worker.

[28] Similar results emerge for the measure of human capital calculated from the production function that includes the human capital measure. Results are available from the authors.

participate in the expansion of total factor productivity experienced through the time fixed effects. Rather such increases in total factor productivity were restricted to the middle-income, and to a lesser extent the high-income, countries.

Second, the significant negative effect of inflation on total factor productivity in Table matches similar significant negative effects in low- and middle-income countries. The effect in high-income countries, although negative, is not significant.

Third, the effects of the terms of trade and human capital on total factor productivity exhibit different stories across the three income groups. One, middle-income countries experience a significant positive link between the terms of trade and total factor productivity; low-income countries, a significant negative link; and high-income countries, no significant link. Two, high-income countries experience a negative effect of human capital on total factor productivity while middle-income countries experience a significant positive effect. Low-income countries conform to the threshold effect encountered in Table 2. That is, until openness is large enough the effect of human capital on total factor productivity is negative. Once openness reaches a certain level (i.e., 7 percent of GDP, lower than the 11 and 50 percent in Table 2), human capital possesses a positive effect on total factor productivity.

Finally, our openness variable (exports to GDP) continues its strong positive effect on total factor productivity in each income group. Our trade orientation variable (deviations from purchasing power parity) ceases to have a significant effect on total factor productivity in each income group, although it possesses a strong negative effect in Table 2. Such findings require that differences in deviations in purchasing power parity between groups is much more than differences within income groups, a finding that we see in the data.

In sum, the disaggregation of countries into comparable income categories uncovers some new insights from our total factor productivity regressions. Low income countries do not experience the improvement in total factor productivity resulting from the time fixed effects. Such effects emerge in the middle- and high-income countries, although the strongest effects are in the middle-income countries. The human capital and terms of trade variables have different effects in the different income groups. The negative effect of inflation on total factor productivity confines itself to the low- and middle-income countries.

4. Conclusion

We study the effects of openness, trade orientation, and human capital on total factor productivity for a pooled cross-section, time-series sample of developed and developing countries. We estimate total factor productivity from a parsimonious specification of the aggregate production function involving output per worker, capital per worker, and the labor force, both with and without the stock of human capital. Then, we search for possible determinants of total factor productivity, with special emphasis on trade variables.

We find that opening the economy to trade generally benefits total factor productivity. Opening the economy to trade means increasing exports to GDP, improving the terms of trade, and lowering the real value of the domestic currency. Moreover, the stock of human capital contributes positively to total factor productivity in many, but not all, specifications. That is, human capital has a negative effect on total factor productivity in high-income countries and a positive effect in middle-income countries. The effect of human capital on total factor productivity in low-income countries moves from negative to positive as the country moves from a low to a higher level of openness. As a result, counterproductive effects emerge from human capital investment within the low-income countries unless the country achieves a certain level of openness.

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Table 1: **Production Function Estimates**

	lny	*lny*	*lny*	*lny*
lnk	0.4756*	0.4712*	0.3951*	0.4751*
	(18.86)	(18.64)	(9.38)	(18.81)
lnL	-0.0988‡‡	-0.1383‡	-0.1988**	-0.1510‡‡
	(-1.32)	(-1.78)	(-2.39)	(-1.40)
lnh		0.1136‡		
		(1.81)		
lnH lnk			0.0091**	
			(2.38)	
lnH lnL				0.0025
				(0.67)
$time_1$	-0.1097*	-0.1005*	-0.0936*	-0.1071*
	(-3.99)	(-3.55)	(-3.25)	(-3.80)
$time_2$	-0.0339‡	-0.0268‡‡	-0.0224	-0.321‡‡
	(-1.66)	(-1.30)	(-1.08)	(-1.56)
$time_3$	0.0316**	0.0360**	0.0379**	0.0326**
	(2.13)	(2.40)	(2.53)	(2.19)
$time_4$	0.0426*	0.0456*	0.0441*	0.0460*
	(3.04)	(3.01)	(2.91)	(3.03)
$time_5$	0.0330‡‡	0.0263	0.0215	0.0312‡‡
	(1.60)	(1.26)	(1.02)	(1.50)
$time_6$	0.0328	0.0195	0.0125	0.0293
	(1.23)	(0.71)	(0.45)	(1.08)
$\bar{R}^2$	0.7860	0.7872	0.7885	0.7857
SEE	0.1269	0.1266	0.1262	0.1270

Note: All regressions employ the fixed-effect technique. Each variable is measured as a deviation from its mean over time, except the 6 time dummy variables (i.e., $time_i$, i = 1, 2, ..., 6) that capture the fixed effects over time. The variables are defined as follows: *y* equals real GDP per worker; *k* equals the capital stock per worker; *L* equals the stock of workers; *H* equals the stock of human capital; and *h* equals the stock of human capital per worker. See the Data Appendix for more details about the definitions and sources of data. $\bar{R}^2$ is the adjusted coefficient of determination and *SEE* is the standard error of estimation.

* means significant at the 1-percent level.
** means significant at the 5-percent level.
‡ means significant at the 10-percent level.
‡‡ means significant at the 20-percent level.

Table 2: Total Factor Productivity Regressions

	lntfp		*lntfp*		*lntfph*	
lnH	0.0090 (0.29)	-0.0961‡‡ (-1.64)	0.0258 (0.81)	0.0129 (0.19)	0.0437‡‡ (-1.39)	-0.1357* (-2.32)
lnx	0.1237* (6.08)	0.0925* (3.70)	0.1131* (5.63)	0.1039* (4.16)	0.1207* (5.97)	0.0935* (3.76)
lnH lnx		0.0395** (2.12)		0.0063 (0.30)		0.0346‡ (1.87)
lntot	0.0283‡‡ (1.38)	0.0286‡‡ (1.40)	0.0368‡ (1.82)	0.0323‡‡ (1.61)	0.0295‡‡ (1.45)	0.0298‡‡ (1.46)
lnpd	-0.0703** (-2.03)	-0.0821** (-2.35)	-0.1053* (-3.00)	-0.1088* (-3.13)	-0.0779** (-2.26)	-0.0882** (-2.54)
$ln(1+\pi)$	-0.1550* (-3.78)	-0.1560* (-3.82)	-0.1430* (-3.53)	-0.1377* (-3.39)	-0.1548* (-3.79)	-0.1557* (-3.83)
σ_x	-0.0023* (-3.14)	-0.0028* (-3.65)	-0.0025* (-3.38)	-0.0029* (-3.81)	-0.0024* (-3.20)	-0.0028* (-3.63)
σ_{tot}	0.00003 (0.23)	0.00004 (0.30)	0.0002‡‡ (1.43)	0.0003‡‡ (1.65)	0.00003 (0.21)	0.00004 (0.27)
σ_{pd}	0.0006‡‡ (1.60)	0.0008‡ (1.94)	0.0008** (2.12)	0.0009** (2.30)	0.0006‡ (1.68)	0.0008** (1.97)
σ_{π}	0.0116‡‡ (1.33)	0.0117‡‡ (1.35)	0.0105 (1.22)	0.0103 (1.21)	0.0115‡‡ (1.33)	0.0116‡‡ (1.34)
$time_1$	-0.1061* (-6.36)	-0.1001* (-5.95)	-0.0711* (-3.40)	-0.0673* (-3.27)	-0.1123* (-6.78)	-0.1071* (-6.39)
$time_2$	-0.0336** (-2.22)	-0.0303** (-1.99)	0.0007 (0.04)	0.0038 (0.20)	-0.0369** (-2.45)	-0.0340** (-2.25)
$time_3$	0.0306** (2.27)	0.0321** (2.40)	0.0603* (3.41)	0.0628* (3.53)	0.0302** (2.26)	0.0315** (2.37)
$time_4$	0.0515* (3.61)	0.0511* (3.59)	0.0319** (1.97)	0.0307‡ (1.89)	0.0548* (3.86)	0.0594* (3.84)
$time_5$	0.0312** (2.06)	0.0270‡ (1.77)	-0.0004 (-0.02)	-0.0039 (-0.20)	0.0348** (2.31)	0.0312** (2.05)
$time_6$	0.0264‡‡ (1.53)	0.0201 (1.15)	-0.0214 (-0.91)	-0.0261 (-1.12)	0.0295‡ (1.71)	0.0240‡‡ (1.38)
lnH d75			0.0513* (3.24)			
lnH lnx d75				0.0176* (3.27)		
$\sigma_{tot}d75$			-0.0006* (-2.74)	-0.0006* (-2.89)		
$\bar{R}^2$	0.3040	0.3101	0.3311	0.3372	0.2836	0.2880
SEE	0.1166	0.1161	0.1143	0.1138	0.1159	0.1156

Table 2: (continued)

Note: See Table 1. Results of estimating equation (11) where the dependent variables are, in turn, the natural logarithm of total factor productivity derived from production functions that exclude (*tfp*) and include (*tfph*) human capital. Other variables are defined as follows: *x* equals the ratio of exports to GDP; *tot* equals the terms of trade; *pd* equals the local price deviation from purchasing power parity; π equals the inflation rate; *d75* equals zero in 1960-64, 1965-69, and 1970-74 and equals one in 1975-79, 1080-84, and 1985-89; and σ_i equals the standard deviation of i = *x, tot, pd,* and π over each 5-year sub-period. Moreover, just like the time dummy variables, *d75* is not adjusted for its mean in the fixed-effect estimation.

* means significant at the 1-percent level.
** means significant at the 5-percent level.
‡ means significant at the 10-percent level.
‡‡ means significant at the 20-percent level.

Table 3: Total Factor Productivity Regressions by Income Category

	lntfp (22 low)		*lntfp (38 middle)*		*lntfp (23 high)*	
lnH	0.0555	-0.1321‡‡	0.1073**	0.0469	-0.1527**	-0.0224
	(1.12)	(-1.37)	(1.86)	(0.37)	(-1.97)	(-0.09)
lnx	0.1252*	0.0912*	0.1138*	0.0860‡	0.2095*	0.2723**
	(4.00)	(2.67)	(3.08)	(1.37)	(3.98)	(2.25)
lnH lnx		0.0680**		0.0236		-0.0456
		(2.25)		(0.55)		(-0.58)
lntot	-0.0768**	-0.0782‡	0.0808*	0.0788*	0.0292	0.0351
	(-1.71)	(-1.78)	(2.94)	(2.83)	(0.64)	(0.74)
lnpd	0.0266	-0.0385	0.0022	0.0064	-0.0180	-0.0219
	(0.42)	(-0.56)	(0.03)	(0.10)	(-0.24)	(-0.29)
$ln(1 + \pi)$	-0.0880*	-0.0921‡	-0.2475**	-0.2396**	-0.0121	-0.0361
	(-1.56)	(-1.67)	(-2.37)	(-2.27)	(-0.10)	(-0.27)
σ_x	-0.0083	-0.0065	-0.0025*	-0.0027*	-0.0031**	-0.0025‡‡
	(-1.21)	(-0.96)	(-2.94)	(-2.90)	(-2.09)	(-1.43)
σ_{tot}	0.0026**	0.0035**	-0.0001	-0.0001	-0.0025	-0.0026
	(1.81)	(2.41)	(-0.77)	(-0.75)	(-1.06)	(-1.10)
σ_{pd}	0.0010**	0.0013*	-0.0007	-0.0008	-0.0015	-0.0016
	(2.10)	(2.66)	(-0.67)	(-0.73)	(-0.88)	(-0.92)
σ_π	-0.0060	-0.0080	0.0315**	0.0307‡	-0.0170	-0.0143
	(-0.31)	(-0.42)	(1.78)	(1.73)	(-0.96)	(-0.78)
$time_1$	-0.0384	-0.0235	-0.1330*	-0.1300*	-0.1068*	-0.1127*
	(-1.11)	(-0.68)	(-5.13)	(-4.90)	(-3.64)	(-3.61)
$time_2$	0.0251	0.0256	-0.0656*	-0.0632*	-0.0281	-0.0348
	(0.82)	(0.85)	(-2.87)	(-2.72)	(-1.04)	(-1.18)
$time_3$	0.0225	0.0110	0.0367**	0.0386**	0.0646*	0.0616**
	(0.77)	(0.38)	(1.84)	(1.90)	(2.75)	(2.55)
$time_4$	-0.0165	-0.0067*	0.0733*	0.0724*	0.0240	0.0274
	(-0.55)	(-0.23)	(3.48)	(3.42)	(0.92)	(1.02)
$time_5$	-0.0096	-0.0073	0.0490**	0.0468**	-0.0031	0.0044
	(-0.31)	(-0.24)	(2.16)	(2.02)	(-0.11)	(0.14)
$time_6$	0.0168	0.0009	0.0395‡	0.0353	0.0493**	0.0541‡
	(0.44)	(0.02)	(1.42)	(1.22)	(1.87)	(1.95)
$\bar{R}^2$	0.2541	0.2846	0.4499	0.4477	0.3423	0.3379
SEE	0.1240	0.1215	0.1134	0.1137	0.0904	0.0907

Table 3: (continued)

Note: See Table 1. Results of estimating equation (13) where the dependent variables are, in turn, the natural logarithm of total factor productivity derived from production functions that exclude (*tfp*) and include (*tfph*) human capital. Other variables are defined as follows: *x* equals the ratio of exports to GDP; *tot* equals the terms of trade; *pd* equals the local price deviation from purchasing power parity; π equals the inflation rate; and σ_i equals the standard deviation of i = *x, tot, pd,* and π over each 5-year sub-period.

* means significant at the 1-percent level.
** means significant at the 5-percent level.
‡ means significant at the 10-percent level.
‡‡ means significant at the 20-percent level.

Data Appendix:

As noted in the text, the panel data set includes information from 83 countries over the 1960 to 1989 period. Observations are generally averaged over five year sub-periods -- 1960-64, 1965-69, 1970-74, 1975-79, 1980-84, and 1985-89. Thus, the panel includes 498 observations (83 countries and 6 time periods). The countries included in the sample were restricted merely by data availability. Table A lists the countries ranked by their total factor productivity calculated from the production function that excludes human capital. The Table also lists the ranking of the countries based on the total factor productivity estimated when human capital was included in the production function. The rest of this Data Appendix provides more information about the sources and in some cases estimation of the data.

Physical Capital

Most data on the physical capital stock comes from the Summers and Heston (1991) Penn World Table 5.6 (PWT5.6). Data for some countries in some years were missing from this table. To maintain a reasonably large sample, we estimate the capital stock series for some countries, where either the data on important components of the capital stock are available, or where data on the total capital stock are available for some years. We considered the following procedures in estimating the capital stock series.

1. For those countries that do not have capital stock data available for the beginning of the sample, we choose the steady-state method to estimate missing values. At the steady state, the capital output ratio (K/Y) is constant. This implies that the rates of change in capital and output are equal. Furthermore,

$$dK_t = I_t - \delta K_t\ , \Rightarrow (dK_t/K_t)\ (K_t/Y_t) = (I_t/Y_t) - (\ \delta K_t/Y_t).$$

Since the steady state levels of output and capital grow at the same rate, we have the following:

$$(dY_t/Y_t)\ (K_t/Y_t) = (I_t/Y_t) - (\ \delta K_t/Y_t) \Rightarrow (g_t + \delta)\ (K_t/Y_t) = (I_t/Y_t).$$

Thus, solving for the steady-state capital output ratio gives the following:

$$(K_t/Y_t)^* = (I_t/Y_t)^*/(g^*_t + \delta),$$

where "*" refers to steady-state values and δ equals 7 percent.

The steady-state growth rate of output (g^*) does not equal the actual growth rate for any country. Rather, as assumed by King and Levine (1994), we use the following relationship:

$$g^* = \lambda g + (1 - \lambda) g_W,$$

where g is the period-average actual growth rate for the country in question, g_W is the actual world growth rate estimated at 4 percent per year, and λ = 0.25, a measure of mean reversion in the growth rates, following Easterly et al. (1993). This, then produces the steady-state capital output ratio [$(K_t/Y_t)^*$].

Finally, multiplying the steady-state capital output ratio by the average output for the five-year period yields the average capital stock for the period, and dividing by the average number of workers for the same period produces the per worker capital stock.

2. When the capital stock in the initial years is available, we follow the perpetual inventory method to calculate the capital stock as follows:

$$K_t = I_t + (1 - \delta) K_{t-1}.$$

Finally, the estimated numbers are adjusted based on any discrepancy, in the first year the actual numbers are again available, between the estimated and actual numbers.

Human Capital

We employ the average educational attainment (years of schooling) for the adult population, available from the NBER/Barro-Lee (1994) data set.

Terms of Trade

Our main source for export and import prices (and unit values) is *International Financial Statistics* (CD-ROM, July 1996, and several yearbook print issues). Various sources are used to compile the trade price data that are missing from the *International Financial Statistics* (various issues). Some come from the World Bank *World Tables* (various issues). The remaining data are compiled, and in some cases estimated based on information, from United Nations *Monthly Bulletin of Statistics* (various issues), *International*

Financial Statistics Yearbook (various issues), *Direction of Trade Statistics Yearbook* (various issues), and UNCTAD *Handbook of International Trade and Development*, (1994).

Many of the estimated numbers resulted from the use of proxies such as unit values of the commodities or commodity groups that contribute a major share of trade (e.g., export price of phosphate for Jordan, crude petroleum price for Algeria, and cotton and coffee prices for Nicaragua); share-weighted average of major trading partner's import prices (for export prices of the country in question); and export prices (for import prices) where a county's commodity trade is significantly diversified but trade is largely concentrated with a small number of countries (e.g., France's import and export prices proxy Niger's export and import prices for 1959-66, and for the same period for Trinidad & Tobago the import prices are the import-share-weighted average of wholesale prices of the United States and the United Kingdom, and export prices of Venezuela).

Inflation

The chief source of data on inflation is the database for Fischer's World Bank growth project, contained in the World Bank Growth Database. Inflation rates are annual percentage changes in the consumer price index. We added the data for 1960 and 1989 from the *International Financial Statistics* (various issues). For Guinea-Bissau (1960-87), we use, for lack of better data, the average inflation for Africa; and for Jordan (1960-67), the average inflation for "Other Middle East." Both of these series come from the *International Financial Statistics Yearbook* (various issues). Finally, for seven other countries for a few years, we used the GDP deflators, again from the *International Financial Statistics Yearbook* (various issues).

Local Price Deviation from Purchasing Power Parity

This variable comes from the PWT5.6. The variable *P* in PWT5.6 measures the local price of an identical basket of goods for all countries relative to the price in the United States. Hence it is a measure of the local price deviation from purchasing power parity, with the United States as the reference country.

Openness

We use two measures of openness -- the ratio of exports plus imports to GDP and the ratio of exports to GDP. If exports and imports always move closely together, then the two measures may provide the same information. Levine and Renelt (1992) indicate that these two measures provide the same qualitative results in their analysis of the determinants of growth. We find that exports to GDP performs uniformly better in our analysis of the determinants of total factor productivity.

The data for exports plus imports to GDP come from the PWT5.6. This data base, however, does not separate exports from imports. Hence, to generate exports to GDP, we use *International Financial Statistics Yearbooks* (various issues) for both exports and GDP. To fill in some missing export data for some countries in a few years, we use the *Direction of Trade Statistics* (various issues), the United Nations *Monthly Bulletin of Statistics* (various issues), and the UNCTAD *Handbook of International Trade and Development* (1994).

Volatility Measures

We use volatility measures of (1) inflation, (2) terms of trade, (3) local price deviation from purchasing power parity, (4) exports-plus-imports-to-GDP ratio, and (5) export-to-GDP ratio. We measure volatility as the standard deviation of a variable for the 5 years that constitute the respective 5-year period in the sample.

Table A

Country	Rank *tfp*	Rank *tfph*	Country	Rank *tfp*	Rank *tfph*
United States	1	1	Hong Kong	43	45
Trinidad-Tobago	2	7	Mauritius	44	49
United Kingdom	3	3	Fiji	45	57
France	4	4	Israel	46	55
Bangladesh	5	2	Uganda	47	39
Jordan	6	12	Greece	48	51
Venezuela	7	9	Haiti	49	42
Netherlands	8	13	Turkey	50	41
Argentina	9	11	Syria	51	50
Canada	10	14	Portugal	52	46
Algeria	11	8	South Korea	53	53
Brazil	12	5	Malta	54	63
Iran	13	6	Senegal	55	52
Australia	14	18	Paraguay	56	61
Mexico	15	10	India	57	38
West Germany	16	16	Iceland	58	64
Italy	17	15	Dominican Republic	59	59
New Zealand	18	28	Thailand	60	54
Belgium	19	24	Ghana	61	56
Japan	20	17	Colombia	62	58
Austria	21	22	Philippines	63	60
Sweden	22	27	Peru	64	62
South Africa	23	20	Cyprus	65	66
Uruguay	24	30	Ecuador	66	65
Yugoslavia	25	26	Swaziland	67	69
Spain	26	23	Bolivia	68	67
El Salvador	27	29	Jamaica	69	70
Mozambique	28	19	Panama	70	72
Tunisia	29	25	Botswana	71	71
Denmark	30	36	Papua New Guinea	72	68
Pakistan	31	21	Honduras	73	73
Nicaragua	32	33	Guyana	74	77
Guatemala	33	32	Zambia	75	74
Barbados	34	48	Lesotho	76	78
Chile	35	37	Sri Lanka	77	76
Malaysia	36	34	Malawi	78	75
Singapore	37	40	Kenya	79	79
Ireland	38	43	Niger	80	80
Indonesia	39	31	Togo	81	81
Norway	40	44	Zimbabwe	82	82
Finland	41	47	Guinea-Bissau	83	83
Zaire	42	35			

Table A: (continued)

Note: The countries are ranked based on the logarithm of total factor productivity calculated from the production function specifications that exclude (*tfp*)and include (*tfph*) our measure of human capital. The actual values of the logarithm of total factor productivity are available on request.