The Productivity Convergence Debate: A Theoretical and Methodological Reconsideration

by

Bruce Elmslie*
William Milberg**

Working Paper No. 120

June 1994

*University of New Hampshire
**The Jerome Levy Economics Institute of Bard College and New School for Social Research

The authors wish to thank Irma Adelman, John Cornwall, Antoinette James, Lei Jang, Andrew Kliman, Farhad Rassekh, Mark Setterfield, Anwar Shaikh, Peter Skott and Anthony Thirlwall for helpful comments.

Abstract

Two fundamental issues have been ignored in the convergence debate which are addressed in this paper. First, there has been little attention paid to the development of a general model able to explain convergence <u>or</u> divergence. Second, in the rush to put data to a convergence hypothesis, researchers have failed to consider certain methodological procedures with respect to the treatment of capital. To remedy this problem we use an input-output approach to measure catch-up. To address the theoretical lacunae we present case studies of Portugal and Japan, two countries which by 1959 had attained the threshold level of development required to join the "convergence club", but which, for various historical (path-dependent) reasons, have diverged rapidly from each other in the period since the late 1950's.

JEL Classification: 04, F02

The Productivity Convergence Debate: A Theoretical and Methodological Reconsideration

1. Introduction

The debate over the question of whether national productivity levels have converged over time has yielded an array of ambiguous, if not conflicting, results. Most studies which include only the OECD countries show that the dispersion of productivity levels across countries has diminished over the past 100 years, with some considerable slowing, if not reversal, in the period since 1973. Those studies which include a broader sample of countries provide much less evidence of convergence. Many of these studies actually reveal a divergence between the level of productivity of the richest and the poorest nations over time.

While the convergence debate has been extremely lively, two fundamental issues have been ignored and will be addressed in this paper. First, there has been little attention paid to the development of a general model of cross-country growth patterns able to account for the possibility of convergence or divergence. Second, in the rush to put data to the loosely-defined convergence hypothesis, researchers have exhibited a failure to consider certain well-established methodological procedures, especially with respect to the operationalization of the concept of capital. To remedy the methodological problem we propose the use of an input-output approach to the measurement of catch-up. To address the theoretical lacunae in the convergence literature we focus on Portugal and Japan, two countries which by 1959 had attained the threshold level of development required to join the "convergence club", but which, for various political, cultural and historical (path-dependent) reasons, have diverged rapidly from each other in the period since the late 1950's. This case study stresses the historical evolution of institutions and policies and emphasizes cumulative causation, learning by doing, trade openness and an activist trade policy in explaining why some countries are able to converge to the level of productivity of the leading country and some countries diverge from that level in spite of equally concerted efforts. Our methodological and theoretical reconsiderations of the convergence literature are not independent. Recognition of the capital measurement problem forces us to put into question the assessment of the degree of international productivity convergence and thus to rethink the theoretical foundations of the widely-accepted convergence theories. The extreme differences in rates of convergence evidenced by the input-output study indicates the need to look closer at the historical and institutional contingencies behind the radically different performance of countries who at a particular moment had found themselves at a similar point on the catch-up trail. Before turning to the input-output analysis and historical study, we briefly review the theories of convergence that have dominated the recent flurry of research.

2. Theory

Abramowitz's (1986) impressive paper indicates that for all the massive amounts of research aimed at measuring the degree of convergence among various groups of countries, there is surprisingly little work developing a theory of such a phenomenon. The original rationale for the concept of convergence was Gershenkron's (1952) study of Russian industrialization, which stressed "the advantages of relative backwardness." The idea is that for a nation with certain institutions developed to an (unspecified) threshold level, imitation is easier than innovation and "backward" countries should enjoy a more rapid growth rate than advanced countries. A convergence of the standard of living of these countries should result. The convergence hypothesis has enormous intuitive appeal but has been of relatively little interest to traditional neoclassical economists since it lacks a basis in rational choice, microeconomic theory.[1]

The motivation for the recent flurry of research on the question of the international convergence of productivity perhaps explains the lack of development of a comprehensive theoretical accounting for the phenomenon. The apparent decline of the U.S. in the world economy in the mid-1980's led many to seek an explanation in the long-term convergence of productivity levels across countries. The U.S.

economic decline could then be located in the inevitable catch-up by rivals, and not in any inherent American incompetence, laziness or cultural decay.[2] Instead of developing theoretical models, economists have undertaken econometric studies, all premised on an acceptance of the crude form of the Gershenkron hypothesis. Thus the theoretical development of the Gershenkron hypothesis has been somewhat *ad hoc*. But amidst the spate of recent studies, three distinct theories of convergence have emerged.

The first two have been termed by Baumol (1992) as the "common forces" explanation and the "contagion" model. According to the common forces theory, there is a single steady-state growth path around which all countries eventually congregate, not because of any interdependence but due to some inherent limit to growth. That is, countries face diminishing returns in some form. Baumol (1992) and Dollar and Wolff (1992) focus mainly on diminishing returns to capital which lead the growth rate to rise at a decreasing rate as accumulation occurs. The logic is purely neoclassical: as capital accumulates its marginal product falls and so does the incentive to invest. Capital thus flows to the poor countries, labor flows to the rich countries and the growth rate in rich countries falls as the capital-labor ratio falls. Baumol mentions two other diminishing returns phenomena which potentially lead to convergence. One is the "cost disease of handicraft services," that is the fact that in certain endeavors (medicine, law, performing arts, research and development) it is impossible to raise labor productivity beyond a certain level. Once a country reaches this level, its productivity growth rate is constrained.[3] The other possibility is the diminishing returns to educational attainment: once a country's population achieves a certain level of education, additional educational attainment does not lead to further productivity gains. The inevitability of convergence implied by the common forces view has its institutional counterpart in the Olson's (1982) hypothesis of "institutional ossification" due to the role of special-interest groups in democratic regimes.[4]

The contagion model is the case of catch-up based on the ease of imitation compared to innovation. The purported relative ease of catch-up is rooted in the multiple channels for technology transfer, the international mobility of capital and labor embodied knowledge, and international competition. The contagion theory is perhaps the most widely held theory of convergence among economists.[5] Recent research in this vein has largely been to select, in an *ad hoc* manner, the variables which would be expected to encourage catch-up and regress the growth rate on these variables. Most authors include a "relative backwardness" variable (usually the per capita GNP gap vis-a-vis the frontier country), and a size variable to control for increasing returns. Barro (1991) also includes trade openness, degree of price distortion, and educational attainment as explanatory variables. Rassekh (1992) focuses exclusively on trade openness, while DeLong and Summers (1992) concentrate on durable capital goods investment. Lichtenberg (1992) focuses on educational attainment, and Blomstrom and Wolff (1992) test for the role of multinational corporations. Alam (1992) attempts to proxy Abramowitz's (1986) notion of "social capability" with an index of "corporatism" which measures the degree of "institutionalized negotiation, bargaining, collaboration, and accord about wages and 'incomes policies' between representatives of the major economic groupings in the society (most typically labour confederations and employers' associations) and often including, in addition, representatives of government."[6] Nelson (1990) and Nelson and Wright (1992) could also be said to hold the contagion view, although they generally do not rely on regression analysis. For these authors the catch-up to the U.S. by other countries in the post-1972 period is due to the U.S. inability to maintain a dominance in mass production and in high-tech goods production. The causes of this inability are due as much to structural developments in the world economy (e.g. the successful integration of Western Europe) as to any developments in the U.S.

The emphasis of the *ad hoc* contagion models is the explanation of convergence. While this is a perfectly valid task, it avoids the general question of why a given country does or does not join the so-called "convergence club," that is the group of countries in the process of catching up to the frontier country. Put another way, the *ad hoc* contagion models do not attempt to define the characteristics of the threshold level of development required for membership in the convergence club.

What is the crucial level of development at a given historical moment to attain the required threshold? The problem with the common forces and the contagion models is their inability to account for the vast number of poor countries who have failed to converge, much less catch up entirely. The rush to explain convergence left unanswered (except in the negative) the question of why a large number of countries never were able to join the convergence club. A number of recent studies confirm that many countries have endured relative stagnation while only those lucky club members chugged along on the catch-up trail (DeLong, 1988, Baumol and Wolff, 1988, Verspagen, 1991, Chatterji, 1992, Blomstrom, et al, 1992, Hikino and Amsden, 1992). The common forces model would certainly seem to fail in the face of this evidence alone, unless one argues that there is not enough time-series data available to make a judgment. The contagion model is not necessarily contradicted by this evidence, but it explains the inability of countries to catch up only in the negative, that is as the state of not having attained a certain level of, say, educational attainment or capital accumulation. Even Baumol (1992, p. 35) admits, "[T]he line separating those eligible for membership in the convergence club and those foreclosed from membership has not been determined unambiguously."[7]

The third explanation of the convergence phenomenon seeks to account explicitly for the possibility of convergence or divergence.[8] These models build on what Abramowitz terms "social capacities" and attempt to identify the threshold level of such capabilities required for a nation to diverge or converge. Such abilities may include, but are certainly not limited to, the notion of "absorptive capacity" stressed in the contagion literature. Fagerberg (1988), for example, stresses that contagion alone is insufficient for convergence, but must be combined with appropriate "national technological activities." Hikino and Amsden (1992) describe a process of development which allows for the possibility of both convergence or divergence in their model of "late-industrialization," which gives instititutional definition to the threshold level of development whose attainment is required for membership in the convergence club. Three requirements for the ability to implement such a development policy are (1) a certain threshold level of wealth accumulation, (2) a relatively equal distribution of income, and (3) a relatively well-educated civil service. Absent these characteristics, a country is likely to diverge since its growth rate will not be able to keep up with that of the leading countries, much less surpass it. Hodgson's (1989, 1991) emphasis on the non-codifiability of knowledge--and thus the difficulty of its international diffusion--provides a similar perspective on the convergence process as non-inevitable and dependent on domestic institutions and cultural practices. Hodgson (1991) turns the Olson hypothesis on its head, stressing political pluralism and political disruption as indicators of social capabilities, but rejecting the notions that institutions naturally "ossify" and that leading countries naturally decline.

Formal models that explicitly allow for the possibility of convergence or divergence tend to stress absorptive capacity alone. Verspagen (1991), for example, develops a simple model where catching-up or falling behind depends on the lagging country's "intrinsic learning capability," which determines the rate of spillover of knowledge from the leading country. The level of development of infrastructure (proxied by electricity generating capacity) represents the capability to assimilate knowledge spillovers from the leading country. A learning capability in the laggard country above a certain level will bring convergence. Otherwise, the laggard country's growth rate remains below that of the lead country. Testing the model for a sample of 135 countries, Verspagen gets results which support the model. Chatterji (1992), in a model which also emphasizes capacity to absorb new technology, finds that there exist two mutually exclusive convergence clubs, one for wealthy countries and one for poor ones, where the division between wealthy and poor is determined endogenously in the model. The ultimate level of convergence for the poor group is 1/30 the level of income of the U.S., the frontier country in the wealth group. This result confirm's Gomulka's (1987, 1990) hypothesized "hat-shape relationship" between technology gaps and growth rates.

The discussion of Japan and Portugal below is an attempt to build on this body of work and develop a model centering on endogenous technical progress, external economies and trade in goods with production characteristics favorable or unfavorable for convergence. The idea behind the model is traced back to Adam Smith's writings on trade and uneven development. Smith's underlying theory of exchange led him to the theory that specialization and international trade may lead to either convergence or divergence in development and technology.[9] Smith's description of economic and technological divergence has its direct counterpart in modern positive-feedback theories of trade and development. Kaldor (1972, 1985) emphasized the cumulative causation of an initial productivity lead based on the existence of dynamic scale economies. Given increasing returns, trade is not automatically beneficial to all countries. International trade expands markets and extends the division of labor, but some countries are left behind in the process:

> There are a number of factors... that create spontaneous tendencies to imbalance which may well mean that the growth of some of the participants is enhanced while the growth of others is diminished. In contrast to the classical theory of international trade, free trade or even a reduction of barriers to trade may stunt the growth of some industrial areas and enhance the growth of others. Free trade therefore is not necessarily to the benefit of each participant, as it is under the theories of Ricardo, John Stuart Mill, Heckscher, Ohlin, or Samuelson. (Kaldor, 1985:71)

Krugman (1981) put a similar general story of international trade into a simple model. Given the existence of external economies, the country with a small head start in an industry will continually increase its productivity advantage over lagging countries. In a trade context the model posits that the opening of trade causes the "head start" advanced countries to specialize in the external economies-to-scale industries while the lagging countries are forced out of these industries. We do not expect advantages to relative backwardness because continual productivity gains are caused by external economies which are not transferable as are technologies. Trade and time cause initial productivity differences to be magnified; the advantages of relative backwardness are negative.

Our approach differs slightly from Kaldor and Krugman by explicitly focusing on the characteristics of production that lead goods to possess these so-called dynamic or non-dynamic returns. The role of international trade in determining rates of convergence and divergence is that of the determinant of specialization. In an abstract sense, goods may be classified as either zero-feedback or positive-feedback goods, depending on the scale economies and positive spillovers their production generates in a particular context. The production of zero-feedback goods generally makes use of low-skill workers with little labor force commitment. Technology is often embodied in standardized machinery that has been perfected to the point of requiring a low-skill operator. Also, these goods are often produced with labor intensive techniques, and production "blueprints" that are unrelated to positive-feedback goods. This implies that technologies employed in the production of these goods do not benefit from spillovers of technological changes occurring in other goods. Standardization of both product and production process are characteristics which dominate zero-feedback goods.

In contrast, the production of positive-feedback goods requires skilled labor, and is characterized by technologies that are both embodied and disembodied, less standardization of both product and production technique, and ease of technology transfer both within specific good categories and between goods. This last characteristic implies that technology spillover is rapid even between different goods. In positive-feedback goods, dynamic returns dominate standardization of product and production process.

The determination of whether a good is of the zero- or positive-feedback variety depends on both the (historically specific) technological characteristics of the good and its production process, and the institutional features of the economy producing it. Since international trade tends to lead to greater specialization in production, it determines in part whether a country captures positive-feedback, dynamic returns, or whether it is dominated by zero-feedback goods. But even a particularly favorable specialization pattern does not provide an a priori guarantee of a country's convergence. Many countries seek to "lock in" to specialization in positive-feedback goods; only some succeed. The determining factors are institutional capabilities and rigidities, including political factors. While the U.S., for example, experienced industrial labor supply and demand enhancement as a result of 19th century productivity gains in agriculture, Portugal's concentration on agricultural production generated no such advantages, due to an inappropriate transportation network and land which was poorly suited for the particular crops that the government promoted. Moreover, the outcome of a particular specialization pattern is historically contingent: Both the U.K. and Japan used linkages to the textile sector to generate positive feedbacks in the 19th century, but today, such a strategy would likely not provide the convergence boost. Thus while our emphasis is on cumulative causation, we stress the role of Arrovian "learning by doing" as much as Kaldorian investment-driven technological progress. These processes are perfectly compatible. As Hodgson (1991, p. 157) remarks, "Economic growth is predominantly a cognitive, learning process in which the scope of learning is progressively extended by gross investment."

The postitive- versus zero-feedback perspective leads us to look at the types of linkages which develop in an economy to understand long term patterns of convergence. A pattern that allows a country to establish strong technological and informational linkages both intra-country and intercountry will generate a convergence path. Trade is influential in building these linkages. Where these linkages are weak, we expect a divergence path to develop. Moreover, once this pattern of convergence or divergence has begun (i.e. once the path is determined), patterns are self re-enforcing. Krugman (1987, 1991) and Arthur (1989) demonstrate the difficulty of overcoming an initial vicious path of divergence. Increasing returns act to lock in certain patterns, and countries that specialized in zero-feedback goods find themselves outside the converging group. Breaking the pattern of divergence set by this pattern of specialization is found to be extremely difficult. A simple model of this process is developed in Appendix B. The model develops the zero feedback - positive feedback distinction to demonstrate the development of two convergence clubs rather than one. Countries that are able to specialize in positive-feedback goods converge at ever increasing productivity levels while those countries specializing in zero-feedback goods converge at a low and stagnant level. Thus, we show divergence between groups and convergence within groups.

3. Methodology

There has been a diverse set of research methods employed to assess the degree of convergence of national productivity levels. The simplest approach is to correlate "technology gaps" in some initial period with growth rates. The former is often proxied by the nation's level of productivity compared to that of the frontier country. A negative correlation provides evidence of convergence. The most commonly used productivity measure is total factor productivity.[10] Total factor productivity is defined as the value of output per dollar of inputs. In general,

$$TFP = (v_i Y_i) / (w_j X_j) \tag{1}$$

where TFP is total factor productivity, Y are outputs, X are inputs and v and w are output and input weights respectively. All studies of convergence based on TFP growth assume only two inputs (labor and capital) and constant returns to scale Cobb-Douglas technology. TFP is then equivalent to the Solow residual, so-called because of its discussion and measurement in Solow's (1957) seminal article. Letting A represent output not explained by capital and labor use, the production function is:

$$Y = A(L^{\alpha} K^{1-\alpha}) \tag{2}$$

where Y is aggregate output, L and K are aggregate labor and capital respectively and α is labor's share of income. The translog index of TFP is defined by taking logs and solving for the Solow residual:

$$TFP = \ln A = \ln Y - \alpha \ln L - (1-\alpha)\ln K \quad (3)$$

The wage share parameter α serves as the weighting scheme for measuring input use.

The validity and interpretation of the Solow residual, and the aggregate production function on which it is based, came under intense scrutiny in the "capital controversy" of the 1960's and 1970's. For a number of years after this debate, the use of the aggregate production function waned. In a disturbing development for those who acknowledged the validity of the capital critique, the aggregate production function has made a resurgence in research on convergence.[11]

The capital controversy concerned the issue of the interdependence of income distribution and the value of the capital stock. The Cambridge, U.K. critique of the aggregate production function was that the value of the capital stock is a function of the distribution of income between wages and profits. The neoclassical model is flawed because the value of the capital stock cannot be known until the profit rate is known, but the profit rate (equal to the marginal product of capital) is unknowable without knowledge of the value of the (aggregate) capital stock. One implication of this circularity critique is that the aggregate production function has been shown to be invalid except within the confines of a one-commodity world (Garegnani, 1970), or when the capital-labor ratios and technologies are equal in the production of all goods (Samuelson, 1962).

The practical problem in the use of the aggregate production function is the potential bias it brings to the analysis. Important for the purposes of this paper are the implications of this critique for empirical analysis of convergence. If the neoclassical theory of distribution is invalid, and the value of capital is a function of distribution (which it must be in any general aggregate production model), then two major problems arise for the analysis of convergence. First, the capital stock data used in the empirical analysis do not account for the role of distribution and may be distorted as a result. Second, estimates of the Solow residual, also based on this discredited growth model, may also be distorted.[12]

TFP growth (TFPG) is defined as the amount of growth of output not accounted for by growth in labor and capital:

$$TFPG = \hat{Y} - \alpha\hat{L} - (1-\alpha)\hat{K} \qquad (4)$$

where a ^ over a variable represents the time derivative in the log of the variable. Of note in this common formulation is the assumed constancy of α with respect to time. Regardless of the weighting scheme chosen to perform the TFPG calculation, α is a constant. This specification leaves such calculations vulnerable to the critique of Shaikh (1980, 1987) that the residual will not measure technical progress, as it is so often described. Instead, the residual will reflect distributional changes. According to Shaikh (1980, p. 85), "Solow's measure of technical change is merely a weighted average of the growth rates of the wage rate, w and the rate of profit, r."[13] Shaikh shows that <u>any</u> data (thus the "humbug production function") will provide a good fit of a constant returns to scale Cobb-Douglas specification assuming the wage share is relatively constant. Hsing (1992) further develops the critique of the aggregate production function by demonstrating that the measure of technical change $\left(\frac{\hat{A}}{A}\right)$ is itself inconsistent with neutrality and homogeneity. Hsing further shows that reformulating $\frac{\hat{A}}{A}$ to conform to neutrality and homogeneity results in a production identity rather than a production function.

The importance of this critique for the current purposes is that it implies that TFP may capture things other than technical progress and may simply represent changes in distribution. In their comparison of the convergence of TFP with that of direct labor productivity, Dollar and Wolff (1992) show that in the 1963-1972 period TFP converged faster than labor productivity, with the opposite occurring following 1972. Following the above discussion, this result may simply reflect that technical change is embodied in inputs and that the convergence of technologies may not have stopped since 1973. The lack of TFP convergence in the later period may reflect a lack of change in the functional distribution of income in that period across the sample countries, not a lack of diffusion of technology. Dowrick and

Nguyen (1989) find that TFP converged more rapidly than per capita income. This result could reflect a bias in TFP. Rapid TFP convergence could be based on distributional trends, not technical change.

To avoid such ambiguities we propose the use of a concept of capital as heterogeneous. This vertically integrated approach, using the work of Leontief (1966) and Pasinetti (1981), avoids the bias inherent in the homogeneous capital measures. With input-output data available for a considerable number of countries over a significant period of time, there is no reason not to apply such a methodology to *international* comparisons and thus to the question of convergence itself.[14] It is to this task that we now turn.

The approach adopted in this paper is the vertically integrated measure of productivity that looks at direct and indirect labor productivity in a sector. Vertical integration captures the interdependence of sectors, providing a more comprehensive measurement of labor productivity than simple direct measures.[15]

The vector of vertically integrated labor coefficients (vilc's) is calculated as follows:

$$\mathbf{v} = \mathbf{l}(\mathbf{I}-\mathbf{A})^{-1}$$

where $\mathbf{v}$ = the 1xn vector of vilc's

$\mathbf{l}$ = the 1xn vector of direct labor coefficients

$\mathbf{I}$ = the nxn identity matrix

$\mathbf{A}$ = the nxn transactions matrix

Not only is $\mathbf{v}$ a more comprehensive measure than a direct measure but it also captures dynamic scale economies, since productivity in a given vertically integrated sector is a function of productivity in all its intermediate sectors. Because of the wide variance in input composition among final goods sectors, we would not expect each sector to share equally the advantages of dynamic scale economies. Vertically integrated analysis thus captures the importance of Kaldor-Young dynamic returns at a disaggregated level. The simple direct measure fails to capture the dynamic returns since each final goods sector's performance is considered in isolation from all others.

In input-output analysis changes in production over time take the form of changes in the matrix of technical coefficients - a vector for each sector. However, the direction and magnitude of this change is ambiguous. Vertically integrated analysis reduces the input-output current flows matrix to a vector, and thus a scalar for each sector. Productivity change can be measured as changes in this single coefficient. Such a measure of technical change is unambiguous, yet retains the information provided by input-output tables.[16]

The United Nations ECE input-output data base allows the use of vertically integrated analysis in an assessment of international productivity divergence, for a limited set of countries over the period 1959-1975.[17] Table 1 shows the sectoral breakdown of the input-output sectors. Convergence is measured in two ways: first, the ratio of highest to lowest vilc across countries is calculated. An increase in this ratio implies divergence and a decrease implies convergence. Second, the coefficient of variation[18] (cv) in each vertically integrated sector across countries over time is calculated. Declines in the cv imply convergence and increases imply divergence in a given sector. The results of these two measures are presented in Tables II and III.

The bottom line of Table II shows the median of the sectoral ratios of highest to lowest vilc by year. This ratio declined from 4.86 in 1959 to 3.62 in 1975, implying that on average the country with the lowest productivity in each sector partly "caught up" to the leading country in that sector. This provides support for the Gershenkron hypothesis, and is consistent with a number of the recent studies discussed above.

Looking at the coefficient of variation of specific sectors in Table III, no clear-cut tendency for divergence or convergence is observed over the entire period. The number of sectors in which there was convergence was exactly equal to the number of sectors in which divergence was observed over the 1959-1975 period.

Not surprisingly, the comparison of end points (1959 and 1975) hides some interesting fluctuations over the sample period. Specifically, there was considerable convergence between 1959 and 1970, and then equally large divergence between 1970 and 1975. In Table III we see that between 1959 and 1965, 11 of 14 sectors showed convergence. Again, between 1965 and 1970, convergence occurred in 11 sectors. But from 1970 to 1975, convergence occurred in only 4 sectors: metal ore and other mining, basic metals, machinery, transport and other manufactured goods, and construction. Moreover, the median coefficient of variation rose from .4139 in 1970 to .6138 in 1975. The median for 1975 increases almost to the original 1959 lèvel of .6180. This break in the convergence tendency observed in the 1975 data is confirmed by the ratios in Table II, comparing the highest to lowest productivity in each sector over time. The median of the ratios of highest to lowest sectoral productivity levels declines steadily from 1959 (4.86) to 1970 (2.92) and then jumps back up in 1975, practically to its 1965 level. The picture from this sample is thus considerably more muddy than the Dollar and Wolff (1992) results indicate, and requires an explanation that goes beyond the simple Gershenkron hypothesis.[19]

The evidence from the input-output study demonstrates that simple monotonic convergence did not occur at the sectoral level in the sample countries for which input-output data are available. According to Table II, in 1959 and 1965, Portugal was the low productivity country in three sectors: metal ore and other mining, non-metallic mineral products, and construction. In 1970 and 1975, Portugal was still the low productivity country in the same three sectors, but in 1970 it became the low productivity country in seven sectors[20] and in 1975 it was the low productivity country in eleven of the fourteen sectors. Japan was the low productivity country in six sectors in 1959, 10 sectors in 1965, three in 1970 and only 1 in 1975. The data indicate that over the 1959-1975 period, Portugal failed to join the convergence club while Japan became a card-carrying member.

Per capita income figures roughly mirror those of the sectoral productivity values. Table IV reports per capita income levels for each country in the sample, plus the United States, over the same time period. This table indicates that Japan rivaled Portugal as the least developed country as measured by per capita income in 1959. Over the sample period the ratio of per capita income for Japan and Norway (the leader in the sample) jumps from .41 in 1959 to .76 in 1975, while the same ratio for Portugal and Norway moves from .28 in 1959 to .36 in 1975. These numbers amount to a rate of convergence of 59% for Japan and only 24% for Portugal. The numbers for the other countries in the sample as well as for the United States may also be calculated.

Given Portugal's apparent divergence in most sectors, it is interesting to ask if the lack of unambiguous convergence in the sample countries can be fully explained by the inclusion of Portugal. To address this, we have recalculated the ratios without Portugal. Table V reports total productivity ratios for the low and high productivity country in each sector. By excluding Portugal we note that overall convergence did occur between the sample countries in each period. The median total productivity ratio falls from 4.29 in 1959 to 1.91 in 1975. Moreover, the median ratio fell in the 1970 to 1975 sample period. The strong divergence shown in Table II can be attributed to Portugal's performance in relation to the other sample countries. The convergence trend does show signs of slowing during the 1970 to 1975 period for Germany, Italy, Japan and Norway. This is shown by the fact that even though the median ratio fell, 7 of the 14 sectors diverged over this period. This is compared to 5 sectors diverging from 1959 to 1965 and 4 sectors diverging from 1965 to 1970. However, the fact remains that Portugal is responsible for the median divergence reported in Table II. Portugal's role is again confirmed using the coefficients of variation for Germany, Italy, Japan and Norway reported in Table VI. Between 1959 and 1975, there was divergence in only one sector (petroleum and coal products) and the median coefficient of variation falls from .6375 in 1959 to .2818 in 1975. Moreover, from 1970 to 1975 the median falls from .3506. The divergence observed in Tables II and III for the 1970 to 1975 period is due to the divergence of the least developed country, Portugal.

The remainder of the paper is devoted to applying our theoretical framework to the question of why Portugal and Japan experienced such different paths over our sample period. We have argued that the input-output approach is preferable to the aggregate production function in assessing the degree of convergence. But in order to explain the convergence/divergence tendencies we must push our methodological reassessment further. While most attempts to explain convergence consist of cross sectional regression analysis, we propose an historical account of political and institutional factors in the particular cases of Japan and Portugal. Implicit in this methodological choice is the belief that regression analysis is insufficient to capture the theoretical dynamics of positive feedbacks associated with specialization and international trade. Our methodological choice thus reflects a realist perspective, in which economic and political institutions play a fundamental role and are irreducible to the activities of individual agents. In Lawson's (1993) words, these social structures are "inescapably geohistorically grounded."

4. A Tale of Two Countries

Japan

The data covering the period from the late 1950's to the middle of the 1970's clearly support the view that Japan experienced rapid convergence toward the developed countries. Further inspection reveals that this pattern is part of a long-run trend. Table VII reports direct productivity ratios for the U.S., Norway, and Japan from 1870 to 1979. These data reveal a clear convergence path over the entire period. From 1870 to 1938 Japan converged toward the United States and Norway. In 1870, the measure of productivity differential between the U.S. and Japan stood at .9975, but by 1938 the measure was down to .6679. The destruction of Japan during World War II is evident. In 1950 the measure was

.8612 and it did not drop below the 1938 level until 1970. During the period from 1960 to 1973 (the approximate sampling period above) we see continuous convergence. The rapid convergence from 1960 to 1970 appears as a catch-up for lost ground from the war. Generally, the periods before and after this show persistent, if unsteady, convergence. The results from a comparison to Norway are extremely similar. A persistent convergence path is demonstrated before the war, followed by rapid catch-up from 1950-1973.

As Japan developed, it directed resources toward manufactures and away from primary products.[21] Table VIII reports data on Japan's exports from 1874 to 1970. Clearly the trend is toward manufacturing sectors. From Table IX we note that in 1874 the ratio of manufacturing exports to total was .423. This ratio continuously rises to 1970. WWII does not even stop this trend. By far the most important sector in manufacturing exports is textiles. In 1874 the ratio of textile exports to total manufacturing exports is .571. This ratio grows to .628 in 1895 and maintains its dominance until 1935.[22] From 1935 to 1970 the ratio falls from .545 to .120, with the sharpest decline occurring after 1955. The decline in export performance in textiles is consistent with the total labor productivity data which show that Japan became the low productivity country in textiles by 1970, and was only better than Portugal in 1975 (see Tables II and V).

The data indicate that manufacturing in general, and textiles in particular, played a major role in Japan's convergence. We now further develop this line of argument by focusing on textiles and manufacturing. Specifically, we focus on the role played by positive feedbacks in Japan's convergence, and argue that external economies played a major role in the early development of the textile industry and external economies generated by the military provided for the later growth (1900-1920) and development of the heavier industries such as chemicals, metals and machinery. These developments set Japan on the convergence path that we observe from 1959 to 1975. This path was severed by WWII but quickly reestablished after the war.

i) Textiles

As indicated above, the textile industry was extremely important in Japan's early development. The industry was Japan's first large-scale, modern industry and was responsible for a third of all industrial production from 1890-1930 (Yamazawa, 1990:70). Table IX documents that textiles accounted for over half of all manufacturing exports until 1939. By 1920, Japan passed Great Britain as the world's leading exporter of cotton textiles. The growth of textile exports from 1900 to 1935 is astonishing. In 1900 textile exports were valued at 97.1 million yen at constant prices, by 1935 the export value reached 1665.1 million, an increase of 1600 percent. Moreover, the growth of the cotton textile industry provided important support for downstream industries in spinning machinery and tools so that by the late 1920's spinning machinery was a net exporting industry (Akamatsu, 1961).

Government involvement in cotton textiles began early. Japan's trade surpluses of the pre-Restoration period quickly turned into large deficits. From 1874 to 1880 the total deficit at constant prices was 460.5 million yen, 92.9 million more than total exports. Textile imports accounted for 45% of all imports and the value of these imports exceeded the total value of exports.[23] Because of their importance, the government began an extensive import substitution program in cotton textiles. This was an important decision. Textiles proved to be a positive feedback industry, useful for its technological spillovers, its demonstration effects and its downstream industry benefits.

The government began by buying two cotton spinning plants in 1878, and in 1879 it also bought ten more plants for sale on easy terms to private investors and provided financing for three additional plants. "[T]he government hoped that its new nonmilitary industries [cotton and wool textiles] would have a demonstration effect in familiarizing Japanese with factory production, training administrative and technical staff, and accumulating experience that could be made generally available." (Crawcour, 1988:612) This effort paid large dividends even though the government-run enterprises failed to make a profit. "[T]he State shouldered the early risks, reconnoitered the path of technological advance, and patronized many private ventures which followed on its heels." (Lockwood, 1955:507) From 1883 to 1893 a large number of spinning companies were established without government aid, and by 1895 a small trade surplus in textiles developed. The new private companies learned a great deal from the government's operations and failures. In 1884 the first major plant, the Osaka Spinning Company, began production using cheap Chinese cotton and steam power. This factory was also built much larger than the early government ones; 10,500 spindles compared to 2000, allowing the firm to take advantage of scale economies (Yamazawa, 1990). Within four years the operation was making large profits and paying high dividends. In 1888, the Japan Cotton Spinners' Association was organized. This organization was developed to ensure that technology, production, and cost information flowed freely between producers. Its purpose was to ensure large and continuous external economies for all its members.[24]

The cotton spinning industry went through several stages of development. First was the importation of technology. In 1882, the Osaka company ordered its plant design and all its machinery from the Platt Brothers, a British engineering company. Moreover, the company made extensive use of the Platt Brothers' technical expertise. Foreign technicians generally played a major role in the transfer of technology to the Japanese industry.

Second, the Japanese took the foreign technology and then adapted it to its own requirements. By running factories at two twelve-hour shifts per day, and only resting the machines two or three days a month, the effective labor-capital ratio was two and one-fifths higher in Japan than in Britain (Ranis, 1957). This resulted in a higher depreciation rate that allowed Japanese cotton spinning firms to maintain the best techniques rather than produce with technologically dated machines. Advances from mules to reels and the development of bundling press equipment provide excellent examples (Saxonhouse, 1974).

The Japan Cotton Spinners Association also played a major role in insuring that all firms maintained the latest techniques by insuring the rapid dissemination of the best possible information for its members.

> The following information, broken down by firms, was published on a monthly basis in the Association's journal... (1) Average number of spindles operated per day; (2) Working days per month; (3) Working hours per day; (4) Yarn produced by count; (5) Raw cotton consumed; (6) Workers, male and female; and (7) Wages, male and female... [C]omplete cost data for certain mills were [also] occasionally published... [The journal also] translated particularly interesting articles appearing in foreign language journals. (Saxonhouse, 1974:160)

The Association was very influential and always encouraged its members to share the costs and benefits of technological acquisition and development. This cooperation meant that "the cost of acquiring technological information for any given Japanese spinning firm was extremely low by international standards" (ibid: 163).

Finally, the success of the cotton spinning industry led, through the Association, to the development of downstream indigenous industries producing spinning tools and machinery.[25] The borrowing of British technology led to Japan's first major internationally competitive nonmilitary machine industry. The Japanese made their first copies of English hank-cop reelers in 1888. By 1892 no new orders for English hank-cop reelers were made, and by 1907 no orders for any English machinery were made (ibid.: 155).

From a perspective that emphasizes cumulative causation and external economies (i.e. positive feedbacks), we are led to conclude that the success of textiles in Japan was the direct result of an active pursuit of foreign technological knowledge and its dissemination by the Association. This led to the development of domestic downstream industries which could develop important indigenous technologies leading to still further development of other industries. Cumulative effects, begun by textiles, impacted both on the industry itself and on other industries in the economy. In explaining the convergence of Japan over the period to 1975, it is fundamental to look at the early development of textiles as a prime element in the story. Japan's first modern manufacturing industry developed by borrowing foreign technology which it was quickly able to assimilate, copy and improve. Many of the day-to-day improvements in technology which resulted from cumulative experience in production were quickly disseminated to all firms by the Association. The government began the industry with the intention of creating an increasing returns, spillover industry that would propel the entire economy forward. The early decision to promote textiles helped to set Japan on a path of convergence toward the western powers.

ii) The Role of the Military

Another major element in the story of convergence is the early Japanese militarism. External economies from its military build-up aided the development of textiles and led to the development of Japan's heavy industry including metals, machinery, and later, chemicals.

Several writers have argued that Japanese militarism was a major drag on the economy during the Meiji Restoration.[26] Much of this work focuses on the increased taxation and government spending brought on by Japan's expansionism as evidence of its growth-retarding influence. However, other writers have concluded that Japan's military build-up played a great part in its "industrial revolution." "Imperialism... coincided with rapid industrialization," and brought Japan the status it craved as a major power (Iriya, 1989). We argue that Japanese militarism did play a substantial role in the development of light and heavy industry,[27] with the greatest impact coming from the increased demand for industrial products and the technology disseminated to build these products. The latter aspect is emphasized here.

The military was a center for the dissemination of high technology capital equipment and technical expertise to private industry in Japan. Yamamura (1977) provides a rough measure of the technological gulf that existed between military arsenals (including satellite plants and other government financed factories created for the military), and private shipyards and factories. He measures what he calls "prime-mover capacity" measured in horse power for both military and non-military industry from 1899 to 1912. The number of workers in each sector is divided by this capacity variable to obtain a productivity measure. Military arsenals are shown to be 42% more productive in 1899 and 55% more productive in 1912. The technology gap was substantial during this period, and the size of the gap was increasing. The questions concerning us here are how the military obtained and disseminated the technology.

Quickly after rising to power, Meiji leaders moved to increase Japan's military power. By 1880 four arsenals with satellite plants and three government shipyards were operating to supply the military. The government shipyards were the first to build iron ships in Japan. Most of the technology necessary to build modern military equipment was bought and borrowed from abroad. "[I]n 1884, the arsenal [Tokyo] had Belgian, French, and German engineers and foremen, imported machinery, [and] 2,094 workers...." (Yamamura 1977:114) Other arsenals in Osaka, Yokosuka and Tsukiji also developed early by the same process of importing technology in the form of capital equipment and technicians. To supplement the flow of foreign technology, many Japanese engineers were sent abroad to acquire knowledge. The development of machine-tool factories and shipyards developed according to the same basic pattern.

The importance of this technological acquisition by the military was that it resulted in a rapid dissemination of the technology to private firms at low costs.[28] This process of dissemination took many forms including allowing firms to purchase foreign (and arsenal-produced) machinery owned by the government at subsidized rates, giving no-interest loans to firms purchasing technology, and direct technical assistance.

The rapid growth of technical knowledge by the arsenals and the rapid pace of the spillovers continued, and was accelerated by the Sino-Japanese War (1895),[29] and the war with Russia in 1904. "[T]he most significant effects of the Russo-Japanese War were the rapid dissemination of modern technology to a large number of private firms and a sudden accelerated growth in the fledgling and often struggling private machine and machine-tool makers who received increased and timely military demand and technological assistance." (Yamamura, 1977:121) This process of technological spillover led directly to the development of endogenous technical progress in private factories and shipyards. The combined effects of the transfer and development of technology resulted in Japan's private shipyards being as advanced as any in Europe by 1912.[30] These advances resulted in the increased competitiveness of Japan in international markets, allowing Japan to benefit greatly from WWI and to establish new trading arrangements and expand exports. Most important, however, is that the technological spillovers created in Japan's early industrial efforts set it on a path of continued convergence toward the Western powers. Once this convergence path was established, it created the opportunities for its maintenance. The conditions necessary for the rapid rate of convergence we observed from 1959 to 1975 in Tables II and III were laid years earlier by Japan's decisions to import substitute in cotton textiles and to develop as a major military power. The success of these policies as a development strategy resulted from the assimilation of western technology and the rapid rate of spillover of technology within the industry and the economy. In essence, the decision to industrialize by encouraging positive feedback industries set Japan on the convergence path that we observe in the data to 1975.

Portugal

Portugal provides an interesting case study against the simple Gershenkron hypothesis. By the 1950's the major roadblocks to rapid convergence had been removed. Yet, in productivity terms, this country diverged from the other countries in our sample. This section reviews the historical record of Portugal to argue that its trade relations and long established trade patterns may have played a vital role.

The question is not if Portugal developed over the sample period. It did. Table VI shows that Portugal's per capita GDP grew at about the same rate as Norway's.[31] Krugman and Macedo (1981:54-55) characterize Portugal by 1973 as "fairly typical of the group of middle income nations sometimes referred to as... 'nics'," adding that Portugal was "able to achieve rapid economic growth during the 1960s and early 1970s via increased trade, [and] exploiting their relatively abundant supplies of semiskilled industrial workers." Portugal did develop, but it did not converge in absolute terms as Gershenkron would lead us to expect. Why?

The Fascist government of Oliveira Salazar can partially explain both. When the new government took power in 1928, Salazar began building his "economic corporation" which was set up to link government and business. A leading historian of Portugal wrote that, "the corporate system built up an economically organized country, an interventionist state essentially different from the liberal, 'laissez-faire' republican order." (Marques, 1976:180) A large part of this system was devoted to the development of infrastructure. The total road network more than doubled from 1925 to 1950. Port facilities were extensively improved so as to allow larger ships and more traffic. Telegraphs and telephones were also greatly expanded. "[T]he public works policy bore fruit, making possible - along with the general expansion of Europe - the rapid economic development of Portugal in the 1950s and the 1960s." (ibid.: 198)

Still, productivity convergence did not occur. Several reasons can be given for this. First was Salazar's anti-democratic bent. Examples of this include harsh censorship rules, the active Secret Police, and the aggressive National Guard. Salazar (a former university professor) was also extremely suspicious of intellectuals, resulting in Portugal's high illiteracy rates. Because of this anti-education bias, Portugal fell further behind the rest of Europe in terms of science and technology creation.[32] Second was Portugal's major resource commitment to keeping its remaining colonies. However, some economic analyses suggest that the captive markets and cheap supplies of raw materials more than offset Portugal's military and administrative expenses in keeping the colonies. (Stallings, 1981) And, "the war [in Angola] became a factor of economic growth. It even encouraged Portuguese industries connected with the army." (Lucena, 1979:77)

Finally, and importantly, Salazar made a decision early in his regime to emphasize a stagnant non-increasing returns industry, grain. The main concern here was to attain self-sufficiency in grain production. In 1929 Salazar began the *campanha do trigo* (wheat campaign). The 1930's saw vast amounts of resources devoted to increasing the harvests, and agricultural land and wheat output continued to increase to the 1960's. The results of this campaign were disastrous, most soils were never properly conditioned for grain production and per acre yields eventually fell. (Marques, 1976)

Agriculture is not necessarily a constant returns industry. Rapid technical progress in agriculture has made productivity increases very rapid in many countries. However, for Portugal this was not the case. Even though the government encouraged and protected agriculture, no serious attempt was ever made to modernize that sector's archaic production methods (Murteira, 1979).[33] Even with the original goal of self-sufficiency, agricultural imports of grains, fish and meat accounted for 13% of imports by 1973. The resources poured into agriculture over the years meant that when Portugal finally made a serious transition from agriculture to manufacturing in the 1950's and 1960's, it began much further behind its major European trading partners than if it had started earlier.[34] Most of the growth of the 1960's occurred in manufactures and construction. But the stagnation of agriculture helped to keep Portugal from making the investments in technology necessary to converge from such a low starting point. Unlike Japan, Portugal's government designed no specific policies to create the technology transfer and spillover. No policy existed to generate convergence through encouraging external economies of any kind. In fact the import substitution policy for agriculture seemed to discourage these types of activities.

Portugal's pattern of specializing in zero-feedback goods has a long history. This history is characterized by Portugal's willingness to grant trade concessions (to Great Britain) in exchange for military protection. This pattern killed off promising industrialization efforts (again in textiles) in 1703 with the signing of the Methuen Treaty. This treaty reopened Portugal to English woolen cloth and wool manufactures in exchange for Portugal's wines being allowed into England at a tariff one-third lower than that on French wines. The effects of the treaty were that "[a] few years after 1703, the import of English woolens quadrupled, eliminating the entire domestic production..." (Sideri, 1970:45)[35] Sideri goes on to conclude that, "the Treaty caused the destruction of the only sector [textiles] which could have served as the leading sector of the industrialization process, and whose very existence would probably have prevented the 'technology gap' which still affects Portugal today." (ibid: 47) Trade policies do have long term effects, if Portugal had had a manufacturing sector at the beginning of the industrial revolution in the middle of the 18th century, it would have been in a position "to assimilate the new production techniques that were being developed. To the nonexistence of a manufacturing nucleus at a stage when production techniques were being revamped in the last quarter of the century, must be ascribed the fact that Portugal became an agricultural dependency of England." (Furtado, 1963:90).

Other industrialization efforts met similar fates. Around 1770 Portugal developed a plan that reestablished manufacturing, especially along the coast. The effort ultimately failed, partly because of the invasion of France that forced Portugal back to pre-1770 trade patterns, especially with Great Britain. Portugal was left with an economy dominated by a traditional, slow growth agricultural sector with only small pockets of primitive manufacturing. During the second half of the 19th century Portugal attempted again to industrialize; this time by building its infrastructure. This effort failed. As an example, from 1855 to 1859 light manufacturing in textiles and chemicals averaged approximately 7% of exports, but by 1890 no industrial products were exported (in percentage terms) (Sideri, 1970:170 and 175). In sum, trade policies that resulted in Portugal's specialization in zero feedback industries did play a significant role in its failure to converge to the wealthier European countries. By the late 1960's and early 1970's, Portugal did converge slightly in terms of overall per capita income. However, this convergence of per capita income did not result from a convergence of vertically integrated labor productivity. In these terms Portugal was still diverging in 1975. Perhaps this is part of the reason behind Portugal's failure to continue its slow convergence of per capita income since 1975 as is demonstrated by the Summers and

Heston (1988) data set. It was not grounded in the secure foundation of vertically integrated labor productivity convergence.

5. Conclusion

This paper demonstrates that while Portugal and Japan were at similar stages of development in terms of technology and per capita GNP in 1959, by the mid 1970's Japan had converged quickly to the standard of living of the U.S. while Portugal had not. Our explanation of the two countries' convergence experiences focuses on the role played by increasing returns, learning by doing, and technological-spillover (i.e., positive-feedback goods) industries. In increasing returns models, patterns of convergence or divergence can become self-perpetuating as initial conditions become locked in. If cumulative causation and technological lock-in are important elements in determining convergence or divergence paths, then economists need to look to turning points in a country's history to analyze how these paths are established. For Japan, we focused on the early decisions by the Meiji government to foster cotton textiles as an import competing industry, and to build a high-technology military industry. These sectors proved to be very dynamic in terms of technology creation and dissemination, and the cultivation of other related industries such as machinery, shipbuilding, steel, etc. For Portugal, we focused on the persistent failure to develop such industries. Historically, Portugal gave up on industrialization efforts as trade concessions to Great Britain, establishing a pattern of specialization in low-productivity-growth agricultural products. This set the stage for the productivity divergence witnessed from 1959 to the mid 1970's.

The main point is not that positive-feedback industries tell the whole story. We have argued, however, that early historical patterns of political and social action can have important long-term effects. As Hodgson (1991, p. 162) puts it, "...events occuring during a crucial and formative period of change may greatly influence later socio-economic outcomes." We have argued, for example, that when international trade acts to expand small initial differences (in productivity, etc.), divergence can be an endogenous result of exchange rather than an anomaly generated outside of exchange.

The ability or inability of a nation to converge to the productivity level of the country on the global frontier no doubt depends on that nation's attainment of a certain threshold level of income, education, capital accumulation, and equality of income distribution. We have emphasized the role of institutional development, including an ability to manage international trade and capture external economies, and to coordinate investment. The determination of the required threshold and the factors necessary for its attainment are difficult to capture in a single formal model, and it is not surprising that no choice-theoretic micro model has been developed to explain the phenomenon. We have proposed instead an eclectic approach which involves the use of input-output data to analyze the degree of convergence or divergence and historical analysis to capture the conjuncture of socio-economic factors that influence the process. "Capital" is considered heterogeneous and produced, thus overcoming the bias inherent to analysis based on homogeneous capital and aggregate production functions. Overall our approach is not a far cry from the original approach by Gershenkron (1952) to his "advantages of relative backwardness" hypothesis, which took the form of a careful institutional study of the development of Russian socio-economic development.

Endnotes

1. Gomulka (1987), for example, describes the rationale for convergence a "commonsense notion".
2. Baumol, Blackman and Wolff (1989) and Marris (1982) are good examples. Nelson (1990) and Nelson and Wright (1992) locate convergence in U.S. decline, but do not depict this as inevitable.
3. Presumably this is consistent with the view that the productivity growth slowdown in advanced industrial countries over the past twenty years is due to the increasing share of services in total output.
4. See also Mueller (1983), and Hodgson (1988).
5. Among the first studies along these lines was the work of Gomulka (1971, 1979). In the more recent literature see, for example, Abramowitz (1983), Baumol (1986), DeLong (1988), Baumol and Wolff (1988), Gomulka (1990), Barro (1991), and Baumol (1992).
6. Quoted by Alam (1992) from Cameron (1982).
7. Moreover, the *ad hoc* models have an ambiguous interpretation. When all other factors are accounted for, what is the meaning of the technology gap term? Specifically, most of the studies of the Gershenkron hypothesis use regression analysis. First it is observed if the base year level of productivity is inversely correlated with the growth rate during the period under consideration. If this relationship ("gross convergence") is weak, then further analysis is undertaken to control for other factors, including educational attainment, investment in machinery and equipment, degree of openness to trade, etc. Usually when this is done, the "productivity gap" variable becomes significant. That is, the advantages of backwardness are shown once other variables are controlled for (so-called "net convergence"). But by isolating all these other variables, they are leaving the backwardness variable void of meaning. In itself the backwardness variable is only a proxy for these other factors which (presumably) could be measured explicitly. The variable

has no meaning in itself, except as a proxy for technological disadvantage, which itself is meaningless unless combined with a theory of technological diffusion.

8. Note that these explanations are different from models of "uneven development." The latter are aimed at explaining divergence and thus, like the common forces and contagion models, emphasize only one possible outcome. Some prominent models of divergence include Dixon and Thirlwall (1975), Krugman (1981) and Mainwaring (1991). Also see Milberg and Elmslie (1993).

9. For a more complete analysis of Smith's theory of trade and development see Elmslie and James (1993).

10. See, for example, Baumol (1986, 1992), Baumol, Blackman and Wolff (1989), Wolff (1991), Dollar and Wolff (1988, 1992) and Dowrick and Nguyen (1989).

11. Note that the resurgence in popularity of the aggregate production function is not limited to the convergence literature. The "new" growth theory and the New Classical macroeconomics are also based on this discredited concept. (See Romer, 1986, Plosser, 1989)

12. Of course the rejection of the Solow residual is equivalent to a rejection of the neoclassical notion of a shift versus a movement along a given production function. Kaldor (1961) rejected the feasibility of this distinction and thus turned to a technical progress function as an alternative.

13. The percentage rate of change in A equals the following: $\hat{A}/A = [(1-s)\hat{w}/w + (s)\hat{r}/r]$, where s, r, and w are the constant share of income going to capital, the rate of profit, and the wage rate. In a disaggregated, homogeneous input, homogeneous output model, with Hicks neutral technical progress, $\hat{A}/A$ is immune to changes in w and r (i.e., a movement along a linear wage-profit frontier). However, absent these strict assumptions, or those adopted in Samuelson (1962), $\hat{A}/A$ is influenced by changes in wage and profit rates, changes in the

composition of output, and changes in the valuation of capital. All of these are independent of changes in technology.

14. Baumol, Blackman and Wolff (1989) do calculate input-output based measures of labor and total productivity, but these are done only for the case of the U.S. in 1947 and 1976, and in order to confirm the NIPA-based observed stagnancy of labor productivity in service sectors in the U.S. resulting from "cost disease".

15. Momigliano and Siniscalco (1984) argue that the direct approach will be misleading if indirect effects are significant. Also see Milberg and Elmslie (1992).

16. See Pasinetti (1973).

17. See United Nations (1976). This is the most up-to-date internationally compatible input-output data set. Maddison (1982, 1991) and Summers and Heston (1988), the usual data sources for convergence tests, provide only aggregate data and are used below for the purpose of general comparison with our disaggregated results.

18. The coefficient of variation is the standard deviation divided by the mean.

19. More recently, Dollar and Wolff (1992) report a major slowdown in the rate of convergence in nine countries after 1972. This is consistent with the results reported here.

20. The exception is that Italy appears as the low productivity country in sector three in 1970. This is obviously a data error. Italy was the high productivity country in sector three for 1959 and 1965. Moreover, the ratio jumps from 4.05 in 1965 to 13.75 in 1970 and back down to 2.30 in 1975.

21. As Table VIII reports, primary products exports did rise until WWII. This export expansion clearly represents a rapid rise in agricultural productivity that characterised the Meiji period. As we will show was the case in manufacturing, this increase in agricultural productivity resulted from direct government policy. This policy was aimed at increasing the information flow

between farmers as to the best practice techniques, and the transferring of foreign techniques. The latter effort began by bringing in foreign experts from the United States and Great Britain. However, the large scale techniques encouraged by these consultants proved unsuitable to Japan's small plot farms. The Japanese then sought the expertise of German and Dutch scientists and engineers. They encouraged improvements in technique and seed, as well as the increased use of fertilizers. These changes were a major source of improved agricultural productivity during the Meiji period. The increase in agricultural productivity was sought by the government largely as part of its overall industrialization effort. (Maddison, 1965)

22. In the early period exports were dominated by silk textiles, later cotton textiles became a primary export.

23. These figures were developed from Yamazawa and Yamamoto (1979).

24. The members also agreed not to hire skilled workers away from each other. When this pledge failed, the association acted to mediate (Crawcour, 1988).

25. The dyestuffs industry was also an important downstream industry developed directly from textiles (Yamazawa, 1990).

26. Oshima (1965) is one example.

27. For example, cotton textiles exports exceeded imports for the first time in 1897. This export success was aided greatly by the victory in the Sino-Japanese War which resulted in the opening of the cotton trade to China.

28. Cotton textiles was an early benefactor. The Osaka plant used gears supplied by an arsenal, while most other early plants used steam engines produced by an arsenal (Yamamura, 1977).

29. The Yawata Iron Works was created in 1895 because of the increased demand for iron associated with the war. With great technical assistance, production began in 1901 and was Japan's first successful major heavy industry (Iriya, 1989).

30. These shipyards also produced locomotives, turbines, railroad cars and other machinery for the private sector (Yamamura, 1977).

31. In fact Portugal's per capita GDP grew faster than Norway's from 1965 to 1970.

32. The major exceptions were tropical medicine and civil engineering.

33. This is confirmed by the vertically integrated analysis above. Portugal is second only to Japan in 1959 and 1965 as the lowest productivity country in agriculture, and it is the lowest productivity country in 1970 and 1975.

34. In 1950, 48% of employment was in agriculture, while agriculture accounted for 28% of the GNP and 70% of exports. By 1970, agriculture accounted only for 32% of employment and 17% of GNP, while manufactured goods accounted for 60% of exports. (Murteira, 1979)

35. The treaty brought a formal end to Portugal's first major attempt an industrialization policy. In the late 17th century, D'Ericeira (superintendent of manufactures Portugal) developed an industrialization plan centering on glass and textiles. This effort included "hiring foreign experts and artisans from France, England, Spain, and Venice; lending funds; and granting all sorts of privileges to the new industries." (Marques, 1976:382)

References

Abramowitz, M., 1983, "Notes on International Differences in Productivity Growth Rates," in Mueller, D. (ed.) *The Political Economy of Growth*, New Haven: Yale University Press.

_______, 1986, "Catching Up, Forging Ahead, and Falling Behind," *Journal of Economic History*, 46, June, 385-406.

Akamatsu, K., 1961, "A Theory of Unbalanced Growth in the World Economy," *Weltwirtschaftliches Archiv*, 86.

Alam, M., 1992, "Convergence in Developed Countries: An Empirical Investigation," *Weltwirtschaftliches Archiv*, 128, No. 2, 189-201.

Arthur, B., 1989, "Competing Technologies, Increasing Returns, and Lock-In by Historical Events," *Economic Journal*, 99.

Barro, R., 1991, "Economic Growth in A Cross-Section of Countries," *Quarterly Journal of Economics*, 106.

Baumol, W., 1986, "Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show," *American Economic Review*, 76, No. 5, December, 1072-85.

________, 1992, "Multivariate Growth Processes: Contagion and Common Forces as Possible Sources of Convergence," presented at conference on "Historical Perspectives on the International Convergence of Productivity," New York University, April.

________, Blackman, S., and Wolff, E., 1989, *Productivity and American Leadership*, Cambridge: MIT Press.

________, and Wolff, E., 1988, "Productivity Growth, Convergence, and Welfare: Reply," *American Economic Review*, 78, 1155-59.

Blomstrom, M. et al., 1992, "A Cross-Country Study of Growth in Developing Countries," presented at conference on "Historical Perspectives on the International Convergence of Productivity," New York University, April.

________, and Wolff, E., 1992, "Multinational Corporations and Productivity Convergence in Mexico," presented at conference on "Historical Perspectives on the International Convergence of Productivity," New York University, April.

Cameron, D., 1982, "Social Democracy, Corporatism, and Labor Quiescence: The Representation of Economic Interest in Advanced Capitalist Societies," presented at Stanford University.

Chatterji, P., 1992, "Convergence and Growth Amongst Rich and Poor," mimeo, Vassar College.

Crawcour, E. Sydney, 1988, "Industrialization and Technological Changes, 1885-1920," in P. Daus ed., *The Cambridge History of Japan*, Vol. 6, Cambridge: Cambridge University Press.

DeLong, J.B., 1988, "Productivity Growth, Convergence, and Welfare: Comment," *American Economic Review*, 78, No. 5, 1138-54.

_______, and Summers, L., 1992, "Equipment Investment and Economic Growth," *Quarterly Journal of Economics*, May.

Dixon, R. and Thirlwall, A.P., 1975, "A Regional Growth Model Along Kaldorian Lines," *Oxford Economic Papers*, 27, 201-14.

Dollar, D. and Wolff, E., 1988, "Convergence of Industry Labor Productivity Among Advanced Economies, 1963-1982," *Review of Economics and Statistics*, 70, Nov., 549-58.

________, and ________, 1992, "Capital Intensity and TFP Convergence by Industry in Manufacturing, 1963-1985," presented at conference on "Historical Perspectives on the International Convergence of Productivity," New York University, April.

Dowrick, S. and Nguyen, D., 1989, "OECD Comparative Economic Growth 1950-85: Catch-up and Convergence," *American Economic Review*, 79, No. 5, December, 1010-30.

Elmslie, B. and James, A., 1993, "The Renaissance of Adam Smith in Modern Theories of International Trade," *Perspectives on the History of Economic Thought*, IX.

_______ and Milberg, W., 1992, "International Trade and Factor Intensity Uniformity: An Empirical Assessment," *Weltwirtschaftliches Archiv*, 128, No. 3, 464-86.

Fagerberg, J., 1988, "Why Growth Rates Differ," in Dosi, G., et al., *Technical Change and Economic Theory*, London: Pinter Publishers.

Furtado, C., 1963, *The Economic Growth of Brazil*, Berkeley: University of California Press.

Garegnani, P., 1970, "Heterogeneous Capital, the Production Function and the Theory of Distribution," *Review of Economic Studies*, 37, June, 407-36.

Gershenkron, A., 1952, "Economic Backwardness in Historical Perspective," in B. Hoselitz ed., *The Progress of Underdeveloped Areas*, Chicago: University of Chicago Press.

Gomulka, V., 1971, *Inventive Activity, Diffusion and the Stages of Economic Growth*, Aarhus: Institute of Economics and Aarhus University Press.

_______, 1979, "Britain's Slow Economic Growth: Low Innovation Versus Increasing Inefficiency," in Beckerman, W. (ed.), *Slow Growth in Britain: Causes and Consequences*, Oxford: Oxford University Press.

_______, 1987, "Catching-up", *New Palgrave Dictionary of Economics*, London: Macmillan.

_______, 1990, *The Theory of Technical Change and Economic Growth*, London: Routledge.

Hikino, T. and Amsden, A., 1992, "Staying Behind, Stumbling Back, Sneaking Up, Soaring Ahead: Late-Industrialization in Historical Perspective," presented at conference on "Historical Perspectives on the International Convergence of Productivity," New York University, April.

Hodgson, G., 1988, *Economics and Institutions*, Cambridge: Basil Blackwell.

_______, 1989, "Institutional Rigidities and Economic Growth," *Cambridge Journal of Economics*, 13(1), March, pp. 79-101.

________, 1991, "Socio-political Disruption and Economic Development," in Hodgson, G. and Scepanti, E. (eds.), *Rethinking Economics*, Aldershot: Edward Elgar.

Hsing, M., 1992, "On the Measurement of Aggregate Production Functions," *Cambridge Journal of Economics*, 16, 463-74.

Iriya, A., 1989, "Japan's Drive to Great-Power Status," in M. Jansen ed., *The Cambridge History of Japan*, Vol. 5, Cambridge: Cambridge University Press.

Kaldor, N., 1961, "Capital Accumulation and Economic Growth," in F. Lutz ed., *The Theory of Capital*, London: Macmillan.

________, 1972, "The Irrelevance of Equilibrium Economics," *Economic Journal*, 82(4), December, pp. 1237-55.

________, 1985, *Economics Without Equilibrium*, New York: M. E. Sharpe.

Krugman, P., 1981, "Trade, Accumulation, and Uneven Development," *Journal of Development Economics*, 8.

________, 1987, "The Narrow Moving Band, the Dutch Disease, and the Competitive Consequences of Mrs. Thatcher: Notes on Trade in the Presence of Dynamic Scale Economies," *Journal of Development Economics*, 27.

________, 1991, *Geography and Trade*, Cambridge: MIT Press.

________, and de Macedo, J.B., 1981, "The Economic Consequences of the April 25th Revolution," in J.B. de Macedo and S. Serfaty eds., *Portugal Since the Revolution: Economic and Political Perspectives*, Westview Press.

Lawson, T., 1993, "The Nature of Post Keynesianism and its Links to Other Traditions: A Realist Perspective," presented at Post Keynesian/Classical economics conference at the University of Utah.

Leontief, W., 1966, *Input-Output Economics*, New York: Oxford University Press.

Lichtenberg, F., 1992, "Have International Differences in Educational Attainment Levels Narrowed?" presented at conference on "Historical Perspectives on the International Convergence of Productivity," New York University, April.

Lockwood, W.W., 1955, *The Economic Development of Japan, Growth and Structural Change, 1868-1838*, Princeton, NJ.: Princeton University Press.

de Lucena, M., 1979, "The Evolution of the Portuguese Corporatism Under Salazar and Caetano," in L. Graham and H. Makler eds., *Contemporary Portugal: The Revolution and Its Antecedents*, Austin: University of Texas Press.

Maddison, A., 1965, "Japanese Economic Performance," *Banca Nazionale Del Lavoro Quarterly Review*, No. 75, 299-354.

________, 1982, *Phases of Capitalist Development*, Oxford: Oxford University Press.

________, 1991, *Dynamic Forces in Capitalist Development*, Oxford: Oxford University Press.

Mainwaring, L., 1991, *Dynamics of Uneven Development*, Aldershot: Edward Elgar.

Marques, A.H. de Oliveira, 1976, *History of Portugal*, 2 volumes, New York: Columbia University Press.

Marris, R., 1982, "How Much of the Slow-Down Was Catch Up?," in R.C.O. Mathews ed., *Slower Growth in the Western World*, London: Heinemann.

Milberg, W. and Elmslie, B., 1993, "The Advantages of Relative Backwardness in the OECD: An Input-Output Approach," in I. Rima ed., *The Political Economy of Restructuring*, Aldershot: Edward Elgar.

________ and ________, 1992, "Technical Change in the Corporate Economy: A Vertically Integrated Approach," in W. Milberg ed., *The Megacorp and Macrodynamics: Essays in Memory of Alfred Eichner*, Armonk: M. E. Sharpe.

Momigliano, F. and Siniscalco, D., 1984, "Technology and International Specialization," *Banca Nazionale del Lavoro Quarterly Review*, No. 150, 257-84.

Mueller, D. (ed.), 1983, *The Political Economy of Growth*, New Haven: Yale University Press.

Murteira, M., 1979, "The Present Economic Situation: Its Origins and Prospects," in L. Graham and H. Makler eds., *Contemporary Portugal: The Revolution and Its Antecedents*, Austin: University of Texas Press.

Nelson, R., 1990, "The U.S. Technology Lead: Where Did it Come From and Where Did it Go?," *Research Policy*, 19, 117-32.

________, and Wright, G., 1992, "The Rise and Fall of American Technological Leadership: The Postwar Era in Historical Perspective," *Journal of Economic Literature*, 30, 1991-64.

Ohkawa, K. and Rosovsky, H., 1973, *Japanese Economic Growth*, Palo Alto: Stanford University Press.

Olson, M., 1982, *The Rise and Decline of Nations*, New Haven: Yale University Press.

Oshima, H., 1965, "Meiji Fiscal Policy and Economic Progress," in W.W. Lockwood ed., *The State and Economic Enterprise in Japan*, Princeton University Press.

Pasinetti, L., 1973, "On the Notion of Vertically Integrated Analysis," *Metroeconomica*, 25, 1-29.

________, 1981, *Structural Change and Economic Growth*, Cambridge: Cambridge University Press.

Plosser, C., 1989, "Understanding Real Business Cycles", *Journal of Economic Perspectives*, 3, No. 3, 51-78.

Ranis, G., 1957, "Factor Proportions in Japanese Economic Development," *American Economic Review*, 47.

Rassekh, F., 1992, "The Role of International Trade in the Convergence of Per Capita GDP in the OECD: 1950-85," *International Economic Journal*, 6, 1-16.

Romer, P., 1986, "Increasing Returns and Long-Run Growth," *Journal of Political Economy*, 94, 1002-37.

Samuelson, P., 1962, "Parable and Realism in Capital Theory: The Surrogate Production Function," *Review of Economic Studies*, 37, 407-36.

Saxonhouse, G., 1974, "A Tale of Technological Diffusion in the Meiji Period," *The Journal of Economic History*, XXXIV.

Shaikh, A., 1980, "Laws of Algebra and Laws of Production: the Humbug Production Function II," in E. Nell, ed., *Growth, Profits and Property*, Cambridge: Cambridge University Press.

________, 1987, "Humbug Production Function," in *The New Palgrave*, J. Eatwell, et al., eds., London: Macmillan Press.

Sidieri, S., 1970, *Trade and Power: Informal Colonialism in Anglo-Portuguese Relations*, Rotterdam University Press.

Solow, R., 1957, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39, 312-20.

Stallings, B., 1981, "Portugal and the IMF: The Political Economy of Stabilization," in J.B. de Macedo and S. Serfaty eds., *Portugal Since the Revolution: Economic and Political Perspectives*, Westview Press.

Summers, R., and Heston, A., 1988, "A New Data Set of International Comparisons of Real Product and Price Levels: Estimates for 130 Countries," *The Review of Income and Wealth*, 34, 1-25.

United Nations, 1976, *Standard Input-Output Tables of ECE Countries for Years Around 1959, 1965, 1970, and 1975*, New York: UN Statistical Commission and Economic Commission for Europe.

Verspagen, B., 1991, "A New Empirical Approach to Catching Up or Falling Behind," *Structural Change and Economic Dynamics*, 2, No. 2.

Ward, M., 1985, *Purchasing Power Parities and Real Expenditures in the OECD*, Paris.

Wolff, E., 1991, "Capital Formation and Productivity Growth Over the Long-Term," *American Economic Review*, 81, No. 3, June, 565-79.

Yamamura, K., 1977, "Success-Ill Gotten? The Role of Meiji Militarism in Japan's Technological Progress," *The Journal of Economic History*, XXXVII.

Yamazawa, I., 1990, *Economic Development and International Trade: The Japanese Model*, East-West Center: Honolulu.

_______ and Yamamoto, Y., 1979, *Foreign Trade and Balance of Payments*, Vol. 14 of K. Ohkawa, M. Shinohara, and M. Umemura, eds., *Estimates of Long-Term Economic Statistics of Japan Since 1868*, Tokyo, Toyo Keizai Shinposha.

Table I

Final Aggregated Industrial Sectors

Sector	Industry Group	Corresponding Original Sectors in the Input-Output Data Base 1959-1965	1970-1975
1	Agriculture, hunting, fishing and forestry	1	1
2	Coal mining, crude petroleum, and natural gas	2	2, 3
3	Metal ore and other mining	3	4, 5
4	Food, beverages and tobacco	4	6
5	Textiles and clothing	5, 6	7
6	Wood, wood products, paper and printing	7	8, 9
7	Chemicals and rubber	8, 9	10
8	Petroleum and coal products	10	11
9	Non-metallic mineral products	11	12
10	Ferrous and non-ferrous metals (Basic Metals)	12	13
11	Machinery, transport and other manufactured goods	13, 14	14, 15
12	Electricity, gas and water	15	16, 17
13	Construction	16	18
14	Trade, distribution, transportation, storage and communication	17, 18	19, 21, 22

Table II

Total Productivity Ratios 1959-1975*

Sector	1959 High/Low	Countries	1965 High/Low	Countries
1	3.76	[J/G]	3.36	[J/G]
2	10.93	[J/N]	11.70	[J/N]
3	6.96	[P/I]	4.05	[P/I]
4	2.41	[I/G]	2.23	[J/G]
5	5.92	[I/N]	3.15	[I/N]
6	4.38	[I/G]	3.66	[J/G]
7	4.20	[I/N]	2.86	[J/N]
8	4.12	[J/N]	6.56	[J/N]
9	4.02	[P/N]	2.71	[P/N]
10	6.29	[J/N]	3.50	[J/N]
11	5.19	[J/N]	3.87	[J/P]
12	8.95	[J/N]	10.68	[J/N]
13	6.74	[P/N]	4.37	[P/N]
14	4.52	[J/N]	4.10	[J/N]
MEDIAN	4.86		3.77	

Sector	1970 High/Low	Countries	1975 High/Low	Countries
1	2.97	[P/G]	4.11	[P/G]
2	5.97	[G/P]	9.86	[I/P]
3	13.75	[I/J]	2.31	[P/J]
4	3.60	[P/G]	4.67	[P/G]
5	3.28	[J/N]	6.46	[P/N]
6	2.37	[J/I]	4.85	[P/I]
7	2.41	[P/N]	3.54	[P/N]
8	3.44	[G/I]	5.43	[P/I]
9	2.44	[P/N]	3.53	[P/N]
10	2.87	[G/P]	1.90	[G/N]
11	2.28	[J/N]	2.43	[J/N]
12	1.86	[P/N]	3.20	[P/I]
13	3.65	[P/N]	3.70	[P/N]
14	2.69	[P/N]	3.54	[P/N]
MEDIAN	2.92		3.62	

*The countries included in this table are Germany, Italy, Japan, Norway, and Portugal. To properly interpret this table, remember that a high vertically integrated labor coefficient implies low total productivity. Thus the country in the numerator (e.g., Japan in sector 1 in 1959 and 1965) is the low-productivity country, while the country in the denominator (e.g., Germany in sector 1 for all years) is the high-productivity country.

(Source: Elmslie and Milberg, 1992)

Table III

Coefficients of Variation of Vertically Integrated Labor Coefficients*

Sector	1959	1965	1970	1975
1	.4599	.5035	.4413	.6567
2	.8438	.7266	.6061	.9444
3	.8454	.5754	.9839	.3826
4	.3069	.2960	.5408	.7370
5	.6414	.4640	.4267	.7390
6	.4730	.4511	.3943	.7250
7	.5854	.3887	.2960	.4866
8	.5946	.7187	.5156	.7259
9	.5465	.4003	.4011	.6207
10	.7297	.4382	.3742	.2423
11	.6746	.6014	.3460	.2965
12	1.1706	1.2936	.2754	.5936
13	.7536	.6223	.6222	.6069
14	.5722	.5060	.3739	.5290
Median	.6180	.5047	.4139	.6138

*The countries included in this table are Germany, Italy, Japan, Norway, and Portugal.

(Source: Elmslie and Milberg, 1992)

Table IV

Gross Domestic Product Per Capita

(Thousands of 1975 $US)

Country	1959	1965	1970	1975
Germany	4876	6209	7443	8067
Italy	2969	3952	5028	5685
Japan	2003	3391	5496	6518
Norway	4866	6205	7104	8580
Portugal	1360	1850	2575	3057
United States	7321	8634	9459	10197

(Source: Summers and Heston, 1988)

Table V

Total Productivity Ratios 1959-1975 Excluding Portugal*

Sector	1959 High/Low	Countries	1965 High/Low	Countries
1	3.76	[J/G]	3.36	[J/G]
2	10.93	[J/N]	11.70	[J/N]
3	2.36	[J/I]	1.88	[J/I]
4	2.41	[I/G]	2.23	[J/G]
5	5.92	[I/N]	3.15	[I/N]
6	4.38	[I/G]	3.66	[J/G]
7	4.20	[I/N]	2.86	[J/N]
8	4.12	[J/N]	6.56	[J/N]
9	2.13	[I/N]	2.25	[I/N]
10	6.29	[J/N]	3.50	[J/N]
11	5.19	[J/N]	3.87	[J/P]
12	8.95	[J/N]	10.68	[J/N]
13	2.54	[J/N]	2.13	[I/N]
14	4.52	[J/N]	4.10	[J/N]
MEDIAN	4.29		3.43	

Sector	**1970 High/Low**	**Countries**	**1975 High/Low**	**Countries**
1	2.24	[J/G]	1.87	[J/G]
2	3.61	[G/J]	6.32	[I/J]
3	13.75	[I/J]	1.57	[N/J]
4	2.41	[J/G]	2.04	[J/G]
5	3.28	[J/N]	3.46	[J/N]
6	2.37	[J/I]	2.34	[J/I]
7	1.98	[J/N]	1.92	[J/N]
8	3.44	[G/I]	4.59	[G/I]
9	1.56	[J/N]	1.73	[J/N]
10	1.86	[G/N]	1.90	[G/N]
11	2.28	[J/N]	2.43	[J/N]
12	1.19	[G/N]	1.26	[G/I]
13	1.55	[I/N]	1.53	[J/N]
14	2.32	[J/N]	1.86	[J/N]
MEDIAN	2.30		1.91	

*The countries included in this table are Germany, Italy, Japan, and Norway.

(Source: Milberg and Elmslie, 1993)

Table VI

**Coefficients of Variation of
Vertically Integrated Labor Coefficients*
Excluding Portugal**

Sector	1959	1965	1970	1975
1	.5267	.5586	.3577	.2936
2	.9193	.8374	.4424	.8063
3	.3311	.2501	1.1092	.2160
4	.3256	.3258	.3924	.3230
5	.7662	.5133	.4655	.5013
6	.5481	.4895	.4183	.3836
7	.6462	.4489	.2707	.2699
8	.6413	.7725	.6028	.7704
9	.3393	.3808	.2045	.2624
10	.7022	.4754	.2547	.2596
11	.6540	.5448	.3316	.3454
12	1.2319	1.3279	.0783	.0944
13	.3434	.3533	.2146	.1949
14	.6337	.5638	.3434	.2465
MEDIAN	.6375	.5291	.3506	.2818

*The countries included in this table are Germany, Italy, Japan, Norway.

(Source: Milberg and Elmslie, 1993)

Table VII

GDP/Man-Hr in 1970 US$

Year	USA	Japan	USA-Japan / USA	Norway	Norway-Japan / Norway
1870	.70	.17	.9975	.40	.575
1880	.88	.20*	.7727	.46	.565
1890	1.06	.24*	.7735	.56	.571
1900	1.29	.32*	.7519	.63	.492
1913	1.67	.37	.7784	.82	.549
1929	2.45	.64	.7387	1.28	.500
1938	2.62	.87	.6679	1.62	.463
1950	4.25	.59	.8612	2.03	.709
1960	5.41	1.03	.8096	3.04	.661
1970	6.96	2.79	.5991	4.78	.416
1973	7.60	3.49	.5408	5.28	.339
1978	8.19	4.22	.4847	6.43	.344
1979	8.28	4.39	.4698	6.65	.340

*Interpolated using constant geometric growth, 1870-1913 data (n.a.)

(Source: Maddison, 1982)

Table VIII

Japan Commodity Exports by Industry at Constant Prices 1874-1939, 1951-1970*

Year	Processed food	Text- iles	Wood Prod.	Chemicals	Ceramics	Metals	Machin- ery	Misc. Manuf.	Total Manuf.	Primary Products	Total Exports
1874	1.8	9.3	0	3.2	.1	1.5	0	.3	16.3	20.5	38.5
1880	2.2	14.5	0	8.4	.6	2.5	0	1.7	29.9	29.6	61.4
1885	3.1	24.3	.2	10.2	.8	6.6	0	2.5	47.8	37.1	88.8
1890	2.1	27.5	.2	13.8	1.5	12.5	.1	4.0	61.8	49.9	115.7
1895	4.8	81.9	.7	19.6	2.6	10.2	.3	10.3	130.5	71.2	209.1
1900	8.3	97.1	23.4	25.7	4.2	13.0	.8	17.2	169.8	77.6	262.5
1905	35.3	164.3	9.4	40.2	9.6	14.3	3.7	29.3	306.2	74.1	400.6
1910	33.0	290.7	17.1	56.4	11.5	29.5	7.4	43.6	489.1	104.6	628.3
1915	46.3	420.1	18.7	95.1	19.1	56.8	18.4	100.3	774.9	143.4	968.3
1920	50.6	475.3	20.7	87.4	23.9	56.0	36.9	82.4	833.2	91.6	995.6
1925	79.8	768.8	16.2	99.9	35.1	49.8	26.1	82.0	1157.8	145.8	1435.9
1930	119.7	871.3	15.8	171.5	53.2	106.1	72.4	106.2	1516.4	136.8	1755.3
1935	208.5	1665.1	42.8	311.2	103.8	256.2	251.3	216.7	3055.7	210.5	3411.1
1939	235.9	1353.5	106.2	395.9	113.8	232.6	456.6	252.9	3147.4	278.6	3480.0
1951	13.7	135.4	4.8	16.8	20.4	72.9	29.5	17.5	311.0	16.4	332.3
1955	33.8	257.7	15.5	31.5	32.5	116.8	87.3	40.8	615.8	37.5	668.5
1960	68.4	428.8	21.4	89.8	56.1	192.9	320.3	126.3	1304.0	75.8	1405.9
1965	81.1	519.0	35.7	309.8	95.4	618.4	1043.4	224.7	2927.5	93.4	3057.7
1970	148.2	768.9	37.2	872.3	129.8	1160.0	2986.0	284.2	6386.7	85.8	6547.8

Source: Estimates of Long-Term Economic Statistics of Japan Since 1868 eds. Kazushi Ohkawa, Mizohei Shinohara, and Malaji Umemura, Volume 14, Foreign Trade and Balance of Payments, Ippei Yamazawa and Yuzo Yamamoto, Toyo Keizai Shinposha: Tokyo, 1979. Crawcour (1988) cites Japanese language critiques of this 14 volume data set.

*1874-1939 are given in 1935-1936 prices in million of yen; 1951-1970 are given in 1965 prices in billions of yen.

Table IX

Changes in the Importance of Manufactures in Japanese Exports

Year	**Total Manuf./Total**	**Textiles/total Manufactures**	**Manuf. Exports*/ GNP**
1874	.423	.571	-
1880	.487	.485	-
1885	.538	.508	-
1890	.534	.445	-
1895	.624	.628	-
1900	.647	.572	-
1905	.764	.537	.046
1910	.778	.594	.062
1915	.800	.542	.090
1920	.837	.570	.072
1925	.806	.664	.093
1930	.864	.575	.109
1935	.896	.545	.166
1939	.904	.430	.141
1951	.936	.435	.037
1955	.921	.418	.063
1960	.928	.329	.084
1965	.957	.177	.116
1970	.975	.120	-

*GNP data is taken from Japanese Economic Growth: Trend Acceleration in the Twentieth Century by Kazushi Ohkawa and Henry Rosovsky, Stanford University Press: Stanford, 1973. To 1939, GNP is given at 1934-36 prices in million yen, from 1951, GNP is given at 1960 prices in billion yen.

Appendix A: Data Sources and Manipulation

a. Input-Output Tables

The **A** matrices of each country were constructed from the *Standardized Input-Output Tables of ECE Countries for Years around 1959, 1965, 1970, and 1975* published through the United Nations by the Economic Commission for Europe. Each transaction matrix for years around 1970 and 1975 is aggregated to 24 sectors by the ECE utilizing the post-1965 International Standard Industrial Classification (ISIC). Most sectors are aggregated to the 2-digit level. Each matrix for years around 1959 and 1965 is aggregated to 20 sectors by the ECE using the pre-1965 ISIC.

In order to make the tables compatible with each other and the available labor data, certain manipulations of the data were performed. First, the tables were made compatible. Italy had one sector that was not reported in 1970 and 1975; this sector had to be filled in order for the results to be comparable between countries. The missing sector is other mining (ISIC 29). The methodology to develop the Italy sector was to take the data from France and assume $x_{ijy}/l_{iy} = x_{ijz}/l_{iz}$ where i and j are standard input-output sectors, and y and z are each country. The x_{ij} for Italy was then divided by its purchasing power parity exchange rate (z/y) to make it conform with the rest of the table. The sectoral output data are derived by assuming that $x_{iy}/l_{iy} = x_{iz}/l_{iz}$. Again, this is divided by the purchasing power parity exchange rate.

The vertically integrated labor coefficients were made compatible between countries by converting the country-currency-denominated output to a dollar-denominated output, multiplying by the United States purchasing power parity exchange rate from *Ward (1985)*. Also, the output was deflated by dividing by a wholesale price index (1970 = 100) for general goods published in the *Statistical Yearbook (1977)*.

Second, in order to make the tables consistent with the labor data, we aggregated the 24 sectors for 1970 and 1975 and the 20 sectors for 1959 and 1965 into 14 sectors shown in Table I.

b. Labor Data

The labor data used to develop the direct labor coefficients are taken from the *Yearbook of Industrial Statistics, Vol. 1, 1976* edition published by the United Nations, and from *Labour Force Statistics, OECD, 1986*. To obtain the missing sector for Italy the following methodology was employed: $l_{iy}/X_{iy} = l_{iz}/X_{iz}$ for countries y and z.

Appendix B: A Model of Convergence and Divergence

Consider a simple Ricardian **m** country, one factor world producing **n** goods with constant returns to scale at any time **t**. Following Krugman (1987), actual labor productivity at any point in time is a function of cumulative output. Goods are defined by the effect of experience on productivity and the effect of output on experience. Let X_{ij} indicate the output of any good **i** from country **j**. For reasons that become clear later, these goods are called positive-feedback goods. Also, let x_{ij} represent the output of any zero-feedback good **i** produced by country **j**. Given a Ricardian formulation of the model, we obtain the following:

$$\begin{aligned} X_{ij}(t) &= A_{ij}(t)\ L_{ij}(t) \qquad i = 1-h \\ x_{ij}(t) &= a_{ij}(t)\ l_{ij}(t) \qquad i = h-n \end{aligned} \tag{1}$$

where L_{ij} and l_{ij} are the labor used to produce X_{ij} and x_{ij} respectively, and $A_{ij} = X_{ij}/L_{ij}$ and $a_{ij} = x_{ij}/l_{ij}$.

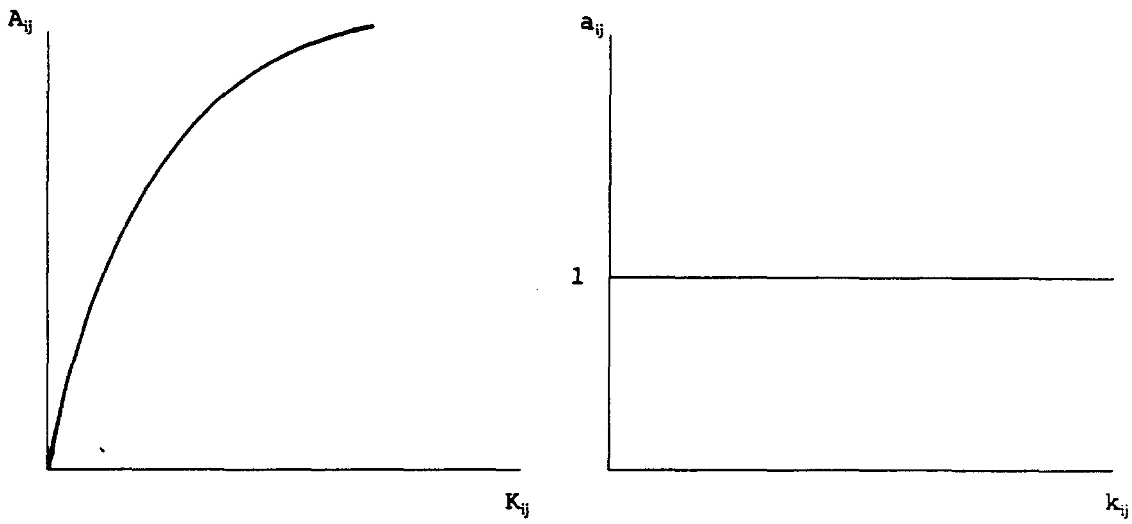
Over time, as experience accumulates, productivity increases due to learning. Thus:

$$\begin{aligned} A_{ij}(t) &= K_{ij}(t)^{\epsilon_j} \qquad 0<\epsilon_j<1 \\ a_{ij}(t) &= k_{ij}(t)^{\lambda_j} \qquad 0\leq\lambda_j<1 \end{aligned} \tag{2}$$

where K_{ij} and k_{ij} represent accumulated knowledge in the production of any X_i and x_i for each country **j**. One distinguishing characteristic between positive and zero-feedback goods is that $\epsilon_j > \lambda_j$ for all **j**'s. In practice, goods have more or less positive feedback characteristics. For simplicity assume that $\lambda_j = 0$ and $\epsilon_j > 0$. The relationship between productivity and output for positive and zero-feedback goods is shown in figure 1.[1]

[1] Note that in the general case a_{ij} is below A_{ij} for any constant level of $K_{ij} = k_{ij}$.

Figure 1



Knowledge is accumulated by increased output. However, knowledge in any given good X_i and x_i is augmented not only by increases in a commodity's own output, but also by the increased output of other industries (i.e., producers of jet aircraft learn from the aerospace industry, etc.). Thus:

$$K_{ij}(t) = \int_o^t X_{ij}(z) + \delta x_{ij}(z)dz \qquad 0 \leq \delta < 1$$
$$k_{ij}(t) = \int_o^t \alpha X_{ij}(z) + \beta x_{ij}(z)dz \qquad 0 \leq \alpha < 1 \qquad 0 < \beta < 1 \tag{3}$$

where t is time, z is the integration factor over time and δ, α, and β are parameters specifying the rates of knowledge spillover.

Knowledge is transmitted perfectly between positive-feedback goods, but these goods can gain knowledge from zero-feedback goods as well. The closer δ is to zero, the less of this type of knowledge accumulation that takes place. Zero-feedback goods producers also accumulate knowledge, but this occurs at a slower rate which is determined by α and β.

Thus, two characteristics distinguish positive from zero-feedback goods. First, from equation 2, learning has a stronger effect on the labor productivity in positive-feedback goods production. Second, from equation 3, knowledge is accumulated faster for any given increase in output for positive-feedback goods.[2]

Now, assuming full employment, fixed labor forces in each country **j**, and no savings, we may open the model to international trade. Countries will specialize production in either a positive-feedback or a zero-feedback good. The determinant of any country's specialization pattern may be any number of factors.[3] For example, country 1 may have a technological advantage in the production of any positive-feedback good, thus it has a high ϵ. Country 2 may be larger, thus possessing a great deal of experience, or its laborers may have a strong tastes for a particular good, also resulting in a larger accumulation of knowledge. Whatever the reason, some countries specialize in a positive-feedback good while others specialize in a zero feedback good.

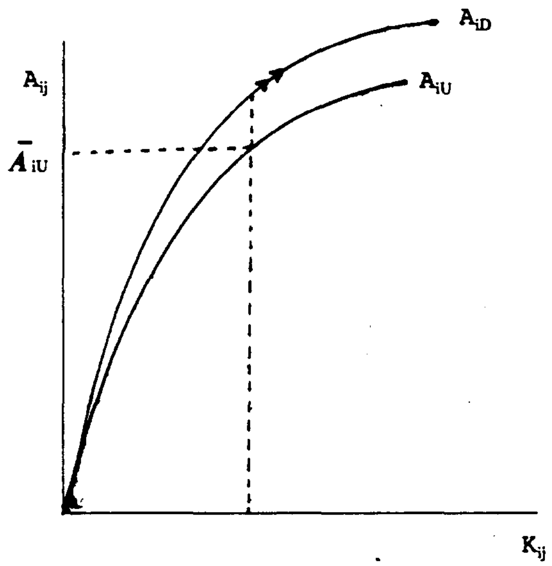
Continuing with the special case example where $\lambda = 0$, we denote countries specializing in positive-feedback goods as D and countries specializing in zero-feedback goods as U. Also assume in this case that specialization is based on a technology gap between D and U in the production of positive-feedback goods. Thus, for any given K_i, $A_{iD} > A_{iU}$. The opening to trade forces U out of positive-feedback production. As shown in figure 2, this causes A_{iU} to stagnate at $\bar{A}_{iU}$, while A_{iD} increases with increased knowledge.

---

[2]For the special case described in Figure 1, knowledge plays no role in increasing labor productivity.

[3] Given that this is not a model interested in establishing one major factor determining trade patterns, we are not particularly concerned with what determines trade patterns in any specific case.

Figure 2



Relative productivities continually diverge (i.e., trade causes a divergence of relative productivities so that $\frac{A_{iD}}{\bar{A}_{iU}} = \frac{K_{iD}^{\epsilon_D}}{K_{iU}^{\epsilon_U}}$ continually increases. In the special case, the zero-feedback goods play no direct role in the measure of divergence.

The result of international trade is not one "convergence club" but two. D countries converge to each other, at ever increasing productivity levels, while U countries converge at a stagnant level. A further important result of the continued divergence between the D and U countries is that once a pattern of specialization is established it is ever more difficult to overcome. This is the lock-in result often referred to in the positive feedback literature.