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ADAPTIVE ECONOMIC GROWTH

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ADAPTIVE ECONOMIC GROWTH

Abstract

This paper outlines an evolutionary theory of adaptive growth based on the twin principles of enterprise and the co-ordinating role of markets. The central organising idea is that economies never grow without simultaneous development. Growth as conventionally understood is a product of structural change and economic self-transformation, and these processes are closely connected with but not reducible to the growth of knowledge. The dominant theme is enterprise, the variations it generates, and the multiple connections between investment, innovation, demand and structural transformation. We explore the dependence of macroeconomic productivity growth on the diversity of technical progress functions and income elasticities of demand at the industry level, and the resolution of this diversity into patterns of economic change through market processes. We show how industry growth rates are emergent phenomena, constrained by higher order processes of emergence that convert an ensemble of industry growth rates into an aggregate rate of growth. The growth of productivity, output and employment are determined mutually and endogenously, and their values depend on the variation in the primary causal influences in the system.

INTRODUCTION

The purpose of this paper is to provide an evolutionary account of technical progress and economic growth in which the central phenomena to be explained are self-transformation, the emergence of macro-structure from micro-diversity and co-ordination through markets. Like Nelson and Winter (1974), we argue that macroeconomic explanations of economic growth that are driven by technical progress should be compatible with the vast diversity of micro level evidence concerning the events and processes that constitute the notion of 'innovation'. Modern theories of endogenous growth, even in their most sophisticated forms (see, for example, Aghion and Howitt (1998)) do not do this in any comprehensive manner. We argue that this is a fundamental shortcoming, because it is the generation and resolution of economic diversity that is the principal source of growth. Without the recognition of economic diversity, it is not possible to formulate a theory of economic growth that connects with the actual processes of development and change that we observe in historical time. How we assemble the macro from the micro is a central theme of this paper as is the related issue of the audit trail by which we track the emergent consequences of individual innovations. Like endogenous growth theory, however, we do place considerable emphasis on dynamic increasing returns as a key element in the understanding of the connection between innovation, enterprise and adaptive growth. However, the perspective we take is that pioneered by Allyn Young and Nicholas Kaldor.

Growing economies self transform, and so the problem of growth is a problem of adaptation; of changing the allocation of resources and the composition of demand in response to the opportunities opened up by the growth of knowledge. Much of this knowledge is practical knowledge, defined in relation to technique, organisation and consumption practice, and it is generated in the context of the market process and the resultant patterns of growth. It is naturally endogenous. The essential point is that the growth and application of knowledge are embedded in the economic process itself. As Schumpeter insisted, such transformation arises from *within* the socio-economic system. In the Schumpeterian account, enterprise driven, adaptive development is the primary phenomenon and aggregate growth is a secondary consequence. Although enterprise is the vector for the acquisition and application of knowledge, it is markets that facilitate the transmission and co-ordination of knowledge both prior to, and during, the occurrence of trade and contracting. Knowledge is not something that is outside the economic process, as if it is just a given factor of production. If we make enterprise and the market the twin pillars of economic growth, then it is the development of knowledge that renders the underlying process of economic evolution as both adaptive and transformational in character.

In thinking about economic growth in this way, two broad questions arise: How does enterprise connect with economic growth? How can we construct a growth theory that captures the creative and adaptive features that characterise all economic change?' Our answers lead us to a theory of growth premised on the view that markets are essential to the co-ordination of micro-diversity (Eliasson, 1998; Silverberg and Verspagen, 1998; Fagerberg and Verspagen, 1999). It differs from many accounts of growth in a number of important ways. First, the analytical framework that we present is quite different to those that treat growth as a macroeconomic phenomenon *simpliciter*. All of the aggregates that we deal with are constructed consequences of the interaction between different industries in relation to the growth of productivity and the distribution of the ensuing increments in demand. The macroeconomic dimension of our analysis relates to the connections that exist between the ensemble of activities that define an economic system. It deals with the *interdependence* between economic sectors, because productivity growth in one sector spreads to others via income and expenditure flows through markets. Growth rates are emergent system properties, they are premised on interdependence and these system properties are inseparable from the manner in which activities are co-ordinated and ordered.

Secondly, it is central for the following exposition to recognise that enterprise economies are inherently restless, they experience continual change in relation to the relative importance of different economic activities; the qualitative nature of these activities changes over time and they are never in a steady state of growth, as this is usually conceived. The idea of steady-state growth in a capitalist economy is, we are afraid, untenable simply because the idea of the steady growth of knowledge is untenable. This, of itself, poses a deep challenge for growth theory. The steady state devices applied to semi-stationary growth (Bliss, 1975), or to proportional dynamics (Pasinetti, 1993) are no more than means to reduce the economy to a single sector in the sense that the relative proportions of different activities are frozen in time[1]. There is neither structural change in these contrived macro worlds nor development, only uniform expansion or, just as readily, uniform contraction. In approaching the analysis of economic growth in this way, we effectively rule out any meaningful connection between the growth of knowledge and the growth of the economy. This is why the theory of economic growth must begin with the idea of self-transformation. In turn, self-transformation implies that the diversity of growth rates that we observe in the economy is crucial to the process of growth and that the decline in some productive activities is just as important part of the picture as the expansion of others.

Thirdly and consequently, aggregate, measured growth is no more than a statistical feature of economic systems; we can measure in macro economic terms but we cannot understand growth in these terms. The fact that the economy is an ensemble does not justify its analysis as an aggregate entity. This is not simply because aggregation obscures the significance of diversity and economic structure, as if the latter were a needless statistical complication in the analysis of growth. Rather it is because transformation or adaptation is the way the economy responds to emergent novelty in the form of innovation. To hide this is to remove from view the very process that explains the growth of productivity and output. We call this the ‘ensemble approach’ to economic growth, in which, the aggregate properties of an economic process depend on its structure and they change with that economic structure. Macro phenomena are necessarily constructed statistics and they have no independent existence beyond their reflection of the underlying structure of the ensemble. As we shall see, the way we aggregate and the weights we use in adding across different activities is dependent on the precise theory of co-ordination and change that we invoke. Consequently, from a macro perspective, we cannot confront the importance of two of the most important stylised facts of modern economic growth; namely, the wide micro diversity of productivity across different industries and the ever-present element of structural change over time (Kuznets, 1954, 1971, 1977; Harberger, 1998). Nor can we incorporate the role of demand in shaping growth patterns between industries; indeed it is remarkable that the modern growth story is a predominately a supply side account of the expansion of productivity and inputs. Changes in demand are ignored and the coordinating role of markets in the growth process is lost from view. Market co-ordination is central to any understanding of growth but co-ordination is not equilibrium, it is order, and in knowledge-driven economies, order is forever changing (Loasby, 1999).

Fourthly, the origins of restless capitalism lie in its unlimited capacity to generate new knowledge and new behaviours from within, and it is this propensity for endogenous variation that makes it so dynamic, sufficiently so that economies may be completely transformed in structure over relatively short periods of historical time. Moreover, every advance in knowledge creates the conditions for further advances; in the language of systems theory, economic growth is an autocatalytic process in which change begets change. But variety and innovation are only part of the picture. Equally important is the co-ordination of variety by market institutions to determine how differences in behaviour are resolved into evolving patterns of economic activity. The growth consequences of novel behaviour are deeply dependent on the way in which economic activities are co-ordinated within market processes; and these processes of co-ordination require a demand side as well as the more familiar supply side perspective on the innovation process.

Fifthly, the theoretical and empirical challenge is to place structural change and the adaptive reallocation of productive resources at the core of the theory and to let these processes drive, and be driven by technical progress. We argue that this requires an evolutionary analysis and such evolutionary methods are inherently statistical in nature. Therefore, we deal below with the central problem of how to combine lower level variables into higher-level averages, and how to relate statistical moments around these averages to the pattern of economic change. We find it helpful to distinguish secondary moments between endogenous variables from primary moments defined over the given data of the economy, and then to explain those secondary moments and their changes in terms of the more fundamental primary equivalents. Thus, the variables to be explained are in the form of co-distributions, for example, between growth rates and profit margins and the explanation is in terms of co-distributions between capital output ratios and income elasticities of demand at industry level.

Finally, in developing this evolutionary approach to economic growth, we intend to achieve two main objectives. The first is to further develop evolutionary economic theorising beyond the partial frameworks of firm and industry, which have so far characterised its development. The second is to connect evolutionary growth theory to the immensely rich literatures, which study innovation and its management, the history of technology, and the capabilities of firms and other institutions that jointly shape the growth and application of knowledge. These literatures are natural complements to an evolutionary theory of economic growth; they frame our understanding of the processes generating and limiting innovation, and they provide countless empirical examples to shape our thinking on the knowledge-growth connection. An equilibrium, macro-oriented theory of growth cannot make these connections, an evolutionary theory can (Montgomery, 1995; Foss and Knudson, 1996). It may also contribute towards meeting the considerable challenge of writing a reasoned history of capitalism (Freeman and Louca, 2001).

A summary of the argument may help here. The theory of self-transformation relies on the interaction between three processes acting across an ensemble of interconnected industries that constitute the 'economy'. These are the dynamics of investment and induced productivity growth, the dynamics of demand growth, and the aggregate constraint imposed by the co-ordination that takes place in the capital market. On this interconnected ensemble we can define whatever aggregate measures we wish, but we do not require these aggregates to mimic the behaviour of any micro representative agent. That would be a most counter evolutionary requirement to impose on the aggregation process, for we are concerned with the emergence of patterns at higher levels that are not present at lower levels of aggregation. In turn, these higher levels of emergence act as constraints on lower levels of emergence. The chief example of such a constraint is quite familiar - that injections must equal leakages, in the aggregate flow of expenditure.

In each industry, we have dynamic increasing returns in which output growth induces productivity growth along the Smithian lines developed by Young and Kaldor and, taking the ensemble of industries together, we establish the conditions for defining their relation with the average rate of productivity growth. This is necessarily equal to the rate of growth of per capita income, which in turn induces growth in the per capita level of demand for the output of each industry. In this way growth feeds on itself, it is autocatalytic, and feedback effects from the growth in demand make the rates of industry productivity growth interdependent. The uneven distribution of growth across industries produces structural change in the economy automatically, and, the consequent changes in the relative importance of the different industries, redefines the dynamic complementarity between them. Thus, aggregate growth rates are emergent phenomena, they arise because of the economic interaction between the industries but they are not independent of the aggregate requirement that leakages equal injections.

This top-level capital market constraint interacts with the conditions of increasing returns, to determine simultaneously and endogenously the rate of output growth and the rate of productivity growth. In this analysis, structure matters and structure implies degrees of correlation between the determining elements involved in the evolutionary process. This element of correlation is the prerequisite of an evolutionary process. The evolutionary process, in turn, alters structure yielding an adaptive, far from equilibrium process of self-transformation that is fuelled by the continual generation of economic novelty. This is not a new story to anyone who has thought through the implications of the famous dictum that the division of labour determines and is determined by the extent of the market. However, it is a story that allows the weaving together of diversity in technical progress with diversity in demand dynamics to generate endogenous, evolutionary growth and adaptation.

SOME EVIDENCE OF ONGOING STRUCTURAL TRANSFORMATION

It should not be necessary to belabour the evidence in favour of the ongoing structural transformation of economies as they develop and grow; the support for this most important of stylised facts is conclusive (Pasinetti, 1993; Freeman and Louca, 2001; Cornwall and Cornwall, 2002). To an earlier generation of growth economists nothing was more natural than to point to the changing composition of economic activity both qualitatively and quantitatively in the course of economic development. Fabricant (1940) can be permitted to speak for the many others of this generation of economists:

> “When we turn from the averages and concentrate upon the movements of manufacturing production in individual industries, we find *sharp differences* in the secular rates of change in the physical output of these industries. In every period, some decline, some forge ahead, and only a few industries follow the general trend of manufacturing output. These disparate rates of growth affect, and *are affected by* changes in the structure of industry, in technical processes, in the kind of goods produced and in the distribution of employment.” (our emphasis, p. 9)

No better statement could encapsulate the themes of this paper. Growth is not generated at the macro level, and the aggregate growth rate is a statistical construction in relation to which there may be no industry that grows at the average rate for all industries. Because growth rates differ across activities, the economic system evolves and with it the relations between averages and their components. Induced changes in structure continually redefine the economy wide relations between productivity growth, employment growth and output growth and the contributions that each industry makes to these aggregates.

The evidence can be used to tell different stories according to the level of economic aggregation that is employed. The picture within industries is of a different kind to that between industries, which, in turn, differs from broad comparisons in terms of the grand sectors, agriculture, manufacturing and services, defined by Colin Clark, among others. In this section we use the NBER–CES Manufacturing Productivity dataset covering 459 four digit SIC industries over the period 1958 to 1996[2]. Relative to most macro datasets, this provides highly disaggregated information; although it can be argued that it is still highly aggregated relative to the level of individual markets, products and firms. Thus, while it can be still be used to identify some features of structural transformation, much remains hidden. This data allows computation of the shares of each industry in total employment and total output (measured by deflated shipments) together with the levels and rates of change of labour productivity. If structure is changing the first place to look is at the patterns of the employment and output shares and the changes they evince over time. In the case of semi-stationary, proportional growth these shares must be constant, which is only possible if all industries grow at the same rate and if all rates of productivity growth are the same.

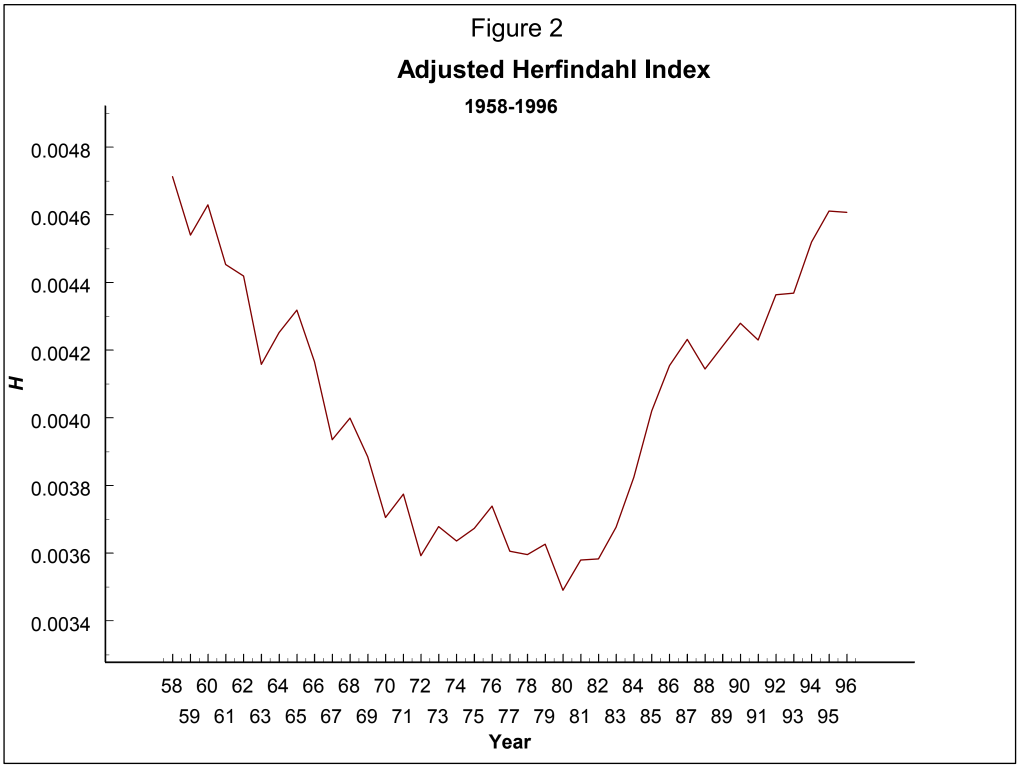
This is a hypothesis that we can reject with confidence. In the absence of any structural change, the employment share structure in the base year should exactly predict the employment share structure in all subsequent years, and similarly for the output shares.

Figures 1a and 1b show the consequences of using the output and employment shares in the base period to predict the corresponding shares in the years up to 1996. Each graph shows the correlation coefficient between the shares in each successive year t and the base year shares for employment and output respectively. If there had been proportional growth, these correlation coefficients would remain constant at unity but, as we see, they decline virtually monotonically, becoming weaker as time passes. Also shown in Figure 1c are the results of a different test, namely the correlation between employment and output shares over time and, as shown, this also weakens but less dramatically. This simply reflects the fact that the industry productivity levels in successive years are correlated more weakly.

An alternative way of measuring the rate of structural change is to compute the variation over time for the Herfindahl indices of employment and output. If there was proportional growth these indices would be constant. Figure 2 shows the variation over time in the Herfindahl index for employment shares, $H = \Sigma e_j^2$. This index measures the average employment share at each date. From Figure 2 we see persistent evidence of structural change in the economy's employment pattern. The rate of change of the Herfindahl is readily seen to be proportional to the covariance between employment shares and employment growth rates

$$\frac{dH}{dt} = 2\Sigma e_j \left(n_j - n\right) e_j = 2C_e \left(e\, n\right)$$

where n_j is the growth rate of industry employment and $n = \Sigma e_j n_j$ is the aggregate employment growth rate across all the industries. Consequently, the Herfindahl is rising or falling as employment shares are positively or negatively correlated with the growth rates of employment in each sector. The rather dramatic fall and rise of the index provide clear evidence against the hypothesis of proportional growth[3].



Although this evidence raises interesting questions in its own right, these cannot be answered without an appropriate analytical framework. If structural transformation is pervasive and ongoing it can only be because the forces shaping the evolution of demand and the development of technology in the various industries are operating unevenly. Any theory of structural transformation must be capable of connecting together the uneven incidence of "demand and supply" forces to show how the evolution of individual industries is connected to the evolution of the economy as a whole. This is the task addressed in the remainder of this paper. In any growth model the phenomena that must be explained are the growth rates of output, employment and productivity, and it is on these relations alone that our framework is focused.

THE BASIC FRAMEWORK

Imagine an economy to be describable in terms of an ensemble of distinct activities, or industries, each one producing a single product. Each industry is distinguished by the unique knowledge base that is embodied in its production methods. We suppress all internal differences across firms within each industry, simply to focus on the interactions between the different industries. In relation to technology, the chief simplification we allow is that the capital coefficient, 'b_j' is the same for all firms within the industry and that all innovations are Harrod neutral improvements in processes of production; progress is purely labour augmenting. These capital coefficients will differ between industries in the subsequent analysis. Let a_j be unit labour requirements, then labour productivity for the industry is, of course, $q_j = 1/a_j$. Since these industry 'technical' coefficients are fixed by the state of knowledge, there is no possibility of factor substitution within the sector in the sense of changes in input proportions within a given technology but there can be adaptation between sectors. At levels of aggregation above the industry, input proportions will change in response to the different growth rates of the various industries, but this is not factor substitution in the traditional sense it is instead factor reallocation or adaptation. It is, of course, a considerable simplification that product innovations are ruled out of this account, particularly in the light of the arguments below about the evolution of demand. However, the traditional reasons for following this particular pattern of enquiry will be obvious in terms of the literature on economic growth.

At each moment in time the structure of the ensemble is captured in the shares in aggregate employment and output of each industry. Let z_j be the share of industry j in the output of all the industries and e_j be the corresponding share of total employment. The measures of output shares are contingent on the particular set of price weights used to construct the aggregate measure of output. We take these prices as given. Average unit labour requirements across the ensemble are $\bar{a}_z = \sum z_i a_i$ and average, ensemble labour productivity is $\bar{q}_e = \sum e_j q_j$, from which it follows that, $\bar{a}_z \bar{q}_e = 1$, while $e_j q_j = z_j \bar{q}_e$. Consequently, across industries, output structure and employment structure differ to exactly the degree that productivity levels differ from average productivity.

As with all evolutionary arguments, what are to be explained are the differential growth rates of output, employment and productivity across the ensemble. Without differential growth we cannot have structural change and, unless these growth rate differences are endogenously determined, we cannot have self-transformation. In elaborating this point it is useful to consider the following relations. Firstly, that

$$g_j = g_z + \hat{z}_j \quad \text{and} \quad n_j = n + \hat{e}_j$$

Each growth rate, of output (g_j), in the first case, of employment (n_j) in the second, is equal to the average growth rate (g_z and n) plus the appropriate rate of growth of the share of that industry in the aggregate ($\hat{z}_j$ and $\hat{e}_j$). Obviously, when the industry and aggregate growth rates are equal, structure is frozen, the case of proportional growth. Moreover, when the structures change so necessarily do the average growth rates, even when the individual growth rates are given.

Secondly, that

$$\hat{e}_j + \hat{q}_j = \hat{z}_j + \hat{q}$$

This relates the two measures of structural change in an industry to the deviation of that industry's productivity growth ($\hat{q}_j$) from the population average rate of productivity growth ($\hat{q}$). Consequently, in an industry in which productivity increases at the average rate, the output share will change at the same rate as the employment share. We can see immediately that proportional growth necessarily implies that all sectors have a common rate of productivity growth, a position that is not conformable to the facts.

In the analysis below, we reject the idea of a production function that offers smooth substitution possibilities either at industry or economy levels of analysis, and we abandon the possibility of analysing the growth process in terms "shifts in" and "movements around" a production function. This is for two reasons. Firstly, in general, there is no specification of the technologies of the different industries that can eliminate capital reversing price effects, and these effects destroy the hypothesis of normal substitution between capital and labour in response to changes in the relative cost of labour and "capital" (Harcourt, 1972; Bliss, 1975; Kurz and Salvadori, 1995). Secondly, and more fundamentally, we maintain that all changes in technique require a change in practical knowledge so that the fundamental phenomenon is innovation *qua* adaptation, not factor substitution in a 'given' state of knowledge. Evidence concerning the localised nature of progress provides a powerful underpinning for this view (Antonelli, 2001; Atkinson and Stiglitz, 1969).

This is not as drastic step as it might seem. A theory of adaptive growth must necessarily focus on *changes* in technology rather than the *state* of technology and as, Usher (1980) put the point, ‘no progress’ means ‘no growth’. Although there are many uses to which a fixed technology framework can be useful in economic analysis, it is simply a mistake to suggest that a detailed analysis of a stationary economy is a necessary precursor to the study of economic growth. By the same token, we reject the idea of an aggregate stock of knowledge that is matched to an aggregate production function. No such aggregates can exist for we have no means to combine together different kinds of knowledge into one measurable stock entity. In the analysis that follows, we let knowledge be specific to a particular industry. The growth of this specific knowledge plays a central role in the analysis that follows but it is not quantified except in so far as its growth is intimately tied to the transitions through which productive processes move in each industry.

PRODUCTIVITY GROWTH AND THE FABRICANT LAWS

If we reject any reference to the production function and aggregate knowledge in the growth process, how can we build up an account of the self- transformation of industries and, ultimately, economies? Such an account should make the transformation process endogenous, it should connect with the sector specific growth of knowledge and it should emphasise the fundamental features of enterprise in relation to investment and innovation. It should involve markets in the process of translating creativity into patterns of growth and decline and be able to aggregate out a macro-level account of economic change. If we are to choose any principle that draws together these desiderata it is that the division of labour is limited by, and in turn limits, the extent of the market. Changes in the division of labour require changes in technology in the broad, and extension of the market requires the growth of per capita income. No other principle would seem to have the ability to unify the transformation of production methods and the extension of demand to create an endogenous theory of enterprise and economic transformation.

This principle requires a representation that makes it operational in an analytical sense. Although there are different ways of doing this, we have chosen the familiar technical progress function as the way of linking the improvement in productivity to the economic conditions in each industry. This replaces the static concept of the production function with a dynamic representation of increasing returns that parallels the acquisition and application of knowledge. We also believe that it is inappropriate to imagine that the growth and application of knowledge comes from nothing, that it can be independent from investment. In the following adaptive growth model, business investment is fundamentally important in three complementary ways: as means to expand productive capacity, as contributor to aggregate demand, and as carrier and stimulant to productivity growth. Innovation is inseparable from business investment in an enterprise economy so let us first consider how business investment acts as the carrier of technical progress.

In a remarkable empirical investigation into the growth of manufacturing in the USA over the period 1899-1939, Solomon Fabricant (1942) set out the basis the view that we espouse. He drew attention to the fact that rapidly growing output in an industry is usually associated with rising employment and increasing labour productivity and that when output is in decline so is productivity. Across industries, there are wide variations both in levels of productivity and in growth rates of productivity, so Fabricant saw that the way was open to explain these differences in terms of the differential growth of the markets for different groups of products. Moreover, growth of output is usually associated with net investment, and conversely, such that output growth usually implies the growth of measured capital per worker. The significance of this was not only that investment creates the capacity to serve a growing market but that is the major channel through which technical advances "cut into unit labour requirements" (p. 96). The great significance of Fabricant's work lay in the fact that it could provide analytical foundations for a non-aggregative theory of endogenous growth and self-transformation on 'Smithian' principles.

The starting point is a general definition of investment, as any use of productive resources that improves the capacity of productive assets of any kind, assets being defined in the conventional way, by the ability to yield future income streams. Investment is the activity that enhances productive economic capabilities and, in this sense, it is much broader than the laying down of new plant and capital infrastructure. Investments in human capital, in research and development, in improvements in the organisation of firms are all of importance in this view (Scott, 1989). Investment can then be interpreted as the cost of making the arrangements to improve capabilities and thus the cost of generating improvements in productivity. Of course, any change in such capabilities will require the growth of knowledge somewhere in the economy but the kinds of knowledge required tend to vary enormously and cannot be reduced to any common denominator. When we broaden the conception of knowledge in this way it becomes obvious that the growth of the market also requires the growth of knowledge. Thus, we can distinguish those improvements in productivity that are directly related to investment in current productive capacity, and all other residual improvements in productivity that are investment related but where those investments leave current capacity unaffected.

Following Eltis (1973), we can formulate this argument in a simple way through the concept of a technical progress function for each industry of the following form

$$\hat{q}_j = \alpha_j + \omega_j \left(\frac{I}{Q} \right)_j$$

where I / Q is the rate of investment in physical capacity expansion, ω_j is the coefficient that translates that investment into productivity growth and α_j is the residual rate of productivity growth, which depends to a degree all the remaining kinds of non-capacity expanding investment. It can be shown that the investment ratio is $b_j g_j$ and, if we set aside, for now, questions concerning variations in capacity utilisation as the economy fluctuates, we can reasonably assume that the growth rate of capacity is the same as the growth rate of actual output. If this is accepted it follows that the progress function becomes

$$\hat{q}_j = \alpha_j + \beta_j g_j \tag{1}$$

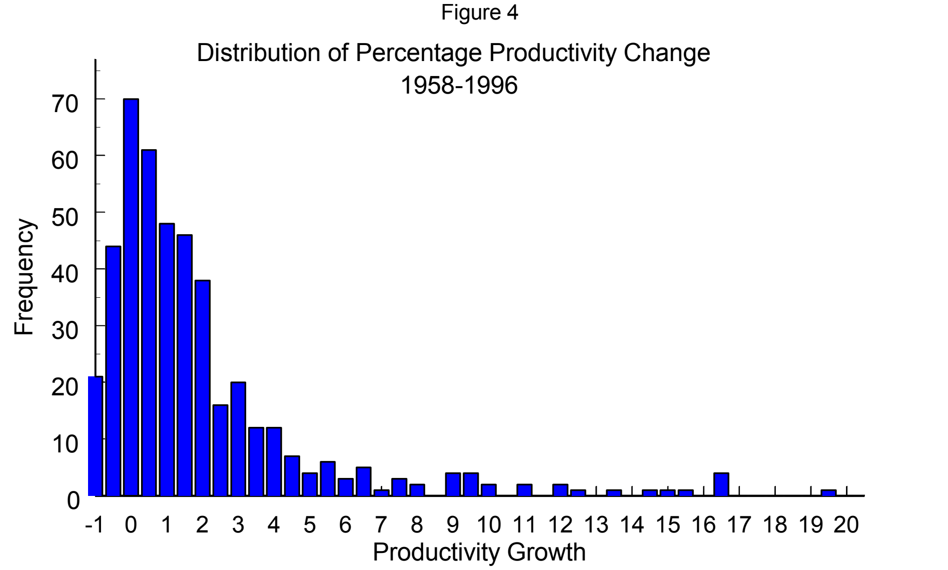
This is precisely Fabricant's Law. With $\beta_j = b_j \omega_j$ less than one, output growth results in productivity growth, and productivity growth is consistent with employment growth provided that the industry's market is growing quickly enough. The coefficient β_j, is the measure of the degree of dynamic increasing returns in the industry, whereas the coefficient α_j is the measure of all those residual influences on technical progress that do not depend on the *immediate* expansion of the market for an industry. What that rate of expansion is can be decomposed into the general growth of output across the ensemble of industries and the change in the relative position within the ensemble of any given industry, as indicated previously.

Relation (1) is fundamental to all that follows, it is the basic building block of our endogenous theory of growth, and it is the closest we can come to incorporating the growth of knowledge into the analysis. Indeed the key point about any endogenous growth theory is that it requires some specification of the economic determinants of technical progress. We should note immediately that the same relation has been introduced in other guises, in the work of Kaldor (1957), in his exposition of the Verdoorn law, which, in Verdoorn's original account, we should note, has very different foundations from those articulated by Fabricant[4].

The same NBER productivity data set that we used above to explore the rate of transformation within the US manufacturing sector can also be used to investigate Fabricant's Law, half a century on. In Figure 3, we show the trend in the growth of labour productivity for manufacturing as a whole, in which there is some evidence of acceleration from 1990. Around this average there is a wide dispersion of rates of productivity growth in the individual industries, as shown in the frequency distribution, Figure 4. Taking all the industries together, 65 have negative productivity changes over the period while the mean for all the industries is 22.8 percent. The highest percentage change in productivity is 2809 percent in the computing sector.

Figure 3

Figure 4



To check the Fabricant relations we show first in Figure 5a the OLS regression between output growth rates and employment growth rates across all 459 manufacturing sectors for the period 1958 to 1996. The estimated equation is

$$n = -1.55 + 0.57g$$
$$\underset{(0.37)}{} \quad \underset{(0.07)}{} \quad R^2 = 0.67$$

from which we infer that on average a 10% increase in aggregate output is associated with an 4.3 % increase in labour productivity. If we look within this aggregate we find a considerable diversity of empirical form of the employment, output growth relations. Figure 5b gives the scatter plot of the OLS estimates for the individual values of α and β in those 419 sectors where the estimates are significant at a 5% confidence level[5]. With one exception, all the β coefficients are less than unity confirming the presence of dynamic increasing returns. To a much lesser degree, the α coefficients are positive since there are a substantial number of the industries where there has been residual technical regress. It will be apparent that, inasmuch as these regressions support the existence of technical progress functions, there is clearly considerable diversity at the industry level with no apparent correlation between the estimated values of α and β. Thus, Fabricant's Law stands up remarkably well as a robust empirical descriptor of the relation between technical progress, investment and the growth of the market. It is not our purpose to explore here the origins of the differences in the technical progress functions summarised in Figure 5b, for that would be a major undertaking, drawing on our understanding of differences in the conditions of innovation across industries. Rather we turn our attention to how the Fabricant relation can be used as the building block for a theory of self-transformation.

Fabricant was well aware that no industry stands in isolation in relation to the growth of productivity since

> "[g]rowth in the efficiency of any single industry or group of industries - manufacturing or non-manufacturing - is thus intimately related to developments elsewhere in the economy. Advance in manufacturing productivity is part of the evolution of the *entire industrial system"* (p.163. our emphasis).

This is not an invitation to provide a macroeconomic account of the growth process but rather, a plea to be sensitive to important relations within the ensemble of manufacturing activities. Fabricant has in mind two broad kinds of interrelationship. The first is technological, where a particular development has applications beyond the sector in which it originated, he gives, among several examples of this phenomena, the diffusion of electric power and the spread of the linear production line beyond the auto industry. Modern economists would recognise this as a 'spillover effect', although not one that could be viewed as passive and costless by the recipients of the external knowledge.

Figure 5a

The Fabricant Relationship

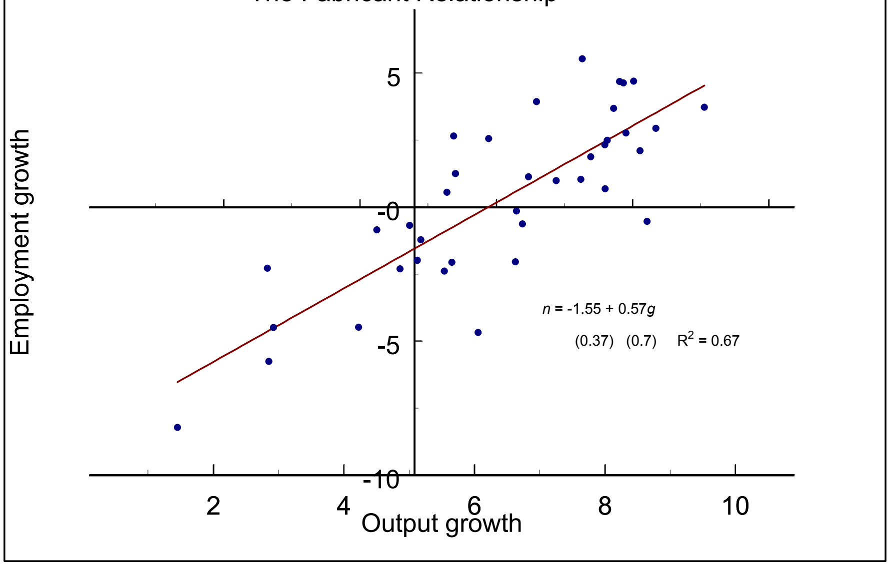
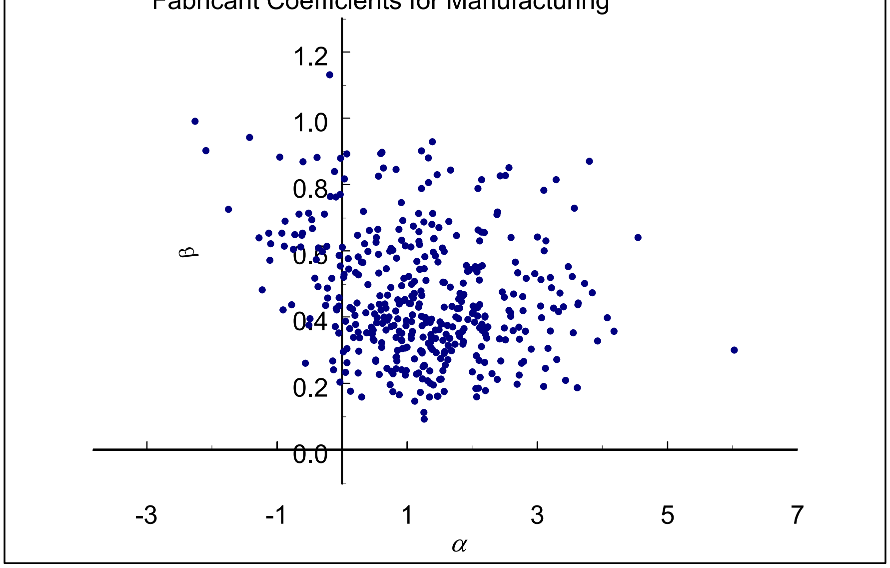


Figure 5b

Fabricant Coefficients for Manufacturing



Fabricant's second argument deserves far more attention than he gave it, and it relates to demand side processes and the extension of the market. As he suggests, an industry can only expand as far as its customers allow and one of the principal determinants of this constraint is the rate of growth of per capita income in the economy. Here Fabricant drew attention to the growth of the output of goods that had formerly been produced in households and farms and indeed the production of fabricated goods in general. However, since every individual sector makes a contribution to overall productivity growth it follows immediately that the productivity growth rates of the various industries are economically interdependent. It is through this insight that we can turn Fabricant's law into a theory of growth and self-transformation and, in the process, bring to the fore the role of demand and consumption practices in relation to innovation and productivity growth. This requires some understanding of the forces determining the rate of growth of demand and the way in which the growth of each market is connected to the growth of productive capacity and investment.

DEMAND AND STRUCTURAL CHANGE

Demand in general plays a small role in modern growth theory, yet it was at the centre of the dynamic process that Adam Smith enunciated so long ago. Since structural change is shaped by differential growth rates of demand and since differential growth rates of demand, and thus output, are a cause of differential rates of productivity growth we have the basis of a virtuous circle in which demand growth and productivity growth are mutually sustaining.

As soon as we abandon the method of proportional growth there is immediate scope for giving demand side forces a key role in the explanation of structural change and for giving far more attention to the role of demand in the innovation process. Indeed, one of the more obvious reasons why industry growth rates differ is to be found in hypotheses about the evolution of demand. As Pasinetti expressed it "... any investigation into technical progress must necessarily imply some hypotheses ... on the evolution of consumer preferences as income increases". He went further "[i]ncreases in productivity and increases in income are two facets of the same phenomenon. Since the first implies the second, and the *composition* of the second determines the relevance of the first, the one cannot be considered if the other is ignored" (our emphasis, 1981, p. 69).

In dealing with demand, there are three general matters to be considered: shifts in "preferences" in association with technical progress, particularly in relation to the emergence of new sectors and new products; changes in average prices between sectors, particularly if the outputs concerned are close substitutes; and the matter which Pasinetti considered, namely, different income elasticities of demand for the different sectors. Like him, we deal only with this last matter, leaving the other aspects of demand and innovation for further study. Pasinetti, did not develop his treatment of demand in any depth in either of his major works on structural change (1981, 1993), yet it is not difficult to do.

We shall find it convenient to work with per capita income elasticities for each industry, ψ_j, defined as the ratio of the growth in per capita demand for each industry to the growth rate of per capita income, thus

$$\psi_j = \frac{g_j - n}{g_z - n}$$

where n is the rate of growth of total employment, and $g_z = \sum z_j g_j$ is the rate of growth of aggregate output[6]. These elasticities provide us with the basis for a sorting process across the set of industries since they give rise to different growth rates of demand and output. Of course, in emphasising the role of income elasticities in the inter-industry sorting process we should not be deluded into thinking that we have said anything terribly profound. What is needed is some empirical and conceptual understanding of the determinants of income elasticities in general, and in relation to innovation in particular. This we do not yet have, nor do we need it for immediate purposes[7].

We assume, as we are entitled to do in a theory of secular growth, that in each industry prices are set by firms such as to co-ordinate the rate of growth of the market with the rate of growth of capacity, and we use the same symbol g_j to denote both. Then we can write the rate of growth of that industry as

$$g_j = n + \psi_j \hat{q} \qquad (2)$$

where $\hat{q} = d \log \bar{q}_e / dt$ is the yet to be constructed aggregate rate of productivity increase. The immediate consequences of this formulation are twofold. Firstly, the rate of growth of each industry cannot be determined before we have determined the rates of growth of employment and productivity across the ensemble[8]. Thus, the pattern of growth rates that emerges is simultaneously determined with the aggregate rate of growth of employment and productivity. Secondly, the pattern of growth rates also determines the necessary pattern of co-ordinating prices and hence the corresponding shares of wages and profits in aggregate output via the investment behaviour in each sector. Consequently, the variance of the industry growth rates is related to the variance in the income elasticities of demand by the condition

$$\sum z_i (g_i - g_z)^2 = V_z(g) = \hat{q}^2 V_z(\psi)$$

Thus, the greater the rate of productivity growth the greater is the variance in the industry growth rates for a given variance in the income elasticities. This is a good example of the notion sketched above that a secondary moment, the variance of growth rates, is functionally dependent on a primary moment, the variance in per capita income elasticities of demand. It is also a generalisation of Pasinetti's perspective on the importance of the differences in demand conditions for different sectors in explaining the determinants of the pattern of economic growth. It should be noted that, in (2), we have defined the elasticities of demand so as to allow the distribution of demand to be influenced by the growth in per capita income. This does not mean that the elasticities are constant over time, and, in general, they cannot be, a conclusion that is implicit in the idea of Engel's Law in which the elasticities decline with increases in per capital income[9]. The simplification, that population growth is neutral in its demand composition effects, is precisely that, a convenient simplification. What matters is that per capita income growth and population growth have differential demand effects and this is what we have captured in (2) and its consequences below.

We now have the basis for establishing a relation between aggregate productivity growth and the individual industry rates of productivity growth. It is obvious that $\hat{q}$ will be a weighted average of the individual productivity growth rates. 'What then are the appropriate weights to construct this ensemble average, to capture the organic unity of the set of activities?'[10]. To determine them, note that n_j is the rate of growth of employment in sector j so $g_j = n_j + \hat{q}_j$, whence $n_j - n = \psi_j \hat{q} - \hat{q}_j$. Now if we weight this last expression by the employment shares e_j we find that

$$\sum e_j (n_j - n) = \left(\sum e_j \psi_j\right)\hat{q} - \sum e_j \hat{q}_j = 0$$

since $\sum e_j n_j = n$ by definition. Thus, our weighting scheme is provided by

$$\hat{q} = \frac{1}{\sum e_j \psi_j} \sum e_j \hat{q}_j \qquad (3)$$

Unless, $\sum e_j \psi_j = 1$, these weights do not sum to unity[11]. Indeed, it follows immediately that

$$\sum e_j \psi_j = 1 + \frac{C_z\left(\psi_j \bar{a}_j\right)}{\bar{a}_z}$$

where $C_z\left(\psi_j \bar{a}_j\right)$ is the 'z'-weighted covariance between industry income elasticities and average unit labour requirements in each industry. Thus, the employment-weighted average of the income elasticities has unit value only if this covariance is zero, which given no compelling reason to think otherwise, we assume not to be so[12].

THE INTERDEPENDENCE OF RATES OF PRODUCTIVITY GROWTH

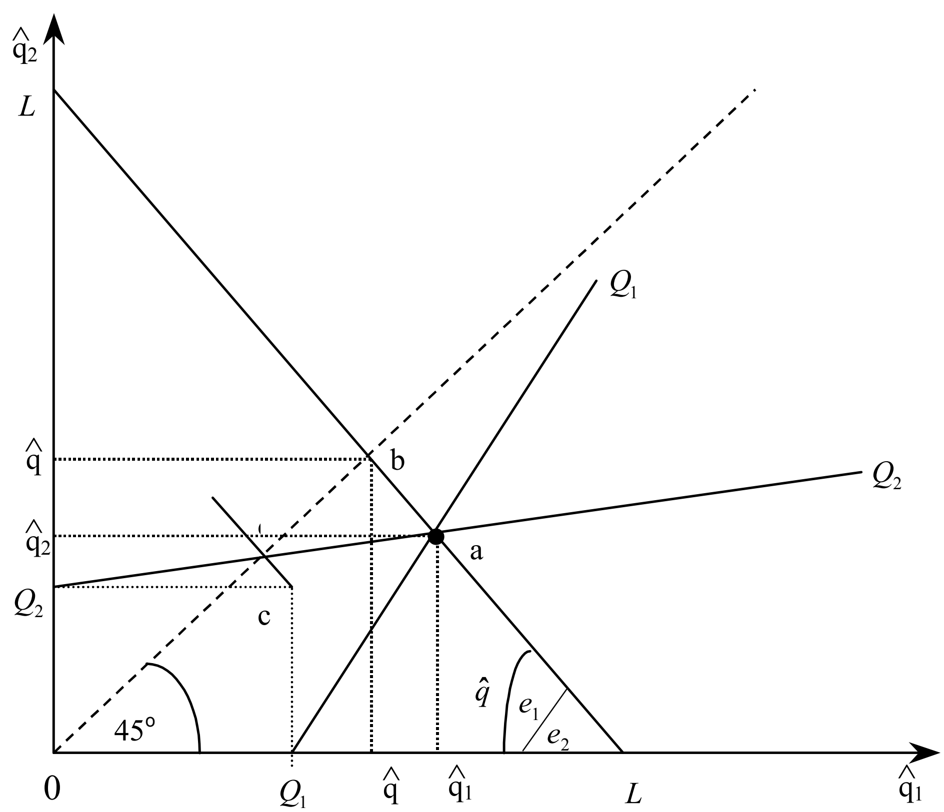
Having established the relation between the aggregate and the industry rates of productivity growth, let us consider now the consequence that the industry productivity growth rates are mutually interdependent. In so doing we are following the line of enquiry first introduced by Allyn Young (1928) who saw clearly how increasing returns generates reciprocal interdependence of productivity growth between the different industries.

In each industry there is a technical progress function, ((1) above) premised on a stream of potential innovations that raise labour productivity in a Harrod neutral way. The effects of this new knowledge are translated into productivity growth through the mechanisms embodied in (1), which, in turn, depend on the market co-ordination of capacity expansion and growth of demand through the pricing behaviour of firms in each industry. The significance of this formulation is that it links productivity growth to output growth, and thus to structural change through the role of the different income elasticities of demand. Now using (2) and (3), each progress function can be written as

$$\hat{q}_j = \alpha_j + \beta_j \left[n + \psi_j \left(\frac{\sum e_j \hat{q}_j}{\sum e_j \psi_j} \right) \right] \tag{4}$$

This expresses Young's central point, which is that productivity growth in any one sector increases with productivity growth in all other sectors provided that its output is a normal good, and these productivity growth rates are mutually determined through the coordination of demand and capacity in the market process. Such normal goods have complementary but reciprocal effects on each other's productivity growth. Equation (4) constitutes an ensemble of simultaneous productivity growth equations, the solution of which in the two-industry case is sketched in Figure 6. The schedules Q_1 and Q_2 are the reciprocal productivity functions for each industry, and they intersect at '*a*' to determine the respective market co-ordinated rates of productivity growth.

Figure 6



Through point '*a*' draw the straight line L-L with slope, e_1 / e_2, the relative employment shares, to intersect the 45° line at '*b*'. This point measures the rate of aggregate productivity growth, $\hat{q}$ [13], and, as drawn, $\hat{q}_1 > \hat{q} > \hat{q}_2$. Consider now point '$c$' and its related point 'd', which jointly depict the pattern of productivity growth if there are no demand feedback effects in either sector. The proportionate difference between the points 'b' and 'd' is then a measure of the importance of reciprocal interdependence in the growth process, it measures what we shall term the "Young effect"; the stimulus to growth generated by the autocatalytic nature of increasing returns.

The point about positive feedback, as Young emphasised, is that it augments growth within and between sectors, amplifying the wellspring of progress, which is provided by the enterprise relations between processes of innovation and investment in the broad[14]. In this way, we can comprehend his insistence that changes in one sector induce changes in other sectors mutually reinforcing the growth of productivity in and within all the sectors. As he put it, "[e]very important advance in the organisation of production … alters the conditions of industrial activity and initiates responses elsewhere in the industrial structure which in turn have a further unsettling effect" (p. 533). The precise form those changes in organization take is not the issue in question, rather it is the reciprocal effects on productivity growth that matter. Could growth be more adaptive than this?

What is the aggregate rate of productivity growth? To establish this we simply weight each industry equation (4) by the corresponding employment share weights and sum to yield the following

$$\hat{q} = \frac{\overline{\alpha}_e + \overline{\beta}_e \cdot n}{\left(\sum e_j \psi_j\right)\left(1 - \overline{\beta}_u\right)} \tag{5}$$

In this expression, $\overline{\alpha}_e = \sum e_j \alpha_j$ is the average rate of residual progress, as influenced by investments unrelated to current capacity, and $\overline{\beta}_e = \sum e_j \beta_j$ is the average progress elasticity constructed with the employment shares. However, $\overline{\beta}_u = \sum u_j \beta_j$, is another average progress elasticity, derived from the weights $u_j = e_j \psi_j / \sum e_j \psi_j$, the contribution which that industry makes to the employment weighted average of income elasticities. Of course, the u_j weights are proper weights satisfying $\sum u_j = 1$ [15]. The conditions for the Fabricant's Law to hold in the aggregate are $\overline{\beta}_e < 1$, and $\overline{\beta}_u < 1$, which are certainly satisfied if the individual progress elasticities are less than unity. For then we are assured that growth is autocatalytic, with demand, output and productivity growth mutually reinforcing one another.

Rearranging (5) we can express Fabricant's Law across the ensemble of industries, as the averaged relation between productivity growth and output growth, thus

$$\hat{q} = \frac{\overline{\alpha}_e + \overline{\beta}_e g_z}{\left(\sum e_j \psi_j\right)\left(1 - \overline{\beta}_u\right) + \overline{\beta}_e} \tag{5'}$$

Equations (5) and (5') combine the reasoning behind the Fabricant technical progress function with the reasoning behind endogenous growth theory, remembering the very important proviso that the development of knowledge (productivity) cannot be separated from the growth of the individual sectors. The growth of applicable knowledge is to this degree a market dependent and positive feedback process. What average productivity growth is cannot be independent of the structure of the ensemble of industries, as reflected not only in the direct employment shares but equally in the various co-variances implicit in these aggregate relations.

The conclusion from this is that growth amplifies the effects of innovation and links the productivity dynamics of different industries together in a transparent way, a way that depends upon demand sorting linkages[16]. Notice carefully, however, that Figure 6 represents a process of growth co-ordination at a point in time. It does not represent growth equilibrium in some more general sense, as a fixed attractor on which productivity patterns converge and stabilise. Indeed, it is a fundamental assumption of our evolutionary perspective that growth is open-ended, that there is not any state of dynamic rest in the presence of innovation driven growth. Thus, points 'a' and 'b' are continually on the move as the relative employment shares and the rates of innovation and output growth vary over time, even with a given pattern of residual rates of technical progress. The economy is simultaneously co-ordinated and restless, as all knowledge-based economies must be. One way to emphasise this is to recognise that neither of the aggregate progress elasticities $\overline{\beta}_e$ and $\overline{\beta}_u$ are constants; they vary with each change in the composition of employment, and, just as one should expect, the dynamic properties of the economy change as its structure changes[17]. These are the simple consequences of the importance of increasing returns in the presence of market co-ordination.

CLOSING THE SYSTEM: THE ENDOGENOUS NATURE OF GROWTH AND PROGRESS

The combination of Fabricant's Law and differential income elasticities of demand provides an account of productivity growth differences at the industry level and the aggregate rate of productivity growth. In each case, the rates of productivity growth are an emergent consequence of market coordination of demand and capacity expansion. However, we have yet to determine what the aggregate rate of productivity growth will be. There are limits to the exploitation of increasing returns and these are naturally set by limits to the growth of the market in the aggregate.

To express it more formally, the sets of relations, (5), which lead to Fabricant's Law, provide only one relation to determine two unknowns, and without determining both of them the industry rates of productivity growth cannot be established. A relation is missing and here there are at least two possibilities. The first is to claim that the rate of growth of employment, n, is given, by virtue of arguments in relation to the growth of population, labour migration, changing gender composition of the population, and changes in institutional rules in relation to the market for labour. Whatever the rationale, the full employment value of 'n' determines $\hat{q}$ through (5) and correspondingly determines the growth rate of output, g_z. This is the route explicitly followed by Arrow (1962) and Jones (1995a and b) in their versions of endogenous growth, for they both end up with the claim that productivity growth is proportional to the growth in employment, albeit for different reasons. However, in this formulation, even a stationary population is consistent with unlimited growth provided the ongoing growth of knowledge is translated into residual rates of productivity growth[18].

The alternative closure is to argue that the aggregate growth rate of the economy is determined by aggregate investment and saving behaviour. On this view, the requirements for macroeconomic co-ordination set the aggregate constraints on the relations between growth rates at industry level. In following this approach, some hypothesis has to be adopted on the nature of capital markets and saving behaviour. Here it is sufficient to work through the argument on Harrodian lines, for Harrod can justifiably be claimed to be the first of the endogenous growth theorists, in the modern sense[19].

We start by assuming that all profits are distributed and that the aggregate saving ratio of households is a constant, s_H [20]. All investment is funded via the capital market and for this market to clear the saving ratio must equal the aggregate investment ratio for the economy. Now, because $(I/Q)_j = b_j g_j$ we can also write the aggregate investment ratio as

$$\frac{I}{Q} = \sum z_j b_j g_j = \bar{b}_z g_v$$

where $g_v = \sum v_j g_j$ is defined using the weights $v_j \bar{b}_z = z_j b_j$, so that v_j measures the proportionate contribution that each industry makes to the aggregate capital output ratio. From this, we immediately obtain a version of the familiar Harrod condition

$$g_v = \frac{s_H}{\bar{b}_z}$$

However, g_v in this formula is not the growth rate of aggregate output as normally defined, which is of course, g_z, the output share weighted average of the industry growth rates. The two growth rates would only be equivalent in conditions of proportional growth, *that is, when growth is not associated with development,* but here they are logically different and are related by the condition

$$g_z = g_v - \frac{C_z(g\,b)}{\bar{b}_z}$$

In this expression $C_z(gb)$ is a secondary covariance since the growth rates are endogenously determined. However, because of the relationship between demand growth and aggregate productivity growth it follows that this secondary covariance is equal to, $\hat{q}C_z(\psi b)$. Thus, the relationship between the aggregate growth rates becomes

$$g_z = g_v - \frac{C_z(\psi\, b)}{\bar{b}_z}\hat{q}$$

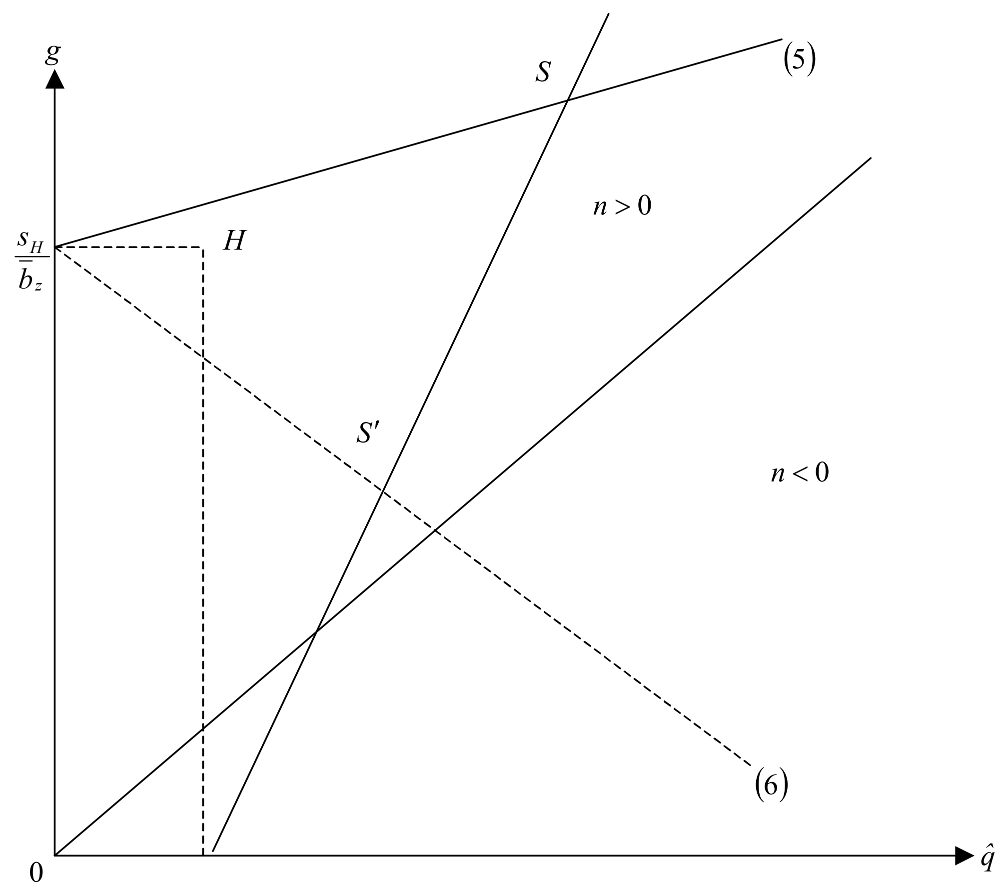
From which it follows that the growth rate of output proper, is related to the growth rate of productivity by the relation,

$$g_z = \frac{s_H}{\bar{b}_z} - \left[\frac{C_z(\psi\, b)}{\bar{b}_z}\right]\hat{q} \tag{6}$$

That is to say, the aggregate growth rate is not independent of the forces making for uneven rates of growth in the individual sectors; the growth rate depends on the variety within the system. Thus, the two expressions for the growth rate of output are only equivalent if aggregate productivity is constant or if the covariance between the income elasticities of demand and the industry capital:output ratios is zero for all possible structures of the economy. This is only feasible if all the capital:output ratios are the same or if all the industry income elasticities are unity, in which case the output structure of the economy does not change over time. As soon as we abandon these requirements for proportional growth, we find that structure and diversity once again influences the relation at the macro level between output growth and productivity growth, and this structure is captured by the primary covariance term in (6).

Now, if we combine together relation (6) with Fabricant's Law (5'), we can simultaneously determine the mutually consistent values for the growth of aggregate output and the growth of aggregate productivity. This solution is sketched in Figure 7 where we have assumed for purposes of illustration that $C_z(\psi\, b)$ is negative. The negative association between the rates of growth of output and productivity reflects the "most favourable case" in that the industries with above average income elasticities of demand are also the industries with above average capital productivity. Productivity growth consequently has an accelerating effect on output growth since it concentrates the latter in industries with a relatively greater productivity of invested capital[21]. Since Fabricant's Law provides a positive association between the two rates of growth, the solutions for g_z and $\hat{q}$ follow, as shown. The point labelled H is the Harrod solution, with no structural change and productivity growth independent of output growth. The solution at S is the Schumpeter point with mutual interdependence of productivity and output growth. It will be clear that, *ceteris paribus,* a higher saving ratio implies higher values for output growth and productivity growth as does a higher value for the exogenous progress rate, $\overline{\alpha}_e$. That the joint distribution of income elasticities of demand and capital output ratios matters for this outcome, is entirely a product of our evolutionary framework. This is the virtuous circle case in which both forms of growth are mutually reinforcing in terms of aggregate demand as well in terms of Fabricant's Law.

Figure 7



If the covariance between the values of b and ψ is zero we are back to Harrod's case, in which the growth rate of output is independent of the growth rate of productivity, the world of proportional growth. Conversely, if this covariance is positive, the worst case, productivity growth and output growth are negatively related from the aggregate demand side, the solution S' in Figure 8. It is clear that the differences between these three cases are reflected in the corresponding rate of growth of total employment. If the point S lies above the 45 degree line then employment growth is positive and conversely if the solution lies below this boundary.

Growth in all its senses, output, employment and productivity, is endogenous, and the nature of the endogeneity depends on the prevailing structure of the economy, which is itself adapting under the forces of innovation and the distribution of demand. This system evolves, it adapts to the opportunities created by technical progress, it is restless. Thus, to claim, as we have, that it is coordinated by market processes in relation to the various industries and in relation to the market for capital is not to claim that it is in equilibrium. Indeed, capitalism in equilibrium seems from this view a contradiction in terms. There are always reasons to change prevailing arrangements and every change opens up new opportunities for further change*, ad infinitum,* and this is the powerful message first stated by Smith, refined by Young and given empirical content by Fabricant, Kaldor and others.

There is an important question remaining in this treatment of growth – how is the aggregate capital output ratio determined? Although we have treated the capital: output ratios in each industry as constants, unaffected by the rate of technical progress in that industry, it does not follow that the aggregate capital: output ratio will be constant. In general, it will not, precisely because the economy is evolving and adapting to the uneven growth of knowledge across the industries. The capital output ratio is defined as $\bar{b}_z = \sum z_j b_j$, and, since the b_j are given by assumption, it follows that

$$\begin{aligned}\frac{d}{dt}\bar{b}_z &= \sum\left(\frac{d}{dt}z_j\right)b_j = \sum z(g_j - g)b_j \\ &= C_Z(b, g) \\ &= \hat{q}C_z(\psi, b)\end{aligned}$$

The aggregate capital: output ratio is invariant to structural change only when the growth rates and capital output ratios of the industries are uncorrelated, and this is so either when productivity growth is zero or when the income elasticities and capital coefficients are uncorrelated.

This is an example of a more general evolutionary theorem. Namely, that an aggregate is stationary if its components are uncorrelated with the dynamic 'causes' that determines the changing relative importance of each component in the aggregate. As a general rule, in an evolving economy Harrod neutrality at industry level will not produce Harrod neutrality at the economy level. What is true at the micro level of the members of a population is not necessarily true at the aggregate level of that population, and the purpose of the aggregation procedure is to identify how and why the emergent macro properties do not mimic the corresponding properties at industry level.

All this tells us that the structure of the economy matters fundamentally for the evolving relations between capacity growth, productivity growth and employment growth. The interaction of macroeconomic constraints and Fabricant's Law, generates growth rates for output and productivity but in no sense do these correspond to any steady state growth equilibrium. These growth rates are restless and they change from within. A given value for productivity growth in the aggregate, is translated into diversity of demand and output growth at the industry level and, thus, into a changing structure of output. In turn, this induces differences in productivity growth at industry level, which means that the employment structure changes at a different rate from the output structure. These changes in structure redefine the aggregate relations, including the capital output ratio that produced the given rate of productivity growth from which we started and so time passes meaningfully by. Diversity is the key to adaptive, restless capitalism; and it is the diversity in technical progress elasticities, in capital output ratios and in income elasticities of demand that we have shown to be the basis for the inseparability of growth and self-transformation.

THE MODE AND TEMPO OF EVOLUTIONARY GROWTH: REVOLUTIONARY GRADUALISM

We have argued that economic growth originates from the diversity of creative behaviours in relation to investment and innovation and their co-ordination within and between sectors. This is the Schumpeterian theorem that capitalism develops from within. Now it is clear that our awareness of these dynamic processes will be critically sensitive to the level at which we conduct the analysis. The more we aggregate the more we hide the underlying mechanisms of enterprise and economic change, the more we emphasise inertia rather than flux and adaptation. Thus, as well as working up from the industry level we could equally well work down to the evolution of increasing returns in individual firms. Important though this step is it risks missing the main point, which is that increasing returns is not simply a matter of what happens in individual firms rather it is more fundamentally a matter of the relations between firms and thus between different industries. As Young put it, l*arge* production should not be confused with *large- scale* production.

One can see immediately that there is a long chain of influences through which a new innovation within any one industry is ultimately captured in the statistics of aggregate productivity growth. In a multi-industry economy it is a remarkable innovation indeed, which shows up from its inception as a measurable change in the aggregate productivity growth rate. Such innovations need to affect many sectors simultaneously and these are rare[22]. The connection between innovation and growth is important precisely because innovation is deeply rooted across the economic system as an organic whole, it is not the prerogative of individual sectors. This helps throw some light on the one important category of change that we have ignored, the addition of 'new' sectors and the demise of 'old' ones. New sectors can be vibrant sources of innovation and evolutionary competition but their emergence is likely to have little initial aggregate effect simply because they will, only account for a small share of total employment and output. Similarly, old sectors tend to fade away, to disappear not with a bang but with a whimper, and they have ceased to be economically significant perhaps long before they disappear from the economic record[23]. In this way, the choice between economic gradualism and economic punctuation as descriptions of adaptation depends very much upon the level at which one is looking. Nevertheless, this is an inherent feature of enterprise capitalism in which immense microdiversity is co-ordinated to produce the greater semblance of order at higher levels of aggregation. The simple point about market capitalism is that it has, as it were, the characteristic of inducing anarchy and translating it into order.

CONCLUDING REMARKS

Why is capitalism restless and adaptive? The answer provided here is that economic agents are not passive recipients of messages emanating from the environment, they are not cybernetic reactors to use Langlois' perceptive phrase (Langlois, 1983). Rather they are imaginative and creative interpreters of messages flowing from an environment which itself is a product of human design. This creativity is deeply intertwined with the processes of investment and innovation that form the core of our approach to an enterprise theory of endogenous economic transformation. In turn, these same processes are deeply connected with the growth of knowledge. Consequently, knowledge grows inseparably from the day-to-day conduct of economic activity. It is inevitable that this new knowledge is unevenly distributed and that it opens up further opportunities for innovation and investment, that is, new growth opportunities. Such knowledge driven systems are not only unpredictable in detailed consequences; they are necessarily evolutionary in their nature. Thus, we have sought to clarify the links between variety in efficiency, innovation and investment as the pillars of the creative view of economic growth.

We have chosen adaptive or restless capitalism as a suitable metaphor for the nature of economic transformation, precisely because of its link with evolutionary processes. Growth depends on variety in microeconomic behaviours, on investment and innovation, and in the co-ordination of those behaviours by market processes. In the immense micro-diversity of creative behaviours lies the foundation for growth in output and productivity. We have not attempted to connect this picture of open-ended growth with the important growth and development literature, created in the 1950s by among others Nurkse (1953) and Hirschman (1958). This highly original set of ideas linked growth to structural change within a world of disaggregated economic sectors, demand interlinkages and increasing returns to create exactly the kind of dynamic, reciprocal complementarities that are highlighted in this paper. In his Ohlin lectures, Krugman (1995) provided a detailed critique of that literature, advancing the claim that it failed to develop, and is now largely forgotten, because it did not come to terms with the connection between increasing returns and imperfectly competitive markets. We doubt whether this is the whole story. For we have suggested that the issue is not a question of increasing returns and imperfectly competitive equilibrium but rather increasing returns in relation to the competitive market process.

This is the core of the Smith-Young-Kaldor perspective on which this paper has been built. There are numerous sources of and kinds of increasing returns, many of which are incompatible with any competitive equilibrium. In contrast, competition as an evolutionary process takes all forms of increasing returns in its stride, they simply speed up and influence the direction of change, and in no way threaten the wreckage of the economic analysis. They are the link between market selection and the regeneration of variety. Hence, growth, technical progress and the competitive process are inseparable; they are genuinely adaptive evolutionary processes driven by microeconomic diversity and co-ordinated by market and other institutions to generate emerging, ever-changing patterns of economic structure. If those development theorists have been forgotten it is more likely to be because the idea of equilibrium, competitive or not, was for them anathema.

Space precludes any development here of the implications for growth policy. Suffice it to say that they would follow from a bottom up rather than an aggregate economy down perspective; that they would depend on the stimulation of enterprise and entrepreneurship; and that they would depend upon the open, unbiased operation of market institutions. They are properly described as policies for an experimental economy (Foss and Foss, 1999) and the problem for the policy maker is that they must accommodate the waste and narrowly conceived inefficiency, which is essential to all evolutionary processes.

We have made much of the idea that capitalism in equilibrium is a contradiction in terms. By this, we do not mean that we can dispense with market co-ordination as a central element in our economic understanding. One can dispense with particular hypotheses about individual behaviour, one cannot dispense with interaction. How the pieces fit together as a system is what the economics of growth and self-transformation is about and this means that one must treat seriously the instituted market and non-market context in which enterprise paints its picture. This requires that we pay attention, not only to capital, labour and commodity markets but equally to the non-market institutions, which shape the growth and application of new knowledge at the level of the industry and firm. Enterprise is as much about the framing context as it is about idiosyncratic behaviours. In this regard, for example, the innovations systems literature has an important contribution to make to our understanding of economic growth as an evolutionary process (Edquist, 1996; Carlsson, 1995; Nelson, 1993; Freeman, 1987). History is open-ended, so is economic transformation at all its levels.

Notes

[1] This is not to argue that proportional dynamics does not have its uses, as for example, in the Von Neumann growth model. However, what this method seems entirely incapable of addressing, is the two-way relation between the growth of knowledge and the growth of economic activity. Has any historian ever found proportional dynamics a useful device to order the record of the past? We think the reader knows the answer.
[2] This dataset is published on the NBER website (www.nber.org/data)
[3] The measure of the Herfindahl index is sensitive to the level of aggregation and the number of sectors included at each level. We have scaled its value to lie between zero and unity. Unscaled, its minimum value is 1/459 which equals 0.002179.
[4] For an outstanding review of this literature see Scott (1989), also Bairam (1987).
[5] Because of the statistical problems that arise in directly regressing productivity growth on output growth all our results are based on the regression of employment growth on output growth from which the productivity relation is inferred.
[6] If we distinguish two uses for each good, in consumption and in investment, we can further decompose these total elasticities as follows

$$z_j \psi_j = (1-s) c_j \psi_{cj} + s i_i \psi_{Ij}$$

where s is the aggregate saving ratio, c_j is the fraction of the industry's output absorbed in consumption, and i_j is the corresponding fraction absorbed in investment ($c_j + i_j = 1$). Thus ψ_{cj} is the per capita consumption elasticity, and ψ_{Ij} is the per capita investment elasticity. Summing across the sectors yields

$$\psi_z = \sum z_j \psi_j = 1 = (1-s)\psi_c + s\psi_I$$

[7] See Bianchi (1998) for a very useful discussion of innovation and consumer behaviour.
[8] Letting each industry growth rate depend additionally on the pattern of prices, in replicator fashion, would not alter, only deepen this result. See Montobbio, 2002 for a development of this replicator principle.
[9] To see this, let the savings ratio, s, be a constant, for which it follows that $\psi_c = \psi_I = \psi_z = 1$. Over time ψ_z evolves with changes in structure and changes in the elasticities according to the relation

$$\sum \dot{z}_j \psi_j + \sum z_j \dot{\psi}_j = 0$$

But $\dot{z}_j = z_j(g_j - g_z) = z_j(\psi_j - \psi_z)\hat{q}$, from (2). Thus

$$\sum z_j \dot{\psi}_j = -\hat{q} \sum z_j (\psi_j - \psi_z)\psi_j = -\hat{q} V_z(\psi_j)$$

where $V_z(\psi_j)$ is the weighted variance in income elasticities of demand. It follows that $\sum z_j \dot{\psi}_j = 0$ if, and only if, productivity growth is zero or if all income elasticities are the same (unity in value). The former assumption rules out technical progress, the latter rules out structural change. Hence we are left with the requirement that

$$\sum z_j \dot{\psi}_j < 0$$

on, average, the per capital income elasticities must decline in this growing economy. If we are prepared to let the rates of decline be uniform at rate ρ, then

$$\rho = -\hat{q} V_z(\psi_j)$$

[10] See Cornwall and Cornwall (2002) for a closely related derivation.
[11] In case it might be thought obvious to weight productivity <u>change</u> by the employment shares given that $\bar{q} = \sum e_j \bar{q}_j$ it should be noted that differentiation of this expression gives

$$\hat{q} = \sum z_j \hat{q}_j + \sum z_j \hat{e}_j$$

where z_j is the share of sector j in aggregate output and $\hat{e}_j$ is the proportionate rate of change of the sector's employment share. This follows since $e_j \hat{q}_j = z_j \hat{q}$.

[12] To derive this, write, $\sum e_j \psi_j = \sum z_j \psi_j + \sum (e_j - z_j)\psi_j$ and recall that $e_j \overline{a}_z = z_j a_j$, with $\overline{a}_z = \sum z_j \overline{a}_j$. The result follows immediately.

[13] Strictly speaking it determines the value of $\left(\sum e_j \psi_j\right)\hat{q}$, but the simplification for diagrammatic purposes is obvious.

[14] Of course, it is trivially obvious that without innovation there would be no technical progress functions, no positive feedback and no productivity growth. We haven't yet escaped from Usher's warning, that no progress means no growth (1980).

[15] Since $u_j \sum e_j \psi_j = e_j \psi_j$, it follows that $\overline{\beta}_e$ and $\overline{\beta}_u$ are related by the condition

$$\overline{\beta}_e = \overline{\beta}_u + C_e(\psi_j \beta_j) / \sum e_j \psi_j$$

When the covariance (employment weighted) between income elasticities and technical progress elasticities is zero then $\overline{\beta}_e = \overline{\beta}_u$.

[16] Another way to generate interdependence would be to assume spillovers between technical progress functions but that is another story.

[17] A little manipulation establishes that, for example, in relation to (5) $d\overline{\beta}_u / dt = C_u(\beta, g)$ and that $d\overline{\beta}_e / dt = C_e(\beta, g)$. As with all evolutionary arguments, variety drives change and the theory tells us how to measure variety.

[18] Young seems to ere when he suggests that there is no limit to expansion with a stationary population and in 'the absence of new discoveries in pure and applied science', see (5) above.

[19] The Harrod model is a more sophisticated version of the so-called A.K model of modern growth theorists. See Kurz and Salvadori (1998) for an elaboration and critique. Other, post-Keynesian, approaches are equally applicable but would not add to the current exposition.

[20] As noted above, this is tantamount to assuming a unitary income elasticity of demand for per capita wealth.

[21] The converse case we leave to the reader, in which there is a pro growth connection with productivity change in (6).

[22] Recent contributions have called these generic developments in technology, 'general purpose' technologies. See, Lipsey *et al* (1998), for an exposition and critique of this concept.

[23] This bears on the disputes in relation to the Industrial Revolution and the rate of productivity growth in the UK at the turn of the 18th century. In its early stages modern manufacturing could not be expected to have much of an effect, its weight was too small. Cf. Mokyr (1987), Crafts (1983). In general, it is, of course impossible to identify the process underpinning capitalism from the record of aggregate growth rates. A revolution may quite feasibly leave measured aggregates unchanged yet completely redefine the structure that produces the chosen numbers.

References

Antonelli, C., 2001, The Microeconomics of Technological Systems, Oxford University Press.

Atkinson, A.B. and Stiglitz, J.E., 1969, 'A New View of Technological Change', Economic Journal, Vol. 79, pp 573-578.

Arrow, K.J., 1962, 'The Economic Implications of Learning by Doing', Review of Economic Studies, Vol. 29, pp. 155-173.

Bairam, E.I., 1987, 'The Verdoorn Law, Returns to Scale and Industrial Growth: A Review of the Literature', Australian Economic Papers, Vol. 26, pp. 20-42.

Bianchi, M. (ed.), 1998, The Active Consumer, Routledge, London.

Bliss, C., 1975, Capital Theory and the Distribution of Income, Elsevier, New York.

Carlsson, B., 1995, Technological Systems and Industrial Dynamics, Kluwer, Boston.

Crafts, N.F.R., 1983, 'British Economic Growth, 1700-1831: A Review of the Evidence', The Economic History Review, Vol. 36, pp. 177-199.

Cornwall, J. and Cornwall, W., 2002, 'A Demand and Supply Analysis of Productivity Growth', Structural Change and Economic Dynamics, Vol. 13, pp. 203-230.

Edquist, C., 1996, Systems of Innovation, Pinter, London.

Eliasson, G., 1998, 'On the Micro Foundations of Economic Growth' in Lesourne, J. and Orléan, A. (eds.), Advances in Self Organization and Evolutionary Economics, Economica, London.

Eltis, W., 1973, Growth and Distribution, Macmillan, London.

Fabricant, S., 1940, The Output of Manufacturing Industries: 1899-1937, NBER, New York.

Fabricant, S., 1942, Employment in Manufacturing: 1899-1937, NBER, New York.

Fagerberg, J., and Verspagen, B., 1999, 'Vision and Fact: A Critical Essay on the Growth Literature', in Madrick, J., (ed), Unconventional Wisdom:Alternative Perspectives on the New Economy, The Century Foundation Press, New York.

Foss, K. and Foss, N., 1999, Organising Economic Experiments: The Role of Firms, DRUID, WP No. 995, Copenhagen Business School.

Foss, N. and Knudson, C. (eds), 1996, Towards a Competence Theory of the Firm, Routledge, London.

Freeman, C., 1987, Technology Policy and Economic Performance, Pinter, London.

Freeman, C. and Louça, C., 2001, As Time Goes By: From the Industrial Revolutions to the Information Revolution, Oxford University Press.

Harberger, A.C., 1998, ‘A Vision of the Growth Process’, American Economic Review, Vol. 88, pp. 1-32.

Harcourt, G.C., 1972, Some Cambridge Controversies in the Theory of Capital, Cambridge University Press.

Hirschman, A., 1958, The Strategy of Economic Development, Yale University Press.

Jones, C.I., 1995a, ‘RandD-Based Models of Economic Growth’, Journal of Political Economy, Vol. 103, pp. 759-804.

Jones, C.I., 1995b, ‘Time Series Tests of Endogenous Growth Models’, Quarterly Journal of Economics, Vol. 110, pp. 495-525.

Kaldor, N., 1957, ‘A Model of Economic Growth’, Economic Journal, Vol. 67.

Krugman, P., 1995, Development, Geography and Economic Theory, MIT Press.

Kurz, H. and Salvadori, N., 1995, The Theory of Production, Cambridge University Press.

Kurz, H. and Salvadori, N., 1998, ‘The “New” Growth Theory: Old Wine in New Goatskins’, in Coricelli, F., Di Matteo, M. and Hahn, F. (eds.), New Theories in Growth and Development, MacMillan, London.

Kuznets, S., 1954, Economic Change, Heinemann, London.

Kuznets, S., 1971, Economic Growth of Nations, Belknap, Harvard.

Kuznets, S., 1977, ‘Two Centuries of Economic Growth: Reflections on US Experience’, American Economic Review, Vol. 67, pp. 1-14.

Langlois, R.N., 1983, ‘Systems Theory, Knowledge and the Social Sciences’, in, Machlup, F. and Mansfield, U. (eds.) The Study of Information, Wiley, New York.

Lipsey, R,G., Bekar,C., and Carlaw,K., (1998). The consequences of Changes in GPTs. In Helpman, E. (ed.), General Purpose Technologies and Economic Growth, MIT Press, 1998, pp. 193-218

Loasby, B., 1999, Knowledge, Institutions and Evolution in Economics, Routledge, London.

Metcalfe, J.S., 1999, ‘Instituted Economic Processes, Increasing Returns and Endogenous Growth, mimeo, CRIC, University of Manchester.

Mokyr, J., (ed.) (1987), The Economics of the Industrial Revolution, George Allen and Unwin, London.

Montgomery, C.A., 1995, Resource-Based and Evolutionary Theories of the Firm, Kluwer Academic Publishers, London.

Montobbio, F., 2002, ‘An Evolutionary Model of Industrial Growth and Structural Change’, Structural Change and Economic Dynamics, forthcoming.

Nelson, R., 1993, National Systems of Innovation, Harvard University Press.

Nelson, R. and Winter, S., 1974, ‘Neoclassical vs. Evolutionary Theories of Economic Growth: Critique and Prospectus’, Economic Journal, Vol. 84, pp. 886-905.

Nurkse, R., 1953, Problems of Capital formation in Underdeveloped Countries, Basil Blackwell, Oxford.

Pasinetti, L.L., 1981, Structural Change and Economic Growth, Cambridge University Press.

Pasinetti, L.L., 1993, Structural Economic Dynamics, Cambridge University Press.

Scott, M. F.G., 1989, A New View of Economic Growth, Oxford University Press.

Silverberg, G., and Verspagen, B., 1998, ‘Economic Growth as an Evolutionary Process’, in, J. Lesourne and A. Orlean, (eds), Advances in Self-Organisation and Evolutionary Economics, Economica, Paris.

Usher, D., 1980, The Measurement of Economic Growth, Blackwell, London.

Young, A.A., 1928, ‘Increasing returns and economic progress’, Economic Journal, Vol. 38, pp. 527-42.