Working Paper

INTERNATIONAL MONETARY FUND

WP/00/17

IMF Working Paper

International Trade and Productivitiy Growth: Exploring the Sectoral Effects for Developing Countries

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IMF Institute

International Trade and Productivity Growth: Exploring the Sectoral Effects for Developing Countries

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Authorized for distribution by Samir El-Khouri

February 2000

Abstract

The paper estimates an empirical relation based on Krugman's 'technological gap' model to explore the influence of the pattern of international trade and production on the overall productivity growth of a developing country. A key result is that increased import competition in medium-growth (but not in low- or high-growth) manufacturing sectors enhances overall productivity growth. The authors also find that a production-share weighted average of (technological leaders') sectoral productivity growth rates has a significant effect on the rate of aggregate productivity growth.

JEL Classification Numbers: F10, F43, O10, O40

Keywords: Productivity Growth, Trade Liberalization, Technological Gap

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I. Introduction

Developing countries do not in general perform research and development, and rely largely on technological knowledge produced in industrial countries. Their productivity growth thus depends, to a large extent, on the rate at which they can acquire technology developed by industrial countries. A popular view is that international trade represents an important conduit for the transfer of technology and trade liberalization would thus enable developing countries to achieve faster productivity growth. A number of recent studies have found a positive link between international trade and productivity growth in developing countries.[1] Coe, Helpman and Hoffmaister (1997), for example, provide evidence that increased trade with industrial countries boosts productivity growth of developing countries via R & D spillovers.[2]

Although the role of international trade in facilitating technology transfer is generally recognized, some reservations remain about the view that free trade enhances productivity growth. An important reservation is that the comparative advantage of developing countries is likely to lie in traditional sectors with slow growth. Unrestricted trade could trap their production in such sectors and, in fact, lead to a lower rate of productivity growth.[3] There is little empirical evidence that bears directly on the role that a developing country's pattern of international trade and production can play in determining its overall productivity growth. Exploring this link is the main objective of this paper. For this purpose, the paper examines the determinants of productivity growth in developing countries, using a methodology that incorporates the influence of sectoral composition of production, as well as of openness at the sectoral level.

Our empirical analysis uses a multi-sector framework based on Krugman's (1985) model of technology gap. In this model, the best-practice technology improves at constant but different rates across sectors. Less advanced countries face longer time lags in acquiring best-practice techniques. They are thus farther behind the technological frontier (have larger

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[1] There is also a considerable literature linking growth of GDP or GDP per capita with various aggregate measures of openness. See Edwards (1993) and Rodrik (1995) for reviews of this literature.

[2] Jaumotte (1998) finds evidence that more trade with industrial countries enables developing countries to narrow their technological gap at a faster rate. Moreover, Hakura and Jaumotte (1998) find that these countries catch up faster, the greater is the share of sectors with large intra-industry trade.

[3] Such a possibility is discussed in the endogenous-growth literature. See Lucas (1988, section 5) for an example based on a model with learning by doing. Grossman and Helpman (1991, chapters 18-19), discuss a number of cases where free trade reduces productivity growth of a technologically-disadvantaged country.

technology gaps) and have a comparative disadvantage in sectors where productivity grows more rapidly. The view that international trade facilitates the transfer of technology is incorporated in the model by allowing a country's technology lag in a sector to be inversely related to the openness of the sector. The aggregate rate of productivity growth in the long run is a weighted average of sectoral growth rates with weights given by production shares. In this setup, although increased openness of a sector does not have a permanent effect on the productivity growth rate, it can raise the growth rate in transition to the long run by shortening the technology lag for the sector.

The above framework is implemented using a panel data set that includes 33 developing countries and covers more than two decades. Data for large industrial countries (that are likely to be technological leaders) is used to estimate long-run rates of sectoral productivity growth. Sectoral indexes of openness are based on exports and imports normalized by domestic production. The multi-sector framework enables us to investigate whether the effect of openness on productivity growth differs between sectors with different growth rates.

The basic framework is discussed in Section 2. Key features of the data are described in Section 3. Results of the empirical analysis are presented in Section 4. Section 5 concludes the paper.

II. Basic Framework

This section describes a multi-sector framework based on Krugman's (1985) model of technology gap, which underlies the paper's empirical analysis. Let $A_j^*(t)$ denote total factor productivity (TFP) corresponding to the best-practice technology for sector j at time t. Assume that it grows at a constant rate and can thus be expressed (after dropping the time argument) as

$$A_j^* = \exp[\gamma_j t]. \tag{1}$$

The rate, γ_j, orders sectors according to a technology scale (for example, high-tech sectors have relatively large growth rates). Countries acquire the best-practice technology with a time lag. Thus country i's TFP in sector j evolves according to

$$A_j^i = \exp[\gamma_j (t - \lambda_j^i)] , \tag{2}$$

where λ_j^i is the country's sectoral technology lag. This lag equals zero for the technological leader in the sector who has immediate access to the best-practice technology.

According to (1) and (2), a country's sectoral productivity gap (relative to the technological leader) is $A_j^* / A_j^i = \exp[\gamma_j \lambda_j^i]$. This gap depends on both the growth rate and the technology lag for the sector. Note that if a country has the same technology lag in all sectors ($\lambda_j^i = \lambda^i$), its productivity gap in a sector would be larger, the higher is the sector's growth rate. Developing countries would face longer technology lags than industrial

countries. They would thus be farther away from the technology frontier in high-tech sectors and tend to have a comparative disadvantage in these sectors.

Let g_j^i $(\equiv \dot{A}_j^i / A_j^i)$ denote the rate of country i's TFP growth in sector j (with a dot over a variable representing its derivative with respect to time), and use (2) to obtain

$$g_j^i = \gamma_j (1 - \dot{\lambda}_j^i). \tag{3}$$

In the long run, the technology lag would be constant and country i's TFP growth rate in each sector would equal the rate for the technological leader. In transition to the long run, however, the technology lag could decrease or increase and thus the country's sectoral TFP could grow faster or slower than the leader's TFP.

The technology lag can depend on a number of factors. We focus on the hypothesis that an increase in openness leads to a more rapid transfer of technology (i.e., a shorter technology lag). We thus express the technology lag as

$$\lambda_j^i = \phi_j(v_j^i), \tag{4}$$

where v_j^i is an index of openness for country i's sector j with $\phi_j'(v_j^i) < 0$. The function $\phi_j(v_j^i)$ is assumed, for simplicity, to be the same for all countries but is allowed to differ across sectors. The choice of the openness index depends on how international trade affects the technology transfer process.

There are several mechanisms through which an increase in international trade could facilitate the transfer of technology. First, increased contact with foreign agents could lead to a more rapid transmission of foreign technological knowledge. Second, greater exposure to foreign products may make imitation easier. Both of these mechanisms suggest that transfer of technology in a sector would depend largely on trade within the sector. It is also possible that trade in one sector may enhance productivity in another via input-output relations. For example, larger imports of foreign intermediates could increase the access to foreign technological improvements embodied in such goods and facilitate production of final goods. The relative importance of exports and imports in technology transfer would depend on the mechanism at work. For example, imports are crucial in acquiring embodied foreign technology and would play a more important role in imitation. Exports, on the other hand, could provide greater contact with foreign agents than imports. The paper's empirical analysis assumes that the openness index depends on both import and export intensities and lets the data determine the relative importance of each intensity.

The implications of the above model can also be derived for the aggregate rate of TFP growth. Letting $\bar{g}^i$ denote this rate, we can define it as the following weighted average of the sectoral rates:

$$\bar{g}^i = \sum_j s_j^i g_j^i, \tag{5}$$

where s_j^i is the output share of sector j in country i. Using (3)-(5), we obtain the following key relation that underlies the empirical analysis in the next section:

$$\bar{g}^i = \sum_j s_j^i \gamma_j - \sum_j s_j^i \gamma_j \phi_j'(v_j^i)\dot{v}_j^i . \quad (6)$$

In (6), the first term on the right hand side represents the aggregate growth rate in the long run. Note that if output shares vary across countries, the aggregate rate will not converge among countries in the long run. In this case, the long-run aggregate growth would be slower for countries that specialize in the products of low-tech sectors. The second term captures transitional dynamics caused by changes in technology lags arising from sectors becoming more or less open. The effect of a change in a sector's openness index ($\dot{v}_j^i$) can vary from one sector to another because of differences not only in s_j^i and γ_j but also in $\phi_j'(v_j^i)$. Note that if there is little scope for technology transfer in sectors at the lower end of the technology scale, $\phi_j'(v_j^i)$ would tend to be small for sectors with low γ_j. Increased openness of such sectors, in this case, would have little impact on overall productivity growth.

The above model could be relevant for a country at any stage of economic development but it is designed especially for developing countries where international trade is a major source of technology transfer. The empirical analysis below estimates a regression equation based on (6) and tests the influence of sectoral composition of production and international trade on overall productivity growth, using a sample consisting mostly of developing countries.

III. Data

This section briefly describes some key features of the data used in the empirical analysis. Sources of all data and further details are given in Data Appendix. To estimate the empirical model based on (6), the paper uses a data set that includes 44 countries (of which 33 are developing countries) and the 1970-93 period.[4] The data set also covers 10 sectors. As the paper is mainly concerned with the role of international trade in manufacturing industries, manufacturing is broken down into nine sectors (at the 2-digit ISIC level) but all nonmanufacturing industries are aggregated into one sector.[5]

The estimates of long-run sectoral growth rates, γ_j's, are based on the long-period TFP growth performance of large OECD countries, France, West Germany, Japan, the United Kingdom and the United States. This group includes countries with large R & D expenditures, which are likely to be close to the technological frontier (have short technology lags). Simple averages of the five large countries' long-run (1970-93) sectoral TFP growth

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[4] For five of these countries, Argentina, Bangladesh, Dominican Republic, Kenya, and Panama only a part of the period is covered.

[5] Satisfactory data on sectoral composition of nonmanufacturing is also difficult to obtain for many developing countries in our sample.

rates are used to measure γ_j's.[6] For each country, the TFP growth rate of a sector is calculated as the difference between the rate of growth of sectoral output (value added) and a Cobb-Douglas weighted average of growth rates of capital and labor in the sector.

For each of the ten sectors, Table 1 shows the mean (and the standard deviation) of the long-run sectoral TFP growth rates for the five large countries. On the basis of this measure, the table classifies the nine manufacturing sectors into low-growth, medium-growth and high-growth groups. The long-run TFP growth rate for the nonmanufacturing sector is very close to the growth rates for manufacturing industries in the low-growth group. The sectoral means (and standard deviations) of the long-run sectoral TFP growth rates for a sample of twelve OECD countries are also shown in Table 1. This data are broadly consistent with the three-way classification of manufacturing sectors (according to their TFP growth trends) suggested by the large-country data.[7]

Estimates of sectoral shares, s_j^i's, are based on value-added data. There are a number of gaps in this data and the missing values are imputed or estimated. Estimation of the weighted average of sectoral TFP growth rates, $\bar{g}^i$, also requires TFP data at the sectoral level. As such data are not available for non-OECD countries, we approximate $\bar{g}^i$ by the rate of growth of aggregate TFP, which is calculated as the difference between the rate of growth of aggregate output and a Cobb-Douglas weighted average of growth rates of total capital and labor.[8]

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[6] The sectoral growth rates for a large industrial country i could be expressed as $g_{jt}^i = \gamma_j + \varepsilon_{jt}^i$, where ε_{jt}^i represents deviations from the long run values. Short-run influences and country-specific determinants of innovative activity could lead to large deviations but we assume that the average of ε_{jt}^i across all large countries and the entire sample period is small for each sector and thus our measure provides a useful proxy for γ_j.

[7] An exception is Basic Metal Industries, which would belong to the high-growth group according to the 12-country sample.

[8] Our measure differs from $\bar{g}^i$ [as defined in (5)] as follows. Using the (two-factor) Cobb-Douglas production function and letting a hat over a variable denote its growth rate, we have $g_j^i = \hat{Y}_j^i - \beta_j \hat{K}_j^i - (1-\beta_j)\hat{L}_j^i$, where Y_j^i, K_j^i and L_j^i represent country i's (value-added) output, capital and labor in sector j, and β_j is the share of capital in sector j. Denoting our aggregate measure by $\tilde{g}^i$, we also have $\tilde{g}^i = \hat{Y}^i - \beta \hat{K}^i - (1-\beta)\hat{L}^i$, where $Y^i = \sum_j Y_j^i$, $K^i = \sum_j K_j^i$, $L^i = \sum_j L_j^i$ and β is capital's aggregate share. Assuming that factor prices are the same in each sector, $\beta = \sum_j s_j^i \beta_j$. Using these expressions and (5), we obtain

(continued...)

Table 2 shows the 1970-93 aggregate TFP growth rate for each country in our sample and averages of these rates for different regions. There is considerable variation in aggregate TFP growth rates across countries and regions. East Asia shows the highest TFP growth rate while Sub-Saharan Africa (SSA) and Latin America register the lowest rates. Table 2 also shows (1970-93) average shares of the three manufacturing groups as well as nonmanufacturing. The fast-growing East Asia has the highest share of high-growth manufacturing sectors and the lowest share of low-growth sectors (nonmanufacturing plus low-growth manufacturing). In contrast, slow-growing SSA has the lowest share of the high-growth sectors and (along with South Asia) the highest share of the low-growth sectors. The inter-country differences in sectoral shares, however, are small and thus would account for only a limited variation in cross-country productivity growth. For example, if East Asian production shares were used instead of SSA shares as weights, the weighted average of long-run sectoral growth rates (i.e., $\sum_j s_j^i \gamma_j$) would increase by only 0.001.[9]

The sectoral openness index is based on x_j^i and m_j^i, which are defined, respectively, as the ratios of exports and imports to value added in country i's sector j. Table 3 shows the average change in the sectoral import and export ratios over the sample period for the nine manufacturing sectors and the three manufacturing groups. As the table indicates changes in the trade ratios tend to vary considerably across manufacturing groups and thus the data for total manufacturing is generally not representative of sectoral changes. For example, SSA registers the highest change in both import and export ratios for all manufacturing but the disaggregated data reveals that these changes mainly reflect increases in low-growth sectors. A similar pattern holds for import ratios of the Middle East North Africa (MENA) region, which has the second highest increase in aggregate import ratios over the period. On the other hand, although East Asia exhibits a relatively small increase in the import ratio for all manufacturing, it experiences the largest increase in import ratios for the medium growth sectors.

$\tilde{g}^i - \bar{g}^i = \sum_j s_j^i [\beta_j (\hat{K}_j^i - \hat{K}^i) + (1-\beta_j)(\hat{L}_j^i - \hat{L}^i)]$. This discrepancy would be included in the error term in our regression equations discussed below.

[9] Averages of sectoral production shares and growth rates were used in this calculation.

IV. RESULTS

The empirical model is specified as

$$\bar{g}_t^i = a_1 \sum_j s_{jt}^i \gamma_j + a_{2j} \sum_{j \neq N} s_{jt}^i \gamma_j \Delta v_{jt}^i + u_t \,, \tag{7}$$

where N represents the non-manufacturing sector, u_t is an error term and a's are parameters of the model. This specification can be derived from (6) by assuming that the function $\phi_j(.)$ applies only to manufacturing sectors and using a linear approximation for this function (and measuring time in discrete units so that $\dot{v}_j^i$ is replaced by Δv_{jt}^i). Relation (6) implies that $a_1 = 1$ and $a_{2j}^i > 0$.

As the theoretical model underlying (7) abstracts from short-run (cyclical) effects, a 3-5 year interval is likely to be a more appropriate time unit than a year. The 1970-1993 sample period is thus divided into five sub-periods, 1970-75, 1975-1980, 1980-1985, 1985-1990 and 1990-1993, and a panel based on these sub-periods is constructed. For each sub-period, $\bar{g}_t^i$, γ_j and Δv_{jt}^i are expressed as annual rates and s_{jt}^i as the average value for the sub-period. As discussed in Data Appendix, estimates of the sectoral TFP growth rates, γ_j's, are adjusted to make their weighted average conform to estimates of the aggregate TFP growth rate, $\bar{g}^i$, which are obtained from a different source.

We focus on the case where the openness index for a sector, v_{jt}^i, depends on international trade within the sector. We use the following three measures of this index: (1) the import ratio, m_{jt}^i, (2) the export ratio, x_{jt}^i, and (3) a linear combination of the two ratios (with coefficients of each ratio estimated by the regression). Table 4 shows estimates of (7) under the assumptions that a_{2j} is the same for all manufacturing sectors. The model assumes no fixed country and time effects. This assumption was supported by F tests, which rejected the presence of both types of fixed effects.[10] Regression (1) in the table excludes the effect of the trade variable (i.e., the term including Δv_{jt}^i) while regressions (2)-(4) include this variable using the import, export and linear-combination measures. In all of these regressions, the effect of the term representing the weighted average of long-run sectoral TFP growth rates is significant. Its coefficient, moreover, is not significantly different from one. This finding (as well as the result that fixed country and time effects are absent) is consistent with relation (6). The coefficients of trade variables [in regressions (2)-(4)] have the predicted positive sign but are not significantly different from zero.[11]

[10] A random effect specification was also tested and rejected.

[11] The introduction of trade variables in the regression also makes the coefficient on the weighted-average-growth term closer to the predicted value of one.

The role of openness in transferring technology could be more important in technologically sophisticated sectors than in traditional sectors. To explore this possibility, Table 5 allows a_{2j} to vary across low, medium, and high growth sectors.[12] The results are sensitive to the index used to measure openness. The effect of the trade variable for the medium-growth sectors is positive and significant in regression (1) based on imports while in regression (2) based on exports, it is the trade variable for high-growth sectors which exerts a positive and significant effect. In regression (3) that uses the linear-combination measure, the effect of the export variable (for high-growth sectors) becomes less significant while that of the import variable remains robust (for medium-growth sectors).[13] These results suggest that imports represent a more important vehicle for technology transfer and import-induced transfers occur mainly in medium-growth sectors where the technology is not too sophisticated. Table 5 also shows that regardless of the openness index used, the effect of trade variables is insignificant for low-growth sectors. Thus opening of traditional sectors to international trade appears to have little impact on productivity growth.

It is interesting to examine the magnitude of the effect of the import ratio for the medium-growth group implied by our estimates. Using the average SSA production shares and adjusted estimates of γ_j's for medium-growth sectors, for example, estimates of a_{2j} for this group in Table 5 imply that an increase in the import ratio (for each sector in the group) by 0.1 would raise aggregate productivity growth approximately by 0.006. This effect would not change much if shares for other developing regions were used instead of SSA shares[14]

Our sample includes OECD countries and the growth effects of openness may be less important and different for these countries. To examine this possibility, Table 6 repeats regressions in Table 5 but lets a_{2j} differ between OECD and developing countries for each

[12] The general case where a_{2j} differs across all 9 manufacturing sectors is also examined. In this case, however, it is difficult to obtain precise estimates a_{2j} for each sector because of multicollinearity.

[13] The coefficient of the export variable for medium-growth sectors is negative and significant in this regression. A possible explanation of this result is that it is picking up the effect of the (imperfectly measured) import variable for these sectors, which is negatively correlated with the export index.

[14] The effect on sector j's productivity growth rate equals $a_{2j}\gamma_j \Delta m^i_{jt}$ and would be clearly much larger than the effect on aggregate productivity growth. Note, however, that the estimates of a_{2j} in Table 5 are based on the assumption that an increase in m^i_{jt} reduces the technology lag only in sector j. If technological benefits also spill over to other sectors (a possibility discussed below), a_{2j} estimates may overstate the within-sector effect.

growth group. For developing countries, the trade variable continues to have a strong effect for medium-growth sectors in the regressions using the import (or the linear-combination) measure and for high-growth sectors in the export-based regression. Thus the results for developing countries are similar to those for the whole sample. For OECD countries, however, the effect of trade variables is not significantly different from zero for any growth group in all regressions. This effect, however, is not precisely estimated and, in fact, the hypothesis that the trade effect is the same for both developing and OECD countries cannot be rejected.

We explore two further variations of the model. First, we consider the possibility that trade in one sector facilitates the transfer of technology in another. Although estimation of a general model that allows inter-sectoral effects to differ from one pair of sector to another is not feasible, we did explore a special model which assumes that the effects are the same for spillovers from one sector to another within each growth group as well as from each sector in one group to each sector in another.[15] Estimation of this particular model, however, did not suggest important inter-sectoral spillovers either within or between growth groups.

Second, we relax the assumption that the function $\phi_j(v^i_{jt})$ is linear. To account for a possible nonlinear relation in a simple way, three levels of the (within-sector) openness index are distinguished (on the basis of values at the beginning of each sub-period) and the coefficient of the trade variable, a_{2j}, is allowed to vary across these levels. The cutoffs for different levels of the openness index (as well as a_{2j}) are assumed to be the same within each growth group but are allowed to vary across the groups. The values of cutoffs (for

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[15] Using the import measure, for example, the openness index for sector j can be generalized as

$$v^i_{jt} = \sum_k b_{jk} m^i_{kt} ,$$

where b_{jk}'s represent spillover effects both within and between sectors. The within-sector openness index (used in Tables 4-6) is a special case of this index with $b_{jk} = 1$ for $j = k$ and $b_{jk} = 0$ for $j \neq k$. A model based on the use of the above index in (7) involves estimation of a very large number of interaction terms ($s^i_{jt}\gamma_j \Delta m^i_{kt}$) and is thus difficult to implement. Letting l, m and h represent low, medium and high growth groups, our special model assumes that $b_{jk} = b_{yz}$ for $j \; \varepsilon \; y$, $k \; \varepsilon \; z$ and $y, z = l, m, h$. This assumption allows aggregation of a number of interaction terms and thus significantly reduces the number of variables in the regression equation.

different levels in each growth group) are estimated on the basis of the maximum likelihood criterion.[16]

Key results of this analysis are presented in Table 7, which shows estimates of a_{2j} for the three levels of each group, using the import measure of the trade index.[17] In the case of low and high growth groups, no level has a significant positive effect on productivity growth. All levels of the medium-growth group, however, exert a positive and significant effect, and there are significant differences between the effects of these levels. Interestingly, the effect of the medium level (representing the 0.3-0.5 range of m_{jt}^{i}) is greater than the effects of both low and high levels. The results suggest that there are increasing (spillover) returns to import competition at the low end of the openness index and diminishing returns at the higher end.

As sectoral trade and outputs are determined endogenously, a potential concern about the results is that they could reflect reverse causality running from aggregate productivity growth to changes in trade ratios.[18] There is no reason to expect, however, that causality in this direction would explain the main result that aggregate productivity growth is positively related to changes in import ratios for medium-growth sectors. Indeed, as discussed below, reverse causality is likely to produce the opposite result in the technology-gap model. Suppose, for example, that an increase in a developing country's productivity growth results from a uniform decrease in the technology lag for all sectors (for reasons other than increased openness). The technology-gap model would imply that the country's relative productivity gains would be greater for products with higher growth rates. This effect would tend to extend the comparative advantage of the country to higher-growth goods (in the middle range of the technology scale).[19] In this case, higher productivity growth would involve less

[16] The cutoffs were varied by increments of 0.1 to search for the values that maximize the log likelihood of the regression.

[17] We also estimated the nonlinear regression based on the export measure. Although the effect of the medium level in the high growth group was significantly greater than zero in this regression, the hypothesis that all three levels have the same effect in each group (i.e., the $\phi_j(.)$ function is linear) could not be rejected.

[18] There has been much discussion about the problem of identifying the direction of causality between income per capita and the ratio of aggregate imports (or exports) to GDP. To deal with this problem, Frankel and Romer (1999) have used instrumental variables based on geographic characteristic of countries to identify a strong positive effect of trade on income. This approach, however, is not feasible for our model since geographic characteristics do not provide a good explanation of changes in sectoral trade ratios over time.

[19] Such a result is derived by Krugman (1985) using a Ricardian model with two countries and a continuum of goods.

imports and more home production for the medium-growth sectors and thus lead to (contrary to our results) a negative relation between productivity growth and changes in these sector's import ratios.[20]

The paper has been concerned mainly with the role of international trade in the technology-transfer process. This process could also be influenced by other variables such as the educational attainment of the labor force. If these variables are correlated with sectoral trade ratios, their omission would introduce a bias in the estimates. Although determinants of technology transfer might be related to aggregate measures of openness, there is no reason to suspect that they would be strongly correlated with the import ratios for only a particular growth group (i.e., medium-growth sectors). Thus, it is unlikely that our results reflect the effect of missing determinants of technology transfer.[21]

Finally, it should be emphasized that the paper's classification of industries into three growth groups is based on the growth performance of broad (2-digit) manufacturing sectors. Data limitations did not permit us to use a grouping based on growth characteristics of more narrowly defined industries. Thus our growth groups are only suggestive and our empirical analysis should be thought of as identifying broad characteristics (rather than providing a precise list) of industries where openness improves productivity growth.

V. Conclusions

The paper re-examines the role of international trade in determining productivity growth of developing countries, using a multi-sector framework based on the technology-gap model. A basic assumption of this framework is that sectors differ in their potential for long-run productivity growth. One implication of this assumption is that an increase in the share of high-growth sectors will raise overall productivity growth of an economy. This implication is supported by the paper's empirical analysis, which finds that a production-share weighted average of sectoral productivity growth rates (based on the experience of technological leaders) is a significant determinant of the rate of aggregate productivity growth. It should be emphasized, however, that inter-sectoral differences in productivity growth rates as well as inter-country differences in sectoral shares are not very large and thus the weighted average of sectoral rates provides only a limited explanation of the cross-country variation in aggregate productivity growth.

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[20] Even if the country were to experience uniform productivity growth in all sectors, there would be no presumption that such change would make it less competitive in (and hence increase the import ratio for) medium-growth sectors and thus account for our results.

[21] We did explore the possibility that parameters, a_1 and a_{2j}, are linear functions of an index of human capital per worker based on education levels. This variation, however, had little effect on our results.

An important issue investigated in the paper is whether the effect of increased openness on productivity growth varies across sectors with different potential for growth. An interesting finding of the paper is that this effect depends on the technological sophistication of the sector. In low-growth (traditional) manufacturing sectors, increased international trade has little or no effect on productivity growth. For medium-growth sectors, however, greater import competition is found to have a significant growth-enhancing effect. There is also some evidence that export expansion in high-growth sectors leads to an increase in productivity growth.

The above evidence has interesting implications for trade policy in developing countries. For developing countries specialized in low-growth sectors, a case could be made for stimulating production in sectors with higher growth as a means to increasing overall productivity growth. The finding that increased import competition is an important source of technology transfer for medium-growth sectors suggests, however, that bringing about such a change through the imposition of import restrictions would not be desirable and could, in fact, impede growth.

Table 1. Sectoral TFP Growth Rates

ISIC code Sector	Averages 1970-1993 Large Countries 1/	Averages 1970-1993 ISDB Countries 2/
Manufacturing		
Low Growth		
31 Food, Beverages and Tobacco	0.00606	0.01071
	(0.0037)	(0.0023)
34 Paper, Paper Products, Printing & Publishing	0.00620	0.00877
	(0.0046)	(0.0032)
39 Other Manufacturing Industries	0.00592	0.01002
	(0.0077)	(0.0057)
Medium Growth		
33 Wood and Wood Products	0.01065	0.01217
	(0.0048)	(0.0043)
36 Non-Metallic Mineral Products, Except Fuel	0.01256	0.01338
	(0.0053)	(0.0043)
37 Basic Metal Industries	0.01235	0.02390
	(0.0086)	(0.0058)
High Growth		
32 Textile, Wearing Apparel and Leather	0.01823	0.01912
	(0.0046)	(0.0029)
35 Chemicals & Chemical Products	0.01716	0.02983
	(0.0063)	(0.0040)
38 Fabricated Metal Products, Machinery and Equipment	0.01875	0.01939
	(0.0041)	(0.0029)
Nonmanufacturing	0.00736	0.00792
	(0.0017)	(0.0010)
Total Industries	0.01276	0.01390
	(0.0017)	(0.0010)

Source: See Data Appendix.
Note: Standard errors are shown in parentheses.
1/ This group comprises of France, West Germany, Japan, U.K., and U.S.A.
2/ This group includes Belgium, Canada, Denmark, France, Finland, West Germany, Italy, Japan, Norway, Sweden, United Kingdom, and United States. Although, Australia and Netherlands are also in the ISDB sample, their data on the TFP index is missing.

Table 2. Aggregate TFP Growth and Sectoral Production Shares

Country	Average TFP Growth 1970-1993	Average Sectoral Production Shares: Manufacturing High	Manufacturing Medium	Manufacturing Low	Nonmanufacturing
Algeria	-0.011	0.0459	0.0239	0.0287	0.9015
Argentina 1/	0.004	0.1803	0.0298	0.0777	0.7123
Australia	0.006	0.0918	0.0385	0.0496	0.8202
Austria	0.005	0.1384	0.0542	0.0598	0.7476
Bangladesh 1/	0.007	0.0596	0.0065	0.0297	0.9041
Cameroon	-0.010	0.0342	0.0206	0.0646	0.8808
Canada	0.001	0.0897	0.0284	0.0509	0.8310
Chile	0.016	0.0713	0.0622	0.0629	0.8036
Colombia	0.010	0.1091	0.0234	0.0829	0.7847
Cyprus	0.024	0.0637	0.0284	0.0552	0.8527
Denmark	0.007	0.0929	0.0209	0.0583	0.8278
Dominican Republic 2/	-0.002	0.0369	0.0114	0.1323	0.8331
Ecuador	0.017	0.0905	0.0233	0.0700	0.8163
Egypt	0.005	0.1038	0.0259	0.0406	0.8298
Finland	0.010	0.1111	0.0382	0.0816	0.7691
Germany	0.009	0.2239	0.0462	0.0524	0.6775
Ghana	-0.005	0.0327	0.0246	0.0394	0.9032
Greece	0.006	0.0904	0.0288	0.0414	0.8394
Honduras	0.002	0.0402	0.0201	0.0778	0.8619
India	0.010	0.1042	0.0274	0.0249	0.8435
Iran	-0.017	0.0582	0.0244	0.0212	0.8960
Jamaica	-0.013	0.0736	0.0151	0.0918	0.8195
Japan	0.004	0.1932	0.0477	0.0551	0.7040
Jordan	0.005	0.0520	0.0329	0.0407	0.8744
Kenya 3/	0.015	0.0471	0.0098	0.0473	0.8959
Malaysia	0.013	0.1101	0.0357	0.0505	0.8038
Malta	0.037	0.1569	0.0224	0.0773	0.7435
Mauritius	0.024	0.0923	0.0110	0.0894	0.8073
Pakistan	0.015	0.0819	0.0181	0.0453	0.8545
Panama 3/	0.003	0.0346	0.0121	0.0676	0.8854
Peru	-0.014	0.1176	0.0375	0.0723	0.7746
Philippines	-0.005	0.1145	0.0289	0.1079	0.7488
South Africa	-0.010	0.1213	0.0452	0.0518	0.7817
Senegal	-0.005	0.0404	0.0087	0.0735	0.8865
Singapore	0.019	0.2075	0.0167	0.0322	0.7436
South Korea	0.019	0.1750	0.0395	0.0586	0.7270
Sri Lanka	0.007	0.0860	0.0181	0.0807	0.8153
Sweden	0.003	0.1269	0.0372	0.0559	0.7800
Turkey	0.012	0.1101	0.0301	0.0423	0.8175
UK	0.007	0.1450	0.0301	0.0549	0.7700
Uruguay	0.010	0.1340	0.0158	0.0933	0.7569
USA	0.004	0.1361	0.0230	0.0496	0.7914
Venezuela	-0.013	0.1097	0.0251	0.0483	0.8171
Zimbabwe	-0.002	0.1044	0.0399	0.0747	0.7810
Regions					
East Asia	0.011	0.152	0.030	0.062	0.756
Industrial Countries	0.006	0.131	0.036	0.055	0.778
Latin America	0.002	0.091	0.025	0.080	0.806
Middle East North Africa	0.007	0.080	0.026	0.044	0.850
South Asia	0.010	0.083	0.018	0.045	0.854
Sub-Saharan Africa	0.001	0.067	0.023	0.063	0.848

Source: See Data Appendix.
1/ First sub-period data is missing.
2/ Fourth and Fifth sub-period data are missing.
3/ Fifth sub-period data is missing.

Table 3. Indicators of Changes in Sectoral Openness

Country	Manufacturing All Sectors Imports	Manufacturing All Sectors Exports	High Growth Imports	High Growth Exports	Medium Growth Imports	Medium Growth Exports	Low Growth Imports	Low Growth Exports
	(average change in trade ratios over the five sub-periods)							
Algeria	0.037	-0.001	0.041	0.008	0.025	-0.002	0.044	-0.008
Argentina 1/	0.005	0.001	0.017	0.001	-0.016	0.004	0.016	-0.003
Australia	0.024	0.013	0.031	0.008	0.008	0.016	0.032	0.014
Austria	0.032	0.021	0.047	0.034	0.026	0.015	0.023	0.012
Bangladesh	0.024	0.013	0.044	0.027	-0.006	0.002	0.035	0.010
Cameroon	-0.152	-0.080	0.616	0.067	-0.058	-0.054	-1.015	-0.253
Canada	0.032	0.022	0.044	0.027	0.023	0.026	0.029	0.014
Chile	0.099	0.049	0.094	0.010	0.010	0.055	0.193	0.081
Colombia	0.016	0.019	0.020	0.014	0.020	0.004	0.006	0.038
Cyprus	0.053	0.021	0.119	0.033	-0.005	0.005	0.047	0.024
Denmark	0.005	0.021	0.024	0.038	-0.004	0.033	-0.004	-0.007
Dominican Republic 2/	-0.397	0.341	-0.382	0.086	-0.129	0.292	-0.679	0.643
Ecuador	0.005	0.015	0.001	0.005	-0.048	0.008	0.062	0.031
Egypt	0.120	0.005	0.034	0.004	0.094	0.006	0.231	0.006
Finland	-0.001	0.007	0.017	0.019	-0.014	0.001	-0.005	0.000
Germany	0.028	0.017	0.039	0.019	0.021	0.015	0.024	0.016
Ghana	0.218	1.011	0.268	0.003	0.031	0.043	0.355	2.987
Greece	0.060	0.021	0.044	0.021	0.027	0.030	0.108	0.014
Honduras	0.017	-0.020	-0.052	-0.008	0.155	-0.055	-0.053	0.004
India	-0.004	-0.006	0.003	0.015	0.015	0.002	-0.030	-0.035
Iran	-0.088	-0.005	-0.017	-0.002	-0.109	-0.003	-0.139	-0.011
Jamaica	0.073	0.078	0.067	0.170	-0.168	0.001	0.319	0.064
Japan	0.003	0.000	0.006	0.002	0.000	0.000	0.003	-0.003
Jordan	0.769	0.225	0.252	0.068	0.035	0.034	2.021	0.572
Kenya 3/	0.075	0.019	0.025	0.012	0.205	0.031	0.004	0.017
Malaysia	-0.050	0.047	-0.088	0.026	0.014	-0.006	-0.077	0.122
Malta	-0.002	0.050	0.040	0.113	-0.026	0.003	-0.020	0.034
Mauritius	0.056	0.047	0.025	0.068	0.131	0.007	0.013	0.065
Pakistan	-0.002	0.018	0.030	0.023	-0.038	0.002	0.002	0.028
Panama 3/	1.907	0.056	3.462	0.059	0.226	0.095	1.921	0.016
Peru	0.001	-0.001	0.002	0.006	-0.002	-0.009	0.001	0.001
Philippines	0.001	0.007	0.003	0.024	0.000	-0.035	-0.001	0.030
South Africa	-0.005	0.003	-0.007	0.007	-0.002	0.024	-0.007	-0.021
Senegal	1.730	0.737	-0.258	-0.087	-0.125	0.003	5.573	2.295
Singapore	0.341	0.188	0.062	0.177	0.666	0.238	0.294	0.149
South Korea	-0.006	0.010	-0.022	0.027	-0.011	-0.005	0.013	0.007
Sri Lanka	0.092	0.034	0.158	0.053	0.093	0.009	0.023	0.040
Sweden	0.035	0.025	0.071	0.032	0.016	0.028	0.019	0.014
Turkey	0.017	0.015	0.005	0.022	0.011	0.012	0.035	0.013
UK	0.027	0.018	0.038	0.026	0.019	0.018	0.025	0.009
Uruguay	0.002	0.007	0.027	0.023	-0.040	0.005	0.019	-0.008
USA	0.015	0.009	0.019	0.011	0.011	0.009	0.015	0.007
Venezuela	0.048	0.016	0.067	0.003	0.022	0.028	0.057	0.016
Zimbabwe	0.055	0.029	0.107	0.022	0.032	0.044	0.027	0.020
Regions								
East Asia	0.071	0.063	-0.011	0.064	0.168	0.048	0.057	0.077
Industrial Countries	0.024	0.016	0.035	0.021	0.012	0.017	0.024	0.008
Latin America 4/	-0.013	0.050	-0.014	0.031	-0.020	0.033	-0.006	0.087
Middle East North Africa	0.148	0.049	0.078	0.037	0.002	0.007	0.364	0.103
South Asia	0.027	0.015	0.059	0.029	0.016	0.004	0.007	0.011
Sub-Saharan Africa	0.282	0.252	0.111	0.013	0.031	0.014	0.707	0.730

Source: See Data Appendix.
1/ First sub-period data is missing.
2/ Fourth and Fifth sub-period data are missing.
3/ Fifth sub-period data is missing.
4/ Excludes Panama

Table 4. Basic Regressions

	Regression (1)	Regression (2)	Regression (3)	Regression (4)
$\sum_j s^i_j \gamma_j$	1.34 ** (0.40)	1.25 ** (0.41)	1.16 ** (0.42)	1.14 ** (0.43)
$\sum_j s^i_j \gamma_j \Delta m^i_j$		7.79 (10.02)		6.33 (10.54)
$\sum_j s^i_j \gamma_j \Delta x^i_j$			15.45 (11.75)	11.16 (13.67)
R-squared	0.014	0.014	0.012	0.015
Adjusted R-squared	0.014	0.009	0.007	0.006

Note: Heteroskedasticity consistent standard errors are shown in parentheses. A * indicates that the coefficient is significantly different from zero at the 5% level and a ** at the 1% level.

Table 5. Regressions Distinguishing Sectoral Trade Effects

	Regression (1)	Regression (2)	Regression (3)
$\sum_j s^i_j \gamma_j$	1.19 **	1.21 **	1.20 **
	(0.40)	(0.43)	(0.42)
$\sum_{j \in l} s^i_j \gamma_j \Delta m^i_j$	3.76		26.26
	(70.80)		(143.53)
$\sum_{j \in m} s^i_j \gamma_j \Delta m^i_j$	339.42 **		356.11 **
	(79.07)		(78.28)
$\sum_{j \in h} s^i_j \gamma_j \Delta m^i_j$	-6.76		-8.00
	(9.33)		(9.50)
$\sum_{j \in l} s^i_j \gamma_j \Delta x^i_j$		29.37	-66.42
		(78.58)	(370.71)
$\sum_{j \in m} s^i_j \gamma_j \Delta x^i_j$		-117.16	-150.04 *
		(79.78)	(75.32)
$\sum_{j \in h} s^i_j \gamma_j \Delta x^i_j$		25.92 *	16.91
		(12.44)	(11.64)
R-squared	0.077	0.031	0.105
Adjusted R-squared	0.064	0.017	0.079

Note: Heteroskedasticity consistent standard errors are shown in parentheses. l, m, and h denote low, medium, and high growth sectors. A * indicates that the coefficient is significantly different from zero at the 5% level and a ** at the 1% level.

Table 6. Regressions Distinguishing OECD and Developing Countries

	Regression (1)	Regression (2)	Regression (3)
$\sum_j s^i_j \gamma_j$	1.27 **	1.28 **	1.27 **
	(0.46)	(0.47)	(0.50)
$\sum_{j\in l} s^i_j \gamma_j \Delta m^i_j D_l$	3.02		16.77
	(71.50)		(147.09)
$\sum_{j\in l} s^i_j \gamma_j \Delta m^i_j D_o$	-97.40		210.36
	(1049.41)		(1059.62)
$\sum_{j\in m} s^i_j \gamma_j \Delta m^i_j D_l$	347.54 **		361.29 **
	(81.08)		(80.84)
$\sum_{j\in m} s^i_j \gamma_j \Delta m^i_j D_o$	83.01		199.84
	(209.69)		(227.88)
$\sum_{j\in h} s^i_j \gamma_j \Delta m^i_j D_l$	-6.87		-8.13
	(9.45)		(9.61)
$\sum_{j\in h} s^i_j \gamma_j \Delta m^i_j D_o$	-10.50		-2.39
	(28.62)		(25.45)
$\sum_{j\in l} s^i_j \gamma_j \Delta x^i_j D_l$		30.56	-39.56
		(75.26)	(382.13)
$\sum_{j\in l} s^i_j \gamma_j \Delta x^i_j D_o$		-131.73	-451.61
		(775.73)	(862.81)
$\sum_{j\in m} s^i_j \gamma_j \Delta x^i_j D_l$		-112.93	-146.02
		(83.07)	(78.13)
$\sum_{j\in m} s^i_j \gamma_j \Delta x^i_j D_o$		-149.51	-182.13
		(126.10)	(115.99)
$\sum_{j\in h} s^i_j \gamma_j \Delta x^i_j D_l$		27.10 *	17.63
		(12.80)	(11.94)
$\sum_{j\in h} s^i_j \gamma_j \Delta x^i_j D_o$		0.90	0.75
		(33.88)	(29.88)
R-squared	0.079	0.032	0.107
Adjusted R-squared	0.052	0.004	0.054

Note: Heteroskedasticity consistent standard errors are shown in parentheses. l, m, and h denote low, medium, and high growth sectors. D_l is a dummy variable for developing countries. D_o is a dummy variable for OECD countries (including Greece). A * indicates that the coefficient is significantly different from zero at the 5% level and a ** at the 1% level.

Table 7. Exploring Nonlinearities

Variable	Estimated coefficient	Variable	Estimated coefficient
$\sum_{j} s^{i}_{j}\gamma_{j}$	0.86 * (0.43)	$\sum_{j\in m} s^{i}_{jt}\gamma_{j}\Delta m^{i}_{jt} D_{m2}$	1782.34 ** (527.16)
$\sum_{j\in l} s^{i}_{jt}\gamma_{j}\Delta m^{i}_{jt} D_{l1}$	0.62 (50.97)	$\sum_{j\in m} s^{i}_{jt}\gamma_{j}\Delta m^{i}_{jt} D_{m3}$	305.59 ** (89.41)
$\sum_{j\in l} s^{i}_{jt}\gamma_{j}\Delta m^{i}_{jt} D_{l2}$	-5748.83 (2991.63)	$\sum_{j\in h} s^{i}_{jt}\gamma_{j}\Delta m^{i}_{jt} D_{h1}$	153.27 (180.07)
$\sum_{j\in l} s^{i}_{jt}\gamma_{j}\Delta m^{i}_{jt} D_{l3}$	-566.45 (420.35)	$\sum_{j\in h} s^{i}_{jt}\gamma_{j}\Delta m^{i}_{jt} D_{h2}$	-81.37 (45.03)
$\sum_{j\in m} s^{i}_{jt}\gamma_{j}\Delta m^{i}_{jt} D_{m1}$	921.13 * (460.46)	$\sum_{j\in h} s^{i}_{jt}\gamma_{j}\Delta m^{i}_{jt} D_{h3}$	-2.44 (7.89)
F test 1	2.96 *		
F test 2	4.61 **		
F test 3	1.58		
R-squared	0.141		
Adjusted R-squared	0.103		

Note: Heteroskedasticity consistent standard errors are shown in parentheses. l, m, and h denote low, medium, and high growth sectors. D_{pq} are dummy variables equal to 1 if m^{i}_{jt} is at the qth level $(q=1, 2, 3)$ of the pth growth group $(p=l, m, h)$, and zero otherwise. The cutoffs for levels 1 and 2 are: 0.8 and 0.9 for the low growth group; 0.3 and 0.5 for the medium-growth group; and 0.2 and 0.7 for the high growth group. A * indicates that the coefficient is significantly different from zero at the 5% level and a ** at the 1% level.

F test 1 tests the hypothesis that the coefficients on the terms interacted by D_{lq} are jointly equal.

F test 2 tests the hypothesis that the coefficients on the terms interacted by D_{mq} are jointly equal.

F test 3 tests the hypothesis that the coefficients on the terms interacted by D_{hq} are jointly equal.

DATA APPENDIX

Long-Run Sectoral Growth Rates:

The source of this data for the 5 large countries (used to measure γ_j's) as well as other OECD countries in Table 1 is OECD's International Sectoral Database (ISDB). For each country, the long-run TFP growth rate for a sector was calculated simply as the average rate from 1970 to 1993. ISDB provided estimates of TFP growth rates for the 9 manufacturing sectors but not for total nonmanufacturing. ISDB data for individual nonmanufacturing sectors were aggregated to estimate TFP growth rates for total nonmanufacturing.

Sectoral Shares:

The data were obtained from the UNIDO Industrial Statistics Database 1999 (Indstat3) and the UN's System of National Accounts (SNA). The Indstat3 provides value-added data for industries at the (ISIC Revision 2) 3-digit level. The data were aggregated to the 2-digit level to conform with the sectoral detail in the ISDB data used to obtain long-run sectoral TFP growth rates. For some years, Indstat3 combined certain 3-digit industries from different 2-digit groups and reported value added only for the combined group. In such cases, value added of individual industries was imputed on the assumption that their share (in total value added of the combined group) was the same as the share in a previous year (or the average share over a number of previous years). For some countries SNA data are reported for fiscal years and were adjusted to change the data to a calendar-year basis.

The aggregated Indstat3 data were used to calculate the value added share of each 2-digit manufacturing sector in total manufacturing, s^i_{jm}. The SNA data were used to calculate the shares of manufacturing and nonmanufacturing value added in total value added, s^i_m and s^i_n, respectively. The share of each 2-digit manufacturing sector in total value added, s^i_j, was then calculated as the product of s^i_{jm} and s^i_m. There were a number of gaps in both Indstat3 and SNA data series and the missing values of s^i_{jm}, s^i_m and s^i_n had to be imputed or estimated. If the data were available for a year close to the missing-value year, the share for that year was used as a proxy. If no information was available for a year close by, the missing shares were estimated by regressions expressing shares as functions of time trend. The specification of the regression (for example, whether or not it includes the square of the time trend) was determined by comparing the R-squared of alternative regression specifications. There were no cases where both Indstat3 and SNA share series had to be imputed. The shares were only estimated for the years; 1970, 1975, 1980, 1985, 1990, and 1993. The average shares for sub-periods, 1970-75, 1975-80, 1980-85, 1985-90 and 1990-93 were then calculated simply as averages of values at the beginning and the end of each sub-period.

Sectoral Import and Export Ratios:

The trade data used for measuring these ratios were obtained from Feenstra, Lipsey, and Bowen (1997). They provide country data on manufacturing trade flows for 34 industries classified according to the Bureau of Economic Analysis Manufacturing Industry Classification. This data were aggregated into 9 manufacturing categories matching the (2-digit) ISIC classification. Sectoral import and export ratios were estimated as follows. First, shares of sectoral imports and exports in nominal GDP were calculated using GDP data from the World Economic Outlook. These shares were then divided by sectoral production shares, s_j^i, in order to estimate x_j^i's and m_j^i's for manufacturing sectors. The difference between the values of these ratios at the beginning and the end of each sub-period were used to estimate Δx_j^i's and Δm_j^i's. These differences were then converted to annual rates. Since the trade data are only available up to 1992, the 1992 trade ratios were used as proxies for the 1993 ratios.

Aggregate TFP Growth Rates:

The data on GDP, total stock of physical capital and the total labor force needed to measure aggregate TFP growth were obtained from a revised version of the data set compiled by Bosworth, Collins, and Chen (BCC, 1995). To make the TFP levels comparable across countries, the data on output and physical capital were converted into 1987 international prices using the purchasing power parities data from the Penn World Tables compiled by Summers and Heston. Following ISDB and BCC, estimates of $\bar{g}_t^i$ were derived using the Cobb-Douglas production function and assuming uniform factor shares across countries. Two sets of estimates were used for factor shares. First, an estimate for the share of capital of 0.4 was used for all countries. Under this assumption, the aggregate TFP growth estimates for OECD countries calculated using the BCC data were slightly lower than ISDB estimates. Therefore, in the regression analysis, the ISDB sectoral rates were adjusted downwards to make the weighted average of these rates conform to the BCC aggregate rate. Second, an estimate for the share of capital of 0.4 was used for developing countries and 0.3 for industrial countries. This variation did not significantly affect the regression results, therefore only the results from assuming capital shares of 0.4 across all countries are reported in the paper.

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