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CONVERGENCE CLUBS AND ENDOGENOUS GROWTH

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I. INTRODUCTION

'In the long run we are all dead.' J. M. Keynes.

Despite this truism the behaviour of economies in the long run is of great interest to economists. Indeed, it is possible to build a case that many of today's problems are the result of the short-term horizons of policy-makers who did not attempt to foresee the long-run effects of certain policies (demand expansion, for example) which had short-run appeal. Historically, of course, the process of long-run growth was a major concern of the founding fathers of the subject—Smith, Ricardo, and Marx among others. After a relatively dormant period, interest in long-run growth economics revived after the Second World War in response to the pressing need for reconstruction in Europe and the gradual emergence of the ex-colonial nations.

In the generation or so since the countries of Asia and Africa became independent,[2] there have been some outstanding success stories—but on the whole the record is depressingly grey. In many countries growth has been low and patchy. The disparity between the rich and poor nations remains very wide. A natural question which then arises is whether the current situation is a cyclical phenomena or part of a longer-term trend. Put differently, an important issue is the question of whether or not nations tend to approach each other or move away from each other in the long run—the so-called 'convergence' issue. The convergence hypothesis has been succinctly stated by Abramovitz (1986) who suggested

[1] My interest in this area was stimulated whilst I was visiting Vassar College, USA in 1991–2. My thanks to my colleagues there, in particular Shahrukh Khan. Thanks also to William Baumol, Hassan Molana, and Catia Montagna for helpful and encouraging comments. I am particularly grateful to Colin Mayer for his perceptive comments on an earlier version of this paper. The usual caveat applies.

[2] Most of the Latin American countries have been independent for much longer.

that one interprets convergence as implying a long-run tendency towards the equalization of levels of *per capita* income or levels of per worker product.

This issue was first investigated by Baumol (1986) using data provided by Maddison (1982). The data covered the period 1870 to 1979 for sixteen industrialized nations. Even for these sixteen countries, there was a huge diversity in growth performance with growth in labour productivity ranging from 400 per cent (Australia) to 2,000 per cent (Japan). Baumol (1986) implemented a method of testing the convergence hypothesis by simply running a cross-section regression equation in which the growth rate over the 110-year period was regressed against the initial (1870) level of labour productivity. The actual specification was:

$$ln\,(Y_T / Y_0) = a + b\, ln\, Y_0 \qquad (1)$$

where Y stands for labour productivity and the subscripts T and 0 denote the terminal and initial period respectively. For each country, the LHS of (1) is a measure of the growth rate of Y over the period. The estimated coefficient of b turned out to be both *negative* and *significant*. This implied that the fast growing countries were those which initially had a low level of productivity and vice versa. Thus there appears to be strong evidence in favour of catching up and the convergence hypothesis. The same data revealed that:

> In 1870, the ratio of output per work-hour in Australia, then the leader in Maddison's sample, was about eight times as great as Japan's (the laggard). By 1979, that ratio for the leader (the United States) to the laggard (still Japan) had fallen to about 2. (Baumol, 1986)

These results indicated what Baumol (1986) described as 'the convergence phenomenon and its pervasiveness'.

The simplicity and conclusiveness of Baumol's results are disarming. None the less, three separate but related issues arise from the analysis. At the conceptual level, there is the question of whether negative correlations between growth and initial level of productivity (or real GDP *per capita*) are in fact sufficient to establish convergence. At the theoretical level, the question which must be raised is whether there is any good theoretical model which might account for the convergence hypothesis. And, at the empirical level, there is the issue of whether Baumol's findings carry over when one examines other data sets, especially those which include a wider set of countries.

This paper is about these issues. In section II, we explore the meaning of convergence in greater depth and argue that simple regressions like (1) do not do it full justice. In section III we discuss theoretical developments which allow analysis of the convergence hypothesis. We argue that the traditional neoclassical growth model does indeed predict convergence of a limited kind. We also examine the recently burgeoning literature on endogenous growth models which have quite different implications. In section IV we discuss attempts to test the convergence hypothesis using a much broader data set than Maddison's. We propose a framework which has rich implications for different kinds of convergence possibilities. Section V concludes.

II. CONVERGENCE AND CATCHING UP

Like many other 'grand' themes that have percolated in economics, convergence needs to be defined succinctly and unambiguously before it has much operational value.[3] Baumol (1986) and subsequently others[4] have equated convergence with a negative value of b in an equation like (1); in other words, convergence is fully identified with a negative relationship between growth and the initial level of the relevant variable. In most studies the relevant variable has been real *per capita* income rather than labour productivity. The set of countries for whom such a negative relationship holds is then referred to as belonging to the 'convergence club'. Is this procedure appropriate?

[3] Other examples of 'grand' themes which had to undergo the same process of circumcision are deindustrialization, dualism, etc.

[4] See, for example, Barro (1991).

Let us call the period of time spanned by the initial and terminal years, a 'generation'.[5] Clearly, so long as the focus of attention is one generation only, there is some merit to defining the convergence club as the set of countries for whom growth and initial level are negatively correlated. However, this condition of negative correlation between growth over the period and initial level is not sufficient for the variance of real *per capita* income to be lower at the end of the period than at the beginning. Quite simply the absolute gap between two convergence club members can be bigger at the end of the generation than it was at the beginning, despite the negative relationship. A numerical example will suffice to explain this point. Suppose we estimate (1) for a set of countries and it turns out that $a = 7$ and $b = -3$ so that (1) can be rewritten as :

$$ln\,(Y_T\ /\,Y_0\ ) = 7 - 3\ \ ln\,Y_0. \tag{2}$$

The conventional analysis would argue that the set of countries belongs to a convergence club. Consider any two countries A and B from the set and rewrite (2) as :

$$ln\,Y_T\ = 7 - 2\,ln\,Y_0 \tag{3}$$

Suppose that Y_0 for A and B is 100 and 1,000 respectively so that taking logarithms (to base 10)[6] implies that $ln\,Y_0$ is 2 and 3 respectively. Hence from (3) we obtain $ln\,Y_T$ as 3 and 1 respectively, which implies Y_T is 1,000 and 10 respectively. Thus at the end of the generation the absolute gap between A and B is 990 as opposed to 900 at the beginning! This is not catching up and does not correspond to an intuitive notion of convergence. We shall refer to this negative relationship as the existence of *weak convergence*.

More importantly the conventional analysis offers no concrete answer to the question: convergence to what? Suppose the same growth process implicit in (1) were to repeat itself generation after generation. The question that naturally arises then is: does there exist a steady state towards which some countries converge and what are the characteristics of this steady state? This motivates the following definition of convergence. We define *strong convergence* as requiring two conditions: first, the existence of a steady state in which *per capita* real income is equalized; and secondly the presence of dynamic forces which in the long run drive the world economy to this steady state.

Maintaining (1) as the basic vehicle of analysis, it is possible to obtain necessary and sufficient conditions for strong convergence. In steady state, real *per capita* incomes will be equalized at a level Y^* given by $ln\,Y^* = -(a\,/\,b)$. However, the existence of this steady state does not guarantee convergence to it. It can be shown that if, and only if, b is negative and less than 2 in *numerical* value will convergence be assured.[7] In our example above, we deliberately violated this condition (the *numerical* value of b was 3) to demonstrate the point.

The existence of a convergence club is, then, taken to imply the existence of a set of countries which, in the long run, are driven to this steady state with equalized real *per capita* incomes. It is, of course, quite possible, depending on the data, that the conditions for convergence are satisfied only when a subset of countries is included in the sample. In

[5] The use of the word 'generation' is awkward when using the Maddison data which spans 110 years. However, most studies have used a different data set with a time span of 26 years. Hence our choice of the word 'generation'. In principle nothing is changed if we consider the time span to be an 'epoch' rather than a 'generation'.

[6] It is not usual to use logarithms to base 10. We do so here to make calculation easy. Throughout the rest of the paper we intend logarithms to be taken to the natural base.

[7] The formal proof is as follows: rewrite (1) as :

$$y_t = a + (1 + b)\,y_{t-1} \tag{A}$$

where t, $t-1$ have replaced T, 0 respectively and y has replaced $ln\,Y$. This is a standard difference equation and stability requires that:

$$-1 < 1 + \mathrm{b} < 1, \quad \text{viz.}\ -2 < b < 0\,.$$

This is the condition stated in the text.

that case the convergence club is an exclusive club from which some countries are excluded.

The methodology for analysing convergence that we have outlined above can easily be extended to include cases where the basic estimating equation is more complex than (1). We shall exploit it later in the paper in section IV. Despite its simplicity, its implications are quite deep. Our methodology can lead to quite different conclusions from the conventional one when interpreting any set of estimates. We shall illustrate quite how dramatic the difference can be by analysing some estimates provided by Baumol and Wolff (1988)—hereafter referred to as BW.

A major motivation of the BW analysis was to examine the possibility that the convergence club was an exclusive one from which some countries were excluded. Accordingly they based their analysis on a much wider data set than Maddison's.

This data set is the famous Summers–Heston data set which has been used by all subsequent researchers in the field. The data covers a much wider set of countries based on World Bank sources. A major difficulty in constructing data which measures the real income of different countries is the choice of a factor converting the different incomes into a common unit—say constant dollars. Some exchange rate has to be used. The main advantage of the Summers–Heston data over the World Bank's data is that the Summers–Heston data attempts to correct exchange rates for purchasing power parity.[8] If the same basket of commodities costs \$2 in the USA but only 1 peso in Pesoland, then the purchasing power parity value of the peso is \$2 = peso 1. For a variety of reasons the prevailing exchange rate may be quite different, say \$1.50 = peso 1. If the national income of Pesoland is 100 pesos, then using (uncorrected) exchange rates gives a national income for Pesoland of only \$150 whereas the true national income in purchasing power parity terms is \$200. The Summers–Heston data attempts to use such purchasing power parity values to make real income comparisons across countries and for that reason is deemed to be the industry standard for researchers interested in cross-country analysis. The Summers–Heston data contains information (of varying degrees of reliability) on most macroeconomic variables for a wide cross-section of countries. The early version used by BW had data from 1950 to 1980 for some seventy-two countries. The data has recently been updated to include many more countries and runs from 1960 to 1985. This updated Summers–Heston (1988) data set is what most other researchers have used.

Using the Summers–Heston (1984) data, BW concluded that there was an exclusive convergence club from which many countries were excluded. Their methodology was of course based on equating convergence with a negative correlation between growth and initial level. Their basic estimating equation was a slight variant of (1), viz.:

$$ln\,(Y_T/\,Y_0) = a + b\,Y_0\; - c\,Y_0^2 \qquad (4)$$

where Y stands for *per capita* real GDP[9] and the subscripts 0 and T stand for initial and terminal period respectively. BW estimated (4) using the data for seventy-two countries with 1950 as the initial period and 1980 as the terminal period. The estimates they obtained were $a' = 0.586$, $b' = (38/10^5)$ and $c' = (1/10^7)$.[10]

For each country, the LHS of (4) is a measure of the growth rate of Y over the generation, while the RHS is a quadratic in initial Y. The quadratic expression has a unique maximum at $Y_0 = (b/2c) = \$1{,}900$. Clearly for countries with an initial real *per capita* income in excess of this critical value, growth is inversely related to initial level. BW call this set of countries the convergence club. The reverse is true for those countries whose initial Y is below the critical level. This is illustrated in Figure 1.

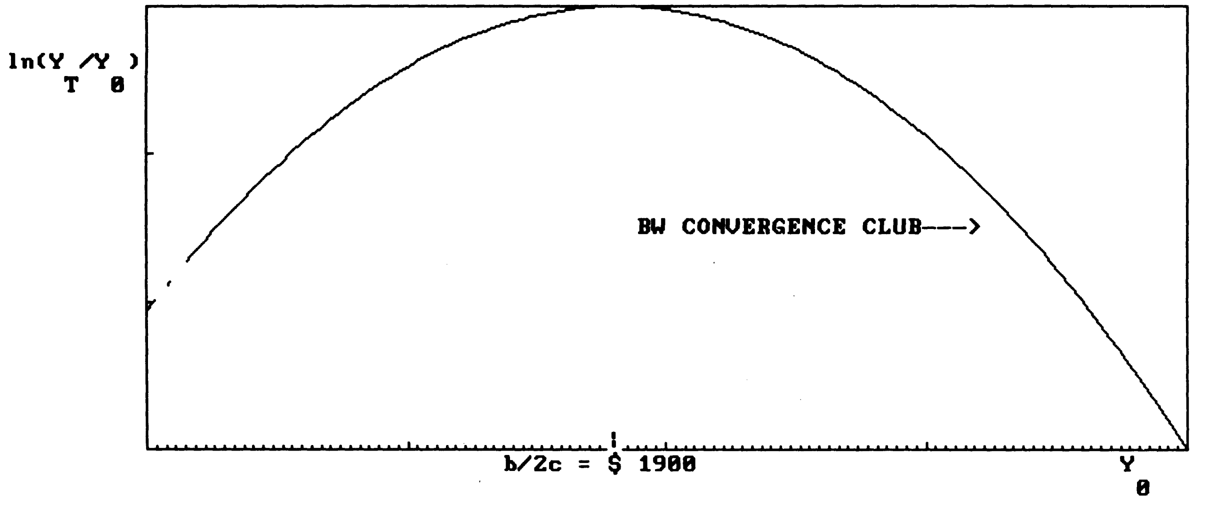
Quite different conclusions are reached by applying our methodology to the BW estimates. There is a slight difficulty in that the BW equation has levels

[8] For details see Summers and Heston (1984).

[9] It is perfectly possible to base the analysis on some other appropriate variable such as labour productivity as Baumol did in his earlier 1986 study. However, there is some doubt about the reliability of the labour productivity data in the Summers–Heston data and so most researchers have used real *per capita* income as the variable under analysis.

[10] There is clearly a misprint in the paper where the value of c' is reported as $(9.9/10^7)$ or $(1/10^6)$. This does not square with later calculations done by the authors.

Figure 1
The BW Convergence Club



of initial income rather than log levels of initial income on the RHS. This implies that the difference equation implicit in (4) is non-linear. However, it can be approximated by a linear equivalent to which our methodology can then be applied. It turns out that the steady-state value implicit in the BW estimates is $4,977. However, the implicit value of b turns out to be –3.06 which is greater than 2 in *numerical* value.[11] This implies, of course, that there is no convergence to the steady state. (Recall that in our earlier example demonstrating non-convergence we had supposed b to be –3). *The convergence club is empty*! It would appear that non-convergence is the norm.

Thus our methodological critique of the conventional approach is of importance in practice. In presenting our own empirical results in section IV, we use an extension of the methodology presented here. Before that we turn to an analysis of theoretical growth models which have a direct bearing on the convergence–non-convergence debate.

III. NEOCLASSICAL AND ENDOGENOUS GROWTH MODELS

The neoclassical growth model of Solow (1956) and Meade (1961) is an important vehicle for the study of economic growth and the analysis of convergence. The key parameter determining the steady-state growth rate of *per capita* income is the rate of *exogenous* technical progress. The model's stability properties ensure that the steady-state growth path is achieved starting from any level of income. What are the implications of this model for catching up and convergence? Imagine two countries identical in all important respects—savings rates, population growth rates, production functions, and the rate of exogenous technical progress—but with one country initially poorer than the other. In steady state both countries will have identical rates of *per capita* income growth. However, in the short to medium run this will not be the case. The poor country will initially have a lower level of capital stock than the richer one. Thus the poorer

[11] For full details of these calculations see Chatterji (1992*a*).

country will have a higher (marginal) productivity of capital and hence a lower capital–output ratio. This implies that in the adjustment to the steady state growth path the poorer country will exhibit faster *per capita* income growth than the richer one.[12]

These implications of the neoclassical growth model have been succinctly stated by Barro (1991) as:

> In neoclassical growth models . . . a country's *per capita* growth rate tends to be inversely related to its starting level of income per person. In particular . . . poor countries tend to grow faster than rich countries. Thus, there is a force that promotes convergence in levels of per capita income across countries.

Note, however, that the convergence implicit in the neoclassical model is of the weak variety. Strong convergence in the sense we discussed earlier is not a property of the model—there is no reason to expect the levels of *per capita* income to be equalized in the long run.

A major weakness of the neoclassical approach to growth is that the main force driving growth in real *per capita* income, viz. the rate of technical progress is exogenous. Two alternative approaches which do not make this assumption are the diffusion hypothesis and the new models of endogenous growth.

The notion that technical progress spreads in an evolutionary manner from innovative to imitating countries via a diffusion process has been proposed and analysed by Nelson and Phelps (1966), Nelson and Winter (1974), and Gomulka (1971, 1986, and 1990). In the context of the convergence debate it has been alluded to by Baumol (1986) and Dowrick and Gemmell (1991). The central conceptual apparatus derives from Gomulka (1971, 1986). The basic idea is that the growth rate of technological change in any country depends on the technology gap between the country and the world leader in technology. The process whereby this happens is technology transfer and innovation.[13] This relationship is also hypothesized to be 'hat'-shaped or inverted U-shaped. This is because countries with a very small gap are under little pressure to imitate the leader whilst countries with a large gap are under high pressure to mimic but lack the ability to do so. Hence, for very different reasons, both these groups have low technological growth. By contrast, countries with a middle-sized gap are under enough pressure to mimic and also have enough infrastructure, sufficient high quality education, a reasonably developed research and development sector, etc. to be able to exploit the gains from technology transfer. Empirical support is adduced using data from fifty-five countries for 1950–68 (Gomulka, 1971) and from the Eastern European countries (Gomulka, 1986).

In operational terms, the growth rate of technology is proxied by the growth rate of real income *per capita* (or labour productivity) whilst the gap is proxied by the difference between the initial level of *per capita* income in the country to that of the world leader. Figure 2 illustrates this.

In Figure 2 the initial gap (measured in natural logarithms) between the *per capita* income of the leader and that of other countries is on the horizontal axis, whilst the growth rate of countries over the period is shown on the vertical axis. The diffusion hypothesis asserts that (depending on the parameters of a relationship such as shown in Figure 2) some countries will converge to the leader in the long run and thereafter grow at the same rate as the leader.

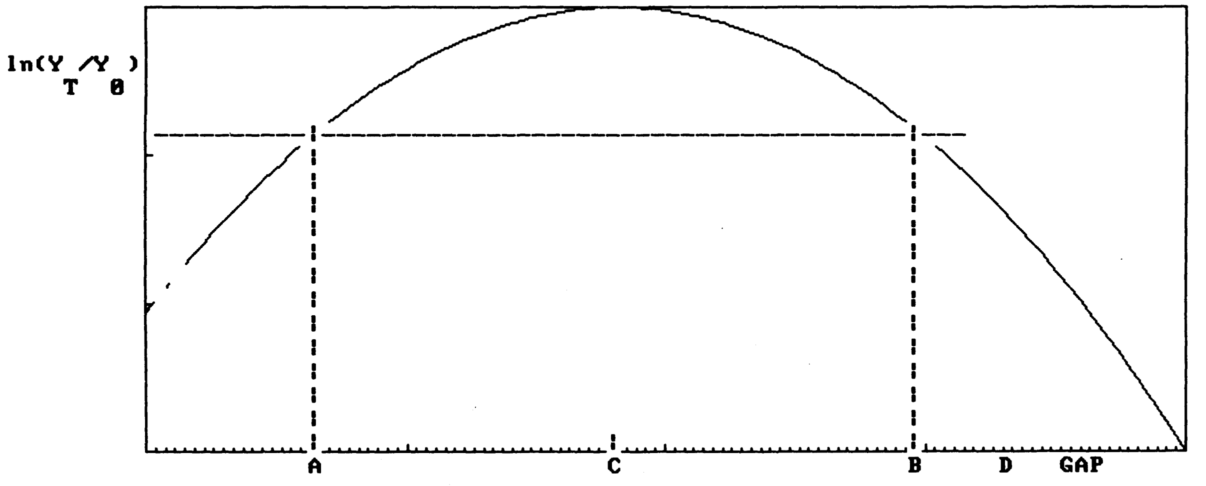
The similarity of Figure 2 to Figure 1 is misleading because the short-run implications are quite different. Figure 2 suggests that countries with widely differing initial real income *per capita*, as at *A* and *B*, have the same rate of growth in the short run. Thus, during the adjustment phase, there is no negative relationship between growth and initial level. As with Figure 1, the negative relationship holds only for some countries—those whose initial gap is larger than at *C*. The country with a gap as at *C* has the largest growth rate. However, to identify the existence of a convergence club, analysis of the long-run properties of the model is required. In the diffusion model illustrated by Figure 2, all countries with an initial gap less than *D* will eventually catch up with the leader (whose growth rate is exogenous).[14] In steady state all these countries will

[12] This point is formally demonstrated by Barro and Sala-i-Martin (1992).

[13] Baumol (1986) advances a not dissimilar argument although the formal embodiment of the argument is quite different.

[14] See Chatterji (1992*a*), where the detailed calculations required to support the analysis are done.

Figure 2
The Diffusion Growth Model



grow at the same rate. These countries constitute an exclusive convergence club. In steady state, members of this club will have a real income *per capita* gap of zero. Thus, unlike in the neoclassical model, the level of *per capita* income is tied down, but only *relative* to the leader. Hence the model does predict strong convergence for a subset of countries.

Figure 2 also illustrates the different implications of the criteria for weak and strong convergence. All countries with initial gaps larger than *D* are excluded from the convergence club because they will not converge to the zero gap equilibrium in the long run. However, these same countries do satisfy the criterion for weak convergence. Similarly, all countries with initial gaps less than *C* do not satisfy the weak convergence criterion but none the less are in the convergence club.

A common feature of the diffusion model and the neoclassical model is that both suggest convergence to a unique equilibria (at least for some countries). Neither considers the possibility of multiple convergent equilibria. This feature is central to the new endogenous growth models developed by Romer (1990), Matsuyama (1991), and Krugman (1991) amongst others. Indeed, Matsuyama (1991) suggests that a primary motivation for analysing multiple equilibria endogenous growth models is precisely because 'The diversity of *per capita* income levels across countries suggests the presence of some sort of multiplicity.'

Another feature of the endogenous growth approach is that growth rates are not exogenous but depend on internal allocation processes. This arises either because of non-decreasing returns to scale or because of production externalities. Mankiw *et al.* (1992) summarize the implications of endogenous growth models to the convergence debate as being that: 'countries that save more grow faster indefinitely and that countries need not converge in income *per capita*.'

In order to bring out the flavour of this class of model, we follow a particularly simple and appealing model due to Krugman (1991) Consider an economy with two sectors—advanced and backward—which are labelled *A* and *B* respectively. In the advanced sector, labour productivity depends on the scale of operations at the *industry* level. This externality is obviously ignored by each firm in its decision making. In the *B* sector, no such externality prevails and labour productivity is constant. Hence the wage differential between the two sectors depends on how large the *A* sector is. Two potential equilibria exist—one with output concentrated in the *A* sector and the other with output concentrated in the *B* sector. I shall refer to these as the high and low equilibria respectively. Krugman demonstrates that under plausible adjustment mechanisms, both these can be stable equilibria depending on the initial allocation of labour in the two sectors. If initial labour allocation in the *A* sector is high enough, then the initial wage differential is such that labour tends to move towards the *A* sector, and thus the high equilibria prevails; conversely if the initial labour allocation is low in the *A* sector. Hence there exists some critical level of labour initially allocated to the *A* sector: if the initial labour allocation to *A* is higher than this critical level, then the economy converges to the high equilibria and conversely. Since initial GNP *per capita* depends positively on this initial labour allocation, it follows that the economy converges to the high equilibria only if its initial *per capita* GNP is high enough to exceed some critical level. Thus both equilibria can be stable, depending on initial *per capita* income.

This dual equilibria endogenous growth model can be easily combined with the Gomulka-type diffusion hypothesis in a number of different ways depending on what precisely is assumed about the manner in which the two sectors benefit from technical progress via diffusion. Thus the rate of technical progress within a country depends partly on exogenous factors (the growth rate of the leader) and partly on endogenous factors (the internal allocation process of the country). One possibility is to assume that both sectors benefit equally but that for each country the leader is different. Suppose that the leader for each country is the one with the next highest *per capita* income. Then the process of growth will be equalizing as each country 'drags' up the one just behind it. For some parameter values, everyone will converge to the same equilibrium in the long run. Testing such a model requires explicit consideration of long-run time series data for each country. Despite its potential appeal, we eschew this approach in favour of a simpler one.

If, as in Gomulka, we assume that all countries have a common leader so that the source of technology diffusion is the same for all countries, then in long-run equilibrium all countries will have the same growth rate (that of the common leader) even though there are two long-run equilibria (a high and a low equilibrium). But countries converging to the low equilibrium, will have a lower level of *per capita* income than those converging to the high equilibrium. Thus in this version of the combined diffusion/dual equilibria approach, it is possible to imagine two separate mutually exclusive convergence clubs, each characterized by strong convergence. In the superior club all countries have the same *per capita* income as the leader and grow at the same rate thereafter. In the weaker club all countries will converge to the same level of *per capita* income but this will be lower than that of those countries in the superior club. This implies that disparities between the rich and poor nations can be indefinitely sustained and, indeed, get bigger. Note that this combined model 'nests' both the endogenous growth and the diffusion hypotheses as special cases. If we fail to identify both a superior convergence club and an inferior convergence club based on starting *per capita* income level, then the endogenous growth view is rejected. If only a single club can be identified, then this supports the diffusion view. If we fail to identify any club, then both views are rejected. This richer possibility is an interesting addition to the set of possible outcomes when examining cross-country data. We return to it in the next section.

IV. ECONOMETRIC RESULTS

Most protagonists in this debate have used the latest Heston–Summers (1988) data. The set of countries considered has generally excluded the oil rich as well as the very small nations (those with populations less than one million). The initial year has been taken to be 1960 and the terminal year 1985.

Several authors such as Dowrick and Nguyen (1989), Barro (1991), Barro and Sala-i-Martin (1992), Dowrick and Gemmell (1991), and Mankiw *et al.*

Table 1
Growth in Real *Per Capita* Income, 1960–85

Group	Number	Mean (%)	Std Dev. (%)	Min. (%)	Max. (%)
Dismal	15	–23	17	–52	–1
Moderate	41	26	14	0	48
Good	37	71	14	51	98
Outstanding	16	128	19	102	158

Source: Summers and Heston (1988).
Notes: The groups are defined by their growth performance as follows: Dismal = negative growth rates; Moderate = growth rates between 0 and 50 per cent; Good = growth rates between 50 per cent and 100 per cent; Outstanding = growth rates in excess of 100 per cent.

(1992), have investigated the convergence issue empirically. The general result is a negative one as stated by Barro (1991):

> The hypothesis that poor countries tend to grow faster than rich countries seems to be inconsistent with the cross-country evidence, which indicates that *per capita* growth rates have little correlation with the starting level of *per capita* product.

Only when attention is restricted to the set of richer (OECD) countries is there some support for the convergence hypothesis as demonstrated by Baumol and Wolff (1988), Dowrick and Nguyen (1989), Dowrick and Gemmell (1991), and Mankiw *et al.* (1992). Another approach is to add further explanatory variables (beyond initial *per capita* income)—in particular initial human capital measures—to the analysis. Barro (1991), Barro and Sala-i-Martin (1992), and Mankiw *et al.* (1992) successfully exploit this approach and show that once other significant explanatory variables are added to the basic regression equation, then the convergence result is re-established *for countries with the same levels of human capital etc*. This is referred to as the existence of conditional (weak) convergence. In general, however, the rejection of weak convergence has been taken to imply implicit support for the endogenous growth model.[15]

Table 1 shows the diversity of growth experience over the period 1960–85. Countries are divided into four groups—those whose *per capita* income growth performances are respectively dismal, moderate, good, and outstanding.

The table suggests why (weak) convergence does not appear to have much support. Even for the high flyers in the Outstanding group, the difference between the best and worst is enormous. There does not appear to be much hope for strong convergence in this data. However, in another study (Chatterji, 1992*b*) we find strong support for the combined endogenous growth/diffusion model.

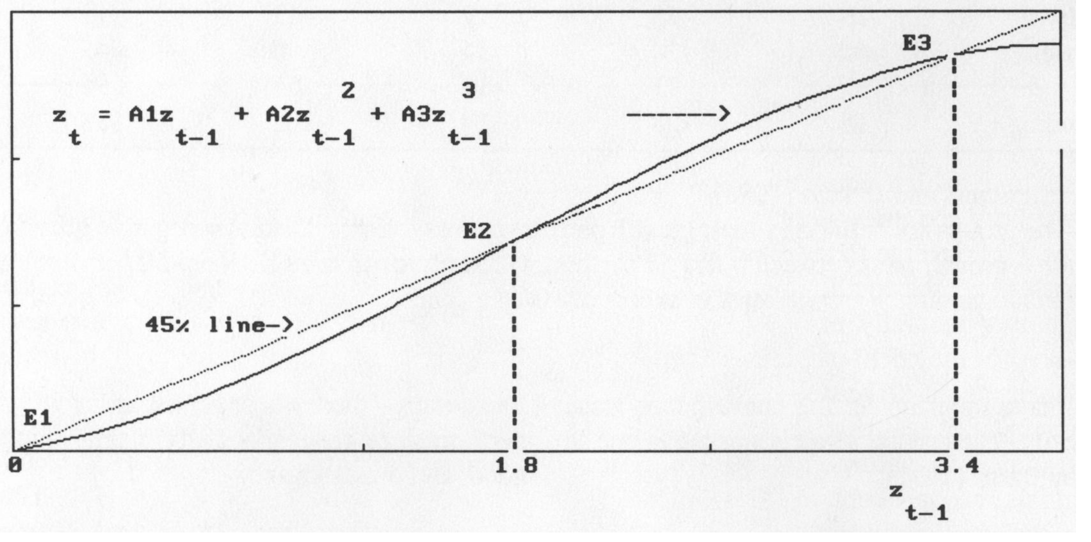
Both in 1960 and in 1985, the country with the highest real income *per capita* amongst the 109 countries in the sample was the USA. Accordingly, the USA was unambiguously identified as the leader. For every country, the gap variable, z, was defined as the difference between the (natural) logarithm of real income *per capita* in the USA and the (natural) logarithm of real income *per capita* in the country in question. This was done both for 1960 (the initial year) and 1985 (the terminal year). This definition measures the gap as a strictly positive number for every country (except the USA for whom the gap is identically zero). The basic vehicle was equation (5) below :

$$z_t = A_1 z_{t-1} + A_2 z_{t-1}^2 + A_3 z_{t-1}^3 \qquad (5)$$

where the subscript t stands for the terminal period of the generation (1985) and $t-1$ stands for the

[15] A significant exception is Mankiw *et al.* (1992).

Figure 3
High and Low Convergence Clubs



initial period of the generation (1960). Equation (5) is a rich specification which allows tests of various convergence hypotheses associated with the different growth models. If A_1 is less than 1 (numerically) and $A_2 = A_3 = 0$, then we get strong convergence to the leader for all countries. If only A_3 equals zero, then for reasonable values of A_1 and A_2 we get the diffusion model where those countries with an initial gap low enough converge strongly to the leader and form an exclusive convergence club from which the remaining countries are excluded. If all three coefficients are non-zero, then the possibility of the combined diffusion/endogenous growth model being appropriate is open.

The regression result was remarkably robust. Over 80 per cent of the variance was explained, the coefficients A_1, A_2, and A_3 were very well determined at non-zero levels and there was no evidence of serious misspecification. Both an inferior club and a superior club are well identified. Figure 3 illustrates this.

In Figure 3 the three equilibria implicit in a cubic equation like (5) are labelled E_1,E_2, and E_3 respectively. Obviously E_1 is the high equilibrium, and E_3 the low equilibrium. The middle equilibrium E_2 is unstable. Recall that the condition for strong convergence in (1) was that b was negative but greater than –2. That condition is equivalent to $(1 + b)$ less than unity in absolute value.[16] Rewriting (1) as:

$$y_t = a + (1+b)y_{t-1} \qquad (1a)$$

we see that $(1 + b)$ is the slope of the RHS of (1*a*). In effect the condition for strong convergence is that the slope of the RHS of (1*a*) is less than unity in numerical value. Applying this analogy to (5), it is clear from Figure 3 that the slope of the RHS of (5) is less than unity at E_1 and E_3 but greater than unity at E_2. Thus E_1 and E_3 are stable equilibria representing strong convergence whilst E_2 is unstable and therefore represents an equilibrium towards which no one will converge.[17] Hence those countries with an initial 'gap' less than $z_2 = 1.8$

[16] See footnote 6.

[17] These can be verified formally by evaluating the derivatives of the RHS of (4) in the neighbourhood of the three equilibria.

Table 2
Growth in Real *Per Capita* Income, 1960–85, Low and High Club Members

Group	Number	Mean (%)	Std Dev. (%)	Min. (%)	Max. (%)
Low club	64	39	51	–52	158
High club	45	65	35	–7	155

converge to the high equilibrium of zero gap; however, those countries with an initial 'gap' in excess of 1.8 converge to the 'low-level equilibrium trap', where the equilibrium gap is 3.4. Thus there are two mutually exclusive convergence clubs—one for the 'rich' nations and one for the 'poor' where the cut-off between rich and poor is an *initial* gap of 1.8. Recall that the gap is measured as the difference in natural logarithms. Taking exponentials, an equivalent statement can be made in terms of the ratio of a country's real *per capita* income to that of the USA. Those countries whose initial real income *per capita* is one-sixth or more of that of the USA belong to the high convergence club.[18] In the long run these countries will enjoy the same *per capita* income as the USA. On the other hand, those countries with an initial real *per capita* income which is less than one-sixth that of the USA belong to the low convergence club. These countries will converge to another steady state characterized by a real income *per capita* approximately one-thirtieth that of the USA.[19] This does not imply absolute poverty since growth will be occurring and a real income of one-thirtieth of the USA may in fact be quite a handsome number. It should be noted that during the transition to the steady state, countries with initial gaps less than 1.8 or bigger than 3.4 are actually catching up on their target leaders, whereas those with an initial gap between 1.8 and 3.4 are slowing down.

Table 2 shows the growth performance of countries in each of the two clubs.There are forty-five countries in the high club and sixty-four in the low club. The low club has a worse mean performance but also a more variable performance than the high club. None the less there are some high flyers in the low club and some laggards in the high club. It should be noted that of the forty-five members of the high club, twenty-nine are LDCs. The remaining LDCs are in the low club. Of particular interest are those countries which are close to the cut-off point of an initial gap value of 1.8. Guatemala, Colombia, and Malaysia all have gaps of just under 1.8 suggesting that they are the marginal members of the high club. By contrast, Mozambique, El Salvador, Panama, Brazil, Ecuador, Guyana, and Sri Lanka, with gaps ranging from 1.85 to 1.95, are the marginal members of the low club. The only real surprise is that Taiwan turns out to be a member of the low club. Clearly special factors are needed to account satisfactorily for Taiwan's growth performance. Table 2 does suggest that simply observing a large diversity in growth performance cannot tell us whether convergent or divergent forces are at work.

V. CONCLUSIONS

This paper has been concerned with the issue of the differential growth rates of different nations. This question has long been the focus of growth economics. In recent years, the availability of improved cross-country data provided by Summers–Heston has lent an added impetus to research in this area.

The literature has in the main concentrated on two main issues. The first is the question of the proximate determinants of economic growth. The second is the related issue of whether initial income (*per capita*) is the major determinant of economic growth. While the motivation for the first question is obvious, the second has been explored because of its bearing on the convergence or catching-up issue. If growth is negatively related to initial *per capita* income, then it has been argued that eventually the

[18] The natural log of 6 is approximately 1.8.

[19] The natural log of 30 is approximately 3.4.

poorer nations will catch up with and converge on the richer nations in terms of *per capita* income. We have shown why such weak convergence is neither necessary nor sufficient for long-run equalization of *per capita* incomes.

The theoretical basis of the 'convergence' hypothesis has been taken to be the standard neoclassical growth model. For given parameters, any reasonable adjustment mechanism suggests that initial income is negatively correlated with growth. By contrast, the burgeoning endogenous growth literature suggests that there is no relationship between growth and initial income. Indeed, since the data lends no support to the weak convergence hypothesis, this has sometimes been taken to imply implicit support of the endogenous growth view. A further difference between these two approaches is that the endogenous growth approach admits the possibility of multiple equilibria. What both approaches have in common is that they tend not to exploit fully the possibility that a country's productivity function may depend on that of another via technological diffusion. The idea that a given country's productivity is influenced by the technological gap between itself and its trading partners is not in itself new. What is shown in this paper is that it can complement the endogenous growth approach to generate new insights—in particular, the existence of more than one convergence club becomes a possibility.

Our estimates suggest that this possibility is a very real one. We show there are two mutually exclusive convergence clubs—one for the 'rich' and one for the 'poor' where the division between rich and poor is endogenously determined. In steady state, the (equalized) *per capita* income of the 'rich' nations will be higher than that of the (equalized) *per capita* income of the 'poor' nations by a constant multiple. Since growth is occurring in steady state, the absolute difference in *per capita* income between 'rich' and 'poor' will grow. This is quite a strong implication which goes beyond the persistence of *per capita* income differentials.

To development economists, these conclusions are not particularly radical. As long ago as 1957, Leibenstein (1957) alerted us to the possibility that some countries may be 'stuck' in a low-level equilibrium trap which of course corresponds to our low convergence club. The contribution of the combined diffusion/endogenous growth model we proposed (and tested) is that it enables one to describe the characteristics of the low-level equilibrium trap and also to identify which nations are caught in it. As Leibenstein suggested, these countries will need a 'big push' to get out of the trap. This suggests that a policy of gentle gradualism by aid agencies and governments of the richer countries will not necessarily help these nations. Indeed, our results suggest that systematic programme aid should be directed towards certain target nations—those which are marginal members of the low club. The 'big push' required for them may not be too difficult to achieve and may well tip them over the margin into the high club, whence self-sustaining growth towards a high *per capita* income is possible. In particular, if one country had to be singled out, it is Brazil with its large population and marginal membership of the low club. This in no way denies the importance and desirability of special aid measures such as food aid or drought relief to countries facing emergency situations.

The externality underlying the persistence of multiple equilibria also suggests the possibility of government intervention. The forms and scale such intervention might take are beyond the scope of this paper and constitute a research agenda in their own right. The same applies to the scale and type of 'big push' policies by aid agencies, international institutions, and governments of the richer nations. Much richer models based on much more detailed country specific data will be required before serious policy alternatives can be discussed.

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