Slightly Revised as of 5/93

REFLECTIONS ON THE GROWTH PROCESS

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June 1990

The phenomenon of economic growth has aroused new professional interest in the past few years, after what can fairly be characterized as a significant dry spell. Much of the new literature has its roots in other parts of our discipline, and accordingly has only limited linkage with the older literature, and what for want of a better term I would call the older "experience" of development economics. The main purpose of this paper is to try to set down some of the lessons that I feel have been learned by development economists over the past several decades, not only from academic studies, but also, and importantly, from the "experiences" of actual countries in their struggles to surmount the temptations and other obstacles that so often block the path to economic development. This summary should serve as a useful backdrop against which to view the contributions of more recent work. At the same time it should provide readers who are outside the area of economic growth analyses with a sense at least of what I would consider to be the "center of gravity" of knowledge and thinking in that field as of the decade of the 1980s.

Though a great deal of wisdom on the subject of economic growth is to be found in economic writers from Adam Smith to Alfred Marshall to Joseph Schumpeter and beyond, I find it convenient to start the present discussion with the familiar Harrod-Domar equation.

(1) $$\Delta Y = \bar{a}_0 \Delta K, \text{ where } (K_0/Y_0) = (1/\bar{a}_0)$$

This equation implicitly attributes all growth in output (Y) to increases in stock (K) of reproducible physical capital. Though all the relevant writers were well aware that growth stemmed from other causes, the Harrod-Domar model, by emphasizing the role of physical capital accumulation in the growth process, definitely led the economics profession as a whole to focus predominantly on saving and investment in analyses and discussions of the growth phenomenon during the late 1940s and the early 1950s. A closely related approach grew out of the input-output literature of the period. This approach involved the measurement of capital coefficients for different sectors of the economy, so that instead of (1) you had

$$(1') \qquad \Delta Y_i = a_{oi}\ \Delta K_i, \text{ where } (K_{oi}/Y_{oi}) = (1/a_{oi}).$$

This variant of the Harrod-Domar assumption was to be found in the multi-sector growth models that proliferated at least through the 1960s.

The next step in the development of our thinking was, to a degree at least, built on the underpinning of an aggregate production function $Y = F(K,L)$. When output was looked upon as being generated in this way, it was found that much of the growth of output was left unexplained by the concomitant increments of capital and labor, as usually defined. Thus we have

$$(2) \qquad \Delta Y = F_K \Delta K + F_L\ \Delta L = R,$$

where F_K and F_L are the marginal productivities of capital and labor, respectively, and where R is the residual change in output, "unexplained" by the increments to the two basic factors. A little manipulation produces two alternative versions of (2), one (2a) expressed in terms of factor shares and percentage rates of growth, and the other (2b) expressed in hybrid form with a focus on I_N ($=\Delta K$) = net investment, then taken as a fraction of aggregate output, Y.

(2a) $$\frac{\Delta Y}{Y} = \frac{KF_K}{Y}\left(\frac{\Delta K}{K}\right) + \frac{LF_L}{Y}\left(\frac{\Delta L}{L}\right) + \frac{R}{Y}$$

$$\dot{Y} = s_K\dot{K} + S_L\dot{L} + (R/Y)$$

[s_K, s_L = shares of labor and capital in Y,

$\dot{K} = (\Delta K/K)$, $\dot{L} = (\Delta L/L)$.

(R/Y) = Residual increment in output expressed as a fraction of Y.

(R/Y) is therefore "part" of the growth rate $\dot{Y}$.

(2b) $$\frac{\Delta Y}{Y} = F_K\frac{\Delta K}{Y} + \frac{LF_L}{Y}\left(\frac{\Delta L}{L}\right) + \frac{R}{Y}$$

$$\dot{Y} = F_K\,(I_N/Y) + S_L\dot{L} + (R/Y).$$

Here capital's contribution to the growth rate $\dot{Y}$ is seen to be equal to the fraction of national output invested (in the home economy) times the marginal productivity of capital, F_K.

We will not tarry with expressions (2a) and (2b), however. They are presented because they are likely to be the focus in which many readers are accustomed to see the growth equation. Those readers can thus be assured that what we are talking about here is the same thing as they are used to working with.

Expression (2) has a natural extension down to the level of a single sector, industry, or firm. If we think of each individual segment as having a production function $Y_i = F_i(K_i, L_i)$ we can then express the segment's output growth as

(2')
$$\Delta Y_i = F_{Ki}\,\Delta K_i + F_{Li}\,\Delta L_i + R_i .$$

This does not look very helpful in the above form, but one gains insight by separating each marginal productivity into two components:

$$F_{Ki} = \bar{\rho} + \delta_i^* \; ; \quad F_{Li} = \bar{\omega} + \lambda_i^*$$

thus we have:

(2")
$$\Delta Y_i = \bar{\rho}\,\Delta K_i + \bar{\omega}\,\Delta L_i + \delta_i^*\,\Delta K_i + \lambda_i^*\,\Delta L_i + R_i \; .$$

Here $\bar{\rho}$ and $\bar{\omega}$ are the economy-wide rates of remuneration of capital and labor, and δ_i^* and λ_i^* measure the extent to which the marginal productivities of capital F_{Ki} and labor F_{Li} differ in sector i from the respective economy-wide average factor rewards. These factors δ^*_i and λ_i^* could measure monopoly markups, and/or the results of economies of scale, and/or taxes applicable to either factors as such (in particular uses) or to the final products made in given uses (since a tax of 20 percent causes the value of marginal product of end factor to exceed its remuneration).

The neat thing about equation (2") is that it can be aggregated over all productive sectors in the entire economy. This, with some understandable caveats with respect to sectors like general government, organized religion, and charitable and other nonprofit organizations, leads to

$$\Delta Y = \sum_i \Delta Y_i = \bar{\rho}(\sum_i \Delta K_i) + \bar{\omega}(\sum_i \Delta L_i) + \sum_i \delta_i^* \Delta K_i + \sum_i \lambda_i^* \Delta L_i + \sum_i R_i \tag{3}$$

$$\Delta Y = \bar{\rho}\,\Delta K + \bar{\omega}\,\Delta L + \left(\sum_i \delta_i^* \Delta K_i + \sum_i \lambda_i^* \Delta L_i + \sum_i R_i\right)$$

$$\Delta Y = \bar{\rho}\,\Delta K + \bar{\omega}\,\Delta L + R.$$

The most important thing about (3) is that it shows how the "standard" residual R can be seen as comprising the sum of a great many individual "segment" R_i, defined at the sector, the industry, or even the firm level.

I quite consciously developed the derivation of (3) using production functions F_i, for a whole array of separate activities, simply because so many people think of this type of growth analysis as somehow being the "production function analysis of growth." My next step, however, is to try to help them overcome that habit. Later on I shall elaborate on the notion that the idea of a reasonable, stable and well-defined production function runs counter to much of what we know about the growth process. For the moment, however, let me simply put out for consideration an alternative way of expressing the neoclassical breakdown of economic growth into its component parts. In this alternative mode we do not particularly think about production functions, only about wages of labor and about rates of return to capital.

A Disaggregative Analysis of the Growth Process

Let us return to (2) which, using production functions, distinguishes between the marginal productivities of capital and labor in different sectors. But now instead of expressing F_{Ki} in terms of $\bar{\rho}$, the economy-wide wage rate plus a deviation λ_i^*, we can go a step further and express F_{Ki} in terms of ρ_i, the actual (observed) rate return to capital in segment i, and likewise express F_{Li} in terms of ω_i, the actual (observed) wage rate of labor in segment i. In this way we obtain $F_{Ki} = \rho_i + \delta_i$ and $F_{Li} = \omega_i + \lambda_i$. This makes δ_i the deviation of m.p.k. from the actual reward earned by capital in segment i, and λ_i (correspondingly) the deviation of m.p.l. from the actual "cost of labor" that in segment. This produces a growth equation

(4) $$\Delta Y = \Sigma_i \Delta Y_i = \Sigma_i \rho_i \Delta K_i + \Sigma_i \omega_i \Delta L_i + \Sigma \delta_i \Delta K_i = \Sigma_i \lambda_i \Delta L_i + \Sigma_i R_i$$

$$\Delta Y = \Sigma_i \rho_i \Delta K_i + \Sigma_i \omega_i \Delta L_i + R .$$

Here the ρ_i and the ω_i are actual "cost of capital" and actual "cost of labor" in each segment, while the δ_i and λ_i are deviations between these factor costs in a given segment and each factor's true marginal productivity in that segment. It is quite appropriate, therefore, to associate these items with externalities of different types (including economies of scale), and to simply include them as part of the residual term.

Having gone this far, keeping a close link to the production functions that are traditional in economic analysis, we can now take the final step of freeing our analysis from that particular conceptual link. Let us have an arbitrarily large number of classifications and labor. Let them even be different in different industries, so that in the sports industry age is the relevant factor, while in the industry providing accounting providing accounting services education is important, and in the management consulting business it is experience.

It does not matter what the criteria are for discriminating, we simply take the wage paid (the "cost of labor") in the preceding period as our proxy measure for the marginal productivity of each sub-group of labor. Letting

$\bar{w}_{ji}$ = last period's wage for class j of labor in segment i

L_{ji} = number of workers of class j operating in segment

we have $\Sigma_j \, w_{ji} \, \Delta L_{ji}$ as the contribution to segment i's growth rates of changes in its use of labor of different types (j) from one period to the next. Thus if segment i upgrades its labor by shifting 10 units from a low-education category where the wage is 100 to a high-education category where the wage is 175, we will find $\Sigma_j \, w_{ji} = 100\,(-10) + 175\,(+10) = +750$. This will be the contribution to growth of the shift in the composition of the labor force. A similar thing would happen in the management consultant industry with a shift away from workers with low experience and toward workers with high experience, or in the sports industry from old players (well past their prime) to younger players (nearing their prime).

All of a sudden we find we can deal with a huge number of categories of labor. We can allow each industry or activity to give us its own categories of labor (in particular, and especially, those categories that best reflect the sources of wage differences within the activity). Likewise, we can have within a given segment different types of capital, with different rates of return. In one area the rate of return to capital may be high because a new innovation has just been discovered, and economic rents are available to those who invest in it (up to the point where these rents are competed away). In another the rate may be high because of tax distortions, in yet another it may be high due to nondiversifiable risks. So rates of return to capital will on the whole vary across categories that are very different from the age-education-experience categories that tend to be most relevant for the wages and labor. No matter--we ideally want to use the categories over which the relevant variation exists. There is no reason for the names of the categories to be the same from one sector or industry to the next, or from one factor to the other within the same sector or industry.[1]

[1]There are many subtleties involved in setting up this sort of framework for growth analysis. If one is thinking in relatively aggregative terms, the most meaningful attribution to an increment of labor or capital is the net wage or net rate of return. Why? Because that is what tends to be the same for each increment in the aggregative category. Thus, the wage for unskilled industrial labor would be 100, if that is the competitive market wage. A distortion would be added in the jewelry-making industry to cover a 20 percent excise tax on jewelry. Different distortions would occur in the steel and auto industries to reflect union-induced wage differentials there. Still different adjustments would be made in construction and lumbering to reflect premia for seasonality plus weather-related risks.

Thus we might have in a given year:

	ΔL_i	Std. Wage	Net Wage	Gross Wage	Attributed to ΔL_i	Attributed to Residual
Jewelry (20% tax)	+10	100	100	120	+1000	+200
Steel and autos (40% union effect)	-8	100	140	140	-800	-300
Construction and lumbering (30% risk premia)	+5	100	130	130	+500	+150

If the same analysis is done in a more disaggregated way, we can work directly with the gross wage in all three cases. We would then have attributed growth of +1200 in jewelry of -1120, in steel and autos, and of +650 in construction and lumbering, with <u>no</u> element being thrown into

Once one gets the idea of "attributing" to each factor in each segment a contribution to growth somehow linked to that factor's payment or reward, one can set things up in a quite simple way. The key is to keep one's eye on the target, which is explaining the growth of, say, Net Domestic Product (the most "convenient" choice for the "dependent" variable.) The "market-price" estimate of marginal productivity of a factor in a given use is then simply its relevant "full-cost" price within that use. If capital's return is high in an activity due both to taxes and to (true) risk elements, then that high return should be used in attributing incremental growth to new investment in that activity. Regardless of whether labor's return is high due to risk or to taxes, the high return should nonetheless be attributed to increments to labor in the industry in question. This of course

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the residual.

It is similar for the capital factor. On a very aggregative level we would tend to look to the rate of return which tends to be equalized across uses. This might be a 10 percent real rate of return. But in the corporate sector the marginal productivity of capital might be 17 percent, with two points going for property taxes and one-third of the remaining 15 points going for corporation income taxes. In agriculture the rate of return might be 12 percent, with just two points going for property taxes, so as to yield a 10 percent net return. In housing the rate of return might be 8 percent, with two points being the effective subsidy paid to this activity. Finally in fishing we might have no taxes apply, but a true risk premium of 30 percent might raise the competitive rate of return to capital in this activity to 13 percent.

Under these conditions an aggregated analysis might show for a particular year:

	ΔK_i	Std. Rate of Return	Net Rate of Return	Gross Rate of Return	Attributed to ΔK_i	Attributed to Residual
Corporate Ind.	+1000	10%	10%	17%	+100	+70
Agriculture	+ 200	10%	10%	12%	+ 20	+ 4
Housing	+ 400	10%	10%	8%	+ 40	- 8
Fishing	+ 100	10%	13%	13%	+ 10	+ 3

A more disaggregated analysis of the same growth of the capital stock could attribute to each segment its own specific gross rate of return, leaving zero as the part attributed to the residual in each case.

comes on top of all the standard reasons (like education, age and experience) why labor's return should be higher in some situations than in others. In each case, for labor, our attribution is the outlay that employers see. For capital, it is the effective "cost of capital," net of depreciation, of course, so long as net domestic product is the variable being explained and gross of depreciation if GDP is the "dependent variable."[1]

Real Cost Reduction: What the "Residual" is All About

Most people think of the Residual Factor in economic growth as an index of output per unit of total input. In the simplest of all cases let $Y_t = A(t) K_t^{\alpha} L_t^{(1-\alpha)}$ be a Cobb-Douglas production function with A(t) as a shifting constant term, reflecting technical advance. Then let $K_t^{\alpha} L_t^{(1-\alpha)}$ be a conveniently chosen geometrically weighted index of inputs. This con-

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[1]GDP is the variable that most people actually use in measuring economic growth. If we are serious that this is the variable whose growth is being explained, then in principle the rates of return we should attribute to net investment (ΔK_i) in each activity are gross-of-depreciation rates of return. These would vary widely from activity to activity, and "explained" growth rates would increase or decrease because of shifts of investment between activities with low depreciation rates (long-lived assets) on the one hand and those with high depreciation rates (short-lived assets) on the other. I think we should accept that GDP is inferior to NDP on a conceptual basis, as a measure of economic growth (since depreciation of capital assets is in principle a negative component of the vector of outputs of an economic activity). Accepting this allows us to deal in a more straightforward way with the capital factor in growth accounting and similar types of analysis. Then, when a practical application is made, the adjustments dictated by the particular case can be implemented. Such adjustments may involve not only depreciation (the critical difference between GDP and NDP) but also purchased inputs (in case the total output of an activity is taken as the output variable, as distinct from a gross-of-depreciation concept of value added (for GDP) or a net-of-depreciation concept of value added (for NDP)).

venient choice obviously leads to $A(t)$ as a measure of output per unit of total input.

More broadly, if we take the residual at time t to be

$$(5) \qquad R_t = \sum_s P_{s,t-1}\,\Delta X_s - \sum_i \rho_{i,t-1}\,\Delta K_i - \sum_j \omega_{j,t-1}\,\Delta L_j ,$$

we can express this, in effect, as a change in an index of output per unit of total input. For this purpose we simply use

$$Y_t = \sum_s P_{s,t-1}\,X_{s,t-1} = \sum_i \rho_{i,t-1}\,K_{i,t-1} + \sum_j \omega_{j,t-1}\,L_{j,t-1} .$$

We first take

$$(5') \qquad R_t = \Big(\sum_s P_{s,t-1}\,\Delta X_s + \sum_s P_{s,t-1}\,X_{s,t-1}\Big) - \Big(\sum_i \rho_{i,t-1}\,\Delta K_i + \sum_i \rho_{i,t-1}\,K_{i,t-1}\Big) - \Big(\sum_j \omega_{j,t-1}\,\Delta L_j + \sum_j \omega_{j,t-1}\,L_{j,t-1}\Big)$$

Then we can divide through by Y_{t-1} to obtain

$$(5'') \qquad \frac{R_t}{Y_{t-1}} = \Big(\frac{\Sigma_s P_{s,t-1}\,\Delta X_s}{\Sigma_s P_{s,t-1}\,X_{s,t-1}} + 1\Big) - f_{K,t-1}\Big(\frac{\Sigma_i \rho_{i,t-1}\,\Delta K_i}{\Sigma_i \rho_{i,t-1}\,K_{i,t-1}} + 1\Big) - f_{L,t-1}\Big(\frac{\Sigma_j \omega_{j,t-1}\,\Delta L_j}{\Sigma_j \omega_{j,t-1}\,L_j} + 1\Big) .$$

Here f_K is $(\Sigma_i \rho_i K_i/Y)$ and f_L is $(\Sigma_j \omega_j L_j/Y)$, so that $f_K + f_L = 1$ and (5") can be written as

(5'") $$\frac{R_t}{Y_{t-1}} = \text{\% change in an index of output minus a weighted average of \% changes in indexes of inputs.}$$

But consider that, using the identity

$$\Sigma_s X_s P_s = \Sigma_i \rho_i K_i + \Sigma_j \omega_j L_j$$

we have
$$\begin{aligned} \Sigma_s P_s \Delta X_s \quad & \quad \Sigma_i \rho_i \Delta K_i \quad + \quad \Sigma_j \omega_j \Delta L_j \\ & = \\ + \Sigma X_s \Delta P_s \quad & + \Sigma_i K_i \Delta \rho_i \quad + \Sigma_j L_j \Delta \omega_j \end{aligned}$$

Now we can collect the terms in the upper line of (6) to form an expression for the residual, R. This gives us

(6') $$\sum_s P_s \Delta X_j - \sum_i \rho_i \Delta K_i - \sum_j \omega_j \Delta L_j = R = \sum_i K_i \Delta \rho_i - \sum_j L_j \Delta \omega_j - \sum_s X_s \Delta P_s.$$

The terms in the right hand side of (6') can be converted into an expression for change in an index of input prices per unit of output price, in just the same way as the terms in the lefthand side of (6') were converted (see [(5) to (5'")] into an expression for change in an index of output per unit of total input. The expression for R in terms of changes in output and input prices is the <u>dual</u> of the expression for R in terms of changes in output and input quantities.

What interpretation can we give to this dual? The best way to get to the answer is to ask two questions: what makes it possible for firms to pay more for inputs while keeping the prices of outputs the same? Or to lower the prices of their outputs while paying the same prices as before for their inputs? The answer is very straightforward, and is the same for both questions: real cost reduction is the key that makes it possible to pay (or reap, in the case of one's own equity) higher rewards to factors while keeping prices constant, or to lower prices while keeping factor rewards constant.

To me this is one of the most crucial insights in all of development economics. Of what does the famous Residual consist? Of everything and anything that makes real costs go down--instilling more discipline in a workforce by hiring a more demanding manager; getting more product out of a workforce by firing a too-demanding manager; getting more out of an assembly line by straightening it out; computerizing a payroll; installing a fax machine; closing down unproductive branches; buying longer-lasting tires for one's fleet of trucks. A list like this could go on forever, and every bit of it is "true" in the sense that each of us could find actual real-world examples to document that each of the above types of action in many occasions did in fact reduce real costs per dollar of final output.

To me we really have a quite complete, and certainly quite satisfactory "theory" of economic growth. That theory is well represented by equation (7).

(7) $$\Delta Y = \sum_i \rho_i \, \Delta K_i + \sum_j \omega_j \, \Delta L_j + R \, .$$

All kinds of investments, with all kinds of rates of marginal productivity, are being made in a complex economy at any one time. Those with high rates of productivity contribute much to growth. Those with low rates of productivity contribute little. Those with negative rates contribute negatively to the growth process. In a market economy, moving capital from a subsidized sector to a heavily taxed sector will tend to contribute positively to growth, because the receiving sector has a much higher ρ_i than the sending sector.

Similarly, the economy gains when labor is moved from a subsidized sector to a taxed sector, because the gross-of-tax wage (the cost of labor to the enterprise) is higher in the latter than in the former.

The main contributions of labor to the growth rate, however, came from the periodic increment to the labor force and, very importantly, from the upgrading of labor through human capital formation. Equation (7) and its predecessors in this paper do not focus on an aggregative amalgam called the stock of human capital. Instead they focus on different categories of labor. Human capital formation shifts a worker from the age-education-experience category to another, presumably a higher-paying one. Formal education does this; so does quasi-formal on-the-job training as well as (in many categories) the simple accumulation of work experience. All these contributions of the labor factor to growth are captured in the second term of equation (7).

The movements encompassed in the first two terms of (7) are not, in principle at least, cost reducing movements. The educated worker earns more than the uneducated one, and to this extent he reaps a benefit from his education. Obviously, to the extent the worker gains, the employer is not simultaneously a gainer. In this framework, employers simply pay for what they get.

There is, however, a neat, and I would say subtle story that can be told with with the aid of (7), Consider an innovation like hybrid corn or green-revolution wheat, or MacDonald's hamburgers for that matter. When the innovation is first adopted, those who choose to adopt it make greater than average returns on their investment. In that instant of first application, a "normal" rate of return is attributed to the ΔK_i of the activity in question. At this point, however, we have a disequilibrium, in that the high rate of return is destined to be competed away as others seek to share in the economic rewards to adopting the innovation. As this happens, year by year the component of growth associated with a higher-than-normal return to capital gets reduced. Instead, consumers benefit from lower prices of the final product.

Real Cost Reduction and "Disequilibrium Growth"

Theodore W. Schultz, one of the most insightful economists of the 20th century, has time and again called attention to the "disequilibrium" nature of the growth process. He was driven to this insight by observation of farmers as they responded to successive innovations such as the mechanical tractor; hybrid corn, the "Green Revolution's" new varieties of wheat and rice in India, the Philippines and other parts of Asia, pesticides, antibiotics, and the like.

Schultz's vision is a simple one. At the beginning, only a relatively few adopt the innovation. Others come later, either as a result of a relatively random trial and error process in which farmers end up sticking with the "good" innovations and abandoning the bad ones, and/or as a result of copying the practices of those who initially adopt an innovation and then prosper as a consequence. The process thus moves from one in which greater-than normal returns are available to those who adopt earliest, to a point of completion at which everybody more or less has to adopt, since the price of the product has fallen so far that anyone holding to the old technology would be forced out of business.

The end result of an innovation process, then, is greater benefit to consumers in the form of a lower real price for the product. The initial adopters receive economic rents, which erode over time as adoption becomes more and more widespread, until finally there are no further rents to be obtained from adoption precisely because, in simple cases at least, everybody by the end of the process has had to become an adopter.

Table 1 presents a scenario that illustrates the process just referred to. Initially, a process uses 400 of capital and 60 of labor to produce 100 of output. All prices and initially 1, and capital's rate of return is initially 10 percent, which is also the market rate of return. For the initial adopters (Period 2) the initial annual return on capital invested in the new process is 35 percent. By period 10, however, the rate of return to investments in the new process is back to 10 percent. The price of the product has been driven down from 1.0 to 0.5. Consumers are benefitting massively, and any producer who tried to produce using the old process would lose his shirt! Between periods 1 and 10 a process of gradual adoption takes place, during which economic rents are gradually bid away, as benefits are transferred to consumers.

I believe this vision of the process of adoption of an innovation is broadly descriptive of the way it really works not just in agriculture but

TABLE 1

SCENARIO OF ADAPTATION TO AN INNOVATION
(normalized on the factor combination K = 400, L = 60)

Period	Factor Amounts		Output			Annual Return on K		Factor Index		Output per Unit of Input Index	Factor Reward per Unit of Product Price
	K	L	Q	x P	= V	Amount	Rate (7) : (2)	Q_F (3)	P_F ÷ (7) x 100	(4) ÷ (9) x 100	(10) ÷ (5) x 100
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0*	400	60	100	1	100	40	10%	100	100	100	100
1**	400	60	200	1	200	140	35%	100	200	200	200
3**	400	60	200	0.8	160	100	25%	100	160	200	200
6**	400	60	200	0.6	120	60	15%	100	120	200	200
10**	400	60	200	0.5	100	40	10%	100	100	200	200

*Old process; **New process.

Assumptions

a. All prices (and wages) are initially equal to 1.
b. The initial and final rates of return to capital are equal to 10%, which is the market equilibrium rate of return.
c. The innovation takes place between periods 0 and 1, and is initially adopted by only a few producers. They get double the output for the same absolute amounts of K and L. This extra output raises the rate of return (to capital invested in the new technology) from 10% to 35%.
d. By period 3, the adoption of the innovation is sufficiently widespread to cause the product price to fall from 1 to 0.8. Rate of Return is now 25%.
e. By period 6, further adoption has driven the product price down to 0.6, return down to 15%.
f. Finally, by period 10, product price reaches 0.5 and the return to capital is once again "normal" at 10%.

in most sectors of the economy and for most innovations. The process reflects beneficent economic forces, in that consumers end up benefiting while adopters reap only transient rewards and laggard producers are outright penalized for sticking too long with outmoded methods. The process is also compatible with both higher rewards to the initial innovators together with a strong tendency driving economic returns to equilibrium levels.

Observations Based on Table 1

1. Factor amounts are kept identical throughout the example. This avoids ambiguities in calculating output per unit of total input, which under these circumstances moves with Q.
2. The excess of the value of output (of the given combination of factors) over 100 represents the above-normal return to capital in the period in question.
3. Initially the productivity of the innovation is fully reflected in an above-normal return to capital.
4. By the end of the process of adoption the productivity of the innovation is fully reflected in a lower price to consumers.
5. During the interim the benefit of the innovation is shared between the "adopters" and consumers.
6. Both the index of output per unit of input (column 11) and that of Factor Reward per Unit of Product Price go up to 200 right away, once the innovation is implemented. [Recall, however, that these are indexes calculated for, say, an enterprise implementing the new technology in the scale specified. They do not show the market-wide quantities of capital, labor, or output.]
7. While the index of factor reward per unit of product prices stays constant at 200 from periods 2 to 10, it is composed of varying benefits to "adopters" and to consumers. Their combined benefit is what stays constant.

The Importance of the "Residual" = TFP = Real Cost Reduction

I believe that most of the economics profession has lost sight of the importance that total factor productivity (TFP) has as a component of the growth rate. Not only is the rate of growth of productivity high in nearly all cases of high observed growth rates, it is also true that the residual is relatively low in nearly all cases of low observed growth rates.

Figures 1 and 2 are built on the basis of data assembled by Hollis Chenery in his paper on "Growth and Transformation."[1] They were compiled after an exhaustive search of relevant empirical studies in which growth rates of total factor productivity were calculated and juxtaposed to a growth rate of value added. The different sources drawn on include studies by Ahluwalia. Aukrust, Balassa-Bertrand, Chen, Christensen-Cummings-Jorgenson, Correa, Denison, Elias, Gaathen, Krueger-Tuncor, and Lampman. They are tabulated separately for Modern Industrial (Developed) Countries (see Figure 1) and for Developing Countries (Figure 2). The scatter diagrams reveal the close association between high TFP growth and high overall growth for both sets of countries.

Perhaps this is the appropriate point to digress on the interpretation of these data. Some would gild the lily by fitting regression lines and calculating R^2s. Others would carp at such a procedure, pointing out that the growth rate of TFP is by construction a component of the overall growth rate [TFP growth = total growth minus growth attributed to increased use of productive factors]. I would take a middle ground. Knowing that TFP is a component of growth, we still have the question, whether it is quanti-

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[1]H. Chenery, M. Syrquin and S. Robinson, Industrialization and Growth (Oxford: Oxford University Press, 1986), pp. 20-22.

FIGURE 1

THE GROWTH OF OUT.& TFP - DEVEL. COUNT.

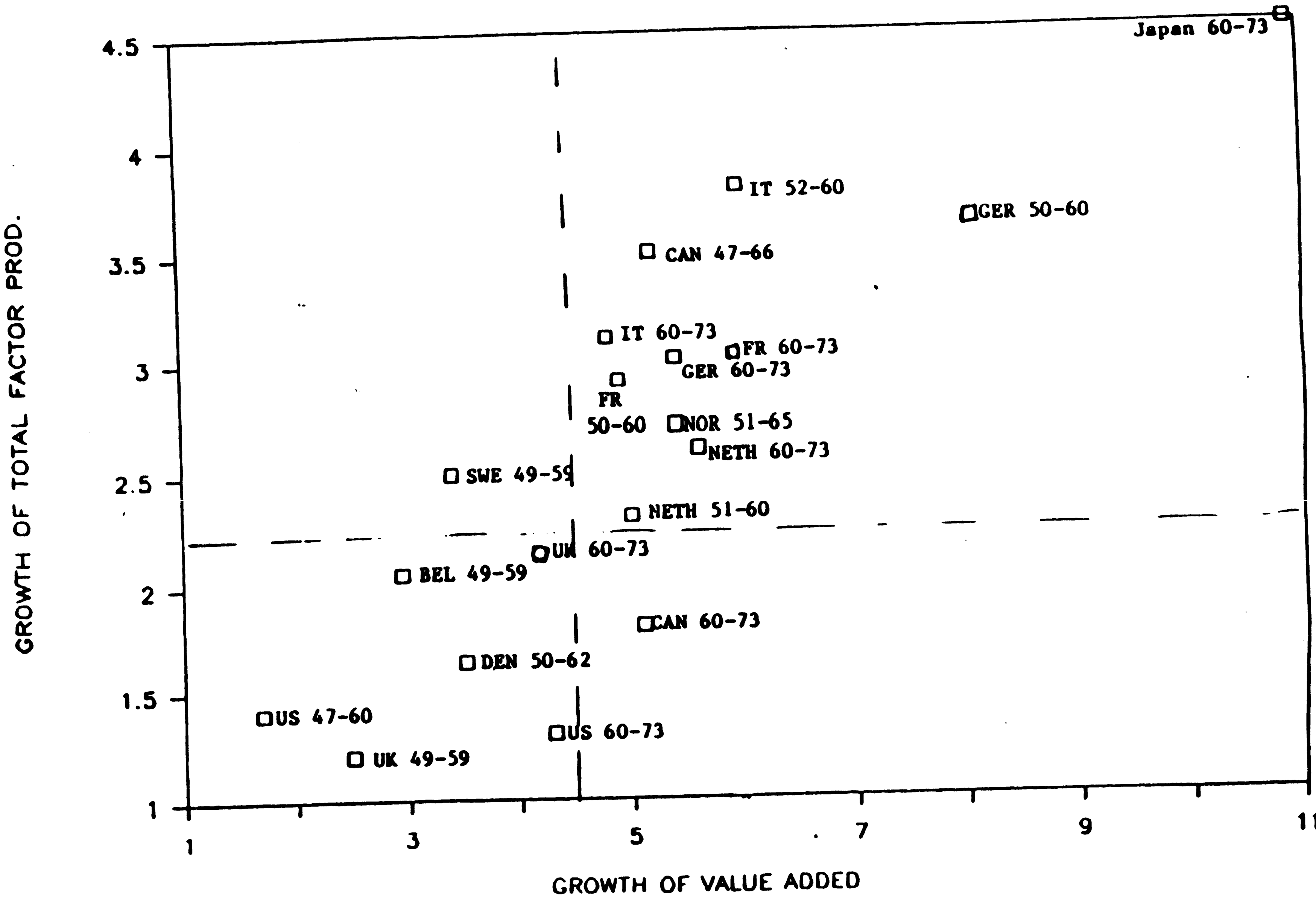
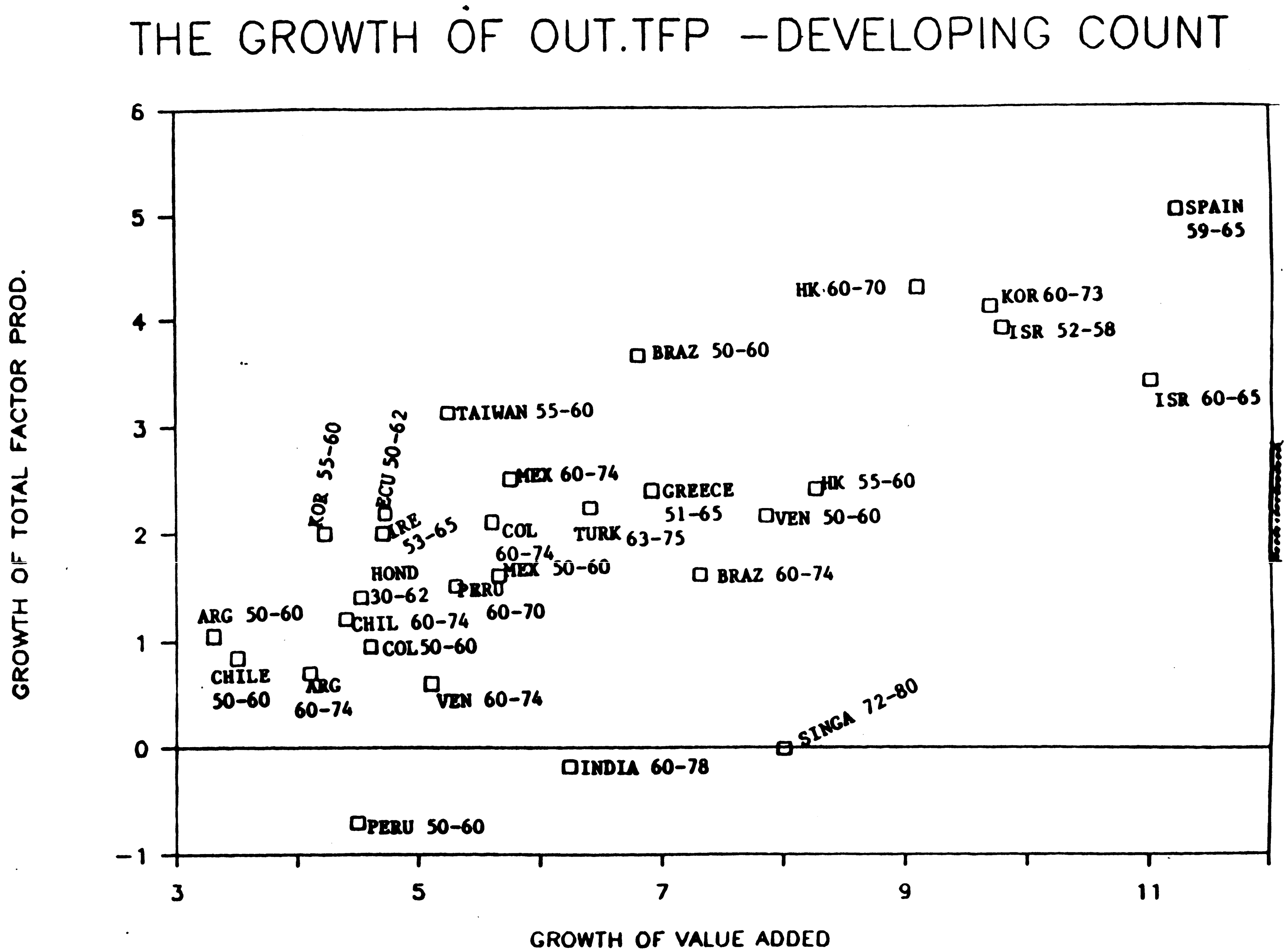


FIGURE 2


THE GROWTH OF OUT.TFP -DEVELOPING COUNT
GROWTH OF TOTAL FACTOR PROD.
GROWTH OF VALUE ADDED
6
5
4
3
2
1
0
-1
3
5
7
9
11
SPAIN 59-65
HK 60-70
KOR 60-73
ISR 52-58
BRAZ 50-60
ISR 60-65
TAIWAN 55-60
KOR 55-60
ECU 50-62
MEX 60-74
GREECE 51-65
HK 55-60
IRE 53-65
COL 60-74
TURK 63-75
VEN 50-60
HOND 30-62
MEX 50-60
BRAZ 60-74
PERU 60-70
ARG 50-60
CHIL 60-74
COL 50-60
CHILE 50-60
ARG 60-74
VEN 60-74
SINGA 72-80
INDIA 60-78
PERU 50-60

tatively important. Is it (1) characteristically high for high-growth countries and low for low-growth countries? And is it an important component of the growth rate, particularly in the cases of high-growth countries? I think we can answer yes to both these questions. It needn't be so. TFP growth could have trivial variations across countries, adding just a constant contribution to growth rates all over the world. Its variations could on the other hand be highly correlated with differences in growth rates, but could be very small in magnitude. Neither of these possibilities characterizes the actual data. TFP growth exhibits wide variation across countries, and is a very big factor in "explaining" why the overall growth rate is high in some cases and low in others.

But does the causality run in the suggested direction, from TFP growth to overall output growth? I feel extremely confident on this score, because of the identification of TFP growth with anything and everything that reduces real factor costs per unit of output. I feel we know, from our own experience and observation, how multifarious are the ways that businessmen find to reduce costs. They are nearly always and nearly everywhere trying to do so, but not always succeeding. When they succeed it may be because of pure luck; it may be through adopting technological advances that are already in place somewhere in the world, but not yet "here"; it may be simply through good management techniques and improved business practices.

Real cost reductions spring from so many causes that it is simply implausible to link them to any single ultimate source, or even to any small number of causal forces. In particular, the simple fact of rapid overall growth is not by itself going to trigger vast numbers of businessmen to find lots of ways of reducing real costs that they would not have found, had growth been a bit slower.

Using Assumptions to Estimate TFP Growth from Readily Available Data

In this section I explore the possibility of getting much more massive data on TFP growth than we are accustomed to have at hand. The trick lies in being ready to make a few critical assumptions. Actually, for the purpose immediately at hand, the results turn out to be extremely robust with respect to variations in the assumptions (within a plausible range, at least).

For this purpose we shall be working with a growth decomposition of the form:

$$\Delta Y = \bar{w}\Delta L + (\bar{r}+\delta)\Delta K + R. \qquad (3)$$

This is useful because it does not require us to estimate capital stocks. The key assumptions concern

a) marginal productivity of capital ($\bar{r}$),

b) capital/output ratio (K/Y),

c) rate of depreciation of the capital stock (δ).

Our assumptions concerning the marginal productivity of capital are roughly based on results obtained in earlier studies. A "standard" control value for m.p.k. is around 7.5%. A very high value is 15.0%. Only "outliers" like Korea and Taiwan have generated estimates of m.p.k. as high as 15%.

Our strategy is to operate with a "high productivity" set of assumptions, which will generate an estimate R_1 of the rate of TFP growth. Our alternative is a set of "more plausible" assumptions, which will generate an estimate R_2 to TFP growth. We will use .15 as our assumed value for the marginal productivity of capital in estimating R_1, and .075 in estimating R_2.

One of the reasons why we have so few estimates of TFP growth at the level of national economies is that for most countries we do not have data on how claims on total output are shared as between labor and capital. A major problem, even where we have data, is the income of unincorporated enterprises, part of which must be imputed to labor, and part of capital. When such tasks have been attempted, the resulting share of labor has typically been between 0.5 and 0.6. Our assumptions about other parameters must be checked to make sure that they do not imply labor shares that are incompatible with this evidence.

For the "high productivity" case, we have assumed a capital/output ratio of 2.5. A 15% return on a capital stock of 2.5 times GDP implies net earnings of capital equal to 37.5% of output. Since we are dealing with GDP as our output measure, we must also take depreciation (capital consumption) into account. Our assumed rate if 5% per annum, conceived of as an average between a rate of perhaps 7-10% on machinery and equipment, and one of perhaps 2-3% on structures. Depreciation at the rate of 5% on a capital stock of 2.5 times output produces capital consumption allowances equal to 12.5% of output. The gross-of-depreciation total earnings to capital is thus 50 (= 37.5 + 12.5)% of GDP.

Thus, for the high productivity case we use a labor share of 0.5. Our basic estimating equation for R_1 is

R_1 = GDP growth rate - [(I/Y) - 12.5](.15+.05) - .5 (Pop. growth rate).

In this we are also using the population growth rate as a proxy for labor force growth.

For the "more plausible" case, we have used a capital-output ratio of 3.2, together with a marginal productivity rate of 7 1/2% per annum. Thus the net return to capital is 24% of output while depreciation (still using a rate of 5% per year) amounts to 16% of output. Labor's share of output is thus 60 [= 100 - 24 - 16]%.

These assumptions imply the following equation for R_2.

R_2 = GDP growth rate - [(I/Y)-16](.075+.05) - (.6) (Pop. growth rate).

The great virtue of making assumptions like these is that they permit us to vastly extend the range of data we can examine in estimating TFP growth in drawing conclusions about it.

Table 2 is based on data from the World Bank's Economic Development Report (1990). The growth rate is that of GDP, averaged over the period 1965-80. The ratio of investment to output is the average for the full 1965-80 period. The population growth figure likewise reflects average growth for the 1965-80 period.

Table 2 is divided into four separate panels, referring respectively to the low, lower-middle, upper-middle, and high income countries. This division ensures at least a minimum level of comparability for the countries being compared. In each panel, countries with high growth rates are listed at the top, those with low growth rates at the bottom.

But now look at the differences in the "Residuals" between the rapid growers and the slow growers. For the low-income countries this difference is 4.15 percentage points for R_1 and 4.71 percentage points for R_2.

TABLE 1a

TFP As A Component Of GDP Growth

Low Income Countries

	GDP Growth	I/GDP	Population Growth	TFP Growth Rate R1	TFP Growth Rate R2
		Rapid Growth			
Indonesia	8.0	15.4	2.4	6.22	6.64
Nigeria	6.9	20.1	2.5	5.12	4.88
China	6.4	24.0	2.2	3.00	4.08
Kenya	6.4	22.2	3.6	2.67	3.47
Lesotho	5.7	11.0	2.3	4.85	4.95
Malawi	5.6	24.4	2.9	1.76	2.81
Medians	6.4	21.2	2.5	3.93	4.48
		Slow Growth			
Nepal	1.9	14.9	2.4	0.22	0.60
Madagascar	1.8	15.0	2.5	0.05	0.42
Zaire	1.4	26.0	2.8	-2.70	-1.53
Ghana	1.4	10.6	2.2	0.69	0.76
Uganda	0.8	10.4	2.9	-0.22	-0.23
Niger	0.3	15.1	2.6	-1.53	-1.15
Chad	0.1	12.0	2.0	-0.80	-0.60
Medians	1.4	14.9	2.5	-0.22	-0.23
Difference in Medians (rapid minus slow)				4.15	4.71

GDP - Gross Domestic Product

TFP - Total Factor Productivity

TGPP Growth - "The Residual"

TABLE 2b

TFP As A Component Of GDP Growth

Lower-Middle Income Countries

	GDP Growth	I/GDP	Population Growth	TFP Growth Rate R1	TFP Growth Rate R2
			Rapid Growth		
Botswana	14.2	35.7	3.5	7.82	9.64
Brazil	8.8	24.1	2.4	5.28	6.35
Ecuador	8.7	21.4	3.1	5.37	6.17
Siria	8.7	22.7	3.4	4.96	5.82
Dom. Republic	7.9	19.9	2.7	5.08	5.80
Malaysia	7.3	22.0	2.5	4.15	5.05
Thailand	7.2	25.2	2.8	3.26	4.37
Medians	8.7	22.7	2.8	5.08	5.82
			Slow Growth		
Peru	3.9	16.0	2.8	1.80	2.22
Nicaragua	2.6	18.6	3.1	-0.17	0.41
Senegal	2.0	16.3	2.9	-0.20	0.23
Chile	1.9	15.6	1.7	0.44	0.93
Jamaica	1.3	23.9	1.3	-1.63	-0.47
Lebanon	-1.2	20.0	1.7	-3.55	-2.72
Medians	2.0	17.5	2.3	-0.19	0.67
Differences in Medians (rapid minus slow)				5.27	~~0.67~~ 5.15

GDP - Gross Domestic Product

TFP - Total Factor Productivity

TGPP Growth - "The Residual"

TABLE 2c

TFP As A Component Of GDP Growth

Upper Middle Income Countries

	GDP Growth	I/GDP	Population Growth	TFP Growth Rate R1	R2
			Rapid Growth		
Korea	9.6	26.6	2.0	5.78	7.07
Gabon	9.5	40.9	3.6	2.03	4.23
Algeria	6.8	37.0	3.1	0.34	2.31
Iran	6.2	27.9	3.1	1.58	2.86
Yugoslavia	6.0	40.8	0.9	-0.11	2.36
Medians	6.8	37.0	3.1	1.58	2.86
			Slow Growth		
Libya	4.2	25.7	4.3	-0.58	0.41
South Africa	3.8	27.7	2.4	-0.43	0.90
Venezuela	3.7	29.0	3.5	-1.36	-0.03
Argentina	3.5	21.7	1.6	0.87	1.83
Uruguay	2.4	13.2	0.4	2.05	2.50
Medians	3.7	25.7	2.4	-0.43	0.90
Difference in Medians (rapid minus slow)				2.01	1.96

GDP - Gross Domestic Product
TFP - Total Factor Productivity
TGPP Growth - "The Residual"

TABLE 1d

TFP As A Component Of GDP Growth

High Income Countries

	GDP Growth	I/GDP	Population Growth	TFP Growth Rate R1	TFP Growth Rate R2
		Rapid Growth			
Singapore	10.1	35.4	1.6	4.72	6.71
Hong Kong	8.6	36.0	2.0	2.90	4.90
Israel	6.8	25.6	2.8	2.78	3.92
Japan	6.5	34.5	1.2	1.50	3.47
Canada	5.1	24.5	1.3	2.05	3.26
Ireland	5.0	25.5	1.1	1.85	3.15
Medians	6.7	30.1	1.5	2.42	3.70
		Slow Growth			
Denmark	2.7	23.6	0.5	0.24	1.45
U.S.A.	2.7	19.2	1.0	0.85	1.70
United Kingdom	2.4	19.6	0.2	0.87	1.83
New Zealand	2.4	26.0	1.3	-0.95	0.37
Switzerland	2.0	27.6	0.5	-1.27	0.25
Kuwait	1.2	14.9	7.1	-2.82	-2.92
Medians	2.4	21.6	0.8	-0.36	0.91
Difference in Medians (rapid minus slow)				2.78	2.79

GDP - Gross Domestic Product

TFP - Total Factor Productivity

TGPP Growth - "The Residual"

Whichever of these two measures of the residual we use, we explain the lion's share of the observed difference of 5 percentage points (6.4-1.4) in the median growth rates of the rapid growers and the slow growers. For the lower-middle-income countries the measured difference in median R's accounts for over 5 percentage points of the observed difference of 6.7 percentage points in median overall growth rates. For the upper-middle-income countries the measured difference in median R's accounts for 2.0 points out of an observed difference in median overall growth rates of 3.1 percentage points. Finally, for the high-income-countries the observed residual difference of 2.8 points compares with an observed overall difference in median growth rates of 4.3 points.

My conclusion from this exercise is that trying to understand more about the residual is the key to our understanding more about the growth process. I am convinced that one will search in vain for major "new" explanatory factors. I am pretty sure that the old lists (of components of TFP) are good ones, and that they are reasonably exhaustive. New insights will be found by carefully studying specific cases, learning where big and small contributions to TFP growth have taken place, and trying (from the nature of each episode or case) to ascertain the specific sources from which each such contribution most likely sprang. This is one of our great challenges for the coming decade.

The Nature of TFP Growth--Yeast or Mushrooms?

I have earlier and repeatedly argued that there are so many ways in which real cost reduction takes place that any search for new "global" explanations is likely to be fruitless. What we have to do is learn more about the process by identifying concretely the sources of major cost reductions wherever we can.

But one can have a vision of real cost reduction that is much like the one I have expressed, and say simply that indeed it has thousands upon thousands of sources, but that, precisely because they are so numerous, one can deal with them using the law of large numbers. These sources could be incredibly numerous, yet be working simultaneously all across the activities of an economy, in such a way as to produce a quite generalized expansion of total factor productivity.

I have taken as a sort of "straw-man" target in this case the commonly used aggregate production equation $Y = F(K, L)e^{\lambda t}$. Here λ plays the role of a generalized TFP growth. Looking at the equation leads one to think of a process where growth is pervasive throughout the economy, rather than highly concentrated. I use here the analogy of dough (to make bread or cake) expanding as a consequence of the yeast that was mixed into it. Here the growth is regular, even, steady. Another good analogy is what happens when air is pumped into a balloon.

But this is not what we observe in the growth process. TFP growth tends to be highly concentrated, to pop up in the most unlikely places, and then to move on to other arenas. As we think of successive great technical advances--in automobile making, in rubber tires, in refrigerators, in television sets, in pharmaceuticals, in plastics, in petrochemicals generally, in telecommunications and most recently, of course, in the computing "industry"--we see advances concentrated in relatively short time spans (like decades) for each industry group, and advances concentrated in specific industry groups in any one particular decade.

I am planning a much more thorough documentation of the above assertion. Table 3 simply represents a first pass. It is based on data presented in Kendrick and Grossman's <u>Productivity in the United States: Trends and Cycles</u> (Baltimore: John Hopkins, 1980). The basic data are measures of total factor productivity, by industry group, in four benchmark years:

1948, 1958, 1967, and 1976. Each of Tables 3a, 3b, and 3c concentrates on the period from one of these benchmark years to the next.

We first record the cumulative TFP growth measured for each industry during the period. Then, we array the industries in descending order, according to their cumulative TFP growth rates. To find out how much total "benefit" was generated by each activity's TFP growth, the growth rate of column (1) is multiplied by base period GDP. This yields the absolute contribution to growth given in column (2). The key datum, in my opinion, is the cumulative sum of these contributions to growth, which is what is presented in column (3). The main message here is how quickly the cumulative total rises.

One problem with working just with cumulative contribution data like those in column (3), however, is that they take no account of the sizes of the industries conceived. Column (5) helps us to make the appropriate comparison, by giving us the cumulative amount of base-year GDP originating in the industries on the list. It is on the basis of column (5) and column (3) that one can make statements like those at the bottom of each table, i.e.:

- The top 30 percent of industries account for 51 percent of the total TFP growth contribution in 1948-58,
- The top 22 percent of industries account for 57 percent of the total TFP growth contribution in 1958-67, and
- The top 20 percent of industries account for 69 percent of the total TFP contribution in 1967-76.

I like the mushroom analogy, because it sort of dramatizes the likelihood that big gains in TFP can happen anywhere--even in the most unlikely places (lumber and textile mill products in 3b, finance insurance and real estate in 3c, railroad transport in both 3a and 3b). The mushroom analogy also sets one's mind to thinking that, even where an event is hard

TABLE 3a

CONCENTRATION OF TFP GROWTH AMONG U.S. INDUSTRIES, 1948-58
[Cols. (2) to (5) in billions of 1948 dollars]

	TFP Growth over Period (1.0=100%) (1)	Absolute Contrib. of TFP Growth [(1)x(4)] (2)	Cum. Sum of (2) (3)	GDP by Industry 1948 (4)	Cum. Sum of (4) (5)
Communication	0.69	2.63	2.63	3.80	3.80
Public Utilities	0.69	2.97	5.60	4.30	8.10
Farming	0.59	13.65	19.25	23.30	31.40
Misc. Manufacturing	0.43	0.73	19.98	1.70	33.10
Electrical Machinery	0.36	1.58	21.56	4.40	37.50
Food & Kindred Products	0.35	3.53	25.08	10.20	47.70
Instruments	0.33	0.36	25.44	1.10	48.80
Mining	0.31	2.92	28.37	9.40	58.20
Construction	0.31	3.54	31.90	11.50	69.70
Tobacco	0.31	0.52	32.42	1.70	71.40
Railroad Transport	0.27	2.40	34.82	8.80	80.20
Chemicals	0.27	1.15	35.97	4.30	84.50
Apparel	0.25	0.92	36.89	3.70	88.20
Lumber & Wood Products	0.24	0.76	37.65	3.10	91.30
Finance, Ins. & Real Est.	0.24	6.43	44.08	26.90	118.20
There follow 15 more industries whose combined results are	0.06	19.21	63.29	121.70	239.90

Top 13%[1] of industries account for 30% of total TFP contribution.
Top 30%[1] of industries account for 52% of total TFP contribution.
Top 49%[1] of industries account for 70% of total TFP contribution.

Source: John W. Kendrick and Elliot S. Grossman, Productivity in the United States: Trends and Cycles (Baltimore: The Johns Hopkins University Press, 1980).

[1]These percentages are contributions to GDP of industries ranked according to their percent rate of TFP growth over period.

TABLE 3b

CONCENTRATION OF TFP GROWTH AMONG U.S. INDUSTRIES, 1958-67
[Cols. (2) to (5) in billions of 1958 dollars]

	TFP Growth over Period (1.0=100%) (1)	Absolute Contrib. of TFP Growth [(1)x(4)] (2)	Cum. Sum of (2) (3)	GDP by Industry 1958 (4)	Cum. Sum of (4) (5)
Lumber & Wood Products	0.72	2.51	2.51	3.50	3.50
Railroad Transp.	0.63	5.52	8.03	8.70	12.20
Textile Mill Products	0.61	2.49	10.52	4.10	16.30
Electrical Machinery	0.55	5.10	15.66	9.30	25.60
Transp. Equipment	0.46	7.05	22.71	15.20	40.80
Chemicals	0.44	3.97	26.68	9.10	49.90
Public Utilities	0.42	4.65	31.33	11.00	60.90
Petroleum and Coal	0.41	1.27	32.60	3.10	64.00
Rubber and Products	0.41	1.23	33.83	13.00	67.00
Mining	0.41	5.20	39.03	12.60	79.60
Communication	0.40	3.61	42.64	9.00	88.60
Trade	0.33	24.93	67.57	76.40	165.00
There follow 18 more industry groups whose combined results are	0.03	7.53	75.10	239.80	404.80

Top 10%[1] of industries account for 30% of total TFP contribution.
Top 22%[1] of industries account for 57% of total TFP contribution.
Top 40%[1] of industries account for 90% of total TFP contribution.

Source: John W. Kendrick and Elliot S. Grossman, Productivity in the United States: Trends and Cycles (Baltimore: The Johns Hopkins University Press, 1980).

[1]These percentages are contributions to GDP of industries ranked according to their percent rate of TFP growth over period.

TABLE 3c

CONCENTRATION OF TFP GROWTH AMONG U.S. INDUSTRIES, 1967-76
[Cols. (2) to (5) in billions of 1967 dollars]

	TFP Growth over Period (1.0=100%) (1)	Absolute Contrib. of TFP Growth [(1)x(4)] (2)	Cum. Sum of (2) (3)	GDP by Industry 1967 (4)	Cum. Sum of (4) (5)
Finance, Ins., Real Est.	1.14	132.25	132.25	115.60	115.60
Apparel	0.37	2.84	135.09	7.70	123.30
Communication	0.34	6.23	141.32	18.10	141.40
Chemicals	0.31	4.85	146.17	15.70	157.10
Electrical Machinery	0.30	5.99	152.16	19.70	176.80
Food & Kindred Products	0.30	6.62	158.78	22.70	199.00
Tobacco	0.29	1.00	159.78	3.50	202.50
Misc. Manufacturing	0.26	0.92	160.70	3.50	206.00
Paper & Products	0.26	2.11	162.81	8.20	214.20
There follow 21 more industries whose combined results are	0.08	41.52	204.33	495.70	709.90

Top 20%[1] of industries account for 69% of total TFP contributions.
Top 30%[1] of industries account for 80% of total TFP contributions.

Source: John W. Kendrick and Elliot S. Grossman, Productivity in the United States: Trends and Cycles (Baltimore: The Johns Hopkins University Press, 1980).

[1]These percentages are contributions to GDP of industries ranked according to their percent rate of TFP growth over period.

to predict, nonetheless one can still do a lot to make conditions more (or less) propitious for that event. For mushrooms it is temperature, humidity, absence of too much light. For economic policy it is a stable framework of laws and regulations within which economic agents can make sound commitments for the middle and long term, as well as the short. It is also the various attributes of that framework--in principle the framework should keep distortions to a minimum and should use the price system as the major channel through which incentives are signalled.

Once one recognizes that the main attribute that TFP advances really have in common is that they all work to reduce the real costs of production, one sees that "getting the prices right" is important not only for reducing or eliminating the efficiency cost triangles that we deal with in the comparative statics analysis of economic efficiency, but also for giving good signals to economic agents as they go about the business of generating "technical advance." It does not make much sense to set up a framework in which agents take actions which they think of as saving costs, and which in fact save private costs to the decision makers themselves, but which do not (or need not) save costs to the economy as a whole simply because the agents worked with a set of wrong prices.

Most Growth is Probably Catch-up Growth

Let us start with a picture of a production frontier as representing the locus of maximum outputs that can be produced with a given factor endowments, given the current state of knowledge. The production frontier, thus defined, moves outward through time only because the factor endowment changes, or because the state of knowledge is improved, say through scientific discoveries. This picture leads us to concentrate our attention, when studying TFP growth, on scientific advance, research and development, new inventions, etc.

While I have no doubt whatsoever of the fundamental role of scientific advance in producing long-term economic growth in the world economy, I believe it is quite wrong to think that most of the TFP growth that we observe and measure is of this type. I believe that the "state of the art" reflected in a real-world production frontier (or production function) is far different from the "state of the art" embodying the full present state of human knowledge.

One lesson that I learned very early was that farmers never seem to achieve the same yields (for given inputs) as experiment stations do. This does not mean that the farmers are fundamentally irrational. Rather, they are working with what they "know," with a body of "knowledge" based on their experience and their observation of others. It demonstrably takes a long time for an agricultural innovation to pass from the experiment station to the point where it is part of the "knowledge and experience" of all the farmers who can profitably use it. In the meantime we are in a transition phase, with output coming from productive operations that are in some sense inferior (i.e., well inside of the "true" production frontier) but which still reflect an intelligent maximizing process on the part of economic agents, taking the "knowledge and experience" of each of them as given.

The above lesson applies as well to farmers in most parts of the world. It also applies, in my opinion, to economic agents quite generally. In a paper[1] written more than a decade ago, and with quite a different

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[1]See Arnold C. Harberger, "Perspectives on Capital and Technology in Less-Developed Countries," in M. Artis and A. R. Nobay,

purpose in mind, I showed that, even after making plausible adjustments for differences in labor quality, developing countries used much more labor in conjunction with the same amount of capital in order to produce the same value of product as the same 3-digit industry was using in the United States. This is only possible, of course, if they are operating on "inferior" production functions. We do not know enough about the process of how a country "gets its act together" to the point of moving rapidly from one set of production functions to another, shifting its own production frontier outward toward our idealized theoretical frontier (that represents the full application of the current state of human knowledge). But this is surely the process through which a whole array of countries--Japan, Spain, Taiwan, Brazil, Korea, Greece, Hong Kong, Mexico, Indonesia, Italy--have passed as they have undergone major spurts and in some cases long and continuing processes of economic growth. This is what we mean when we speak of catch-up growth.

There is a huge research challenge ahead of us as a profession in trying to understand better what actually happens in catch-up growth. But we can be sure it consists overwhelmingly of what we have been talking about in earlier sections--changes in methods and practices which in a thousand and one different ways end up by reducing real costs.

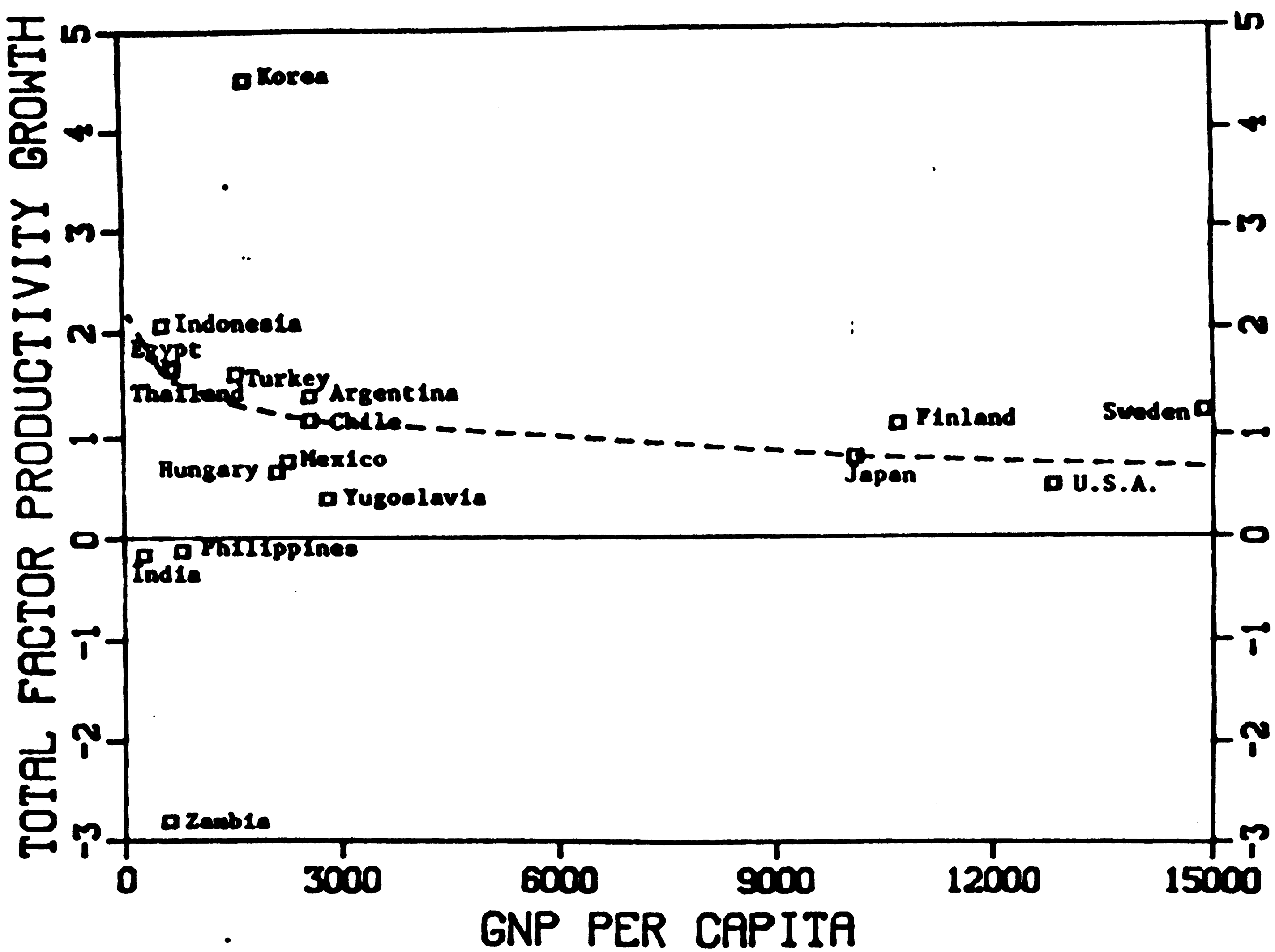
There may be some who are unconvinced by the above assertions that catch-up growth is a very big part of the story of total TFP growth across the world economy. Happily a two-man research team at the World Bank has made a superb start at the challenging task of assembling the relevant evidence. Figure 3 is an example showing how the various graphs of Figure 4 were derived.

The regression lines that are traced in Figures 3 and 4 are to be taken as simply summarizing the data of each graph. Their purpose is to give us the "stylized facts" corresponding to each industry. It should be evident from the graphs that there is a significant tendency for TFP growth to be higher, the farther away a country is from the "true" production frontier given by the "true" state of current knowledge. There is no way to treat these graphs as a scientific test of a hypothesis, if only because data on TFP growth are so hard to come by in developing countries. What I feel the data do accomplish is to provide evidence confirming the belief of many of us that catch-up growth is a real and pervasive phenomenon, that has been the key to growth episodes and experiences in many different developing countries.

When we think about policies to promote the economic advance of LDCs, therefore, we are well advised to place considerable emphasis on those ingredients that create and promote "catch-up growth." By the same token, the challenge to us as a profession is to study enough individual industry cases, and enough individual country episodes of such growth, that we can begin to develop an empirically-founded list of relevant "lessons."

Figure 3

RELATIONSHIP BETWEEN TOTAL FACTOR PRODUCTIVITY GROWTH AND GNP PER CAPITA



(This is Figure 1 from Mieko Nishimizu and John M. Page, Jr., Trade Policy, Market Orientation, and Productivity Change in Industry, The World Bank, March 7, 1990.)

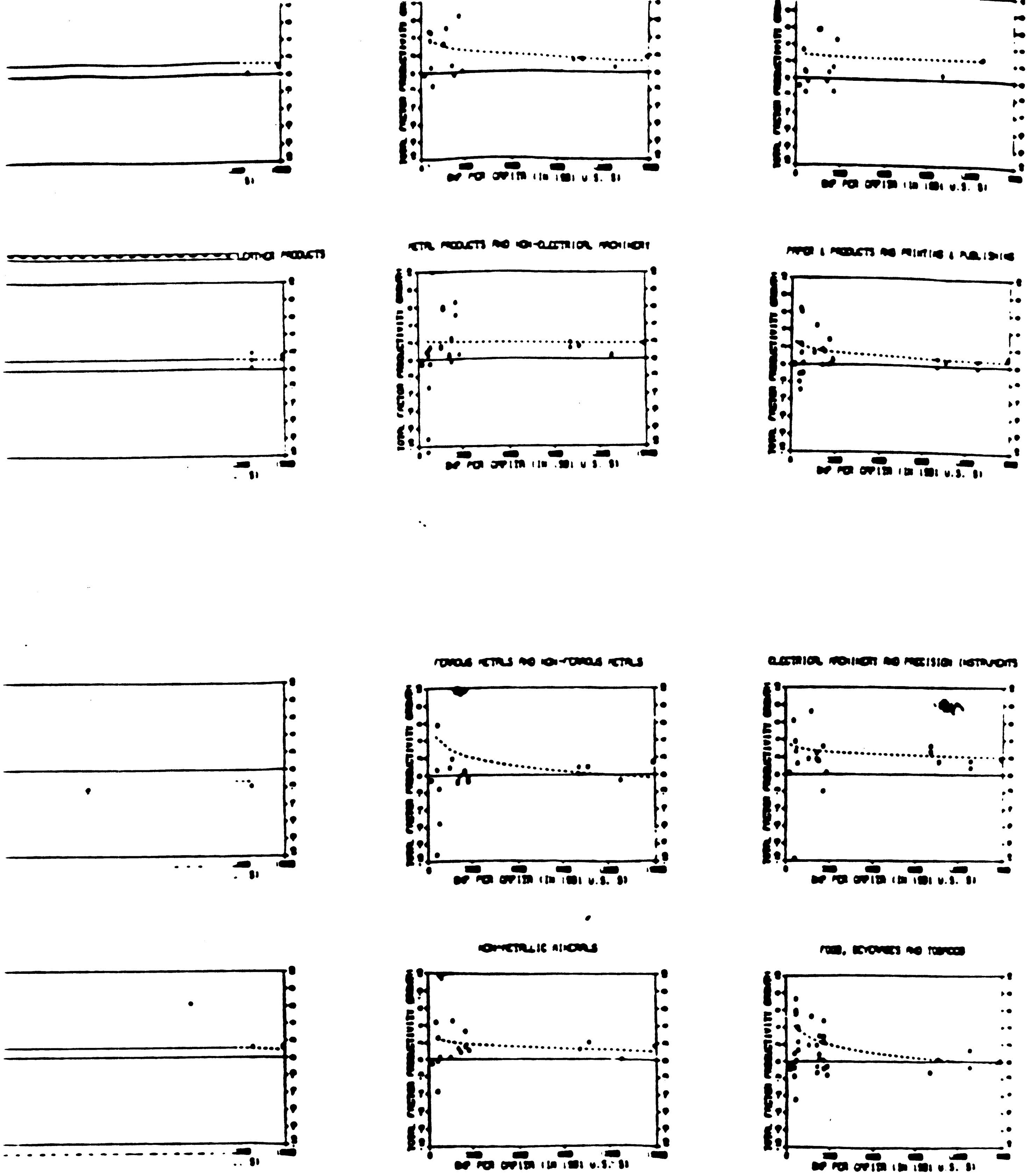


FIGURE 4

TFP GROWTH RELATED TO LEVEL OF GDP PER CAPITA

rom Mieko Nishimizu and John M. Page, Jr., Trade Policy, Market Orienta-
ivity Change in Industry, The World Bank, March 7, 1990.)