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Productivity Growth and Product Variety

Gains from Imitation and Education

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Abstract

Is there a correlation between productivity and product variety? Certainly it appears that the rich countries are more productive and have more product variety than the poor nations. In fact, the relationship is quite strong when measured in levels. Does this same correlation hold up when measured in growth rates? If so, can poor countries imitate the success of the rich?

Addison provides theoretical and empirical reasons to believe the answer to both questions is yes. Recent economic theory suggests that rising variety in factor inputs can help avoid diminishing marginal returns. Product variety can also sustain learning-by-doing which would otherwise be exhausted in a fixed number of products. Finally, invention or imitation adds to the stock of non-rival knowledge. There have been only two previous empirical tests of the correlation between growth in product variety and productivity growth. Both were affirmative but neither examined a wide range of developing countries and neither looked deeper to test what might drive product variety.

This research is based on a cross-country sample of 29 countries (13 rich and 16 poor). The data display a statistically significant and positive relationship between growth in product variety and productivity growth when condition on other variables such as research and development (R&D) employment, macroeconomic stability, and domestic security. These results are robust to the addition and subtraction of various explanatory variables but fragile with respect to an influential data point for Venezuela. Industrial nations tend to generate most of their productivity gains through R&D employment in a stable environment that results in better production processes and product quality. In contrast, the largest source of productivity growth in developing countries is product variety imitation while instability takes away from productivity.

Addison tests various explanations for growth in variety. The results show that nations furthest from the frontier of observable variety tend to imitate fastest, with the ability to imitate being improved by educational attainment and by productivity gains. This could be a source of hope for small, less developed nations. Growth in market size was not correlated with growth in variety, though this may be due to a rather short sample period of only eight years.

In addition to the empirical testing, Addison also contributes to a general discussion of measurement concepts and measurement issues related to product variety and sets out an agenda for further research.

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PRODUCTIVITY GROWTH AND PRODUCT VARIETY:

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PRODUCTIVITY GROWTH AND PRODUCT VARIETY: GAINS FROM IMITATION AND EDUCATION

A. Introduction

1. Casual observation suggests there could be a positive correlation between product variety and productivity in manufacturing. The manufacturing sectors in developed nations are diversified across thousands of product categories while those in the developing countries (DCs) are not. For example, UNIDO data show that Venezuela was producing manufactures in 73 out of 81 broad industrial categories in 1982 while the UK was producing in all categories. This gap in the variety of product categories is much wider when one looks at the Standard International Trade Classification (Revision 2) data for manufactured export variety: Venezuela exported in 187 out of 1,600 categories while the UK exported in 1,582. Similarly, total factor productivity (TFP) in most DCs is generally lower than in the more developed nations. Hall and Jones (1998) find that TFP in the USA was nearly nine and a half times greater than it was in China in 1988 and almost 13 times higher than in Zambia. On average, TFP in the developed countries is twice that of the developing nations.

2. In fact, it is easy to find a strong and statistically significant positive correlation between product variety and TFP across countries in levels. The more difficult question is whether a similar relationship can be established in growth rates. This paper suggests the answer is yes, if the relationship is conditioned by other variables.

3. The rest of the text is organized as follows. Section B provides a brief review of the theoretical and empirical literature. Section C summarizes the new empirical work presented here. Section D lays out the framework for hypothesis testing. The data are briefly described in Section E. The correlation between growth in product variety and growth in productivity is pursued in Section F. The ramifications of the findings for development policy are explored in Section G. Section H concludes with a general summary of the paper and a list of outstanding empirical issues.

B. Literature Review

4. **Theory.** Several models of endogenous growth based on research and development (R&D) suggest a link between product variety and productivity. Their main attraction is the explicit acknowledgement that changes in product variety are the result of deliberate decisions to make costly investments in human capital, and that these investments have an impact on growth. Investments in R&D generate knowledge, some of which is non-rival. The expanding stock of non-rival knowledge is an important input in production that can increase TFP.

5. There are a number of R&D based models of endogenous growth to choose from. Many depict an expansion in the variety of products, or horizontal innovation, as being directly correlated with TFP growth. An example can be found in Romer (1990) where TFP is a function

of variety in intermediate goods. The models by Young (1993) and Aghion and Howitt (1998) are particularly appealing because they highlight an important link between new products resulting from R&D and production cost reductions resulting from learning-by-doing (LBD). Cost reductions from LBD allow producers to maintain some degree of profitability but the gains from LBD decline with production experience. In order to open up new profit opportunities, producers will eventually be compelled to introduce new products. These new goods then provide additional opportunities for LBD. Some of these models are fairly rich in policy implications, notably for government expenditures on education, the composition of educational spending, subsidies for research and development, trade policies and the promotion of inward foreign investment.

6. Finding out what drives variety is also important. It is an interesting topic in its own right, and all the more so if it is correlated with productivity. In addition, the development of a good empirical framework for hypothesis testing requires instruments that can explain growth in variety in case there is contemporaneous correlation between productivity growth and variety growth.

7. One possibility found in the literature for industrial organization and for international trade is that national product variety is driven by population size and income per-capita. For example, if there is imperfect competition within a market due to fixed costs of production (implying increasing returns to scale) with one product per firm, then cournot competition leads to a situation where the number of firms is a function of market size. A simple example can be found in Cabral (2000).[1] A similar conclusion emerges from the demand side. Variety will be correlated with income per-capita when preferences are diverse and goods are not infinitely divisible. For example, with a given budget constraint, a person might choose to own a car but not a motorcycle because cars and motorcycles are not sold in fractions.[2] With a larger income, that same person might own both. Alternatively, both will be sold if the number of consumers with diverse tastes is large enough.

8. There are several alternative hypotheses. The imitation hypothesis found in Barro and Sala-i-Martin (1995) as well as many other texts suggests that growth in product variety should be easiest and fastest for countries furthest from the frontier of observable variety. The underlying assumption is that products would be imitated in order of increasing technological sophistication as a nation's labor force accumulates knowledge and skill. Aghion and Howitt (1998) assume that variety increases through deliberate investments in R&D without regard to the initial level of variety. Nelson and Phelps (1966) and Griffith *et al.* (2000), support the presence of interactive effects where the rate of imitation is modified by human capital.

9. **Previous empirical work.** Several models of endogenous growth and horizontal innovation have been put forth in the last 15 years but, to date, there have been few empirical

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1 The trade literature includes several parallel theories. Linder (1961) argued that countries with similar consumer preferences ought to trade more manufactured goods with one another than with dissimilar countries, with the variety of goods rising in income per-capita. More recent models based on increasing returns and product differentiation such as Krugman (1980) also predict a correlation between market size and trade in differentiated products.

2 They can, however, be rented over time.

tests -- and almost none are pertinent to the issue of product variety. The empirical literature that tests the link between product variety and productivity is very recent and very thin. To date, the works by Feenstra, Madani, Yang and Liang (1999) and by Funke and Ruhwedel (2001) are the most pertinent. Feenstra *et al.* describe a new measure of growth in product variety and establish that product variety growth contributed to the lead in productivity growth held by South Korea over Taiwan. Funke and Ruhwedel expand the analysis to cover 18 OECD countries and also find support for the variety hypothesis.

10. Very little empirical work has been done on the determinants of product variety. The work by Hummels and Klenow (2002) is one of only a handful of quantitative papers on product variety. They find the level of national export variety is robustly correlated with the number of workers and GDP per worker – both measures of market size – in a sample of 110 exporters with 5,000 product categories. They do not, however, investigate changes in variety over time.[3]

C. New Empirical Work and Key Findings

11. This paper provides a summary of new empirical research conducted by the author (2002). The critical question is whether the correlation between variety growth and productivity growth can be found in a larger sample that includes many developing countries (DCs). It would be disappointing for those interested in economic development if the gains from product variety were confined only to OECD countries. To explore this question, a measure of product variety was constructed for a sample of 29 countries covering the period 1979 to 1986. The robustness of the regressors, including variety growth, was tested by using the new Bayesian robustness test developed by Sala-i-Martin (1997) and Dopplehofer *et al.* (2000). Robustness across country observations was also tested by looking for influential points.

12. The main conclusion is that the variety hypothesis finds support, though this result is not robust when an influential data point is removed. One also finds an interesting contrast between sources of growth for the developing and developed nations. While the DCs gain substantially through imitation of variety, R&D employment in the developed nations is important for productivity gains beyond those generated by observable product variety. The results also highlight the importance of macro stability and domestic security. Better performance in these two areas provide the developed nations with a substantial lead over the DCs. Capital imports may also contribute to productivity.

13. Another key finding is that the developed nations show a tendency towards convergence in product variety while the DCs do not. This appears to be explained by the weak educational performance in some countries. In particular, nations furthest behind the frontier of product variety find it easy to imitate, and their ability to imitate is increased by educational attainment. Sadly, not all countries are making effective choices. Colombia, Kenya, Pakistan and Zimbabwe are examples of countries with growth rates in educational attainment well below what cross-country convergence in educational attainment would require.

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[3] They also find import variety is correlated with country size. Klenow and Rodriguez-Clare (1997) found import variety increased in Costa Rica in response to tariff liberalization.

14. There is a surprise too: growth in product variety does not appear to be correlated with population growth, despite the finding by Hummels and Klenow of a significant correlation when the relationship is expressed in levels. This presents a challenge for future researchers to confirm or refute. One might speculate that there *is* a long-run correlation and that the sample period used here was simply too short to detect it.

D. Framework for Hypothesis Testing

15. The starting point for the development of the empirical framework is a system of well identified equations that encompass the key hypotheses found in the literature. A multiple equations approach is required because of the potential endogeneity between productivity growth, growth in product variety and R&D employment. Equations for each of these variables are laid out below.

16. **TFP and Variety in Growth Rates.** The main goal is to test whether period average TFP growth, *gTFP*, in each country *i* over the period starting in time *s* and ending in time *t*, is a function of period average growth in product variety, *gV*, over the same period. These gains are assumed to accrue to all manufacturing products within a country. It is quite likely, however, that gains from product variety will be conditional on one or more additional variables. In particular, the imitation and diffusion literature give prominence to the role of R&D in adapting technology to local conditions. Including R&D will also make allowance for within-product gains such as improvements in production processes and output quality. This can be proxied by using R&D employment *R* in period *s*. Note that the use of *R* in levels is conscious even though *gTFP* and *gV* are defined in terms of growth rates. This was done with the recognition that each scientist and engineer will produce a stream of innovations that will progressively increase productivity. One can therefore write:

1) $$gTFP_{i,st} = \pi_0 + \pi_1 gV_{i,st} + \pi_2 \ln R_{i,s} + \mu_{i,st}$$

The null hypothesis is that π_1 is zero, with the alternative hypothesis being that π_1 is larger than zero. The disturbance term is represented by $\mu_{i,st}$.

17. One way to calculate TFP is to assume that a common (Cobb-Douglas) production function is applicable for all countries in the sample.[4] This allows one to write:

2) $$gY_{i,st} = gTFP_{i,st} + [\alpha \cdot gL_{i,st} + \beta \cdot gK_{i,st}]$$

Thus, by substitution, the test equation 1 is rewritten as:

3) $$gY_{i,st} = [\pi_0 + \pi_1 \cdot gV_{i,st} + \pi_2 \cdot \ln R_{i,s}] + [\alpha \cdot gL_{i,st} + \beta \cdot gK_{i,st}] + \mu_{i,st}$$

[4] Another way to generate TFP estimates is to subtract labor and capital growth rates, weighted by observed factor expenditure shares, from the growth of value-added. This can be done for individual countries and does not require the assumption of the same production function across countries.

18. Three additional regressors may help explain TFP growth. The first is population density. Marshall (1959) suggested that knowledge spillovers would be more likely as the density of people increased, especially among agglomerations of people in similar trades. Ciccone and Hall (1996) rejected the null hypothesis that density has no effect on per-capita output in levels. On the contrary, they found a positive correlation. The period average growth rate for population density, *gDENS* is used because equation 3 is based on growth rates rather than levels. The second additional regressor is period average growth in telephone lines per 1,000 people or *gTELE*. Easterly and Rebelo (1993) find that public investment in telecommunications increases real growth. I assume this effect acts through TFP rather than factor accumulation: increasing communications capacity should increase TFP by allowing non-rival knowledge to flow more easily and by facilitating the coordination of productive processes. The third regressor is the real growth rate of imports of capital goods, *gM*. Keller (1999) finds that imported capital goods can help explain productivity growth. New knowledge may be bundled with imports or imports may induce productivity gains through the competition they create.

19. Two explanations are tried for negative TFP growth.[5] The first is substantial armed conflict (*CONFL*) within a country between times *s* and *t*. It is reasonable to expect that productivity would decline due to chaos and knowledge lost through deaths and emigration.[6] These effects are proxied by the number of war-related deaths per year, normalized by the population at time *s*. The second is the standard deviation of inflation, *SDINFL*, between times *s* and *t* as a proxy for macroeconomic instability. The presumption is that macroeconomic instability makes it difficult to allocate resources to maximize productivity.

20. Following Feenstra *et al.* (1999), export data are used in the construction of a measure of product variety. Feenstra *et al.* included a dummy in their regression equation for the depreciation of the Taiwanese dollar in 1981. This is important because a real depreciation would tend to make it easier to export existing product varieties that were previously too costly for foreign markets. The gains in TFP from depreciation induced variety should be discounted since they do not represent actual gains in varieties produced. Period average growth in the real exchange rate, *gRER*, is therefore included as a control variable. If depreciation induced variety is to be discounted, then the coefficient on this variable should be positive (depreciation is signified by negative growth in the real exchange rate). One could argue for the opposite sign as well. It is possible that depreciation, by making imported inputs more expensive, would induce greater productivity as producers shed unprofitable products and/or used more cost-effective inputs.

21. Equation 3 can be further modified to allow for the possibility that each new product contributes more to productivity than the product that came before. This assumption is a common ingredient in R&D based models. See, for example, chapter 6 of Aghion and Howitt (1998). In other words, the marginal contribution to TFP from variety may increase as nations

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[5] Negative TFP growth is both puzzling and common.

[6] It is also possible that conflict can increase productivity as shown by the case of Liberty Ship production.

move closer to the observable frontier of product variety.[7] This can be captured by multiplying growth in product variety by the logged ratio of initial variety to total observable variety, V_F, where $\pi_2>0$.[8] The final result is:

$$4)\quad gY_{i,st} = \pi_0 + \pi_1 gV_{i,st} + \pi_2 gV_{i,st} \cdot \ln(V_{i,s}/V_F) + \pi_3 \ln R_{i,s} + \pi_4 gDens + \ldots$$
$$\ldots + \pi_5 gTele + \pi_6 gM + \pi_7 CONFL + \pi_8 SDINFL + \ldots$$
$$\ldots + \pi_9 gRER + \alpha gL_{i,st} + \beta gK_{i,st} + \mu_{i,st}$$

22. **Growth in Product Variety.** A review of the literature leaves one without a clear picture of what drives growth in product variety. An encompassing equation is therefore used to capture four competing hypotheses. First, the imitation hypothesis found in Barro and Sala-i-Martin (1995) and in many other texts suggests that growth in product variety should be greatest for countries furthest from the frontier of observable variety. This is measured using the logged ratio of initial variety in each country, V_s, to the maximum at the frontier, V_F. Second, Aghion and Howitt (1998) assume that variety increases through deliberate investments in R&D where $\Delta B=\kappa R$. Third, the work of Nelson and Phelps (1966) and Griffith *et al.* (2000), supports the presence of interactive effects where the rate of imitation is modified by some measure of human capital such as educational attainment, *H*, or R&D employment, *R*. The fourth possibility, found in Jones (1999) and in Chapter 12 of Aghion and Howitt (1998), is that countries with growing populations, *gN*, should display an expansion in product variety.[9]

23. The use of export variety as a proxy for output variety necessitates the introduction of two more variables. First, when using export-based measures of variety, it is reasonable to expect that real exchange rate depreciation, *gRER*, should increase *gV* as more products become more affordable and marketable overseas.[10] Second, one needs to account for the impact of rising productivity. Increased productivity could allow price reductions that would make it easier to market goods overseas. Productivity growth, *gTFP*, is therefore used as a control with respect to export variety. Putting everything together, the final encompassing equation becomes:

$$5)\quad gV_{i,st} = \delta_0 + \delta_1 \ln(V_{i,s}/V_F) + \delta_2 \ln R_{i,s} + \delta_3 \ln R_{i,s} \cdot \ln(V_{i,s}/V_F) + \delta_4 gN_{i,st} \ldots$$
$$\ldots + \delta_5 gRER + \delta_6 gTFP + \varepsilon_{i,st}$$

where δ_1 and δ_3 should be negative because $\ln(V_{i,s}/V_F)$ is always negative. The coefficient δ_5 should also be negative when exchange rate depreciation is indicated by a negative growth rate. The three remaining coefficients should all be positive. A third equation is added below to explain R&D employment.

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7 Alternatively, this variable could also be used as a correction for the fixity of observable variety where small observed changes in variety for nations close to the frontier represent larger actual changes.

8 The time subscript is omitted because observable frontier is fixed for any system of product classification.

9 The author also experimented with using real growth in GDP per capita as the proxy for growth in market size in addition to, and instead, of population growth.

10 Import variety could contract as the exchange rate depreciates. On a related note, one might be concerned about endogeneity between *gM* (in equation 4) and *gRER* (which appears in equations 4 and 5). Addison (2002) finds that the correlation between these period average variables is not statistically significant even at the 15 percent level of confidence in his sample.

24. **Research and Development.** According to Aghion and Howitt (1998), R&D employment is a function of population, *N*, and expected productivity growth which is proxied by observed TFP growth. In addition, it is reasonable to expect that R&D employment will also be correlated with average educational attainment, *H*. One can therefore write:

6) $$\ln R_{i,s} = \rho_0 + \rho_1 \ln N_{i,s} + \rho_2 gTFP + \rho_3 \ln H_{i,s} + \eta_{i,s}$$

All coefficients in equation 6 are expected to be positive. This completes the system of equations.

25. **Identification.** There is now a system of three equations. Each equation in the system is identified in the sense that none can be confused with a linear combination of the others. This satisfies the order condition necessary for identification.[11] A summary of the system of equations is shown in Table 1 below along with signs indicating prior expectations for each coefficient. The variables have been sorted into three groups: those that are potentially endogenous according to the theory, those that are pre-determined and those that are maintained as exogenous.[12]

Table 1: Equations for Hypothesis Testing

	Description	*Equation 4*	*Equation 5*	*Equation 6*
Dependent		*gY*	*gV*	ln*R*
Endogenous				
gTFP	TFP growth (from TFP index)		$+\delta_6$	$+\rho_2$
gY	Manufacturing value-added growth	1		
gV	Variety growth	$+\pi_1$	1	
ln*R*	R&D employment, 1979	$+\pi_3$	$+\delta_2$	1
$\ln(V/V_F)\,gV$	Interactive term	$+\pi_2$		
$\ln(V/V_F)\cdot\ln R$	Interactive term		$-\delta_3$	
gL	Labor force growth	$+\alpha$		
gK	Capital stock growth	$+\beta$		
Pre-determined				
$\ln(V/V_F)$	Distance from variety frontier, 1979		$-\delta_1$	
ln*N*	Total population, 1979			$+\rho_1$
ln*H*	Avg. educational attainment, 1979			$+\rho_3$
Exogenous				
gDens	Growth in population density	$+\pi_4$		
gTele	Growth in telephone lines per 1,000 people	$+\pi_5$		
gM	Growth in capital equipment imports	$+\pi_6$		
Confl	War related deaths/capita, 1979-86	$-\pi_7$		
SDINFL	Standard deviation, CPI inflation	$-\pi_8$		
gRER	Growth of real exchange rate	$\pm\pi_9$	$-\delta_5$	
gN	Urban population growth rate		$+\delta_4$	

a All growth rates are 1979-86 period averages

26. **Endogeneity.** Testing the simultaneous system developed above will be made difficult by the endogeneity between *gY*, *gV* and *R*. Endogeneity creates contemporaneous correlation

11 Necessary but not sufficient. The order condition requires the total number of restrictions, such as setting a parameter to zero, should be at least as great as the number of equations in the system, less one.

12 It is very likely that real exchange rate depreciation and capital imports would be correlated within a single country and across time. The same would be true of the growth capital imports and the growth total imports. This need not be the case for cross-country period averages and, in fact, no significant correlations between these variables were found.

between the regressors and the residual, thus creating biased and inconsistent coefficient estimates. The usual tactic in such cases is to rely on instrumental variables. For this, one needs a good set of instruments that are strongly correlated with the independent variables and not correlated with the disturbance term. Fortunately, the pre-determined and exogenous variables in a simultaneous system of equations are highly suitable for use as instruments because they drive the endogenous variables and because they are uncorrelated with the disturbance term. This suggests the 3 pre-determined and 7 exogenous variables listed in Table 1 above may be used as instruments in the formation of instrumental variables. In the case of equation 4, there may also be endogeneity between *gY*, *gL* and *gK*. Thus, for this equation, the initial (pre-determined) levels of labor and capital $\ln L_s$ and $\ln K_s$ are added to serve as instruments for gL_{st} and gK_{st}.

27. The efficacy of the instrumental variable approach also depends upon how well the instrumental variable estimates substitute for the original data in addition to the avoidance of contemporaneous correlation with the disturbance term. Higher correlations between the instruments and the explanatory variables leads to greater asymptotic efficiency in the estimators. Thus, in addition to the variables listed in Table 7.1 above, several other pre-determined variables are used as instruments in the construction of instrumental variables for the potentially endogenous regressors. These include *LIFE* for average life expectancy, *URB* for the per cent of population living in urban areas, *DENS* for initial population density and *TELE* for telephone lines per 1,000 people. These are all measured in 1979. Also included are a measure of openness to trade, *OPEN*, and a measure of the quality of governance, *GADP*, which both overlap the period 1979-86.

E. The Data.

28. The data are a cross-section of 29 countries for the period 1979-86. The choice of time period was dictated by the data for product variety, an issue taken up below. A summary of the main variables appears in Table 2 below and a list of the countries appears in Table 3. A brief description of the data can be found in the Data Appendix. An in-depth description and analysis of the data for variety can be found in Addison (2002).

29. The product variety data are based on a simple count-based measure of variety *V* and growth in variety *gV*. One starts with a data source that divides output into a fixed number of product categories. Many countries, for example, record output using the International Standard Industrial Classification (ISIC). The problem with output data, however, is that ISIC includes only 81 categories and many countries merge those categories over time.

30. Trade data are far more disaggregated and can serve as a proxy for output variety: a well diversified exporter must be a well diversified producer, although the converse is not necessarily true. The data used here are organized according to the Standard International Trade Classification (SITC Revision 2) which divides manufacturing exports into 1,600 categories. Variety *V* is defined as the number of non-zero export categories in any given year. The variable *gV* is the period average growth rate of *V*. Highly disaggregated trade data are rather noisy, so non-zero categories with values below US$1,000 and exports that were not part of contiguous blocks were both filtered out. The end result was that each product category could be empty,

continuously full, represent a new category of trade or represent a category that becomes obsolete.

Table 2: Data Sources and Descriptive Statistics

		Period	Mean	Standard Deviation	Maximum	Minimum
Output						
Growth in manufacturing value-added (gY)		1979-86	0 033	0.032	0.108	-0.021
Index of total factor productivity (TFP)		1979	1 094	0.402	1 830	0 279
Growth in total factor productivity (gTFP)		1979-86	0 014	0 023	0.043	-0 040
Variety						
Product variety (V)		1979	902.861	581.824	1,594.000	15.000
Distance from frontier of observable variety (ln(*V/V*$_F$))		1979	-0.984	1.168	-0.004	-4.670
Growth in product variety (*gV*)		1979-86	0.038	0 041	0 134	0.000
Factor Inputs						
Value of capital stock (*lnK*)		1979	10.280	1.667	13.941	7.051
Real growth of capital stock (*gK*)		1979-86	0.040	0.023	0 096	0 006
Manufacturing labor force (*lnL*)		1979	6 977	1.567	9.950	3.738
Labor force growth (*gL*)		1979-86	0.007	0.032	0 114	-0 044
Total population (*lnN*)		1979	16.722	1.445	20 326	13.766
Urban population growth rate (*gN*)		1979-86	0.023	0.021	0.081	0 001
Educational attainment (H)		1979	6 015	2 867	11.503	1.715
Educational attainment growth rate (*gH*)	a	1979-86	0.012	0.012	0 054	-0 003
Research and development employment (*lnR*)		1979-86	8 962	2 299	13.375	3 135
Life expectancy (*LIFE*)	a	1979	68.200	7.645	75.800	53.900
Life expectancy growth rate (*gLIFE*)	b	1979-86	0 005	0 002	0 009	0 001
Trade and Knowledge						
Openness to international trade (*OPEN*)	a	1950-94	0.530	0.346	1 000	0 000
Real growth rate in capital equipment imports (*gM*)		1979-86	0.045	0 118	0.567	-0.081
Real growth in manufacturing exports (*gX*)	b	1979-86	0.058	0.094	0 461	-0.027
Telephone lines per 1,000 people (*TELE*)		1979	176 161	165.461	564.020	2 990
Growth in telephone lines per 1,000 people (*gTELE*)	a	1979-86	0.055	0.036	0.172	-0.012
Governance (*GADP*)	b	1986-95	0 764	0.190	0.988	0 407
Security (*CONFL*)		1979-86	0 008	0.030	0 158	0 000
Macroeconomic Management						
Consumer price inflation (*INFL*)	b	1979-86	0.122	0 085	0.426	0.029
Price volatility (*SDINFL*)		1979-86	0.063	0.064	0.270	0.022
Growth of real exchange rate (*gRER*)		1979-86	-0 032	0.077	0.041	-0 407
Other Country Characteristics						
Urban share of population (*URB*)	a	1979-86	59 950	22.153	95.300	15.460
Population density (*DENS*)	a	1979	142.588	155.133	536.480	1 890
Growth in population density (*gDENS*)	a	1979-86	0.015	0.011	0 037	0.000
Mining share of GDP (*MINING*)	b	1988	0 033	0 034	0 111	0.000

a. Used as additional instruments in 2SLS.
b. Used as additional regressors in BACE robustness test.

Source: Addison, 2002.

31. Cross-country trade data arranged by product categories must be used with caution. Not all countries use the same trade category classification system. Concordances must therefore be established to translate the data from an originating country's system into the system of choice, SITC in this case. This would not be a problem except for the fact that some countries switch from one system to another drop category codes, add new codes and even redefine codes. These changes can induce artifacts in the data that look like variety changes even though actual product variety may not have changed at all. Thus, for example, one finds artificial bursts of product

variety in 1977 due to the fact that a number of countries switched from to SITC version 2 from version 1 between 1976 and 1977. Likewise, countries in the European Union switched to the Common Nomenclature system from NIMEXE in 1988 which affected the concordance to SITC version 2. For these reasons, the sample period had to be limited to 1978-87. The filtering process required a further contraction of the sample period to 1979-86.

32. The measure devised by Feenstra *et al* (1999) is also based on disaggregated trade data. Their methodology, however, requires far more complex computational effort.[13] There is an important trade-off: their measure allows for the possibility that the productivity spillovers may be greater for some new goods than for others while the count based measures require the contributions from each new product to be the same.

33. The measures used by Feenstra *et al* and the simpler measure used here are both subject to the limitations of the data. In particular, the use of pre-established product categories makes it impossible to measure gains in product variety within any specific category and beyond the number of pre-established product categories. This puts a premium on the level of disaggregation in the data. One should expect a greater ability to differentiate between nations as the data become more detailed. In fact, by experimenting with SITC trade data at three levels of aggregation (3-digit, 4-digit and 5-digit category codes) one can see that this is indeed the case. As the level of disaggregation increased, the distinction between low variety and high variety nations became much sharper. The ability to see changes in product variety also improve as the data become more detailed. (See Figures 1 and 2 below.)

34. The new data are congruent with the previous empirical work done by Funke and Ruhwedel and by Hummels and Klenow. They tell the same stories. Funke and Ruhwedel found a significant and positive relationship between product variety, proxied by export variety, and GDP per capita for 18 OECD countries.[14] Hummels and Klenow found the same for a much larger sample of 110 exporters. The simple correlation between GDP per capita and variety in the sample of 29 countries used here is 0.82 and the slope coefficient is highly significant at the 1 percent confidence level. A similar relationship can be seen in Figure 3 and Table 3 below which use the new data for TFP and export variety, V. The correlation between TFP in levels and V for 1979 data is 0.65 and the slope coefficient is highly significant at the 1 percent confidence level.

35. The new data are also supportive of the comparison of Korea and Taiwan in Feenstra *et al.* even though they are for the manufacturing sector as a whole rather than for manufacturing sub-sectors. In particular, one can see that growth in manufacturing TFP is faster in South Korea than in Taiwan while the same is true for the measure of product variety. (See Table 4 below.) Funke and Ruhwedel find evidence that this same pattern in growth rates holds true, when conditioned on country fixed effects, for a wider sample of 14 OECD countries.

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13 The author did experiment with the measure developed by Feenstra *et al.* in Addison (2002). This method did not generate a strong signal. This could be due to the shorter time period (1979-86 versus 1972-91) or the more aggregated nature of the data (1,600 versus more than 10,000 product categories) used by Feenstra *et al.*

14 Their data are expressed relative to the US which the authors consider to be the technological leader.

Figure 1: Data Aggregation and Observable Variety

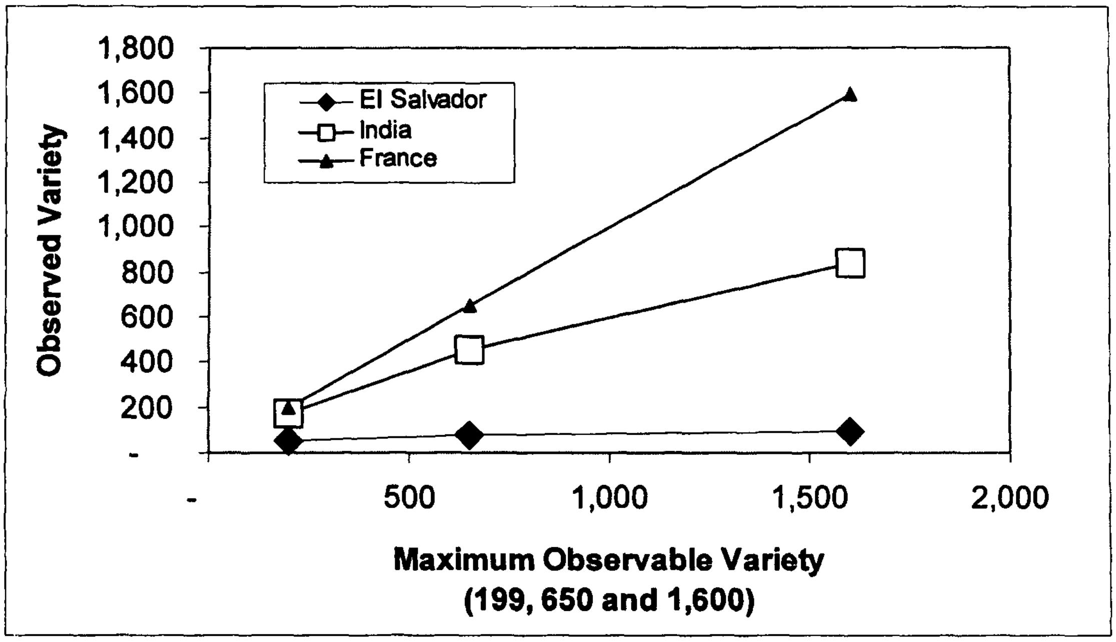
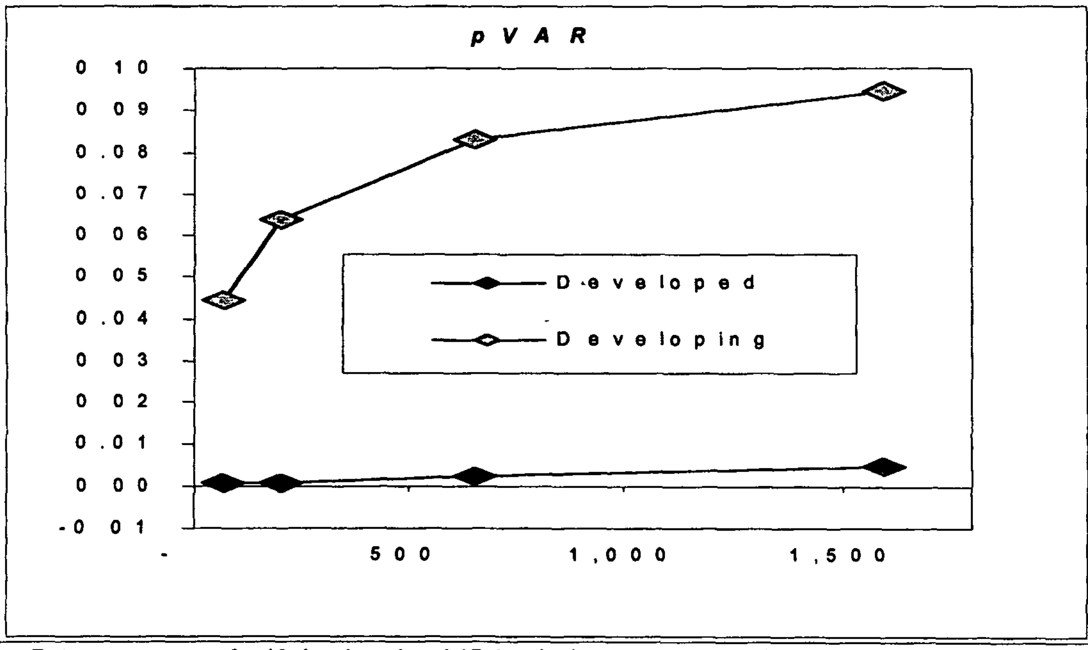


Figure 2: Data Aggregation and Observable Variety Growth



Data are averages for 13 developed and 15 developing countries. Zimbabwe is excluded because it is a large outlier.

F. Results.

36. Before discussing the results reported in Table 5, it would be useful to review the econometric methodology used here for hypothesis testing. Several competing hypotheses were advanced for both TFP growth and variety growth. For example, is TFP growth a function of variety growth, R&D employment, or both? To find out, a simplification search process was used. In the search process, one systematically imposes and tests zero-restrictions on the parameters of an equation that encompasses several competing variables and models. One tests for the redundancy of insignificant variables individually and in blocks. This is also known as the "general-to-specific" approach.[15] The robustness of the regressors, including variety growth, was tested further by using the new Bayesian robustness test developed by Sala-i-Martin (1997) and Dopplehofer *et al.* (2000). Robustness across country observations was also tested by looking for influential points.

37. The Hausman (1978) test was used to test for contemporaneous correlation generated by measurement error as well as the potential endogeneity between *gTFP*, *gV* and ln*R* – and between *gY*, *gK* and *gL*. Addison (2002) provides details on the choice of instruments. Despite the theoretical reasons for expecting contemporaneous correlation, the data fail to reject the null hypothesis of no contemporaneous correlation in each of the regression equations. This might be explained either by the small sample size or by the choice and number of instruments. (The Davidson and MacKinnon (1993) test of over-identifying restrictions was also used to make sure none of the instruments actually belonged in the test equations.)

38. White's (1980) test did detect heteroskedasticity in the equations for *gV* and ln*R*. Thus, White's heteroskedastic-consistent estimator was employed for those equations. The Jarque-Bera (1980) test was used to test the null hypothesis that that the error term is normally distributed. If not, the estimated standard errors would be biased and inconsistent. In all three equations, the data failed to reject the null hypothesis. Finally, the Ramsey (1969) RESET test was used to test the null hypothesis of no mis-specification due to functional form or omitted variables. The data failed to reject the null in each case.

39. **Productivity Growth.** The null hypothesis of no correlation between *gTFP* and *gV*, that π_l=0, is rejected by the data. The elasticity of growth in manufacturing value-added to variety growth is 0.262. In addition to the evidence supporting the variety hypothesis, one can see that R&D employment statistically significant, implying that there are important gains being made *within* product categories as well as *across* product categories. (Table 6 shows that within category gains occur mainly in the developed nations.) Real growth in capital imports also contributes to productivity with an elasticity of 0.132. It is somewhat puzzling to find that real exchange rate depreciation, which ought to militate against capital imports, also boosts

15 D.F. Hendry is one of the leading proponents of this technique. Hendry (2001) claims his new software, *PcGets*, can sort through an encompassing model with 40 irrelevant variables and locate the correct, smaller model 97 per cent of the time. The author has not tried this software yet.

Figure 3: Product Variety and Total Factor Productivity, 1979

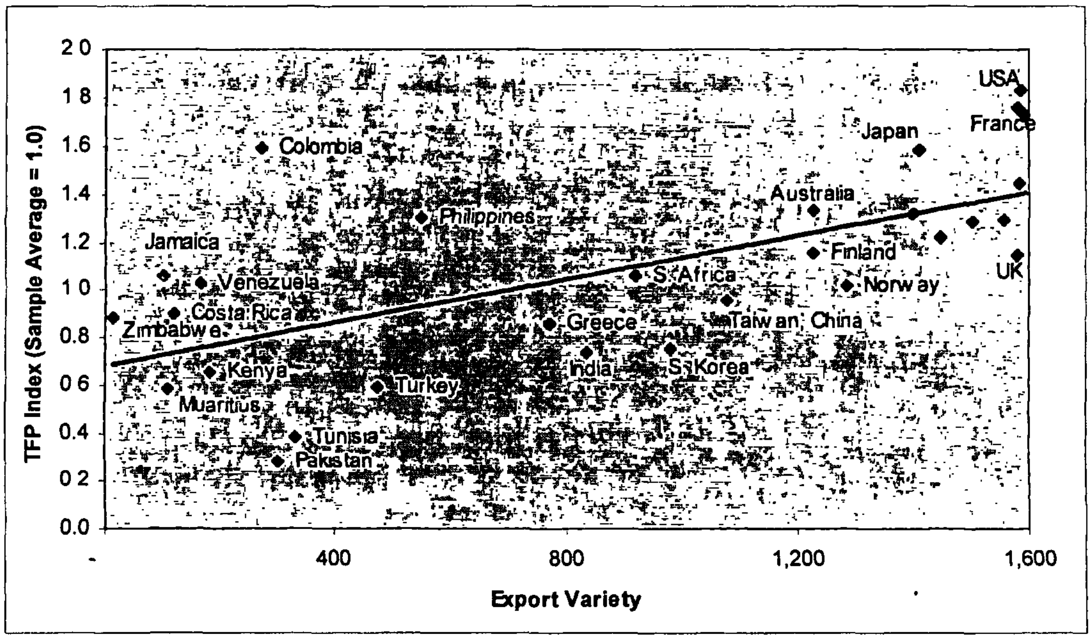


Table 3: Product Variety and Total Factor Productivity, 1979

	GDP/Capita[a]	V	TFP[b]		GDP/Capita[a]	V	TFP[b]
Developed				**Less Developed**			
Australia	12,227	1,228	1.33	Zimbabwe	1,190	15	0.88
Finland	10,262	1,229	1.16	Jamaica	2,508	103	1.06
Norway	11,719	1,284	1.02	Mauritius	4,412	108	0.58
Canada	14,114	1,399	1.32	Costa Rica	3,821	118	0.90
Japan	9,756	1,412	1.58	Venezuela	8,092	165	1.03
Denmark	11,484	1,448	1.22	Kenya	931	182	0.66
Sweden	12,261	1,503	1.28	Colombia	2,878	269	1.59
Italy	9,831	1,557	1.29	Pakistan	1,053	300	0.28
Belgium	10,679	1,579	1.76	Tunisia	2,368	330	0.39
U.K.	10,483	1,581	1.15	Turkey	2,955	474	0.59
Netherlands	11,286	1,583	1.45	Philippines	1,854	547	1.30
U.S.A.	15,637	1,588	1.83	Greece	5,896	771	0.86
France	11,664	1,594	1.72	India	837	834	0.74
				South Africa	3,347	921	1.06
				South Korea	3,321	981	0.75
				Taiwan, Ch.	4,248	1,080	0.96

a Penn World Tables, measured in "international prices," 1985 base year. Simple correlation with variety is 0.82, simple correlation with TFP is 0.70.

b TFP index methodology from Caves, Christensen and Diewert (1982b) Unweighted, geometric sample average equals 1.00.

Table 4: South Korea versus Taiwan, China

	Growth Rates		Levels	
	gTFP[a]	gV	V	TFP[a]
South Korea	4.2	3.1	981	0.75
Taiwan, China	3.2	2.8	1,080	0.96

a. TFP index methodology from Caves, Christensen and Diewert (1982a,b).

productivity. One might speculate that depreciation induces more efficient use of imported intermediates in production. Finally, productivity is reduced by conflict and by macroeconomic instability as proxied by volatility in the inflation rate.

40. The robustness of the results in column 1 were tested using Bayesian Averaging of Classical Estimates (BACE) as documented in Dopplehofer, Sala-i-Martin and Miller (2000). All of the regressors that survived the simplification search, as shown in column 1, were found to be robust except for real growth of imports of capital goods. This remained true when extra variables were added to the equation as another robustness test.[16]

41. It was also discovered that the observation for Venezuela is an influential point with regard to the partial correlation between *gV* and *gTFP*. Excluding it from the dataset renders *gV* insignificant. As Thomas (1997) notes, most economists prefer to retain such influential observations in their samples unless it can be proved that the observation is wrong or inappropriate.

42. A case can be made for retaining this observation. Until the late 1980s, Venezuela was known as a fast growing and stable nation. The period 1979-86 includes the tail end of the second OPEC oil boom. This boom made possible a rapid expansion of education in many oil producing nations, including Venezuela. Average educational attainment between 1975 and 1980 grew by 8.4 percent per annum compared to only 2.4 percent per annum between 1970 and 1975.[17] As can be seen from equations 5 and 6, this would have led to increased R&D employment and increased product variety, both of which would have contributed to productivity on an ongoing basis. Whether or not one agrees with this argument favoring the retention Venezuela, the fragility of the results demands that future research should be aimed at finding out if the partial correlation between *gV* and *gTFP* is increased or decreased by an expanded list of country observations and/or the use of panel data.

43. **Variety Growth.** The simplification search was conducted twice in order to determine whether ln*R* or ln*H* would be the better measure of human capital – with better implying more explanatory power. Both worked well but ln*H* is preferred on the basis of a *J*-test between the two model specifications. In addition, it was found that Zimbabwe was a strong outlier observation that needed a dummy because of it's strong rebound in manufacturing output and variety at the conclusion of its civil war in 1980.

44. The final results confirm that imitation is easier for nations furthest from the frontier of product variety, with imitative ability increased by average educational attainment. (Note: the signs on δ_1 and δ_3 are negative because the log of a fraction, such as V/V_F, is always negative.) Productivity growth contributes to growth in variety with an elasticity of 0.208. Exchange rate depreciation (denoted by a negative change in gRER) is also significant because output variety is proxied by export variety: depreciation makes products less expensive overseas and thus easier to market.

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16 As a result of this process, it was found that the average rate of inflation performed better than the standard deviation of inflation. This result is not shown in Table 5.

17 It is unfortunate that these gains were not maintained in later years.

Table 5: Final Results

	gY *Equation 4*		*pVAR* *Equation 5*	*lnR* *Equation 6*
	OLS	*BACE*	*OLS*	*OLS*
gTFP			δ_6	ρ_2
Coefficient			0.208	18.058
t-Statistic			2.081	2.155
gY				
Coefficient	1	1		
t-Statistic				
gV	π_1	π_1		
Coefficient	0.262	0.410	1	
t-Statistic	2.137	2.445		
ln*R*/1000	π_3	π_3		
Coefficient	5.404	6.519		1
t-Statistic	2.340	2.822		
gN				ρ_1
Coefficient				1 078
t-Statistic				9.111
ln*H*/1000				ρ_3
Coefficient				2.491
t-Statistic				8.119
ln(V_I/V_F)			δ_1	
Coefficient			-0.020	
t-Statistic			-4.453	
ln(V_I/V_F)·ln*H*/1000			δ_3	
Coefficient			-17.062	
t-Statistic			-3 571	
gM	π_6	π_6		
Coefficient	0.132	0.083		
t-Statistic	2.364	1.227		
CONFL	π_7	π_7		
Coefficient	-1.357	-1.427		
t-Statistic	-3.117	-2.913		
SDINFL	π_8	π_8		
Coefficient	-0.172	-0.173		
t-Statistic	-2.574	-2.678		
gRER	π_9	π_9	δ_5	
Coefficient	-0.237	-0.254	-0.089	
t-Statistic	-3.829	-3 117	-7.637	
gL	α	α		
Coefficient	0.383	0.284		
t-Statistic	2.332	1.552		
gK	β	β		
Coefficient	0.683	0 869		
t-Statistic	3.846	2 697		
Zimbabwe			δ_7	
Coefficient			0.405	
t-Statistic			39.066	
Constant	π_0		δ_0	ρ_0
Coefficient	-0.052		-0 004	-13 527
t-Statistic	-2.135		-1 380	-5.428
Adjusted R^2	0.761		0 994	0.866
Joint Significance (F-statistic)	12.167		987 468	52.704
Heteroskedasticity (White)	none		yes	yes
Normal Disturbance (Jarque-Bera)	yes		yes	yes
Mis-specification (RESET)	none		none	none
Contemporaneous Correlation	none		none	none

a. BACE prior assumption is that 8 out of 10 variables regressors should be significant. BACE mixed t-statistics > 2 can be interpreted in fashion similar to OLS t-statistics: 95 percent of the probability density associated with the BACE estimates are non-zero.

45. The developed nations within the sample showed a strong tendency towards convergence to the frontier of observable variety with the developing nations do not. This appears to be explained by the interaction between imitative ability and educational attainment. Most countries in the data sample show good progress in improving educational performance over time. This progress is not uniform. Colombia, Kenya, Pakistan and Zimbabwe as examples of countries with growth rates in educational attainment well below average. By contrast, Tunisia and South Korea are examples of nations where educational growth rates were exemplary.

46. The simplification search also produced a surprise. The data fail to reject the null hypothesis that population growth does not contribute to growth in product variety. The same is true when growth in real GDP per-capita is substituted for population growth – and when both variables are tried concurrently. One might speculate that these variables would indeed be correlated with growth in variety if the time period were longer than the 8 years between 1979 and 1986 used here.

47. **Research and Development.** The results for equation 6 are straightforward. The data fail to reject the hypothesis that R&D employment is a function of population, average educational attainment and expected productivity gains – the latter being proxied by actual productivity gains.

G. Patterns of Growth and Policy Implications

48. Several interesting policy related conclusions concerning the determinants of cross-country patterns of productivity growth can be deduced from the work that appears in Section F above. A decomposition of estimated productivity growth, $gTFP^*$, for the developed and developing countries is provided in Table 6. The average contribution to $gTFP^*$ from each variable is shown for the developed nations and for the DCs – each relative to the full sample mean for each variable. Thus, the fact that most of the developed nations experienced lower growth in output than the DCs implies that average gY^* will be shown as negative for the developed nations and positive for the DCs.

49. The top half of the table shows how $gTFP^*$ is derived from predicted real growth in output, gY^*, less real growth in factor inputs. There is an interesting contrast here. On average, and relative to the sample means, the DCs are accumulating factors while their productivity falls. The opposite situation applies for the developed countries.

50. The bottom half of the table shows the contributions to $gTFP^*$ from the key variables in the model. The developed nations growth (relative to the sample mean) is generated by R&D employment, the absence of conflict, macro stability and capital imports. Of these, the largest contribution comes from R&D employment. This suggests there are important productivity gains coming from sources other than gains in variety such as process innovations and qualitative improvements. In absolute terms, the contributions to $gTFP^*$ in the developed nations from product variety growth and exchange rate depreciation are approximately zero, hence their deviations from the full sample means are negative. The contrast with the DCs is quite striking. Positive contributions to predicted productivity growth in the DCs (relative to the sample mean)

come from gains in product variety (0.74 per cent) and from real exchange rate depreciation (0.64 per cent). Unfortunately, these gains are reversed by low R&D employment, low real growth in capital imports, macro instability and conflict.

Table 6: Decomposition of Contributions to *gTFP*

	Growth Rates (%) [a]		
	Developed [b]	DCs [c]	Difference [d]
Predicted *gTFP [e]**	0.46	-0.40	0.86
Predicted output growth (gY^*)	-1.34	1.16	-2.50
less labor growth ($\alpha \cdot gL$)	-0.83	0 72	-1.55
less capital growth ($\beta \cdot gK$)	-0.98	0.85	-1.83
Predicted *gTFP [f]**	0.46	-0.40	0.86
Variety growth ($\pi_1 \cdot pVAR$)	-0.86	0.74	-1.60
Real exchange rate ($\pi_9 \cdot gRER$)	-0.74	0.64	-1.38
Conflict ($\pi_7 \cdot CONFL$)	0.38	-0.33	0.71
R&D employment ($\pi_3 \cdot \ln R$)	0.79	-0 69	1.48
Macro stability ($\pi_8 \cdot SDINFL$)	0.52	-0.45	0.97
Capital imports growth ($\pi_6 \cdot gM$)	0.36	-0.31	0.67

a. Growth rates are relative to sample means for each variable. The sample excludes Zimbabwe. Totals are subject to rounding error.
b. Average for developed nations less average for full sample.
c. Average for DCs less average for full sample.
d. Developed average less DC average.
e. $gTFP^* = gY^* - \alpha \cdot gL - \beta \cdot gK$.
f From equation 4.

51. **Policy Implications.** The policy ramifications of the results for equation 4 can be seen more clearly if equations 5 and 6 are used to generate the reduced form equation, shown below.[18] Statistically insignificant variables have been omitted.

$$gTFP^* = \frac{\pi_0 + \pi_1\delta_0 + \pi_3\rho_0}{1-\pi_1\delta_6 - \pi_3\rho_2} + \frac{\pi_1\delta_1 \ln(V_t/V_F) + \pi_3\rho_3 \ln H + \pi_1\delta_3 \ln(V_t/V_F)\ln H}{1-\pi_1\delta_6 - \pi_3\rho_2} + \ldots$$

7) $$\ldots - \frac{(\pi_9 + \pi_1\delta_5)gRER}{1-\pi_1\delta_6 - \pi_3\rho_2} + \frac{\pi_6 gM}{1-\pi_1\delta_6 - \pi_3\rho_2} + \ldots$$

$$\ldots - \frac{\pi_7 CONFL}{1-\pi_1\delta_6 - \pi_3\rho_2} - \frac{\pi_8 SDINFL}{1-\pi_1\delta_6 - \pi_3\rho_2} + \frac{\pi_3\rho_1 \ln N}{1-\pi_1\delta_6 - \pi_3\rho_2}$$

52. This reduced-from equation is used to create another growth decomposition in Table 7. The reader is cautioned that the numbers in Table 6 and 7 are similar but not directly

18 Jones (1999) critiques such formulations for individual economies, noting that growth in population or educational attainment should cause accelerating growth in output. Models that explain why this does not actually occur are still being proposed and debated.

comparable. This is because the reduced form version implies slightly different implicit values for ln*R* and *pVAR* and because all coefficients are multiplied by $1/(1-\pi_1\delta_6-\pi_3\rho_2)$.

53. Equation 7 shows that average educational attainment contributes to productivity directly and via its interaction with the variety gap, $\ln(V/V_F)$. The growth decomposition in Table 7 illustrates the magnitude of the contribution. The average developed nation is able to generate productivity gains 1.3 per cent per annum higher than the DCs because of higher educational attainment. (See the "difference" column in Table 7.) Yet the DCs gain 1.8 per cent per annum more than the developed nations through their greater imitative potential and the boost that education gives to imitation through the interactive term. From this, it is easy to deduce that policies that increase educational attainment will have the greatest effect on the DCs, though higher attainment will remain important even for nations close to the variety frontier.

Table 7: Reduced Form Decomposition of Contributions to *gTFP*

	Growth Rates (%) [a]		
	Developed [b]	**Developing** [c]	**Difference** [d]
Predicted *gTFP** [e]	0.35	-0.31	0.66
Predicted Output Growth (gY^*)	-1.46	1.26	-2.72
less labor growth ($a \cdot gL$)	-0.83	0.72	-1.55
less capital growth ($b \cdot gK$)	-0.98	0.85	-1.83
Predicted *gTFP** [f]	0.35	-0.31	0.66
Average Educational Attainment ($\ln H$)	0.68	-0.59	1.27
Education and Imitation	-0.94	0.82	-1.76
Distance from variety frontier ($\ln(V/V_F)$)	-0.47	0.41	-0.88
Interactive term ($\ln(V/V_F) \cdot \ln H$)	-0.47	0.41	-0.88
Trade and Exchange Rate Effects	-0.53	0.46	-0.99
Capital imports growth (*gM*)	0.43	-0.37	0.80
Real exchange rate (*gRER*)	-0.96	0.83	-1.79
Instability and Insecurity	1.06	-0.92	1.98
Conflict (*CONFL*)	0.45	-0.39	0.84
Macro instability (*SDINFL*)	0.61	-0.53	1.14
Total Population ($\ln N$)	0.08	-0.07	0.15

a. Growth rates are relative to sample means for each variable. The sample excludes Zimbabwe. Totals are subject to rounding error.
b. Average for developed nations less average for full sample.
c. Average for DCs less average for full sample.
d. Developed average less DC average.
e. $gTFP^* = gY^* - \alpha \cdot gL - \beta \cdot gK$.
f. From equation 7.

54. Greater macroeconomic and domestic stability provide the developed countries with another 2 per cent per annum advantage over the DCs. The developed nations also gain 0.8 per cent per annum more from real growth in capital imports than do the DCs (though the BACE results in Table 7.33 suggest this may not be robust). This could be attributed to any number of

policies that lead to increasing export output and improving terms of trade. Differences in population size matter as well, conferring a 0.15 per cent per annum advantage to the developed nations.

55. The empirical results also suggest that real exchange rate depreciation contributes to productivity growth. In this regard, it is easy to believe that real depreciation could induce manufacturers to economize on imported inputs, thus increasing their productivity. In particular, the average DC generates 1.8 per cent per annum more from this source than do the developing nations. (The average developed nation did not experience depreciation in my sample period.) Even so, it is hard to argue for exchange rate depreciation as a development policy for several reasons. One, it is in direct conflict with the need to increase real capital goods imports. Two, under most circumstances, depreciation is not correlated with low inflation. Three, greater productivity ought to lead to real exchange rate *appreciation*. Four, it is also bad politics: depreciation by one trading partner could induce others to depreciate in order to remain competitive.

H. Summary and Outstanding Issues

56. Is *gV* positively correlated with *gTFP* when conditioned by several other variables that can be controlled through policy choices? The null hypothesis that π_l=0, meaning that *gV* does not affect *gTFP*, is rejected by the data. This result is robust when tested using BACE. Unfortunately, the presence of an influential point for Venezuela makes the results fragile. It is argued that the Venezuelan observation belongs in the data set. At the same time, future research should seek to test if the partial correlation between *gV* and *gTFP* is strengthened when additional observations are added.

57. The analysis was supported by an investigation into the cross-country determinants of product variety, one of just a very few found in the literature. I found strong support for convergence in product variety where the rate of convergence is modified by average educational attainment. This provides support for the imitation hypothesis. In making this test, I also failed to find support for the alternative hypothesis that variety growth is a function of national population growth.

58. Even if population growth is found important, the results published here suggest that small countries are not doomed to slow growth and low product variety *if* they can improve average educational attainment. In particular, an exploration of equation 6 confirmed that R&D employment is a function of population, average educational attainment and expected productivity growth. As made clear by the reduced form equation 7, this implies that educational policy choices can drive productivity directly through R&D employment and indirectly through the imitation of product variety. Sadly, not all countries are making effective educational policy choices. Colombia, Kenya, Pakistan and Zimbabwe are examples of countries with growth rates in educational attainment well below average.

59. The results also highlight the importance of macro stability and domestic security. Better performance in these areas provide the developed nations with a substantial lead over the DCs.

Capital imports may also contribute to productivity, though the BACE tests suggest this result may not be robust.

60. Many empirical issues remain. It should be acknowledged first that the business of testing TFP growth is, itself, very tricky. There are many methodological issues and pitfalls involved. One issue in this regard is the decision to define productivity in terms of value-added per capital and labor rather than gross output per capital, labor, intermediates and energy. This may create bias in observed productivity because productivity gains from more efficient use of intermediates and energy are ignored. The work by Feenstra *et al* (1999) was the only test of the variety hypothesis where TFP based on gross output was used and this effort was limited to only 2 countries. Second, it would be ideal to find a data source that allows a direct measure of product variety for a wide range of rich and poor countries rather than rely on export variety as a proxy. Third, it would be desirable to use panel data, something that would be possible if only more R&D observations were available. This would allow a test of Granger causality. Fourth, it would be very useful to continue a line of inquiry started by Feenstra *et al*: does input (import) variety matter more than output (export) variety or are they highly correlated? In this regard, it is worth noting that export variety can include intermediates and capital. Sorting these out would be a useful exercise. Finally, it is hard to imagine that gains from product variety are limited to manufacturing. There may be enough data available from other sectors, perhaps agriculture, to allow the question to be pursued elsewhere.

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Appendix A

Data Descriptions and Sources

		Period	Units	Source
Output				
Manufacturing value-added	Y	1979-86	Constant 1980 dollars valued at PPP exchange rates	OECD ISDB World Bank
Index of total factor productivity	TFP	1979	Index	Author
Growth in total factor productivity	gTFP	1979-86	Period average growth rate	Author
Variety	*V*	1979-86	Count of SITC product categories for manufactured goods, mainly in categories 5 through 8	WITS
Factor Inputs				
Value of physical capital stock	*K*	1979-86	Constant 1980 dollars valued at PPP exchange rates	OECD ISDB, Crego, Larson, Butzer and Mundlak (1999) and author
Manufacturing employees	*L*	1979-86	Total manufacturing employment	Martin and Mitra (1999), ILO, UNIDO
Population	*N*	1979-86	Total population	World Bank
Average educational attainment	*H*	1979-86	Years of schooling	Barro and Lee (1994)
Research and development employment[a/]	*R*	1979	Scientists and engineers per million people	World Bank
Average life expectancy	*LIFE*	1979-86	Years	World Bank
Trade and Knowledge				
Openness to trade	OPEN	1950-94	Index bounded by zero and one Measures amount of time a country has been open to trade between 1950 and 1994	Sachs and Warner (1995)
Imported capital equipment	*M*	1979-86	US dollar imports, SITC Category 7, deflated by index of manufactures unit values (MUV)	WITS World Bank MUV
Exported manufactures	*X*	1979-86	US dollar exports, deflated by index of manufactures unit values	WITS World Bank MUV
Telephone lines per 1,000 people	*TELE*	1979-86	Main lines per 1,000 people	World Bank
Governance & Property Rights[b/]	*GADP*	1986-95	Index bounded by zero and one	Hall and Jones (1998)
Security[c/]	*CONFL*	1979-86	Average civil war related deaths per annum normalized by 1979 population	Calculated from data in Sambanis (2000)
Macroeconomic Management				
Consumer price inflation	*INFL*	1979-86	Period average growth rate	Calculated from IMF IFS 64
Price volatility	*SDINFL*	1979-86	Standard deviation in annual CPI inflation rate	Author
Real exchange rate	*RER*	1979-86	Real exchange rate	IMF IFS rec
Other Country Characteristics				
Urban share of population	*URB*	1979-86	Percentage	World Bank
Population density	*DENS*	1979-86	Population per square kilometer	World Bank
Mining	*MINING*	1988	Mining and quarrying share of GDP	Hall and Jones (1998)

a. Based on available data for 1980-91 extrapolated to 1979. Observations for Kenya, Taiwan, Tunisia and Zimbabwe are estimates based on equation 6.

b. Based on Political Risk Services ratings of maintenance of law and order, the quality of government bureaucracy and the degree of perceived government corruption for the period 1986-95. It is assumed these ratings would not be much different from the period 1979-86.

c. Only Colombia, Philippines, Turkey, South Africa and Zimbabwe suffered conflict related deaths.

d. All applicable growth rates based on these data are period averages except *gLIFE* which is defined as the exponential growth rate between data points in 1977 and 1987

Source: Addison, 2002

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