Is International Openness Associated with Faster Economic Growth ?

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Abstract

This paper considers the role of international openness in facilitating income convergence within a model of distribution dynamics. Discriminant analysis is used to sort economies into open and closed groups, and the evolution of the cross-section income distribution modelled for both the whole world and open/closed economies separately. Open economies are found to exhibit substantially different income dynamics and to converge to different levels of income to their closed economy counterparts, differences that remain even after conditioning on relative investment levels.

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1 Introduction

An important strand of the cross-country growth literature is the empirical research into convergence. In addition to the traditional regression-based literature on cross-country convergence associated with, for instance, Barro and Sala-i-Martin (1991), (1992) and (1995) and Mankiw, Romer and Weil (1992), a more recent body of work purports to find evidence that economies are clustering into groups - or convergence clubs - with different convergence properties: Bianchi (1995), Desdoigts (1994), Durlauf and Jonson (1995), Paap and Van Dijk (1994) and Quah (1993b), (1996a), (1996b) and (1996c). This empirical finding does not in itself help to distinguish between growth theories since the existence of bimodality, or twin peaks as it is often more graphically described, is not necessarily inconsistent with conditional convergence in a standard neo-classical growth framework. On the other hand, the finding of bimodality has also helped to generate theoretical research into endogenous growth and convergence clubs. Bliss (1995), Quah (1996b) and García-Peñalosa (1995) are examples of theoretical models that seek to explain the empirical literature of convergence clubs.

Another important strand of the empirical growth literature is research into the relationship between openness to the international economy and a country's rate of economic growth (eg Balassa (1985), Edwards (1992) and Dollar (1992)). In general, researchers tend to agree that outward-orientated countries perform better. In an important contribution, Sachs and Warner (1995) provide evidence for the remarkable result that the only variable on which one needs to condition to observe convergence is the economy's trade regime. In other words, open economies converge *absolutely* but closed economies do not.

In this paper, we seek to investigate whether these two strands of the literature are linked. Is it the case that the bimodality result is associated with differences in trade regimes between countries? After allowing for different trade regimes, does the evidence suggest convergence to a single mode or is bimodality still exhibited? To consider this type of issue, we make use of techniques suited to the analysis of the evolution of the entire distribution of income to re-examine the empirical links between openness and growth.

One of the problems of the openness and growth literature is that there exists no simple, generally accepted theoretically-based means of evaluating openness. Further, evidence provided by Pritchett (1996) reveals that many of the measures used by researchers are pairwise uncorrelated. On the other hand, there is quite a large statistical literature on how to sort data observations into separate populations. Drawing on this literature, we apply a variation of Fisher's Linear Discriminant rule to separate countries into two groups, on the basis of number of *incidence-based* measures of the stance of a country's trade regime.

Using the Summers and Heston (1988) data set, we study 109 countries during the period 1970-89. We first analyse the world cross-section distribution of income and generate the familiar twin peaks result. Examination of the group of open and closed economies shows each group evolving towards a distribution with a single mode: with the majority of countries tending to higher income levels in the open group.

This result does not address the problem of potential omitted variables - that is, there may be some third variable driving both growth performance and trade policy. In particular, evidence presented on the linear regression model by Levine and Renelt (1992) suggests that measures of openness cease to have a significant impact on growth performance when investment shares are introduced as an explanatory variable. We therefore use an approach suggested by Quah (1996b), (1996d) and Andres and Lamo (1995) to condition on investment behaviour. We find that investment does explain some of the polarisation, but that, nevertheless, the transition probabilities conditional on investment still exhibit bimodality for the whole sample, and unimodality when considering the groups of open and closed economies separately.

The structure of the paper is as follows. Section 1 briefly outlines the concepts of convergence and twin peaks in the economic growth literature, and describes a technique for analysing the evolution of the conditional and unconditional cross-section distribution of per capita income. Section 2 briefly outlines the empirical literature on openness and growth, and describes an *atheoretic* approach to evaluating relative openness levels. Section 3 describes the evolution of the conditional and unconditional cross-section distribution of per capita income for the whole sample and for the group of open and closed economies. Section 4 considers the robustness and the significance of the results. Section 5 concludes.

2 Convergence and twin peaks

2.1 Concepts of β and σ convergence

The existing literature on income convergence across economies or regions is characterised by two broad approaches.[1] The first or traditional approach, beginning with Barro and Sala-i-Martin (1991) and (1992), distinguishes two concepts of convergence: β and σ. A cross-section income distribution is said to exhibit *β-convergence* if an economy's rate of growth of income per capita is negatively correlated with its initial level of income. The same distribution shows *σ-convergence* if the cross-section dispersion of per capita incomes falls over time, where dispersion is typically measured by the sample standard deviation. The two concepts are quite distinct: β-convergence is associated with mean reversion and does not imply σ-convergence if the process of mean reversion is offset by new disturbances that tend to increase dispersion. These issues are discussed more fully in the following section (and for a more detailed treatment, see Barro and Sala-i-Martin (1995)).

Much of the debate regarding convergence has occurred within the context of the Solow-Swan (1956) model of growth, which therefore provides a useful introductory framework. One of the implications of this model is that, the further an economy's income per capita is from its steady-state, the higher that economy's rate of growth. Hence, if the determinants of steady-state income are the same across all economies, *β-convergence* should be observed. If the determinants of steady state income vary, then *β-convergence* will only be observed after controlling for a variety of characteristics. This has led to a distinction between *absolute* and *conditional* convergence, where conditional convergence controls for economies' characteristics.

More formally, consider the version of the augmented Solow-Swan growth model developed in Mankiw, Romer and Weil (1992). Rates of investment out of output (s), population growth (n), depreciation (δ) and technological progress (g) are taken as exogenous[2]. The produc-

[1] A third approach has also recently begun to develop, based upon the time-series properties of the income series.

[2] As in the standard representation of the Solow-Swan model, it is assumed here that domestic savings equal domestic investment. It is straightforward to show that the introduction of international capital mobility increases rates of convergence. For a discussion of the impact of the international economy on convergence in this

tion function is given by the standard

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha} \quad ,0 < \alpha < 1 \tag{1}$$

where (A) is an index of technology. Defining, as usual, $k = K/AL$ and $y = Y/AL$, then the evolution of (k) is governed by

$$\dot{k}_t = sy_t - (n + g + \delta)k_t \tag{2}$$

therefore

$$\dot{k}_t = sk_t^{\alpha} - (n + g + \delta)k_t \tag{3}$$

In the steady state, the capital/technology-augmented labour ratio is constant, which implies that,

$$sk^{*\alpha} = (n + g + \delta)k^* \tag{4}$$

hence,

$$k^* = [s/(n + g + \delta)]^{\frac{1}{1-\alpha}}, \tag{5}$$

substituting in $(y = k^{\alpha})$ and taking logs, it follows that the steady-state value of (y) is given by

$$\ln(y^*) = \frac{\alpha}{1-\alpha}\ln(s) - \frac{\alpha}{1-\alpha}\ln(n + g + \delta), \tag{6}$$

Then approximating around the steady state, the speed of convergence is given by

$$\frac{d\ln(y_t)}{dt} = (n + g + \delta)(1 - \alpha)[\ln(y^*) - \ln(y_t)] \tag{7}$$

Solving this differential equation and substituting for the steady-state level of income gives

$$\ln(\tfrac{y_t}{y_0}) = (1 - e^{-\phi t})\tfrac{\alpha}{1-\alpha}\ln(s) - (1 - e^{-\phi t})\tfrac{\alpha}{1-\alpha}\ln(n + g + \delta) \\ -(1 - e^{-\phi t})\ln(y_0) \tag{8}$$

framework see Barro and Sala-i-Martin (1995).

where ($\phi = (1-\alpha).(n+g+\delta)$). Countries converge to their own steady state, and their rate of growth depends on the instantaneous distance from their steady state.(3)

Empirical tests for *β-convergence* have therefore generally estimated a linear regression equation of the form,

$$\gamma_{i,t,t+T} = \alpha + \beta \log(Y_{i,t}) + \Psi X_{i,t} + \varepsilon_{i,t,t+T} \quad \textbf{(9)}$$

(where, γ, is the rate of growth of per capita income in equation **(9)** between (t) and ($t+T$), (Y) is per capita income in the same economy at the start of the sample period and (X) is a vector of conditioning variables). Evidence of absolute *β-convergence* only exists for similar regions or economies such as United States (see for example Barro and Sala-i-Martin (1991), (1992) *op cit*) and the OECD (see for example Baumol (1986) and Durlauf and Johnson (1995)). Nonetheless, once one controls for a variety of characteristics such as investment rates, population growth and school enrolment, evidence for conditional *β-convergence* emerges among dissimilar economies such as those included in the Summers and Heston (1988) data set (see for example Mankiw, Romer and Weil (1992)). In almost all samples, the rate of convergence to steady state is estimated to be about 2% a year. Sala-i-Martin (1994) provides evidence of *σ-convergence* across regions of the United States, Japan, Europe, Spain and Canada.

2.2 Recent concepts of convergence

The second broad approach to research on income convergence - research into multimodality - has sprung from a critique of this traditional approach to estimating convergence made most forcefully in a series of important papers by Quah (1993a), (1993b), (1996a), (1996b) and (1996c).(4) The concept of *β-convergence* is a problem for several reasons. First, Quah (1996a) provides Monte Carlo evidence that, even if the true data generating process for the cross-sectional income distribution is a series of independent random walks, finite sample bias may still generate an estimated rate of convergence of about 2%, the same rate as the estimated rate of *β-convergence* described above.

(3) For a more complete derivation of these results, see, for example, Barro and Sala-i-Martin (1995).

(4) This section draws in particular on Quah (1996a).

However, a unit root in time series can only form a partial explanation for estimated *β-convergence*, as Quah (1996a) himself notes: the sample standard deviations for the estimate of the rate of convergence produced by the Monte Carlo simulations are much higher than found in most cross-section regressions.

A second, more powerful, criticism, is that a negative correlation between initial income per capita and growth rates does not necessarily imply that the cross-section dispersion of income is falling over time (*σ-convergence*). As argued by Quah (1993a), *β-convergence* may be observed in a cross-section distribution of income with unchanged (or even rising) dispersion. In this case, *β-convergence* simply reflects reversion towards the mean, and does not imply a falling cross-section dispersion of income.[5]

More formally, following Sala-i-Martin (1994) and Quah (1996a), suppose that the log of income per capita in each economy $j = 1, ...n$ is independently and identically distributed across the cross section, and evolves over time as;

$$\log y_{j,t} = \beta \log y_{j,t-1} + e_{i,t} \tag{10}$$

where $|\beta| \langle 1$, $y_{j,0}$ is independent of $e_{j,t} \forall t \geq 1$, and where $e \sim iid(0, \psi^2)$ across both the cross section and time. If n is large, then the sample variance of $\log y_{j,t}$ may be approximated by the population variance σ_t^2, which from **(10)** is given by,

$$\sigma_t^2 = \beta^2 \sigma_{t-1}^2 + \psi^2 \tag{11}$$

In steady state, $\sigma_t = \sigma_{t-1}$and hence

$$\sigma^2 = (1 - \beta^2)^{-1} . \psi^2 \tag{12}$$

σ-convergence will only occur if **(12)** is smaller than the cross-sectional distribution of income at the start of time. However, the assumption of stationarity in **(10)** implies there is mean reversion, and hence *β-convergence*. The concept of *β-convergence* can thus be uninformative in answering whether poor countries are catching up with the rich.

However, this does not imply that *σ-convergence* is sufficient for understanding the evolution of the cross-section distribution of income:

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[5] To draw this implication is an example of Galton's Fallacy, as noted by Friedman (1992) and Quah (1993a).

the same level of dispersion is consistent with widely different dynamics. For example, a constant σ is consistent with either a world in which poor countries catch up with and then leap-frog the initially rich, or a world in which countries remain persistently rich or persistently poor.

In order to address these kinds of question adequately, one requires an analysis of the evolution of the entire cross-section distribution of income. An approach to this kind of analysis has been developed recently, by for example, Quah (1993a), (1993b), (1996a) and (1996b) and Bianchi (1995).

2.3 Distribution dynamics

Following from the discussion above, an analysis of the evolution of the entire cross-section distribution of per capita income involves an analysis of two distinct but related concepts. First, one is interested in the shape of the distribution at each point in time: how many modes does it have, what is its mean, how has it changed over time? That is to say, by examining the evolution of the external characteristics of the annual cross-sectional distribution one can make statements about the overall pattern of income inequality. Second, one also needs to understand *intra-distribution dynamics*: are the countries at the top of the distribution last year still top this year, how long does it take to move from the bottom to the middle of the distribution? Without an analysis of this sort, one is unable to distinguish between a scenario in which economies leap-frog each other and one in which relative positions are deeply entrenched.

To study the law of motion for the cross-section distribution of income, we need a model of the stochastic process that describes it. We can do this by using probability measures associated with the cross-section distribution itself. The theoretical framework for this approach is well documented elsewhere (see for instance, Stokey and Lucas (1989), Andres and Lamo (1995) and Quah (1996c)). Drawing on this literature, we model the evolution of the cross-section distribution in terms of a first-order stochastic difference equation.

Let θ_t be a sequence of probability measures associated with the cross-section distribution. Then the stochastic difference equation can be defined by:

$$\theta_t = M(\theta_{t-1}, u_t) \tag{13}$$

where M maps the probability measures plus a disturbance term into probability measures in the next period, and where M is constant over time. As it stands, this formulation is not soluble. However, it can be solved if the disturbance term is ignored. Iterating **(13)**, we can then rewrite it as:

$$\theta_{t+s} = (M)^s \theta_t \qquad \textbf{(14)}$$

We can then make use of the observed sample to make inferences about the long-run distribution of cross-country income which characterises the steady state by letting s go to infinity.

However, since M is infinitely dimensioned, some simplification is required before it can be manipulated in practice. That is, M can be approximated by sub-dividing the set of possible values of relative incomes at regular intervals. If so, then M becomes a transition probability matrix Γ each of whose elements corresponds to the probability that an economy moves from one state into another. This format is now tractable in the following difference equation;

$$\theta_t = \Gamma(\theta_{t-1}, u_t) \qquad \textbf{(15)}$$

The estimates from **(15)** allow us to approximate the steady state. Assuming certain regularity conditions hold, repeated iterations of the matrix converge to the long-run matrix each of whose rows is the ergodic distribution. The ergodic distribution tells us the unconditional probability of an economy ending up in a particular income range. Complete convergence in income across countries would show up as an ergodic distribution degenerated to a point measure. Lack of convergence would be represented as an evenly spread ergodic distribution and polarisation as a series of point measures.(6)

By and large, the results of this approach have provided evidence against the simple convergence hypothesis. Rather, both Quah and Bianchi *op cit.* find evidence of convergence towards a cross-sectional distribution characterised by considerable persistence and a polarisation of income into two convergence clubs. The ergodic world distribution of income is bimodal, with twin peaks at high and low levels of income.(7)

(6) As the number of iterations of the transition matrix is increased, all the rows of the θ matrix converge on the ergodic distribution. This will be given by the eigenvector associated with the largest eigenvalue of the transition probability matrix.

(7) Similar techniques may also be employed to consider the evolution of per capita

2.4 Conditioning

Empirical evidence of bimodality has helped to generate interest among theoretical researchers: Bliss (1995), Quah (1996b) and García-Peñalosa (1995) are examples of theoretical models that seek to explain the empirical literature of convergence clubs. However, the twin peaks result reveals information about the apparent lack of absolute convergence, but *per se* reveals nothing about conditional convergence in a standard neo-classical growth model. The evidence of evolution towards a world polarised between rich and poor is not necessarily inconsistent with conditional convergence. Suppose, for example, that the world is characterised by conditional convergence - as in **(8)** - but that there are two sets of economies A and B. Within each set, the determinants of steady state income are the same. However, there are exogenous variations in these determinants across the two sets of economies. Conditional convergence hence implies that the world cross section distribution of income will evolve to two distinct steady states and that the estimated single ergodic distribution will therefore appear to be bimodal.

An approach has been suggested by Quah (1996b), (1996d) and Andres and Lamo (1995) that seeks to distinguish the impact of particular factors on transition probabilities by estimating conditional probabilities. This approach can be illustrated with reference to the augmented Solow model. Re-arranging **(8),** in which the conditional variables are (n, g, d) as defined in Section 2.1,

$$\begin{aligned} \ln(y_t) = (1 - e^{-\phi t})\tfrac{\alpha}{1-\alpha}\ln(s) - (1 - e^{-\phi t})\tfrac{\alpha}{1-\alpha}\ln(n + g + \delta) \\ + e^{-\phi t}\ln(y_0) \end{aligned} \quad \textbf{(16)}$$

Estimating **(16)** yields a time series of residuals for each country that are orthogonal to the explanatory variables. As such, one can construct a world cross-section distribution of residuals which can be interpreted as a conditional cross-section distribution since, by construction, OLS gives that part of the variation in income unexplained by variations in the explanatory variables. Hence, estimating **(15)** for this cross-section distribution produces transition probabilities that are *conditional on* the explanatory variables (although one may not,

income across regions within an economy (Quah (1995, 1996e)) or across industrial sectors (Cameron, Proudman and Redding (1997)).

for example, be able to interpret the co-efficients if there are omitted variables).

3 Openness

3.1 Openness and growth

A second major strand of the empirical growth literature is research into the relationship between economic growth performance and countries' openness to the outside world. A numer of studies - for instance Balassa (1985), Edwards (1992), Dollar (1992) - have found a positive link between a country's growth rate and its openness to the international economy. In an interesting study of *β-convergence*, Sachs and Warner (1995) measure the impact of post-war trade liberalisation on economic performance and provide evidence in support of the striking proposition that open trade leads to convergent rates of growth. That is, openness leads to higher growth rates in poorer countries than in rich. By dividing the world into a group of open economies and a group of closed economies, the importance of trade is shown in several cross-country growth regressions in which other determinants of growth are held constant. The reason Sachs and Warner (1995) attribute to their finding is technology transfer. Through opening up to the global economy, countries are able to benefit from scientific advances and improvements elsewhere, and this is *sufficient* to allow their income levels to tend towards that of the richest nation. An alternative explanation is capital accumulation within the framework of an augmented Solow model: openness may be associated with higher levels of capital accumulation.

Given these two interesting empirical findings - first, that there is an apparent bimodal ergodic distribution of world income, and second, that there is an apparent association between openness and growth - a natural question to ask is whether the twin peaks result is related to countries' openness. Is it possible that there are two groupings of countries - determined by their relative levels of openness - that explain the twin peaks result?

3.2 Measuring openness

One of the problems with analysing the relationship between openness and growth is that openness is neither directly observable nor has an accepted definition derived from theory. As a result, quite a large literature has grown up proposing and evaluating alternative measures to capture the concept of openness. Following Baldwin (1989) and Pritchett (1996), there are essentially three strands to the literature.

The first relates economic growth to *ex post* measures of openness, such as export shares (eg Feder (1983) and Jung and Marshall (1985)). While a useful approach, export performance is itself not necessarily an indicator of the openness of trade policy. That is, export shares are also determined by other factors, such as country size, geography and location. At the same time, it is potentially problematic if export performance is itself endogenous.

The second strand of the literature attempts to evaluate openness using an *outcome-based* approach. This approach assesses the deviation of the actual outcome from what the outcome would have been without the trade barriers. There are two most frequently used outcome-based measures. One is a trade flow measure based on the residuals from a trade intensity regression indicating the amount by which a country's trade intensity differs from that predicted for a country with similar characteristics. This is sometimes augmented with a modified Hecksher-Ohlin-Vanek (HOV) model of trade flows (eg Leamer (1988)). The other is a price distortion measure, often based on differences in purchasing power parity (eg Pritchett (1996)).

The third strand - the *incidence-based* approach - seeks to measure openness by direct observation of trade measures and has been used in numerous other studies, such as Balassa (1985), Dollar (1992), Edwards (1992) and Leamer (1988). Sachs and Warner's (1995) definition of openness falls into this category, and is a fairly comprehensive measure of the major types of trade restriction. Average tariff rates and non-tariff barriers are direct obstacles to imports of goods and sevices. Black market premia are measures of exchange control. A large premium is evidence of the rationing of foreign exchange, which can prevent the free flow of both goods and capital and studies have found a significant negative correlation between growth and black market premia (eg Harrison (1991)). The dummy variables for socialist economic systems and state monopolies on exports are used to cover countries that limit openness directly by central planning rather than by the types of price and quantity control already mentioned. Although *incidence-based* measures may still be endogenous (given, for instance, the interaction between political economy and economic performance) they are likely to be less endogenous than other measures of openness.

If the three strands of the literature each accurately estimated some underlying orientation of trade policy, one would expect them to generate highly correlated measures of openness. However, Pritchett (1996) provides evidence that there is little pairwise correlation between different measures of openness, and hence little consistency between the three strands of the literature. In this paper, we too follow an incidence-based approach on the basis that it most closely reflects underlying trade policy and most nearly avoids problems on endogeneity. To do so, we make use of the data set provided in Sachs and Warner (1995). A major drawback with the incidence-based approach is that it provides no single measure of openness nor guidance from the theory on how to weight the various important trade variables. On the other hand, the statistical literature provides greater guidance on how to separate data into groups on the basis of their characteristics. In particular, we consider whether *discriminant analysis* can allow us to improve on the allocation process.

3.3 Discriminant analysis

There is quite a large statistical literature on the separation of data into distinct populations on the basis of shared features. Discriminant analysis, therefore, offers one possible - *atheoretic* - means for evaluating relative levels of *incidence-based* openness. The following survey follows closely Mardia, Kent and Bibby (1979). In general, discriminant analysis takes the following form. Consider g populations or groups, $\Pi_1, ..., \Pi_g$. Suppose that associated with each population Π_j, there is a probability density $f_j(x)$ on R^p, so that if an individual comes from population Π_j, he has the probability density function $f_j(x)$. Then the object of discriminant analysis is to allocate an individual to one of these g groups on the basis of its measurements x. Next, a *discriminant rule* d corresponds to a division of R^p into separate exclusive and exhaustive spaces $R_1, ..., R_g$, and where the rule d is defined by,

$$\text{allocate } x \text{ to } \Pi_j \text{ if } x \in R_j \tag{17}$$

$\forall j = 1, ..., g$. Clearly, discrimination will be more accurate if Π_j has most of its probability concentrated in R_j. A major branch of discriminant analysis refers to situations in which we have no prior information about which population an individual is drawn from. In this situation, there are three standard techniques available. The first, and least frequently employed, is a maximum likelihood approach that can be used in the situation in which the probability density functions $f_j(x)$ are known exactly. The second technique - also based on a maximum likelihood approach - can be used when the form of the probability density function for each population is known, but the parameters themselves must be estimated.

The third common approach is an empirical one that does not assume any specific form of the probability density functions for the populations, but looks instead for a 'sensible' rule to distinguish between them. The most common such technique - *Fisher's linear discriminant function* - is based on maximising the ratio of the sum of squares of sub-group means to the sum of squares of observations around their sub-group means. Intuitively, the function sorts the data into groups in such a way as to emphasise both the similarities of elements within the same group and the differences between the representative properties of the separate groups.

The data on measures of openness are taken from Table 6 of Sachs and Warner (1995). There are 83 countries for whom there are data on all six measures of openness and on income and investment. Another 25 have income and investment data and some but not all measures of openness. We also allocate these 25 countries to their respective groups using the discrimination procedure described below, but restricted to the available openness measures. Since it is plausible that there are diminishing marginal costs to being closed, we take the logs of the raw data series, which suggests an implicit log-linear measure of openness. We then apply *Fisher's linear discriminant function* on the four continuous measures of openness, which provides a (83×4) matrix (X) on the logs of continuous openness variables. Given an arbitrary allocation of countries into (g) groups, we look for a linear combination of the rows, $(a'x)$ which maximises the ratio of the between-groups sums of squares to the within-groups sum of squares. Let

$$y = Xa = \begin{bmatrix} X_1 a \\ . \\ . \\ . \\ X_g a \end{bmatrix} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \end{bmatrix} \quad \textbf{(18)}$$

be a linear combination of the columns of X. Then y has total sum of squares

$$y'Hy = a'X'HXa = a'Ta \quad \textbf{(19)}$$

which can be partitioned as a sum of the within-groups sum of squares,

$$\sum_{i=1}^{g} y_i' H_i y_i = \sum_{i=1}^{g} a' X_i' H_i X_i a = a'Wa \quad \textbf{(20)}$$

plus the between-group sum of squares,

$$\sum_{i=1}^{g} n_i (\bar{y}_i - \bar{y})^2 = \sum_{i=1}^{g} n_i \{a'(\bar{x}_i - \bar{x})\}^2 = a'Ba \quad \textbf{(21)}$$

where $(\bar{y}_i)$ is the mean of the ith sub-vector of (y), and (H_i) is the $(n_i \times n_i)$ centering matrix,

$$H_i = I - \frac{i}{n_i} ii' \quad \textbf{(22)}$$

where (i) is the $(n_i \times 1)$ vector of ones. The ratio of the between-groups sum of squares to the between-groups sum of squares is therefore given by the *discriminant ratio*,

$$a'Ba/a'Wa \quad \textbf{(23)}$$

If the composition of the two groups were known *a priori*, we could use **(23)** to back out the implicit weights on the openness variables - given by a - that most distinguished the two groups. However, it is precisely the composition that we wish to establish, and consequently, we need to compare values of **(23)** between allocations to the two groups.

Since, the vector (a) can be re-scaled without affecting the ratio **(23)**, the *discriminant ratio* can be compared for different allocations of countries to groups, and hence the optimal allocation can be chosen as that which maximises the value of the *discriminant ratio.* The information contained in the dummy variable series is then used, to allocate countries to the closed group if they are either classified as socialist or have a government export monopoly.

Given that there are a large number of possible combinations of countries, a survey technique is used to search for the maximum value of the *discriminant ratio.* Each country is allocated randomly to either the group of open or closed economies using a Bernoulli trial - repeated 20,000 times - with given probability (p) of being allocated to the closed group. The resulting values of $(a'x)$ and the *discriminant ratio* associated with the allocation of countries are calculated, and each observation re-evaluated on the basis of its *discriminant score* $(a'x)$. The sample means of the groups of open and closed economies have scores $a'\bar{x}_i = \bar{y}_i$, for $i = 1, 2$. Then the observation (x) can be re-allocated to the population whose mean score is closest to $(a'x)$; that is, allocate (x) to population (i) if,

$$|a'x - a'\bar{x}_i| < |a'x - a'\bar{x}_j|, \forall j \neq i \qquad \textbf{(24)}$$

(When there are only two groups, the allocation produced by the rule **(24)** is equivalent to a special case of the second maximum likelihood approach mentioned above). Application of this rule suggests a process of repeated iteration, which we term the *Iterated linear discrimination function*: each time observations are re-allocated by **(24)** to the open and closed groups, the optimal value of $(a'x)$ can be re-calculated, until convergence is reached. At this stage, the groups of open and closed economies have the desirable feature that the value of $(a'x)$ for each observation is closer to the group mean than to the alternative group mean, and that the value of $(a'Ba/a'Wa)$ increases with each iteration, suggesting a more clear-cut distinction between the groups.

The *Iterated linear discrimination function* converges to the same allocation - which is also the maximum value of **(23)** - in over 95% of trials when there is only one column in (X). The function converges to the same allocation less frequently as the number of columns increases but still converges to the same - and the highest - value of the *discriminant ratio* in 35% of trials as the columns of (X) rises to four, irrespective of the value of (p). Since the *Iterated linear discrimination function* does not converge to the same value 100% of the time, there is some probability that there is a superior allocation that produces a higher value of $(a'Ba/a'Wa)$. However, using standard asymptotic tests for multinomial distributions, we can reject the hypothesis that the probability of finding a higher value is greater than or equal to 0.1%. The data is therefore consistent with our preferred allocation being within the top 99.9% of the distribution of values of $(a'Ba/a'Wa)$.

The allocation of countries derived from the sampling process is given in Appendix 1 and the key results given in Tables A and B below. The values of the four elements of the vector (a) that produces the optimal linear combination of openness measures are provided in Table A. The results of the *iterated linear discriminant function* associated with Table A are given in Table B. In particular, of the total 108 countries in the sample, 28 are classified as open and 80 as closed.

Table A: Value of a' maximising Fisher's Linear Discriminant Function, based on 20,000 trials

Variable	Value of a_i
NTB	+0.0001778
ATR	-0.0195164
BMP70	-0.0840954
BMP80	-0.0075239

Table B: Associated results of the decision rule

Variable	**Value**
Mean of $a'x$ of open group	-0.84515
Mean of $a'x$ of closed group	-0.16540
Value of $a'Ba/a'Wa$	13.2
Number of open economies	28
Number of closed economies	80

4 The Data

4.1 Transition probabilities for the whole world

We start by examining the evolution of the entire cross-country distribution of income per capita - as described in Section 2.3. The data used is drawn from the Summers and Heston (1988) data set and covers 108 countries from 1970 to 1989.(8) We start by using unconditioned data. Income per capita is normalised against US levels, and divided into five states chosen so that the observed sample is approximately divided into equal categories.

(8)The Summers and Heston (1988) data set is the data source used for the great majority of cross-country comparisons of per capita income. An arguable limitation of this source is that GDP data are divided by total poulation rather than hours worked, whereas the latter may be a more appropriate denominator when considering issues of productivity convergence.

Table C: First order, time stationary, annual transition probabilities for the whole sample for real GDP per capita relative to the United States, 1970-1989.
Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
383	1	0.95	0.05	0.00	0.00	0.00
391	2	0.07	0.91	0.02	0.00	0.00
392	3	0.00	0.03	0.92	0.05	0.00
392	4	0.00	0.00	0.04	0.94	0.02
386	5	0.00	0.00	0.00	0.02	0.98
		Ergodic distribution				
		0.293	0.203	0.141	0.157	0.207
		Single-period transition iterated 18 times				
	1	0.6077	0.3164	0.0585	0.0160	0.0015
	2	0.4567	0.3596	0.1230	0.0530	0.0076
	3	0.1216	0.1772	0.3471	0.2856	0.0684
	4	0.0297	0.0684	0.2555	0.4380	0.2084
	5	0.0021	0.0075	0.0466	0.1587	0.7850

Interpretation of the transition probabilities is as follows. The first column gives the total number of transitions from each state over the sample period. Thereafter, each row contains the probability of passing from one state into another. For example, the first row presents the probabilities of moving out of the lowest income state into the first, second, third, etc state in any given year. High values on the diagonal imply that mobility between states in any one year is very unlikely, whereas large values off the diagonal demonstrate higher mobility. Turning first to the estimated unconditional transition probability matrix, the results are presented in Table C. The range of diagonal values is from 0.91 to 0.98, clearly implying a high degree of persistence. This is most acute at the top of the distribution: if an economy is already one of the richest, it is highly likely to stay that way. On the other hand, there are greater signs of mobility in the middle of the distribution. For example there is a 3% chance of an economy in the central state of moving down a state *and* a 5% chance of moving up a state *in any one year*. This degree of mobility is drawn out further when iterated 18 times, that is, the length of the sample period. Whereas an economy initially in the top state has a projected 79% probability of remaining in the top state, an economy in the central state has only a 35% state of ending up in the same state by then end of the period. Table C also presents an estimate of the ergodic distribution, which is an approximation to the distribution's eventual steady state, since it calculates the unconditional probability of an economy ending-up in any particular state. What it shows is evidence of a bimodal distribution. The most common entries are at the highest and lowest states, with density decreasing at the middle income levels.

4.2 Transition probabilities of open and closed economies

We next consider applying the same techniques as in the previous section separately to the groups of open and closed economies. Table D presents the matrix of transition probabilities for the group of closed economies, and Table E, that for the group of open economies. The grid partitions for the two sub-groups have been restricted to be the same as for the whole sample, so that the relative positions of the distributions can be compared.(9) The results are striking. The ergodic distribution of the closed group has a pronounced single peak at the lowest entry, with entries tailing off quickly the higher the income state considered. This is evidence of the countries within the closed group converging towards a steady state at the bottom of the income distribution. While the majority of the annual transition probabilities are within a percentage point or two from the annual transition probabilities for the whole sample, the cumulative difference is pronounced.

(9) When the results are re-estimated with new grids, the results are broadly the same as those presented below.

For example, after 18 iterations, the probability of a closed economy starting in the central group moving down is 36%, compared to only 29% for the entire group. There is, on the other hand, one annual transition probability that is noticeably different for the closed group when compared to the entire group: the annual probability of falling out of the top grouping rises from 2% to 7% if only closed economies are considered; although there is an issue as to how robust this result is given the relatively low number of observations available for the closed group. If we take the result at face value, it suggests that, even if countries are relatively rich, they could end up in the lower reaches of the distribution if closed. In fact after 18 iterations, the probability of remaining in the top ranking is only 29%, while the probability of passing from the top to the bottom of the distribution in this period is over 1%.

Table D: First order, time stationary, annual transition probabilities for the group of closed economies for real GDP per capita relative to the United States, 1970-1989. Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
386	1	0.95	0.05	0.00	0.00	0.00
358	2	0.07	0.90	0.03	0.00	0.00
355	3	0.00	0.04	0.92	0.04	0.00
327	4	0.00	0.00	0.04	0.95	0.01
14	5	0.00	0.00	0.00	0.07	0.93
		Ergodic distribution				
		0.388	0.249	0.181	0.167	0.014
		Single-period transition iterated 18 times				
	1	0.6208	0.2904	00714	0.0170	0.0004
	2	0.4523	0.3322	0.1533	0.0602	0.0020
	3	0.1529	0.2108	0.3554	0.2678	0.0131
	4	0.0395	0.0898	0.2908	0.5371	0.0428
	5	0.0109	0.0351	0.1663	0.4997	0.2879

The results from the group of open economies are also interesting. The evidence of convergence from the estimated ergodic distribution is even more pronounced. The unconditional probability of an open economy ending up in the top bracket is 90%, and only 10% of being in or below the second rank. The impact of openness is most pronounced on poor countries. The annual transition probability out of the lowest ranking is 17%. After 18 iterations, the probability of remaining in the lowest group is only 22% compared to 60% for the whole sample, whereas the probability of remaining within the top grouping rises from 79% to 92%.

Table E: First order, time stationary, annual transition probabilities for the group of open economies for real GDP per capita relative to the United States, 1970-1989. Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
6	1	0.83	0.17	0.00	0.00	0.00
33	2	0.06	0.91	0.03	0.00	0.00
41	3	0.00	0.00	0.98	0.02	0.00
66	4	0.00	0.00	0.00	0.92	0.08
358	5	0.00	0.00	0.00	0.01	0.99
		Ergodic distribution				
		0.000	0.000	0.000	0.100	0.900
		Single-period transition iterated 18 times				
	1	0.2246	0.5197	0.2152	0.0294	0.0110
	2	0.1890	0.4609	0.2782	0.0481	0.0238
	3	0.0000	0.0000	0.6412	0.1959	0.1630
	4	0.0000	0.0000	0.0000	0.2847	0.7153
	5	0.0000	0.0000	0.0000	0.0791	0.9209

The significance of the results can be tested for, based on the asymptotic properties of first-order Markov chains - set out in Anderson and Goodman (1957), and not derived here. Let p_{ij} be the $(ij-th)$ element of the annual transition probability matrix Γ and $\hat{p}_{ij}$ its estimate, then it can be shown that in the limit,

$$\sqrt{(\sum_{t=0}^{T-1} n_i(t)).(\hat{p}_{ij} - p_{ij})} \lim \rightarrow N(0, p_{ij}(1-p_{ij}) \qquad \textbf{(25)}$$

where $(n_i(t))$ is the number of observations in row (i). As a result, standard asymptotic theory for multinomial or normal distributions can be used to test hypotheses about one or more (p_{ij}). In particular, under the null hypothesis that $p_{ij} = p_{ij}^0$ and where $n_i^* = \sum_{t=0}^{T-1} n_i(t)$,

$$\sum_{i=1}^{I} \sum_{j=1}^{m} n_i^* \frac{(p_{ij}^* - p_{ij}^0)^2}{p_{ij}^0} \sim \chi^2 \, with \, m(m-1) \, df \qquad \textbf{(26)}$$

For example, we can test the hypothesis for both the groups of open and closed economies that $p_{ij}^0 = p^0$. That is, the probability of moving into any element of the matrix is the same: there is complete mobility in countries' relative income levels. Evaluating **(26)** under the null for the group of open economies yields a figure for the test statistic of 1,887, compared to a 99% significance level with 20 degrees of freedom of 37.566. The comparable test statistic for the group of closed economies is 4,814. In both cases, we can reject the null hypothesis of even mobility at the 99% confidence level. Clearly, the data are inconsistent with the hypothesis of complete mobility: rather the interest in the test lies - as in standard contingency table analysis - in determining which parts of the transition probability matrix contributed most to the rejection of mobility. For the group of open economies, the contribution of the bottom two diagonal elements contributed some 71% to the total test statistic: providing evidence that the null hypothesis is rejected most forcefully by strong polarisation among the two highest income brackets. On the other hand, the story is reversed for the group of closed economies. The contribution of the three top diagonal elements provided some 60% of the total test statistic. The evidence against mobility was most striking at the bottom of the distribution.

Another test of significance is to re-estimate the transition probability matrix with different transition periods: the results are qualitatively the same whether the re-estimated transition period is 5 years or 18 years, so the numbers are not reported here.

4.3 The effects of openness conditional on investment

Taken together, the results presented above provide evidence that both groups evolve towards unimodal ergodic distributions. That is, convergence in income per capita does occur once one conditions on the trade regime of each country. However, we have not addressed the issue of *omited variables*, we have merely shown an *association* between a particular measure of openness and economic growth. Rather, there may be some other underlying variable(s) that may be responsible both for the behaviour of growth performance - as described in Section 2.4 - and for features of openness.

In particular, Levine and Renelt (1992) show that a large variety of trade policy measures - the ratio of exports to GDP, total trade/GDP, ratio of imports to GDP, average black market premium, and three *outcome-based* measures - are highly correlated with the investment/GDP ratio. Further, linear regression models that produce significant co-efficients when regressing growth rates on trade policy measures cease to be robust when the investment/GDP ratio is also included. We therefore begin by estimating equations of the form of **(7)** in which we introduce investment/GDP shares as the auxiliary variable in (X),[10] for the whole sample and for the sub-samples of open and closed economies.

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[10] Clearly, it would be possible to condition on a whole vector of other variables: the limitations of restricting the vector to a few variables is well-demonstrated by Levine and Renelt *op cit* but is beyond the scope of this study. We chose to experiment by conditioning on investment because it is perhaps the most robust regressor.

Table F: Cross-country growth regressions (dependent variable: annual growth rate of real GDP per capita), 1970-1989.

	Regression (country grouping)			
Independent variable	**1**	**2**	**3**	**4**
	(all)	**(open)**	**(closed)**	**(all)**
Constant	0.014	0.027	0.022	0.018
	(0.012)	(0.022)	(0.019)	(0.016)
Initial GDP per capita	-0.0057	-0.0153	-0.0085	-0.0095
	(0.002)	(0.004)	(0.003)	(0.003)
Investment share	0.0215	0.0422	0.0201	0.0212
	(0.003)	(0.008)	(0.003)	(0.003)
Interraction term	-	-	-	0.0040
				(0.002)
sample size	108	28	80	108
$\bar{R}^2$	0.3414	0.5040	0.4301	0.3737

The results are described in Table F, and show that the effect of investment is both significant and interesting. The impact of investment shares on growth is significantly different to zero for both groups, but the co-efficient is significantly higher in the group of open economies than in the group of closed ones. An interaction term is also included in a regression of the whole sample to take account of incremental effects of openness on investment. The interaction term is constructed to take the value of the investment share if the country is open, but zero otherwise. The co-efficient on the interaction term is again different to zero. Overall, the results in Table F suggest that investment has a larger co-efficient in the group of open economies than the group of closed economies. It is also the case that the mean investment/GDP ratio is higher for the group of open economies than closed.

We next estimate a conditioning regression on income levels relative to the United States, of the form of **(16)**, to generate residuals orthogonal to relative investment shares and hence estimate a conditional transition probability matrix for the whole sample and for the groups of open and closed economies. For the sake of brevity, we briefly describe the results but do not include tables reporting them. The matrix for the whole sample suggests that - as one would expect given the results of the regression analysis - the conditional probabilities off the main diagonal are larger than the unconditional. A large portion of the immobility in country's relative income rankings is associated with differences in investment performance. This is particularly evident when iterated forward 18 times.

On the other hand, the overall conclusion of the transition matrix concurs with that from the unconditional transition probabilities: persistence is highest at the top of the distribution and the ergodic distribution remains bimodal. After allowing for differential investment performances, there is still evidence - albeit, less pronounced - of a world evolving towards two steady states.

The conditional transition probabilities for the group of open economies also display much higher mobility, particularly at the lower ends of the distribution. Again this is shown most clearly in the matrix iterated 18 times. Except in the diagonal element corresponding to the highest income bracket, all of the diagonal (polarisation) probabilities are less than 50%. Nevertheless, the same broad picture emerges as in the unconditional probability matrix. In particular, the ergodic distribution for the group of open economies again tends to one where the mass of density is concentrated at the top of the distribution.

The same conclusion as before also emerges from the analysis of the group of closed economies. The ergodic distribution is unimodal, with the mode at the bottom of the distribution. Overall, therefore, the conditioning results suggest that much of the polarisation in relative income levels is explained away once one allows for differences in investment performance (and we have not addressed the issue of whether differences in investment performance lead differences in openness or *vice versa*). However, conditioning on investment does not explain all the information contained in the ergodic distributions. The transition probabilities conditional on investment still suggest the world has a bimodal steady state, but that the two groups of open and closed economies evolve to different unimodal steady states.

5 Robustness

Inevitably, major changes in the variables used to sort the data will provide a different set of results, particularly given the low pairwise correlation between different measures of openness. On the other hand, we do not wish our results to be highly sensitive to the exact specification of the empirical sorting procedure. In this section, we re-run the transition probabilities for four variations in group allocation, and generate the same result for each variation as for the original allocation.

First, we consider transition probabilities for the same group of open and closed economies used by Sachs and Warner (1995). They classify an economy to be closed if any of the following classifications applies;

- Non-tariff barriers cover 40% or more of trade.
- Average tariff rates of 40% or more.
- A black market exchange rate that is depreciated by 20% or more relative to the official rate during the 1970s or 1980s.
- A socialist economic system.
- A state monopoly on major exports.

This classification produces a group of 39 open economies and 69 closed economies. The estimated transition probabilities based on this allocation are shown in Appendix 2, and show the same unimodality result.

Second, the value of $(a'x)$ chosen to maximise **(23)** gives heavy weight to the black market premium in 1970 (BMP70), and we wish to test by how much BMP70 alone determines the result. We therefore seek the maximum value of **(23)** having imposed equal weights on each element within (a). The results produce an almost identical allocation of countries: the only difference is that Guatemala is now classified as closed. In addition, by imposing a predetermined value for (a), the data matrix (X) is reduced to a single column. This variant therefore increases the proportion of trials to 99% in which the *iterated linear discriminant function* converges to its maximum value. The transition probability matrix is also shown in Appendix 2.

Third, we seek the maximum value of **(23)** excluding BMP70 altogether. Again, the results produce an almost identical grouping: Guatemala and Venezuela are now classified as closed. In short, the data in BMP70 is not redundant - in so far as it does help to distinguish between the data - but neither does it overinfluence the result. The transition probability matrix is shown in Appendix 2.

Fourth, we consider an allocation based on a different measure of trade policy. We classify as open any economy that belongs to one of the world's established (and relatively pro-free trade) trade groupings: the OECD, the EU or ASEAN. Again, the estimated transition probability matrices show different unimodal ergodic distributions for the groups of open and closed economies. These are shown in Appendix 2.

6 Conclusion

In this paper, we have used techniques suited to examining the evolution of the whole cross-section distribution of income to analyse whether there is an association between openness and growth across time and across countries. Considering the world as a whole, we find evidence to support the familiar twin peaks result. Using discriminant analysis, we suggest an *atheoretic* method for sorting countries into groups of open and closed. Taking each group separately, we find the twin peaks result disappears: each group evolves towards its own unimodal distribution. When allowance is made for differential investment behaviour between countries, we find that immobility in relative incomes levels declines considerably. On the other hand, the conditional distribution remains twin peaked for the whole world, and unimodal for the two groups of open and closed economies. Finally, we find the result is not dependent upon the exact specification of our definition of openness.

These results suggest that openness does have an important role to play in the convergence process, even after conditioning on relative investment behaviour. At one level, the results suggest that openness is important because it allows poor countries to catch up with the rich. Conversely, the absence of openness exerts pressure on countries to converge to the lower levels of the cross-country distribution. At another level, tests for convergence can tells us about the effectiveness of growth policies. By implication, our results suggest that if countries introduce the correct trade policies, they can converge to the highest levels.

7 Appendix 1: Country Compositions

Table G:
Open economies

1 Australia	15 Japan
2 Austria	16 Luxembourg
3 Belgium	17 Malaysia
4 Canada	18 Netherlands
5 Denmark	19 New Zealand
6 Finland	20 Norway
7 France	21 Singapore
8 West Germany	22 Spain
9 Guatemala	23 Sweden
10 Haiti	24 Switzerland
11 Honduras	25 Thailand
12 Hong Kong	26 United Kingdom
13 Ireland	27 United States
14 Italy	28 Venezuela

Table H:
Closed economies

1 Algeria	22 Ecuador	43 Madagascar	64 Sierra Leone
2 Angola	23 Egypt	44 Malawi	65 Somalia
3 Argentina	24 El Salvador	45 Mali	66 Sri Lanka
4 Bangladesh	25 Gabon	46 Mauritania	67 South Africa
5 Barbados	26 Gambia	47 Mauritius	68 Swaziland
6 Benin	27 Ghana	48 Mexico	69 Syria
7 Bolivia	28 Greece	49 Morocco	70 Taiwan
8 Botswana	29 Guinea	50 Mozambique	71 Togo
9 Brazil	30 Guinea-Biss	51 Myanmar	72 Tunisia
10 Burkina Faso	31 Guyana	52 Nicaragua	73 Turkey
11 Burundi	32 Hungary	53 Niger	74 Uganda
12 Cameroon	33 India	54 Nigeria	75 Uruguay
13 Central Afr. R.	34 Indonesia	55 Pakistan	76 Yemen
14 Chad	35 Iran	56 Papua New Guinea	77 Yugoslavia
15 Chile	36 Israel	57 Paraguay	78 Zaire
16 China	37 Ivory Coast	58 Peru	79 Zambia
17 Colombia	38 Jamaica	59 Philippines	80 Zimbabwe
18 Congo	39 Jordan	60 Poland	
19 Costa Rica	40 Kenya	61 Portugal	
20 Cyprus	41 Korea	62 Rwanda	
21 Dominican R.	42 Lesotho	63 Senegal	

8 Appendix 2: Unconditional transition probabilities for alternative groupings

Table 1: First order, time stationary, annual transition probabilities for the group of closed economies using Sachs and Warner's definition for real GDP per capita relative to the United States, 1970-1989.
Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
371	1	0.96	0.04	0.00.	0.00	0.00
332	2	0.08	0.89	0.03	0.00	0.00
307	3	0.00	0.05	0.93	0.02	0.00
210	4	0.00	0.00	0.04	0.95	0.01
40	5	0.00	0.00	0.00	0.08	0.93
		Ergodic distribution				
		0.484	0.260	0.160	0.085	0.011
		Single-period transition iterated 18 times				
	1	0.6643	0.2621	0.0646	0.0087	0.0003
	2	0.4881	0.3211	0.1545	0.0345	0.0018
	3	0.1953	0.2506	0.3818	0.1604	0.0119
	4	0.0492	0.1051	0.3016	0.4827	0.0615
	5	0.0140	0.0425	01762	0.4841	0.2831

Table 2: First order, time stationary, annual transition probabilities for the group of open economies using Sachs and Warner's definition for real GDP per capita relative to the United States, 1970-1989.
Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
21	1	0.81	0.19	0.00	0.00	0.00
59	2	0.05	0.92	0.03	0.00	0.00
89	3	0.00	0.00	0.91	0.09	0.00
184	4	0.00	0.00	0.03	0.95	0.03
349	5	0.00	0.00	0.00	0.01	0.99
		Ergodic distribution				
		0.000	0.000	0.050	0.165	0.785
		Single-period transition iterated 18 times				
	1	0.1685	0.5267	0.1786	0.1103	0.0160
	2	0.1406	0.4608	0.2038	0.1636	0.0312
	3	0.0000	0.0000	0.2931	0.5269	0.1799
	4	0.0000	0.0000	0.1593	0.5130	0.3277
	5	0.0000	0.0000	0.0115	0.0691	0.9194

Table 3: First order, time stationary, annual transition probabilities for the group of closed economies derived by imposing equal weights on elements of (a) for real GDP per capita relative to the United States, 1970-1989. Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
386	1	0.95	0.05	0.00	0.00	0.00
376	2	0.07	0.90	0.03	0.00	0.00
373	3	0.00	0.04	0.92	0.04	0.00
327	4	0.00	0.00	0.04	0.95	0.01
14	5	0.00	0.00	0.00	0.07	0.93
		Ergodic distribution				
		0.380	0.256	0.186	0.163	0.014
		Single-period transition iterated 18 times				
	1	0.6150	0.2981	0.0707	0.0158	0.0004
	2	0.4421	0.3449	0.1544	0.0567	0.0019
	3	0.1441	0.2123	0.3699	0.2611	0.0127
	4	0.0369	0.0889	0.2978	0.5338	0.0427
	5	0.0101	0.0344	0.1692	0.4983	0.2879

Table 4: First order, time stationary, annual transition probabilities for the group of open economies derived by imposing equal weights on elements of (a) for real GDP per capita relative to the United States, 1970-1989.
Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
6	1	0.83	0.17	0.00	0.00	0.00
15	2	0.13	0.80	0.07	0.00	0.00
23	3	0.00	0.00	0.96	0.04	0.00
66	4	0.00	0.00	0.00	0.92	0.08
358	5	0.00	0.00	0.00	0.01	0.99
		Ergodic distribution				
		0.000	0.000	0.000	0.100	0.900
		Single-period transition iterated 18 times				
	1	0.3021	0.3014	0.2857	0.0784	0.0324
	2	0.2411	0.2418	0.3317	0.1189	0.0664
	3	0.0000	0.0000	0.4493	0.2895	0.2612
	4	0.0000	0.0000	0.0000	0.2847	0.7153
	5	0.0000	0.0000	0.0000	0.0791	0.9209

Table 5: First order, time stationary, annual transition probabilities for the group of closed economies derived by excluding BMP70 for real GDP per capita relative to the United States, 1970-1989.
Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
373	1	0.95	0.05	0.00	0.00	0.00
381	2	0.07	0.91	0.02	0.00	0.00
369	3	0.00	0.04	0.92	0.04	0.00
342	4	0.00	0.00	0.05	0.95	0.00
29	5	0.00	0.00	0.00	0.07	0.93
		Ergodic distribution				
		0.403	0.275	0.164	0.152	0.006
		Single-period transition iterated 18 times				
	1	0.6157	0.3166	0.0538	0.0137	0.002
	2	0.4649	0.3689	0.1173	0.0481	0.0008
	3	0.1325	0.1968	0.3688	0.2949	0.0070
	4	0.0365	0.0871	0.3182	0.5373	0.0208
	5	0.0097	0.0327	0.1785	0.4912	0.2879

Table 6: First order, time stationary, annual transition probabilities for the group of open economies derived by excluding BMP70 for real GDP per capita relative to the United States, 1970-1989.
Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
6	1	0.83	0.17	0.00	0.00	0.00
15	2	0.13	0.80	0.07	0.00	0.00
23	3	0.00	0.00	0.96	0.04	0.00
57	4	0.00	0.00	0.00	0.91	0.09
349	5	0.00	0.00	0.00	0.01	0.99
		Ergodic distribution				
		0.000	0.000	0.000	0.061	0.939
		Single-period transition iterated 18 times				
	1	0.3021	0.3014	0.2857	0.0743	0.0365
	2	0.2411	0.2418	0.3317	0.1110	0.0743
	3	0.0000	0.0000	0.4493	0.2610	0.2897
	4	0.0000	0.0000	0.0000	0.2219	0.7781
	5	0.0000	0.0000	0.0000	0.0508	0.9492

Table 7: First order, time stationary, annual transition probabilities for the group of closed economies using trade group definition for real GDP per capita relative to the United States, 1970-1989.
Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
375	1	0.95	0.05	0.00	0.00	0.00
370	2	0.08	0.91	0.02	0.00	0.00
360	3	0.00	0.03	0.92	0.04	0.00
348	4	0.00	0.00	0.05	0.95	0.01
41	5	0.00	0.00	0.00	0.05	0.95
		Ergodic distribution				
		0.434	0.260	0.147	0.142	0.017
		Single-period transition iterated 18 times				
	1	0.6436	0.2984	0.0458	0.0119	0.0003
	2	0.4982	0.3529	0.1038	0.0435	0.0015
	3	0.1348	0.1829	0.3678	0.2988	0.0157
	4	0.0362	0.0794	0.3091	0.5275	0.0478
	5	0.0072	0.0230	0.1379	0.4055	0.4264

Table 8: First order, time stationary, annual transition probabilities for the group of open economies using trade group definition for real GDP per capita relative to the United States, 1970-1989.
Grid (0.009, 0.059, 0.114, 0.212, 0.472)

		Grid co-ordinates				
		Transition probabilities				
Observations		1	2	3	4	5
3	1	0.67	0.33	0.00	0.00	0.00
26	2	0.00	0.92	0.08	0.00	0.00
33	3	0.00	0.03	0.94	0.03	0.00
43	4	0.00	0.00	0.00	0.86	0.14
345	5	0.00	0.00	0.00	0.01	0.99
		Ergodic distribution				
		0.000	0.000	0.000	0.077	0.923
		Single-period transition iterated 18 times				
	1	0.0007	0.4028	0.4555	0.0752	0.0658
	2	0.0000	0.3519	0.4656	0.0874	0.0950
	3	0.0000	0.1834	0.4507	0.1266	0.2393
	4	0.0000	0.0000	0.0000	0.1251	0.8749
	5	0.0000	0.0000	0.0000	0.0727	0.9273

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