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Abstract

How has the process of international economic integration advanced over the last four decades? How will the foreseeable future look like? We attempt to answer this sort of questions by considering some methods which have scarcely been used in the literature on globalization. First, we consider a set of indicators which measure not only the degree of openness of economies, but also how connected they are to each other, following Arribas et al. (2007). Second, we assess how these indicators have evolved over time, what the likely steady state distribution might be, and whether results differ depending on a variety of weighting schemes (GDP, population). Results show that, under current trends, the future world will be much more integrated, especially for the most heavily populated countries. However, there is still a long way to go before the Standard of Perfect International Integration can be achieved.

Keywords: International Economic Integration, Globalization, International Trade, Network Analysis, Distribution Dynamics

JEL Classification: F02, F15, Z13

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1. Introduction

Interest in the international integration of economies and the wide perception that we are entering an advanced phase of globalization have stirred up important debates among academics and institutions, of which we find three worth mentioning. The first discusses the at which the integration process is advancing, its regularity from a historic point of view and its consequences for growth and income convergence among countries (Baldwin and Martin, 1999; Crafts, 2000; Milanovic, 2006; O'Rourke and Williamson, 2002; Rodríguez and Rodrik, 2001; Williamson, 1996). The second focuses on the singular characteristics of the most recent wave of globalization, the implications of its present technological basis and its effects on winners and losers in the new competitive setting (Bhagwati, 2004b,a; Rodrik, 1998a,b; Stiglitz, 2002, 2006; Wolf, 2005). The third debate is prospective and is more evident among institutions; it discusses the key factors (demographic, financial, commercial, technological and political) that determine in which settings the world economy will be situated if the trends of recent decades persist for another generation, and the obstacles that might threaten the continuity of this process (World Bank, 2007; OECD, 2007; Goldman Sachs, 2004).

The renewed interest in the advance of integration[1] and the singularities of the most recent wave of globalization are not, as yet, reflected in substantial improvements to the quantitative indicators referring to these processes. On the one hand, when evaluating the advance of globalization, integration indicators in the strict sense and the variables that represent the causes, consequences and obstacles to it, are not sufficiently distinguished (Frankel, 2000; Frankel and Rose, 2000; Rauch and Casella, 2003; Rodrik, 1998c, 2000; Salvatore, 2004; Stiglitz, 2002). On the other hand, the most commonly used quantitative reference to measure integration continues to be the external, commercial or financial degree of openness, an unsatisfactory variable in two important aspects: generally, it does not correct the bias derived from country size, and neither does it reveal one of the most important characteristics of integration today, namely, the development of much denser networks among countries or, as termed by Kali *et al.* (2007), the structure of trade, which refers to the number of trade partners and the concentration of trade among trading partners.

A recent study (Arribas *et al.*, 2007) proposes axiomatic and globalization measures of international economic integration (hereafter IEI) based on distinguishing and combining the degrees

[1] Although we will use the terms "globalization" and "international economic integration" as synonymous we recognize that they are not exactly the same since, as indicated by Rodrik (2000), the latter has a distinct meaning which is self-evident for economists, whereas the former is used in different ways by different analysts. Therefore, when referring to globalization we will be referring solely to its economic aspects.

of openness and of connection—both direct and indirect—of the underlying economies in the foreign trade networks. This approach allows us to define a precise Standard of Perfect International Integration (SPII) (Frankel, 2000) which characterizes the situation in which economies trade among themselves as though no barriers and transaction costs existed. In a world in which technology and the removal of obstacles to commerce make costs of trading with external agents irrelevant, the weight of a country in the demand of another is essentially determined by its size. The SPII provides for a situation in which exchanges take place as if the world operated as true global village, and allows us to to measure the level of integration or globalization reached with regard to it. It also enables us to estimate the extent to which the two determining factors of integration contribute to its evolution, these factors being openness of economies and the changes in their commercial networks with other countries.

Following this methodology, Arribas *et al.* (2007) estimate the degree of openness, of connection and of integration for 59 economies that represent 96.7% of world output, during the period 1967–2004. On the basis of these estimations it will be possible to conduct future analyses of the determinants of the different levels of integration reached and their consequences. According to already available results, the advance of international integration in recent decades has been substantial, evaluated between 75% and 100%, depending on the importance given to the increase of indirect relationships among economies, facilitated by ICT and improvements in transport. However, the distance between the current situation and the SPII is still notable, as we are not yet halfway, due, above all, to the greater domestic bias of the largest economies, for which the degree of openness is limited. Nevertheless, one of the results observed in the cited study is the diversity of situations among countries, both in the degree of integration reached in their paths of advance. In both aspects the differences among countries are noticeable in terms of their degree of openness, but also in the characteristics of their networks (i.e., their trade structures). Thus, there are not only more open or closed countries, but also economies with more stable structures of foreign trade or with a greater bias towards certain trading partners, generally towards the region of the world to which they belong.

The aim of this study, based on the IEI measures of Arribas *et al.* (2007), is to conduct an in-depth analysis of the dynamics of globalization in three directions:

1. To characterize the evolution of the set of integration indicators and project their tendencies, in order to identify the stylized facts of the scenario we are heading towards.

2. To study the speed of the globalization process in the period analyzed and the time required

to achieve a substantial increase in the level of IEI towards which we are moving, under current trends.

3. To evaluate the acceleration in integration that appears to have been happening since the nineties, as a result of technological changes and of the economic orientation of numerous economies during this period.

These objectives are pursued using a variety of techniques. First, we consider the methods by Arribas *et al.* (2007) to measure integration, which combine the traditional degree of openness with a new measure, inspired by network analysis, designed to compute the degree of connection among economies. This focus is not entirely new in international economics, and has received considerable attention in recent studies (Combes *et al.*, 2005; Greaney, 2003; Pandey and Whalley, 2004; Kali and Reyes, 2007; Rauch, 1999, 2001; Rauch and Trindade, 2002; Rauch and Casella, 2003).

In a second stage, in order to assess how integration indicators evolve over time, and to characterize their dynamics, we consider a variety of techniques which have been widely employed in the field of empirical growth and convergence (see Durlauf and Quah, 1999), and in the field of inequality measurement (Shorrocks, 1978).

These techniques enable us to examine a variety of issues related to globalization dynamics. For instance, they provide answers to the question of how the external shape of the degree of openness distribution (for instance) evolves over time, and what type of distribution will emerge in the long run. Clearly, one may infer that multiple scenarios might arise; a few of these possibilities may be a future world in which most economies are very open, or very closed, or a polarized world in which many economies are very open, but many others are quite closed.

Additionally, we can also weigh in the question of whether substantial intra-distribution mobility exists, i.e., in the case of the degree of openness, whether open economies typically stay open, and whether closed economies typically stay closed. Assuming that an economy lies in the lower tail of the distribution of, say, degrees of openness, what would be the probability over a given period of time (1 year, 5 years, 10 years, etc.) that this economy will remain in the same place? What is the probability that it will move to the upper tail of the distribution? That question may likewise be posed with regard to the other sets of indicators, so as to achieve an enhanced view of how globalization evolves throughout time.

This model, although very intensely used by the empirical growth and convergence literature, has not been considered so far to measure the prospects of globalization, despite its potential for providing answers to some relevant questions such as those raised by Rodrik (2000) as to "how much more integration could there be?", or whether international economic integration remains limited, or perhaps some rationale that prevents us from more than "speculating wildly" on the perspectives of international economic integration. The specifics of the dynamics of globalization have received little systematic attention, and the methodologies applied here try to fill the gap.

After this introduction, the remainder of the study is structured as follows. Section 2 summarizes the methodology used to determine the integration indicators employed, and their definitions and properties, following Arribas *et al.* (2007). Section 3 presents the criteria and the formal tools used to study the distribution dynamics of the globalization indicators, based on Quah (1993, 1996b,d) and Redding (2002). Section 4 describes the database used and section 5, the results. Section 6 concludes.

2. Methodology

2.1. Integration indicators: definitions and properties

Arribas *et al.* (2007) introduce measures for international economic integration and globalization starting from a set of basic axioms and the definition of a set of indicators conceived to achieve two objectives: to uncover the role of the network and to define a Standard of Perfect International Integration. These axioms are as follows:

1. *Uncovering the role of the network implies accepting that the advance of international economic integration operates through both higher openness and higher connectedness to other economies, following both direct and indirect paths.*

2. *Any attempt to characterize a scenario in which economies are entirely integrated/globalized (Standard of Perfect International Integration) is to describe the conditions under which the world economy would operate as a global village.*

Therefore, this approach would enable us to assess the distance that separates the current level of international economic integration from the scenario of complete globalization.

The components of the economic network follow. Let N be the set of nodes or economies and g the number of elements in N. We denote by X_{ij} the flow from economy i to economy j and by Y_j the size (GDP) of economy j. The flow from economy i to economy j, X_{ij}, can be measured both through the imports and through the exports of goods and services, and in general it can be evaluated through any other flow measured in the same units as Y_i.

In order to control for home bias, we define $\widehat{Y}_i$ as the exports' share of GDP taking into account the weight in the world economy of the economy considered $\widehat{Y}_i = Y_i - a_i Y_i$, where a_i is the economy i's relative weight w.r.t. to the world economy, $a_i = Y_i / \sum_{j \in N} Y_j$. We also assume that $X_{ii} = 0$ for all economies $i \in N$.

To determine the degree of integration, we proceed in three stages, where different indicators will be defined.

Stage 1: Degree of openness

In the first stage we characterize the degree of openness. We start with the usual definition found in the literature but corrected for home bias so as to take into account the different sizes of the economies under analysis.

If X_{ij} is the trade from economy i to economy j, then

$$DO(X)_{ij} = \frac{X_{ij}}{\widehat{Y}_i} \tag{1}$$

is the relative flow or **degree of openness** between economies i and j which, for the sake of simplicity, will be denoted as DO_{ij}. Given that $X_{ii} = 0$, it follows that $DO_{ii} = 0$.

Definition 1 *Given an economy $i \in N$ we define its degree of openness, DO_i, as*

$$DO_i = \sum_{j \in N} DO_{ij} = \frac{\sum_{j \in N} X_{ij}}{\widehat{Y}_i}. \tag{2}$$

The degree of openness yields results (in general) within the $(0, 1)$ interval, where a value of 0 indicates that the economy is closed (compared to the measure of flow chosen) and a value of 1 indicates a lack of home bias in the economy (total openness).

Stage 2: Degree of total connection

In the economic network, the relative flow from economy i to economy j, in terms of the total flow of economy i is given by

$$\alpha_{ij} = \frac{X_{ij}}{\sum_{j \in N} X_{ij}} \tag{3}$$

where $A = (\alpha_{ij})$ is the matrix of relative flows.

Furthermore, a world economy is perfectly connected if the above value is equal to the relative weight of economy j in a world where economy i is excluded,

$$\beta_{ij} = \frac{Y_j}{\sum_{k \in N \setminus i} Y_k}$$

Note that β_{ij} is the degree of openness between economies i and j in a perfectly connected world, where $\beta_{ii} = 0$; $B = (\beta_{ij})$ is the degree of openness matrix.

Let $\gamma \in (0,1)$ be the share of trade (on average) between two countries which remains in the importing country for internal consumption, whereas $1-\gamma$ is the share of trade between these two countries which is re-exported from the importing country to a third country, possibly after some re-elaboration. Alternatively, we can interpret the inverse of γ as the number of trades (on average) for each commodity, from the first exporting country up to the last importing country.

The total volume of exports from a given economy i to another economy j is the sum of the direct and indirect flows between the two economies, and can be estimated as[2]

$$A^{\infty} = (\alpha_{ij}^{\infty}) = \sum_{n=1}^{\infty} \gamma(1-\gamma)^{n-1} A^n, \tag{4}$$

$$B^{\infty} = (\beta_{ij}^{\infty}) = \sum_{n=1}^{\infty} \gamma(1-\gamma)^{n-1} B^n. \tag{5}$$

Definition 2 *Given an economy $i \in N$ we define the* ***degree of total connection*** *of i as*

$$DTC_i = \frac{\sum_{j\in N} \alpha_{ij}^{\infty} \beta_{ij}^{\infty}}{\sqrt{\sum_{j\in N} \left(\alpha_{ij}^{\infty}\right)^2} \sqrt{\sum_{j\in N} \left(\beta_{ij}^{\infty}\right)^2}}.$$

The degree of total connection is within the $(0,1)$ interval, and it measures the distance between an economy's current flows (either exports or imports) and those it would have in a perfectly connected world. It should approach 1 if the flows of the economy j are proportional to the size of the receiving economies, and be close to zero if the largest economies receive no commodities and the smallest receive all of them.

However, DTC hinges on the γ parameter, which measures how indirect flows affect connections among economies. Thus, the degree of total connection for any economy i is a decreasing function of γ so that the larger the weight of the indirect flows, the larger the DTC will be.

Stage 3: Degree of integration

[2] It can be proved that one way to compute A^{∞} and B^{∞} is by using the expressions

$$A^{\infty} = \frac{\gamma}{1-\gamma}\left([I-(1-\gamma)A]^{-1} - I\right),$$

$$B^{\infty} = \frac{\gamma}{1-\gamma}\left([I-(1-\gamma)B]^{-1} - I\right).$$

where I is the identity matrix of order g (see Arribas *et al.*, 2007).

Definition 3 *Given an economy $i \in N$ we define the* ***degree of integration*** *of i as*

$$DI_i = \sqrt{DO_i \cdot DTC_i}$$

The degree of integration of an economy is the geometric average of both its degrees of openness and total connection; thus DI hinges on both the openness of the economy and the balance in its direct and indirect flows. Therefore, we are taking into account not only how open an economy is, but also its trade structure, namely, how many partners it has, the concentration of trade among partners, how large its partners are, and whether they might re-export to other countries. This means that our measures take into account both traditional measures of openness (export and import volume or shares) and also other measures that could be reflecting trade strategies, including those emerging after the establishment of different trade agreements (see Kali *et al.*, 2007).

3. Dynamics

We use a set of instruments to measure globalization dynamics essentially drawn from the literature on empirical growth and convergence and the literature on economic inequality (see Quah, 1993, 1996b,d; Shorrocks, 1978; Kremer *et al.*, 2001).

In our particular setting, we can refer to $s_{i,t}$ as country i's indicator (either DO, DTC or DI) in period t, whereas $F_t(s)$ refers to the cumulative distribution of $s_{i,t}$ across countries, and corresponding to $F_t(s)$ we can define a probability measure λ_t s.t.:

$$\lambda_t((-\infty, s]) = F_t(s), \ \forall s \in \mathbb{R}. \tag{6}$$

In this context, λ_t is the probability density function for each indicator across countries in period t, and the model analyzes the dynamics of λ_t, i.e., the dynamics of the cross-section distribution of either DO, DTC or DI, for which we consider a stochastic difference equation:

$$\lambda_t = P^*(\lambda_{t-1}, u_t), \ \text{integer } t, \tag{7}$$

where $\{u_t : \text{integer } t\}$ is the sequence of disturbances of the entire distribution, and P^* is the operator mapping disturbances and probability measures into probability measures. In other words, the P^* operator would reveal information on how the distribution of, for instance, the degrees of openness (DO) at time $t-1$ (DO_{t-1}) transforms into a different distribution at time

t (DO_t).

Following Redding (2002), we may assume that the stochastic difference equation is first order and that operator P^* is time invariant. Thus, setting null values to disturbances and iterating in (7) we obtain the future evolution of the distribution:

$$\lambda_{t+\tau} = (P^* \cdot P^* \cdot \ldots \cdot P^*)\lambda_t = (P^*)^\tau \lambda_t \tag{8}$$

If we divide, or discretize, the set of possible values of s into a finite number of cells $k \in \{1, \ldots, K\}$, then P^* becomes a transition probability matrix

$$\lambda_{t+1} = P^* \cdot \lambda_t \tag{9}$$

where λ_t is now a $K \times 1$ vector of probabilities that a given country indicator (DO, DTC, or DI) is located in a given grid at time t.

In the case studied here, discretization is meant to divide the space of possible F_t values into several discrete grid cells, or states, e_k, $k = 1, \ldots, K$. Then, after classifying each country-year observation into one of the K states, we build up a 20×20 matrix whose p_{kl} entries indicate the probability that a country initially in state k will transit to state l during the period or periods considered (T). Thus each row of the matrix constitutes a vector of transition probabilities, which add up to unity. We choose the boundaries between grid cells such that country-year observations are divided approximately equally between the cells, and each cell corresponds to approximately one twentieth of the distribution of either DO, DTC, or DI across countries and time. Therefore, in the case of DO, observations in the first state refer to the more closed countries. This criterion has been followed, amongst many others, by Redding (2002), or Lamo (2000), and constitutes a reasonable choice in the absence of other theoretical justifications. Others have followed different criteria such as choosing the grid arbitrarily yet (according to their advocates) reasonably (Kremer *et al.*, 2001; Quah, 1993). An alternative strategy to avoid the discretization problem is to consider stochastic kernels (Quah, 1996c), which may be thought of conditional density estimation (Bashtannyk and Hyndman, 2001); however, there are some difficulties in estimating the ergodic, or stationary distribution. We deal with this issue further on in the paper.

Therefore, through these transition probability matrices we can measure the probability that a country with a certain degree of openness, degree of total connection, or degree of integration, may move to a higher (or lower) position. To calculate the transition probability matrices we start by discretizing or dividing the set of observations of the variable into a certain number of states e_k. For example, state $e_k = (0.2, 0.4)$ would include those countries with degrees of openness between 0.2 and 0.4. The value of each entry in the matrix indicates the probability that a given country will transit out during the period or periods considered from its initial state to other states.

Transitions are estimated by counting the number of transitions out of and into each cell, i.e., for each p_{kl} cell:

$$p_{kl} = \frac{1}{T-1} \sum_{t=1}^{T-1} \frac{n_{kl}^t}{n_k^t} \tag{10}$$

where T is the number of years or periods, n_{kl}^t is the number of countries moving during one period from class k to class l, and n_k^t is the total number of countries that started the period in class l.

Some authors have claimed that the arbitrary discretization of the state space into a given number of states may affect the results. For instance, Quah (1997) and Bulli (2001) indicate that the process of discretizing the state space of a continuous variable is necessarily arbitrary and can alter the probabilistic properties of the data. Some other authors (Reichlin, 1999) also argue that the apparent long-run implications of the dynamic behavior of the distribution in question are also sensitive to discretization.

However, most of these claims are based on results for 5×5 matrices. We partly circumvent them by considering a much larger number of states (20) than the standard practice. Other methods proposed by the literature to avoid these criticisms (see Johnson, 2005) consider kernel smoothing methods. However, these methods also ultimately discretize, since the functions in which they are based have to be evaluated over a given set of points. If the set of points is large enough, we may end up with the visual impression that there is no discretization. Obviously, choosing an arbitrarily large number of states for the discrete Markov chain methods would yield analogous results.

3.1. Weighted transition probability matrices

Transitions are estimated by counting the number of countries moving from one state to another. However, due to the large disparities between countries observed both across their populations and their economic sizes (GDP), it may be equally relevant to estimate *weighted* transition probability matrices. The underlying idea is that the impact on world globalization will be greater if a larger country transits out than if a small country does so. Therefore, we count countries' transitions, but in this case each country is represented by its entire share of world population (in the case of population-weighted transition probability matrices), or its share of world GDP (in the case of GDP-weighted matrices). This issue is often ignored, although exceptions do exist such as Kremer *et al.* (2001) or Quah (2003).

3.2. Ergodic distributions

Operating with the information offered by the transition probability matrix, we can characterize the hypothetical long term, by means of ergodic, or stationary distribution. Several results or scenarios may arise: from a distribution with the probability mass concentrated mainly in the central class or classes (indicative of convergence "towards the mean", if these central states contain that moment of the distribution) to a more polarized distribution, or one with the probability mass distributed in the extreme classes (tails) of the distribution. Therefore, ergodic, or stationary, distribution helps us to uncover the degree to which the set of countries in our sample presents a tendency to convergence, to polarization, or to other likely scenarios, for any of the indicators considered (DO, DTC, or DI). Therefore, it provides information on the evolution of the external shapes of the distribution of the variables at hand.

3.3. Transition path analysis and mobility indices

Following Kremer *et al.* (2001) we can also assess the speed of convergence to the steady state, or ergodic distribution, by means of the asymptotic half-life of convergence, $H - L$, which reveals how long it takes (years) for the norm of the difference between the current (2004) distribution and the ergodic distribution to decrease by half. Its formula is as follows:

$$H - L = -\frac{\log 2}{\log |\lambda_2|} \tag{11}$$

where $|\lambda_2|$ is the second largest eigenvalue (after 1) of the transition probability matrix.

Finally, we also consider a mobility index from the literature on economic inequality (Shorrocks, 1978; Geweke *et al.*, 1986), which can be applied straightforwardly to our setting. As suggested by Quah (1996a), akin to measures of income inequality designed to collapse the information contained in an entire distribution into a single scalar, a mobility index summarizes the mobility information in a transition probability matrix into one number. We consider the proposals by Shorrocks (1978) and Geweke *et al.* (1986), summarized by Quah (1996a) and also employed by Redding (2002). This index satisfies certain properties; in particular, by defining the mobility index as a continuous real function $\mu(\cdot)$ over the set of transition matrices $\mathcal{P}$, the index satisfies the properties of normalization, monotonicity, immobility, and perfect mobility (see Shorrocks, 1978). The index (μ^1) evaluates the trace of the transition probability matrix and, according to Shorrocks (1978), it discloses information on the relative magnitude of diagonal and off-diagonal terms, and it is identical to the inverse of the harmonic mean of expected durations of remaining in a certain state (Redding, 2002).

Following Quah (1996a), its particular expression is:

$$\mu_1(P^*) = \frac{K - \mathrm{tr}(P^*)}{K-1} = \left(\frac{K}{K-1}\right)\left\{K^{-1}\sum_j (1 - P^*_{jj})\right\} = \frac{K - \sum_j \lambda_j}{K-1} \tag{12}$$

where K is the number of states, P^*_{jj} denotes the j-diagonal entry of matrix P^* representing the probability of remaining in state j, and λ_j are the eigenvalues of P^*.[3] The μ_1 index suggests mobility, since larger values indicate less persistence, or more mobility, in P^*.

3.4. Statistical significance

We also examine the statistical significance of the differences between the transition probability matrices to be estimated. In particular, we examine the differences between unweighted and weighted transition probability matrices, and also between indices obtained for $\gamma = 1$ and for $\gamma = 0.5$. In each case, the null hypothesis is that the compared matrices are equal.

The statistic we use to evaluate the null hypothesis is distributed as:

$$M_1 = \sum_{i=1}^{K}\sum_{j=1}^{K} \pi_i p_{ij} \log_2 \frac{p_{ij}}{t_{ij}} \sim \chi^2_{K(K-1)} \tag{13}$$

where p_{ij} and t_{ij} correspond to the ij cells of the matrices being compared, π_i is the ergodic distribution of the matrix being evaluated, and $\log_2$ is the base 2 logarithm.

3.5. The external shape of the distributions

Although basic results include computation of transition probability matrices and ergodic distributions, we also consider it relevant to provide information on both the initial and final distributions for each of the indicators in Section 2, in order to gain further insights on how distributions have

[3] Quah (1996a) suggests some additional indices which might not always yield non-coincidental results, and are not directly related to each other; however, under some specific circumstances they can be identical (see Quah, 1996a).

evolved. Therefore, for all indicators we provide four sets of additional results, namely, transition probability matrices, ergodic distributions, initial distributions, and final distributions.

However, in their present form, all three sets of distributions share a common disadvantage, namely, they are discrete and probability is spread out across one set of states only. Although we have provided reasons why such a disadvantage may not be as restrictive as some authors suggest, we try to be as informative as possible by also providing the continuous counterpart to this discrete estimation, namely, the nonparametric estimation of density functions via kernel smoothing.

To do this, we consider a kernel estimator for each indicator:

$$\hat{f}(x) = \frac{1}{Nh} \sum_{i=1}^{N} K\Big(\frac{\|x - X_i\|_x}{h}\Big) \tag{14}$$

where x is the point of evaluation, X is the indicator of interest, N is the number of observations (countries), h is the bandwidth, $\|\cdot\|_x$ is a distance metric on the space of X, and $K(x)$ is a kernel function (see Härdle and Linton, 1994) which are generally required to hold that:

$$\int_{\mathbb{R}} K(x)dx = 1, \quad \int_{\mathbb{R}} xK(x)dx = 0, \quad \sigma_K^2 = \int_{\mathbb{R}} x^2 K(x)dx < \infty \tag{15}$$

There are several choices for $K(x)$, which may be defined in terms of univariate and unimodal probability density functions. For simplicity, we consider a Gaussian kernel:

$$K(x) = (1/\sqrt{2\pi})e^{-\frac{1}{2}x^2} \tag{16}$$

Weighting densities (in order to provide continuous counterparts to the weighted initial and final distributions) requires slight modifications. Few studies have considered this, despite its potential relevance in some specific contexts. Following Goerlich (2003), expression (14) is slightly modified to become:

$$\hat{f}_\omega(x) = \frac{1}{h} \sum_{i=1}^{N} \omega_i K\Big(\frac{\|x - X_i\|_x}{h}\Big) \tag{17}$$

where ω_i is the share of either world output or world population (depending on the type of weighting we consider) corresponding to country i.

Estimating the continuous version of the ergodic distributions or, in other words, the continuous state space approach, presents some extra difficulties. In this case, there is practically no related literature. Some studies provide estimations for ergodic densities (see Johnson, 2000, 2005). However, no studies provide, simultaneously, results on ergodic distributions yielded by transition probability matrices and ergodic densities. In order to obtain a fully compatible view between the transition probability matrices results and their continuous counterpart, we generated ergodic densities considering the information in the (discretized) ergodic distributions (1×20).

Specifically, we generated normal distributions for each of the twenty states over which probability is spread out, with a number of observations proportional to each state's share of ergodic probability. This generates a pseudo-histogram in which we do not have bars, but normal distributions. Then we proceed in exactly the same way as when smoothing both initial and final distributions, i.e., by considering kernel methods to smooth the observations in each of these twenty states.

This algorithm yields ergodic densities which are fully consistent with the ergodic distributions computed from transition probability matrices. This continuous state approach turns out to naturally complement the view provided by discrete ergodic distributions, which tend to summarize too much information in too few states. Although the information provided by ergodic densities is essentially the same, it is far easier to analyze.

4. Data and sample

Data were drawn from the `CHELEM` database[4] and correspond to 59 countries that together account for 96.7% of world output and 86.5% of international trade. The variables selected to measure flows between countries are volume of exports.[5] The analysis is restricted to trade on goods only, as it was not possible to split data on service exports between the different exporting countries.

We perform our computations for the 1967–2004 period, for which we had complete information for the 59 countries selected. This period corresponds to what some authors have coined as the second wave of globalization (see O'Rourke and Williamson, 1999, 2002; Maddison, 2001).

All computations were performed for a 20×20 grid, which enables a more detailed assessment of how distributions evolve. However, in order to ease interpretation and understanding, results are displayed with 20×20 matrices converted into 5×5 matrices, summming over each group of four states in the 20×20 matrix. The limits of grids vary, depending on the indicator.

[4] Information on the `CHELEM` (*Comptes Harmonisés sur les Echanges et l'Economie Mondiale*, or Harmonised Accounts on Trade and The World Economy) database is available at `URL` `http://www.cepii.fr/anglaisgraph/bdd/chelem.htm`.

[5] Some authors stress the much greater importance of imports than exports (see Rodrik, 1999). In our case, the computations for indicators based on imports do not alter the general results, although they may differ for some specific countries. These results are not reported due to space limitations, but are available from the authors upon request.

5. Results

Figures 1, 2 and 3 contain information on summary statistics for the three indicators of interest. Figure 1 shows that the average value for DO from 1967 to 2004 increases substantially, especially up to the first oil crisis in the seventies, and also from the early nineties onwards. By the end of the analyzed period the degree of openness approached, on average, 25% of the maximum attainable level, a relatively low value taking into account the fact that we have controlled for the home country bias explained by each economy's size. The coefficient of variation (figure 1, lower panel), which also considers the growing average effect, shows a slight tendency to converge in DO, with the remarkable exception of the first oil crisis.

The upper panel in figure 2 shows that the structure of trade, as measured by the degree of connection among economies, reaches values close to 0.60, and as such, higher than their degree of openness. We can also notice that indirect connections contribute to increasing the degree of connection among economies; note, for instance, that a single indirect connection ($\gamma = 0.5$), meaning that a product is traded twice, raises the degree of total connection to over 0.75 ($DTC > 0.75$). On the other hand, differences among countries, as measured by standard deviation and the coefficient of variation, are lessened if compared to DO, and they are further reduced if we consider indirect connections. However, this indicator shows no tendency to convergence among countries over time.

Finally, descriptive statistics regarding the level of international economic integration, as measured by the degree of integration (DI) are shown in figure 3. The DI index merges the effects of both DO and DTC, showing a steadily increasing path for the analyzed period, over which its value increased by more than 50%. Economic integration has reached levels over 40% higher than what could be attainable in a perfectly economic integrated world with no trade barriers and transaction costs; should we consider indirect connections, the percentage would approach 50%. This growing tendency contributes to reducing convergence among countries regarding DI, i.e., although the average tendency is of increasing degrees of integration, disparities are declining when measured by standard deviation, yet they increase slightly when measured by the coefficient of variation.

Building on the analysis of these two moments in the distributions (mean and standard deviation), we employed the techniques described in Section 3 to explore more thoroughly the dynamics for the three indices, and also forecasted their evolution. Thus, we can disclose not only the ergodic distributions (i.e., distributions corresponding to the steady state) towards which the world economy will head under current trends, but also how long it will take to reach this steady state.

The discrete Markov chain methods introduced in Section 3 provide a more thorough view on dynamics, by focusing on how different parts of the distribution evolve over time. Results on transition probability matrices are shown in tables 1 through 5. Each one contains information on both unweighted and weighted transitions (GDP-weighted and population-weighted), which are presented in three vertically-arrayed panels. In addition, information is displayed sequentially for all indices considered, i.e., degree of openness (table 1), degree of total connection (tables 2 and 3, for $\gamma = 1$ and $\gamma = 0.5$, respectively), and degree of integration (tables 4 and 5, for $\gamma = 1$ and $\gamma = 0.5$, respectively).

Each panel offers information which goes beyond that contained in the transitions of every 5×5 matrix. The first row in each panel provides information on the upper limits of each class. Therefore, table 1.a would suggest that the 20% of country-year pairs with the lowest degrees of openness have $DO < 0.089$, i.e., they export less than 9% of their GDP (corrected for home bias). On the other hand, the 20% of country-year pairs with the highest degrees of openness export more than 31.1% of their home bias-corrected GDP ($DO > 0.311$). The left column of each 5×5 matrix contains the percentage of observations that started the period in a particular class. Therefore, in table 1.a, 21% of observations started the period with $DO < 0.089$, and then remained in, or transited out to other (upper) states; whereas, on the opposite side, 18% of observations started with $DO > 0.311$ and remained in, or transited out to other (lower) states. The upper-left cell of the matrix in table 1.a indicates that 73% remained in the lower class of DO whereas the remaining 20% transited to state 2 (containing observations with DO between 0.089 and 0.151, or 8.9% and 15.1%), 4% to state 3, 2% to state 4 and 1% to state 5. On the other hand, the lower-right cell suggests that only 9% of observations transited to state 4, whereas 89% of observations remained in the highest-degree of openness class. Interpretations are analogous for every cell in the matrix. The elements on the main diagonal provide information on persistence or mobility—if probability approaches 1 or 0, respectively. As we can see, transitions to upper states overshadow those to lower states. For instance, entry a_{22} in the matrix reveals that 57% of observations in state 2 ($DO < 0.151$) remained in that state of openness, 11% of observations transited to state 1, yet a bigger share transited out to upper states (25% to state 3 and 6% to state 4, respectively). This would suggest that once countries reach the highest openness categories, they tend to remain there, suggesting that openness is almost an absorbing state. This result would be consistent with a simple model in which countries seek policies which enhance their long-run openness (Kremer *et al.*, 2001).

Apart from the intra-distribution mobility information contained in the transition matrix, each table also contains information on the shape of the distribution, along with its hypothetical stationary distribution. For the *DO* (unweighted) case (table 1.a), the three lower rows (right below the 5×5 matrix) contain data on the initial, final, and ergodic distributions, respectively. The initial distribution indicates that by 1967 most countries (37%) had degrees of openness below 0.089; a deeper scrutiny reveals that the overwhelming majority of countries had degrees of openness below 0.151 (68%). However, the shape of the final distribution offers quite a different aspect, with probability mass concentrating overwhelmingly in the upper state—i.e., state five, with $DO > 0.311$ contains 49% of the probability mass. This information complements what summary statistics (mean and standard deviation) revealed, adding more precision, as we gain insights on how the entire distribution has evolved over the sample period.

However, this information is of discrete nature, i.e., the view we have on the distributions is reported in five states. In order to circumvent this disadvantage, figure 4 presents the continuous counterpart to the initial distribution, final distribution and ergodic distributions in table 1. It corroborates that dynamics are more complex than what summary statistics revealed, since by 2004 the density clearly shifts to higher levels of the *DO* index, and the aspect of the distribution reveals some intricacies: although state five contains almost half the probability mass, its contiguous state (state 4) contains only 12% of probability, whereas the middle state goes up again (22%). This finding would indicate that, as suggested, dynamics are involved, and in the most recent years most countries are becoming much more open, whereas a non-negligible group lags behind.

The ergodic distribution (shown in the last row of each table) offers a more radical view since, according to the discrete information, probability mass concentrates increasingly in the upper states, with state five containing the largest share of probability mass (72%), i.e., in the stationary state 72% of world economies will have degrees of openness of over 0.311. Therefore, under current trends, the distribution of probability mass will reverse, since by 1967 almost 70% collapsed at lower states, whereas the steady state suggests a similar amount of probability will concentrate in an upper state only (state 5).

The lower panels in table 1 contain information on weighted transitions. Table 1.b is the GDP-weighted counterpart to table 1.a; therefore, it does not show transitions of countries but transitions of shares of world GDP. Accordingly, the first column in the table contains information on the share of world GDP starting in a particular state. For instance, 40% of world GDP pertained to countries that at some point in time had $DO < 0.089$ and five years later either remained or transited out to states of higher openness. On the other hand, those countries starting in the state of highest openness (which then either remained or transited out to other states) have only 5% of world GDP.[6]

In this GDP-weighted case, in which for the sake of comparison the limits of the states are the same as for the unweighted case, entries off the main diagonal are lower, indicating higher persistence—entries on the main diagonal average to 0.76, compared to 0.67 for the unweighted case. This result is corroborated through table 6, which provides results on mobility indices showing that, indeed, mobility is stronger in the unweighted case. Differences are even more marked when comparing the distributions in the last rows of the table. For instance, the initial distribution shows that 37% of countries in state 1 (less openness) had 71% of world GDP; if we extend the selection to state 2, the share of world GDP goes up to 85%. In other words, by 1967 the richest countries were quite closed to trade, and only 15% (12%, 2% and 1% in states 3, 4 and 5, respectively) exported more than 15.1% of their GDP. However, by 2004, the probability is, if not totally reversed, quite different, since even though a large share of world GDP is allocated in relatively closed countries (31% and 16% of probability mass are in states 1 and 2, respectively), a remarkable 27% of probability (world GDP) corresponds to state 5. Again, multi-modality is observed by 2004, both in this table and in figure 4.b, since states 2 and 4 are those with lower amounts of probability mass.

Akin to the unweighted case, the ergodic distribution provides a smoother view in which bi-modality has faded away almost entirely, less corrupted by possible outliers or tendencies which might have accelerated only recently, i.e., if the dynamics of the sample years continue. The change in the situation predicted by the ergodic distribution is impressive: almost 81% of world GDP would correspond to the more open countries (with a level of openness similar to Germany in 2004), whereas only 1% (states 1 and 2) would correspond to the more closed ones. The density function corroborates this finding entirely (figure 4.b), as probability mass concentrates primarily above 0.311, which corresponds exactly to state 5.

Table 1.c is the population-weighted counterpart to table 1.a. In this case, the first column indicates the population corresponding to the countries initially in each of the five states, which then transit out to other states. Similarly to the GDP-weighted case, the largest number of people (56%) inhabits the countries with the lower degree of openness, which after five years transit out to other states. This matrix shows higher mobility, as entries on the main diagonal average to 0.65,

[6] Although we refer to "world GDP", we are considering the GDP corresponding to the 59 countries in our sample which, in any case, account for the largest share of world GDP.

even lower than in the unweighted case. However, more distinctive features of the population-weighted dynamics are revealed by the last three rows in table 1.c. The initial distribution shows the probability mass almost entirely skewed to the left, since 94% of the world population lives in countries with the lowest degree of openness (states 1 and 2). As of 2004, the scenario is quite different, since by then the population tends to live in the most open countries, although to a more limited extent—state 5 comprises "only" 44% of the world population, compared to 78% in state 1 by 1967. Should these 38-year tendencies continue, the stationary distribution would suggest the population will live predominantly mostly in more open countries—i.e., 92% of probability lies in states 4 and 5.

Results corresponding to degree of total connection (DTC) are displayed in table 2 and table 3, for $\gamma = 1$ and $\gamma = 0.5$, respectively. Interpretations are analogous to those for DO. However, since we considered the same criterion for setting the limits between states, these are different, due to the marked discrepancies between the values for DO and DTC—-regardless of the γ considered, i.e., whereas DO values are closer to zero, values for DTC are closer to unity, especially for lower values of γ. Accordingly, the first column of the first panel in each table, corresponding to unweighted transitions, contains a similar number of observations as in the first column in table 1.a. Before proceeding it is worth noting the relevance of the limits between states, which are also different for different values of γ.

In the case of $\gamma = 1$ (table 2), results do not entirely mimic those obtained for DO. In this case, mobility is stronger when weighting by population (entries in the main diagonal average to 0.54, compared to 0.59 in the GDP-weighted case, and 0.56 in the unweighted case), for which we find an ergodic distribution with probability collapsing at upper states (57% of the population would inhabit countries in state 4 and state 5, see last row in table 2.c). In the GDP-weighted case probability tends to distribute in a sort of bimodality, but these correspond to lower values of DTC in the case of $\gamma = 1$.

All these dynamics refer to the unweighted case (table 2.a), which shows more moderate annual transitions compared to table 1.a, as revealed by ergodic distributions showing probability moderately concentrating at upper states (29% for both states 4 and 5, see table 2.a). However, we should bear in mind the fact that the upper limits are higher in the case of DTC, either under $\gamma = 1$ or $\gamma = 0.5$. Comparing both weighting schemes to the unweighted case (i.e., tables 2.b and 2.c vs. table 2.a) provides us with some interesting findings, as both weighted cases show probability initially skewed to the left—i.e., both rich countries and heavily populated countries were rather closed—, whereas for 2004 it is skewed to the right yet only for the population-weighted case. Therefore, the structure of trade would seem to differ substantially between rich and most-populated countries, since the latter show more balanced connections with the rest of the world.

Results for different values of γ change, but the main tendencies hold for $\gamma = 0.5$ (see table 3). The most interesting result is that ergodic distributions show probability collapsing more strongly in the upper states for the unweighted case and, especially, in the population-weighted case (tables 3.a and 3.c). However, for GDP-weighted transitions bimodality disappears and probability tends to accumulate more strongly and increasingly in the middle states (table 3.b). These findings are corroborated through figure 5, which represents continuous counterparts (densities) to tables 2 and 3. They corroborate the discrete analysis for both γ's considered, and for all weighting schemes. When all weighting schemes are compared the finding that the most-populated countries exhibit the most radical tendencies is especially remarkable, as probability mass tends to concentrate more tightly over time and for $\gamma = 0.5$.

Finally, tables 4 and 5, and figure 6, report results on DI, for the two values of γ considered, which merge results for DO and DTC. Again, interpretations should be made with care, since the grids differ from those considered for DO and DTC, and also between different values of γ, which represent a balance between the grids chosen for DO and DTC. Regardless of the γ considered, and the weighting scheme, ergodic distributions show probability collapsing more strongly in the upper states, after departing from initial distributions strongly skewed to the left, and final distributions with the opposite pattern. Differences across weighting schemes are as apparent as for DTC, suggesting that the sources of international economic integration for each country may be different: whereas for the most populated countries they come from a more balanced trade structure, richer countries seem to integrate when they are more open. In general, when accounting for indirect connections ($\gamma = 0.5$), the tendency to concentrate in the upper integration states is stressed for all economies, GDP and population. Specifically, the ergodic distribution predicts that 80% of countries, 72% of GDP and 75% of population will correspond to integration levels above 0.482, i.e., they will have completed half the way to maximum integration.

The continuous counterparts to tables 4 and 5 are shown in figure 6. The view they provide for the DI, analogous to the discrete case, is quite elucidating, as probability shifts rightwards for all instances—regardless of the γ considered and the weighting scheme. Comparing unweighted results (figure 6.a) reveals that integration has shifted rightwards, yet probability is more spread by 2004, indicating an increased variety, which will eventually (ergodic distribution) turn into bi-modality.[7] Weighting by GDP yields similar results, although multi-modality is not so obvious. However, it is in the case of weighting by population that results differ, as we depart from very low values (probability is strongly skewed to the left), it turns clearly bi-modal by 2004 (suggesting some very heavily populated countries are participating in the international integrating process, while others are doing so to a lesser extent), but in the hypothetical long run bi-modality will fade away. In addition, if we compare population-weighted results with either GDP-weighted or unweighted results, regardless of the γ considered, international economic integration will be stronger, suggesting that population will mostly inhabit integrated countries.

Tables 7 through 9 report results on statistical significance of differences across different matrices, which are all significant at 1% significance level.

In order to assess whether the pace of the integration process has intensified from 1990, as figures 1 through 3 seem to suggest, we also computed ergodic distributions resulting from transitions between 1990 and 2004, for all cases considered. Results are displayed in table 10 where, in order to ease direct comparison, results for 1967–2004 are also displayed. In the case of DO, the pace speeds up, as probability mass concentrates more strongly in state 5 for the 1990–2004 distributions. Results for DTC are more difficult to interpret, suggesting that the balanced connections may have diminished over the last few years. Merging results for both DO and DTC, it seems that the evolution in the making of the DI is dominated by DO, as ergodic distributions for the DI index corresponding to the last sub-period tend to concentrate probability overwhelmingly in state 5. All differences between ergodic distributions are significant, as shown by the p-values in the last column of the table.

Finally, we also assessed how long it may take to get close to the steady state, as implied by the structures of the transition probability matrices. As suggested in Section 3.3, a useful criterion of speed of convergence to the ergodic distribution is the asymptotic half-life of convergence, $H-L$, whose results are displayed in table 11 and indicate how many periods (1 period=5 years, since we compute five-year transitions) are necessary for the distance between the current (2004) and the ergodic distribution to decrease by half.

According to table 11, in the case of unweighted $DI^{\gamma=1}$ it would take $5.646\times 5 \approx 28.230$ years to reduce the distance between the ergodic and current (2004) distribution by half, whereas for $\gamma = 0.5$ it would take slightly longer (30.200 years). Results are different for the two weighting schemes. For the GDP-weighted case, the pace slows down, as it would take $8.682 \times 5 \approx 43.410$

[7] Bandwidth selection is critical for this finding, and it could be argued that the bi-modality found is simply a result of under-smoothing. However, the result was robust for several smoothing parameters.

years to reduce the same distance by half, while for population-weighted transitions the path accelerates ($3.827 \times 5 \approx 19.135$). Results are not entirely coincidental if we consider only the 1990–2004 period, according to which speeds of convergence are more alike for the three weighting schemes, especially under $\gamma = 0.5$, suggesting that the source of integration among the most-populated countries, namely, the degree of connection, has decreased over the recent years.

6. Conclusions

According to many opinions, globalization is advancing and, should the underlying trends of recent decades continue, the world economy may be expected to achieve high levels of IEI in the near future. The analysis carried out in this study corroborates this perception, based on instruments that enable careful interpretation of the nature of the process and their driving factors, contributing also to measuring their speed and, above all, to characterizing how economies have evolved in terms of degree of openness, degree of connection, and degree of integration. The point of departure for the research was the axiomatic definition of a Standard of Perfect International Integration (see Arribas *et al.*, 2007), the arrival point for a world economy in which all countries would trade with no frictions, costs or any other type of impediment. Building on the measurement of the evolution from 1967 to 2004, we analyze the dynamics of the integration process with a set of techniques extensively used by the empirical literature on growth, in order to project those tendencies which have existed over the past decades onto the future and to assess the perspectives for IEI.

Results can be summarized following several lines:

1. The openness of economies doubled (on average) from 1967 to 2004, and the distribution dynamics for the degree of openness shows that, by 2004, almost twice the number of countries and population in our sample are situated in economies whose degrees of openness are larger than 30%. If this tendency were to continue, more than two thirds of countries, GDP and world population would be facing much more open scenarios. If we weight, either for economic size (GDP) or demography (population), the process is more intense, and the tendency for the degree of openness to increase is stronger.

2. The degree of connection measures how encompassing and balanced (according to their size) trade relations among economies are, and by the beginning of the 21^{st} century it had reached a remarkably high level. The degree of connection is higher than 60% if we consider only direct connections, and it reaches 75% if we allow for indirect trade connections among

countries. Distribution dynamics are strongly influenced by this fact, since most economies are already closely connected with the rest. Related to this, the biggest advances can be expected from an intensification of indirect connections, for which statistical information is not available, although one may reasonably conclude they are increasing (i.e., the γ parameter is decreasing). As a consequence, one may expect that for most economies the degree of connection will approach its highest level.

3. Both factors referred to above, i.e., degree of openness and degree of connection (trade structure) contribute to economic integration in different ways. The advance in the degree of international integration between 1967 and 2004 was substantial, and the degree of integration index is close to 50%. Should this tendency hold, the number of countries with high levels of IEI will become much higher, as well as the percentage of world population that inhabits these countries. The ergodic distribution corresponding to the degree of integration (DI) illustrates this finding, since probability mass concentrates more strongly over time in those states corresponding to the highest values of DI. Within fifty years, more than 70% of countries, world population and GDP will be half way to the steady state distribution, representing high degrees of integration, although prospects are not as rosy if we assume less indirect connections.

4. The weighted results regarding countries' GDP show that a progressive increase in the weight of economies with high degrees of integration will occur. Some economic areas with average, or low, levels of integration are still important for the world economy, yet with a decreasing weight. But the pace of advance toward world economic integration will accelerate in most countries—especially in the most populated but also in others with high weight in terms of GDP.

5. In the framework of these general trends, the analysis of the distribution dynamics undertaken shows that differences have existed and will not completely vanish in the near future, as shown both by the values of the transition probability matrices, which do not abandon the main diagonal easily, and the ergodic distributions. The ergodic densities (the continuous counterpart to the discrete ergodic distributions) corroborate these findings and, simultaneously, provide further details to the analysis.

In sum, the speed at which IEI is advancing is noteworthy, and the ergodic distribution may quickly be approached, although there is a remarkable heterogeneity among countries in this respect. Most economies are achieving degrees of trade openness and trade structure (degree of connection) which lead to high economic integration levels. However, in many cases this result is still far from the Standard of Perfect Economic Integration as defined. This finding coincides with some of the ideas disseminated by Rodrik (2000), who considered that we are still a long way from a world in which markets for goods, services, and factors of production are perfectly integrated, "contrary to conventional wisdom and much punditry", or with Frankel (2000), who points out that globalization of trade and finance is "less impressive than most non-economists think". The question still remaining relates to which factors and barriers (geographic, political, historical, cultural, or economic) explain, for each different case, the difficulties in obtaining a higher level of integration without costs and without frictions, or oppose it altogether. The results obtained and methods used in our study may provide a base on which to deal with this question.

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Table 1: Transition probability matrix and ergodic distribution, degree of openness (DO), 1967 to 2004, 5-year transitions, limits all years

	Upper limit, all years:				
(Share of observations)	0.089	0.151	0.210	0.311	1.129
(0.21)	0.73	0.20	0.04	0.02	0.01
(0.21)	0.11	0.57	0.25	0.06	0.01
(0.20)	0.01	0.11	0.56	0.30	0.02
(0.20)	0.00	0.02	0.12	0.62	0.24
(0.18)	0.00	0.01	0.01	0.09	0.89
Initial distribution	0.37	0.31	0.19	0.05	0.08
Final distribution	0.08	0.09	0.22	0.12	0.49
Ergodic distribution	0.01	0.05	0.07	0.15	0.72

a) Unweighted

	Upper limit, all years:				
(Share of world GDP)	0.089	0.151	0.210	0.311	1.129
(0.40)	0.83	0.16	0.01	0.00	0.00
(0.27)	0.10	0.64	0.23	0.03	0.00
(0.16)	0.00	0.06	0.64	0.29	0.01
(0.12)	0.00	0.01	0.11	0.72	0.16
(0.05)	0.00	0.00	0.00	0.05	0.95
Initial distribution	0.71	0.14	0.12	0.02	0.01
Final distribution	0.31	0.16	0.22	0.04	0.27
Ergodic distribution	0.00	0.01	0.04	0.14	0.81

b) GDP-weighted

	Upper limit, all years:				
(Share of world population)	0.089	0.151	0.210	0.311	1.129
(0.56)	0.75	0.17	0.07	0.01	0.00
(0.16)	0.11	0.55	0.23	0.11	0.00
(0.14)	0.00	0.08	0.49	0.40	0.03
(0.10)	0.00	0.01	0.12	0.60	0.27
(0.04)	0.00	0.00	0.00	0.15	0.85
Initial distribution	0.78	0.16	0.05	0.01	0.00
Final distribution	0.08	0.27	0.13	0.08	0.44
Ergodic distribution	0.00	0.01	0.07	0.31	0.61

c) Population-weighted

Table 2: Transition probability matrix and ergodic distribution, degree of total connection ($DTC^{\gamma=1}$), with limits corresponding to $DTC^{\gamma=0.5}$, 1967 to 2004, 5-year transitions, limits all years

	Upper limit, all years:				
(Share of observations)	0.617	0.713	0.837	0.918	0.984
(0.51)	0.76	0.17	0.06	0.01	0.00
(0.10)	0.24	0.47	0.24	0.05	0.00
(0.12)	0.06	0.20	0.43	0.27	0.04
(0.15)	0.03	0.03	0.17	0.55	0.22
(0.12)	0.03	0.00	0.04	0.34	0.58
Initial distribution	0.61	0.12	0.08	0.07	0.12
Final distribution	0.46	0.14	0.19	0.19	0.03
Ergodic distribution	0.45	0.12	0.14	0.18	0.11

a) Unweighted

	Upper limit, all years:				
(Share of world GDP)	0.617	0.713	0.837	0.918	0.984
(0.46)	0.74	0.25	0.01	0.00	0.00
(0.23)	0.25	0.62	0.11	0.01	0.00
(0.08)	0.08	0.18	0.50	0.19	0.04
(0.08)	0.00	0.02	0.18	0.44	0.36
(0.15)	0.00	0.00	0.04	0.32	0.64
Initial distribution	0.76	0.04	0.07	0.02	0.11
Final distribution	0.49	0.16	0.26	0.09	0.00
Ergodic distribution	0.34	0.28	0.12	0.13	0.13

b) GDP-weighted

	Upper limit, all years:				
(Share of world population)	0.617	0.713	0.837	0.918	0.984
(0.36)	0.70	0.21	0.09	0.00	0.00
(0.13)	0.14	0.34	0.33	0.18	0.01
(0.19)	0.02	0.12	0.55	0.22	0.09
(0.18)	0.00	0.07	0.15	0.53	0.25
(0.14)	0.00	0.00	0.10	0.32	0.58
Initial distribution	0.62	0.21	0.05	0.05	0.07
Final distribution	0.21	0.04	0.39	0.32	0.04
Ergodic distribution	0.07	0.10	0.26	0.31	0.26

c) Population-weighted

Table 3: Transition probability matrix and ergodic distribution, degree of total connection ($DTC^{\gamma=0.5}$), 1967 to 2004, 5-year transitions, limits all years

	Upper limit, all years:				
(Share of observations)	0.617	0.713	0.837	0.918	0.984
(0.20)	0.76	0.21	0.02	0.00	0.01
(0.21)	0.17	0.63	0.19	0.01	0.00
(0.19)	0.01	0.11	0.65	0.21	0.02
(0.20)	0.00	0.01	0.12	0.64	0.23
(0.20)	0.00	0.00	0.02	0.22	0.76
Initial distribution	0.32	0.20	0.25	0.09	0.14
Final distribution	0.15	0.17	0.22	0.31	0.15
Ergodic distribution	0.05	0.08	0.17	0.33	0.37

a) Unweighted

	Upper limit, all years:				
(Share of world GDP)	0.617	0.713	0.837	0.918	0.984
(0.10)	0.74	0.25	0.01	0.00	0.00
(0.30)	0.12	0.69	0.19	0.00	0.00
(0.21)	0.01	0.20	0.76	0.03	0.00
(0.20)	0.00	0.12	0.84	0.04	0.00
(0.19)	0.00	0.12	0.84	0.04	0.00
Initial distribution	0.14	0.21	0.50	0.04	0.11
Final distribution	0.04	0.08	0.51	0.34	0.03
Ergodic distribution	0.12	0.40	0.46	0.02	0.00

b) GDP-weighted

	Upper limit, all years:				
(Share of world population)	0.617	0.713	0.837	0.918	0.984
(0.07)	0.67	0.31	0.01	0.00	0.01
(0.14)	0.20	0.48	0.31	0.01	0.00
(0.21)	0.01	0.07	0.60	0.31	0.01
(0.30)	0.00	0.00	0.08	0.57	0.35
(0.28)	0.00	0.00	0.02	0.27	0.71
Initial distribution	0.33	0.19	0.17	0.23	0.08
Final distribution	0.09	0.02	0.14	0.63	0.12
Ergodic distribution	0.00	0.01	0.07	0.41	0.51

c) Population-weighted

Table 4: Transition probability matrix and ergodic distribution, degree of integration ($DI^{\gamma=1}$), with limits corresponding to $DI^{\gamma=0.5}$, 1967 to 2004, 5-year transitions, limits all years

	Upper limit, all years:				
(Share of observations)	0.258	0.334	0.398	0.482	0.989
(0.32)	0.74	0.23	0.02	0.00	0.01
(0.24)	0.09	0.61	0.23	0.07	0.00
(0.17)	0.00	0.10	0.59	0.26	0.05
(0.14)	0.00	0.03	0.12	0.60	0.25
(0.13)	0.00	0.00	0.02	0.13	0.85
Initial distribution	0.58	0.27	0.10	0.03	0.02
Final distribution	0.10	0.20	0.24	0.15	0.31
Ergodic distribution	0.01	0.05	0.10	0.21	0.63

a) Unweighted

	Upper limit, all years:				
(Share of world GDP)	0.258	0.334	0.398	0.482	0.989
(0.49)	0.92	0.08	0.00	0.00	0.00
(0.26)	0.04	0.75	0.19	0.02	0.00
(0.15)	0.00	0.11	0.64	0.24	0.01
(0.07)	0.00	0.02	0.16	0.61	0.21
(0.03)	0.00	0.00	0.01	0.13	0.86
Initial distribution	0.73	0.22	0.05	0.00	0.00
Final distribution	0.31	0.23	0.20	0.11	0.15
Ergodic distribution	0.01	0.07	0.12	0.23	0.57

b) GDP-weighted

	Upper limit, all years:				
(Share of world population)	0.258	0.334	0.398	0.482	0.989
(0.59)	0.77	0.21	0.02	0.00	0.00
(0.17)	0.09	0.56	0.21	0.14	0.00
(0.13)	0.00	0.08	0.60	0.25	0.07
(0.07)	0.00	0.02	0.17	0.42	0.39
(0.04)	0.00	0.00	0.01	0.18	0.81
Initial distribution	0.86	0.11	0.02	0.01	0.00
Final distribution	0.08	0.34	0.13	0.08	0.37
Ergodic distribution	0.01	0.02	0.06	0.24	0.67

c) Population-weighted

Table 5: Transition probability matrix and ergodic distribution, degree of integration ($DI^{\gamma=0.5}$), 1967 to 2004, 5-year transitions, limits all years

	Upper limit, all years:				
(Share of observations)	0.258	0.334	0.398	0.482	0.989
(0.21)	0.70	0.23	0.04	0.02	0.01
(0.21)	0.11	0.52	0.30	0.06	0.01
(0.20)	0.02	0.13	0.52	0.30	0.03
(0.20)	0.00	0.01	0.14	0.57	0.28
(0.18)	0.00	0.00	0.00	0.14	0.86
Initial distribution	0.39	0.36	0.17	0.05	0.03
Final distribution	0.09	0.05	0.20	0.22	0.44
Ergodic distribution	0.01	0.01	0.04	0.14	0.80

a) Unweighted

	Upper limit, all years:				
(Share of world GDP)	0.258	0.334	0.398	0.482	0.989
(0.30)	0.63	0.36	0.01	0.00	0.00
(0.37)	0.15	0.60	0.23	0.02	0.00
(0.17)	0.00	0.17	0.56	0.26	0.01
(0.12)	0.00	0.00	0.20	0.55	0.25
(0.04)	0.00	0.00	0.00	0.11	0.89
Initial distribution	0.65	0.22	0.12	0.01	0.00
Final distribution	0.31	0.02	0.34	0.06	0.27
Ergodic distribution	0.00	0.02	0.08	0.18	0.72

b) GDP-weighted

	Upper limit, all years:				
(Share of world population)	0.258	0.334	0.398	0.482	0.989
(0.50)	0.70	0.28	0.01	0.00	0.00
(0.21)	0.11	0.45	0.29	0.14	0.01
(0.10)	0.01	0.14	0.41	0.42	0.02
(0.14)	0.00	0.01	0.11	0.57	0.31
(0.05)	0.00	0.00	0.00	0.14	0.86
Initial distribution	0.75	0.20	0.04	0.01	0.00
Final distribution	0.08	0.21	0.17	0.10	0.44
Ergodic distribution	0.00	0.01	0.03	0.21	0.75

c) Population-weighted

Table 6: Mobility indices[a]

Variable	Transition matrix	μ_1
DO	Unweighted	0.756
	GDP-weighted	0.723
	Population-weighted	0.788
$DTC^{\gamma=1}$	Unweighted	0.834
	GDP-weighted	0.840
	Population-weighted	0.848
$DTC^{\gamma=0.5}$	Unweighted	0.790
	GDP-weighted	0.896
	Population-weighted	0.823
$DI^{\gamma=1}$	Unweighted	0.784
	GDP-weighted	0.763
	Population-weighted	0.811
$DI^{\gamma=0.5}$	Unweighted	0.773
	GDP-weighted	0.762
	Population-weighted	0.789

[a] See main text for definition of μ_1.

Table 7: Statistical significance (χ^2) of matrices equality, degree of openness (DO)[a]

	$\mathcal{M}^{DO}_{\text{unweighted}}$	$\mathcal{M}^{DO}_{\text{GDP-weighted}}$	$\mathcal{M}^{DO}_{\text{POP-weighted}}$
$\mathcal{M}^{DO}_{\text{unweighted}}$	—	0.169	0.251
(p-value)		(0.000)	(0.000)
$\mathcal{M}^{DO}_{\text{GDP-weighted}}$		—	0.252
(p-value)			(0.000)

[a] Notes: null hypothesis is that the pair of matrices corresponding to each cell are the same. We test whether differences are statistically significant. Test statistic is distributed $\chi^2(K(K-1))$.

Table 8: Statistical significance (χ^2) of matrices equality, degree of total connection (DTC)[a]

	$\mathcal{M}^{DTC^{\gamma=1}}_{\text{unweighted}}$	$\mathcal{M}^{DTC^{\gamma=1}}_{\text{GDP-weighted}}$	$\mathcal{M}^{DTC^{\gamma=1}}_{\text{POP-weighted}}$	$\mathcal{M}^{DTC^{\gamma=0.5}}_{\text{unweighted}}$	$\mathcal{M}^{DTC^{\gamma=0.5}}_{\text{GDP-weighted}}$	$\mathcal{M}^{DTC^{\gamma=0.5}}_{\text{POP-weighted}}$
$\mathcal{M}^{DTC^{\gamma=1}}_{\text{unweighted}}$	—	0.336	0.387	0.248	1.261	0.572
(p-value)		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\mathcal{M}^{DTC^{\gamma=1}}_{\text{GDP-weighted}}$		—	0.544	0.641	1.728	1.113
(p-value)			(0.000)	(0.000)	(0.000)	(0.000)
$\mathcal{M}^{DTC^{\gamma=1}}_{\text{POP-weighted}}$			—	0.397	1.946	0.658
(p-value)				(0.000)	(0.000)	(0.000)
$\mathcal{M}^{DTC^{\gamma=0.5}}_{\text{unweighted}}$				—	1.996	0.312
(p-value)					(0.000)	(0.000)
$\mathcal{M}^{DTC^{\gamma=0.5}}_{\text{GDP-weighted}}$					—	0.571
(p-value)						(0.000)
$\mathcal{M}^{DTC^{\gamma=0.5}}_{\text{POP-weighted}}$						—
(p-value)						

[a] Notes: null hypothesis is that the pair of matrices corresponding to each cell are the same. We test whether differences are statistically significant. Test statistic is distributed $\chi^2(K(K-1))$.

Table 9: Statistical significance (χ^2) of matrices equality, degree of integration (DI)[a]

	$\mathcal{M}^{DI^{\gamma=1}}_{\text{unweighted}}$	$\mathcal{M}^{DI^{\gamma=1}}_{\text{GDP-weighted}}$	$\mathcal{M}^{DI^{\gamma=1}}_{\text{POP-weighted}}$	$\mathcal{M}^{DI^{\gamma=0.5}}_{\text{unweighted}}$	$\mathcal{M}^{DI^{\gamma=0.5}}_{\text{GDP-weighted}}$	$\mathcal{M}^{DI^{\gamma=0.5}}_{\text{POP-weighted}}$
$\mathcal{M}^{DI^{\gamma=1}}_{\text{unweighted}}$	—	0.137	0.222	0.059	0.179	0.199
(p-value)		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\mathcal{M}^{DI^{\gamma=1}}_{\text{GDP-weighted}}$		—	0.258	0.207	0.249	0.333
(p-value)			(0.000)	(0.000)	(0.000)	(0.000)
$\mathcal{M}^{DI^{\gamma=1}}_{\text{POP-weighted}}$			—	0.253	0.334	0.262
(p-value)				(0.000)	(0.000)	(0.000)
$\mathcal{M}^{DI^{\gamma=0.5}}_{\text{unweighted}}$				—	0.082	0.190
(p-value)					(0.000)	(0.000)
$\mathcal{M}^{DI^{\gamma=0.5}}_{\text{GDP-weighted}}$					—	0.157
(p-value)						(0.000)
$\mathcal{M}^{DI^{\gamma=0.5}}_{\text{POP-weighted}}$						—
(p-value)						

[a] Notes: null hypothesis is that the pair of matrices corresponding to each cell are the same. We test whether differences are statistically significant. Test statistic is distributed $\chi^2(K(K-1))$.

Table 10: Ergodic distributions, all data vs. 1990–2004 data

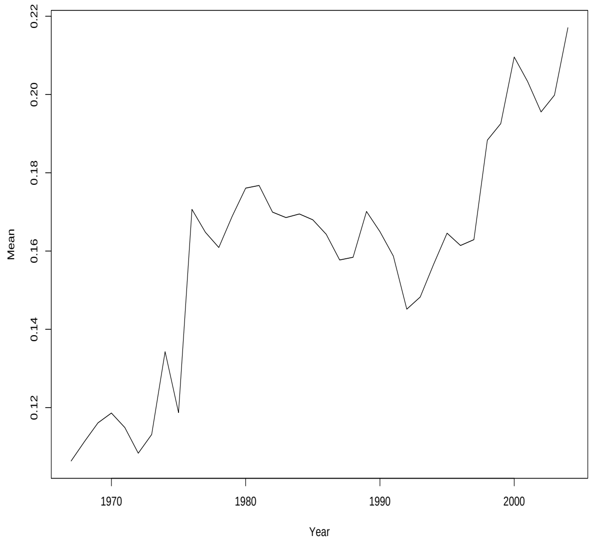
		Ergodic distributions										χ^2(p-value)
		1967–2004					1990–2004					
DO	Upper limits:	0.089	0.151	0.210	0.311	1.129	0.089	0.151	0.210	0.311	1.129	
	Unweighted	0.02	0.05	0.07	0.15	0.72	0.00	0.00	0.02	0.05	0.93	−0.086(0.000)
	GDP-weighted	0.00	0.01	0.04	0.14	0.81	0.00	0.00	0.01	0.03	0.96	−0.020(0.000)
	Population-weighted	0.00	0.01	0.07	0.31	0.61	0.00	0.00	0.03	0.30	0.67	−0.010(0.000)
$DTC^{\gamma=1}$	Upper limits:	0.617	0.713	0.837	0.918	0.984	0.617	0.713	0.837	0.918	0.984	
	Unweighted	0.45	0.12	0.14	0.18	0.11	0.51	0.19	0.13	0.13	0.04	−0.013(0.000)
	GDP-weighted	0.34	0.28	0.12	0.13	0.14	0.70	0.13	0.05	0.08	0.04	0.036(0.000)
	Population-weighted	0.07	0.10	0.26	0.31	0.26	0.21	0.06	0.30	0.26	0.17	0.283(0.000)
$DTC^{\gamma=0.5}$	Upper limits:	0.617	0.713	0.837	0.918	0.984	0.617	0.713	0.837	0.918	0.984	
	Unweighted	0.05	0.08	0.17	0.33	0.37	0.12	0.04	0.25	0.35	0.25	0.032(0.000)
	GDP-weighted	0.12	0.40	0.46	0.01	0.00	0.00	0.00	0.86	0.08	0.06	0.690(0.000)
	Population-weighted	0.00	0.01	0.07	0.41	0.51	0.13	0.01	0.13	0.41	0.32	0.098(0.000)
$DI^{\gamma=1}$	Upper limits:	0.258	0.334	0.398	0.482	0.989	0.258	0.334	0.398	0.482	0.989	
	Unweighted	0.01	0.05	0.10	0.21	0.63	0.00	0.01	0.03	0.09	0.87	−0.041(0.000)
	GDP-weighted	0.01	0.07	0.12	0.23	0.57	0.00	0.00	0.02	0.08	0.90	−0.014(0.000)
	Population-weighted	0.01	0.02	0.06	0.24	0.66	0.00	0.00	0.02	0.26	0.72	−0.005(0.000)
$DI^{\gamma=0.5}$	Upper limits:	0.258	0.334	0.398	0.482	0.989	0.258	0.334	0.398	0.482	0.989	
	Unweighted	0.00	0.01	0.04	0.14	0.80	0.00	0.00	0.02	0.05	0.93	−0.070(0.000)
	GDP-weighted	0.01	0.02	0.07	0.18	0.72	0.00	0.00	0.01	0.04	0.95	−0.015(0.000)
	Population-weighted	0.00	0.01	0.03	0.21	0.75	0.00	0.00	0.02	0.14	0.84	−0.002(0.000)

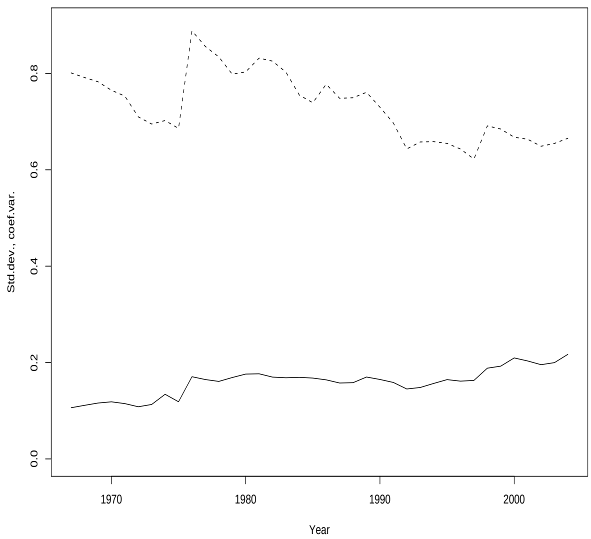
Table 11: Transition path analysis (asymptotic half life of convergence)[a]

Variable	Transition matrix	$H-L$, 1967–2004	$H-L$, 1990–2004
	Unweighted	5.646	5.860
$DI^{\gamma=1}$ (limits $\gamma=0.5$)	GDP-weighted	8.682	7.872
	Population-weighted	3.827	3.701
	Unweighted	6.040	4.991
$DI^{\gamma=0.5}$	GDP-weighted	8.235	4.400
	Population-weighted	3.621	4.053

[a] See main text for definition of $H-L$.

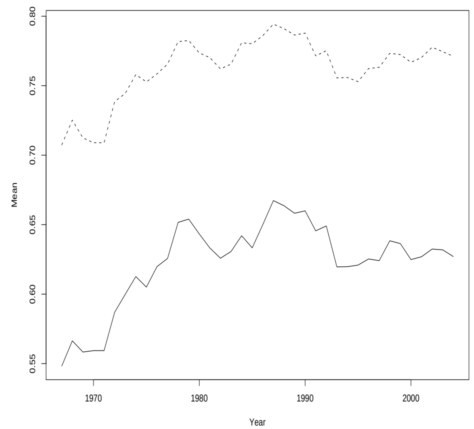
Figure 1: Descriptive statistics for *DO*, 1967–2004



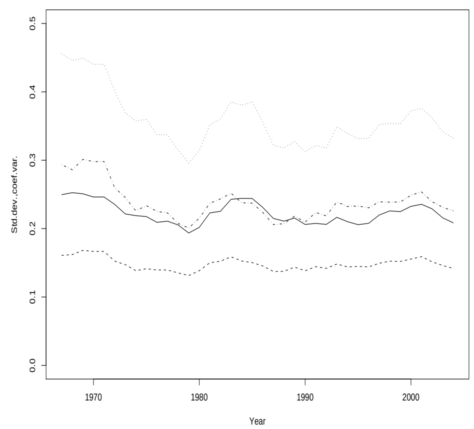


Standard deviation —— Coefficient of variation ------

Figure 2: Descriptive statistics, DTC 1967–2004

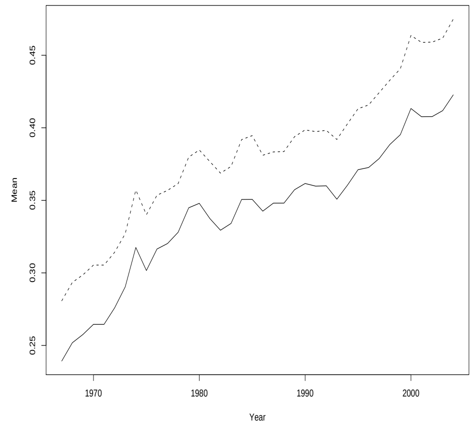


$\gamma = 1$ ——— $\gamma = 0.5$ - - - - - -



$\gamma = 1$, std.dev. ——— $\gamma = 0.5$, std.dev. - - - - - - $\gamma = 1$, coef.var. ······· $\gamma = 0.5$, coef.var. -·-·-·-

Figure 3: Descriptive statistics, DI 1967–2004



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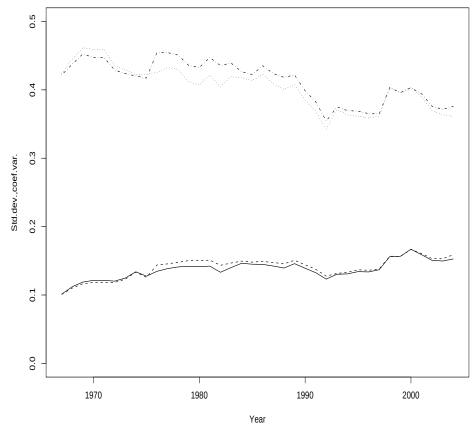
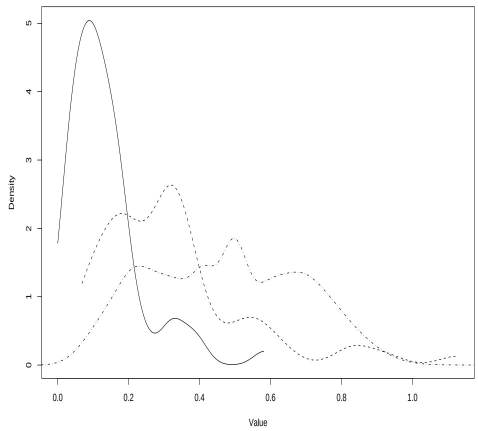
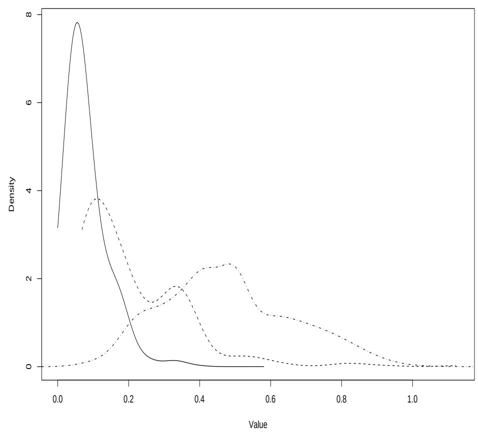


$\gamma = 1$, std.dev. ——— $\gamma = 0.5$, std.dev. - - - - - - $\gamma = 1$, coef.var. ······· $\gamma = 0.5$, coef.var. -·-·-·-

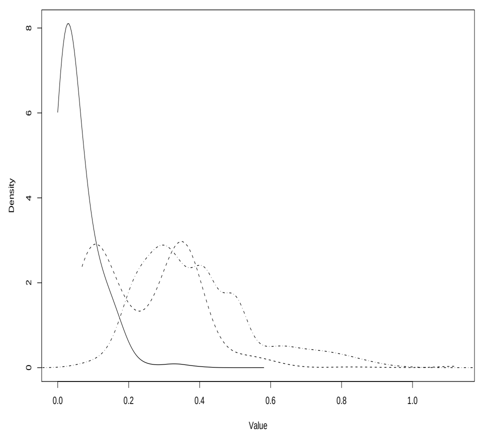
Figure 4: Degree of openness (*DO*), densities, 1967 vs. 2004 vs. ergodic



a) Unweighted



b) GDP-weighted

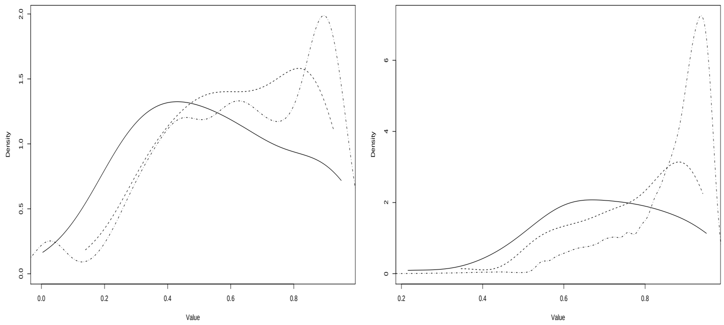


c) Population-weighted

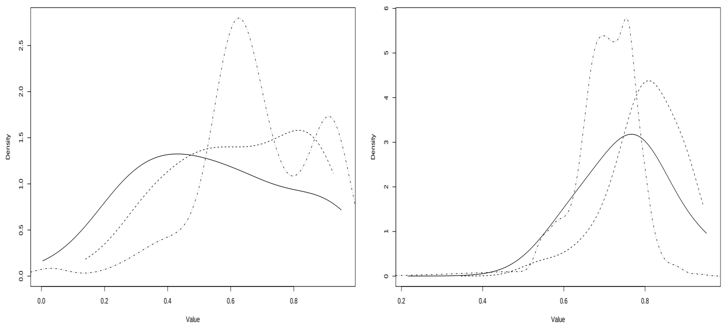
1967 ——— 2004 ------ Ergodic -·-·-·-·-

Figure 5: Degree of total connection (DTC), densities, 1967 vs. 2004 vs. ergodic

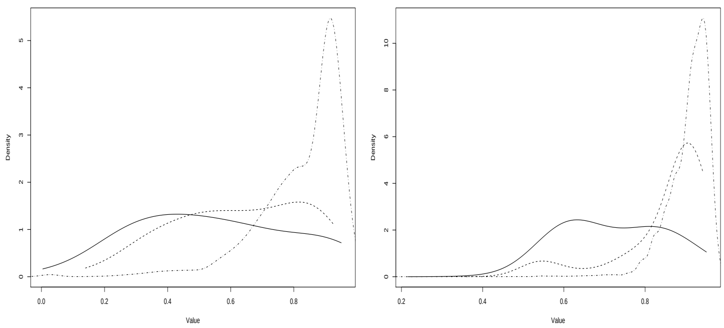
$\boldsymbol{\gamma = 1}$ $\boldsymbol{\gamma = 0.5}$



a) Unweighted



b) GDP-weighted

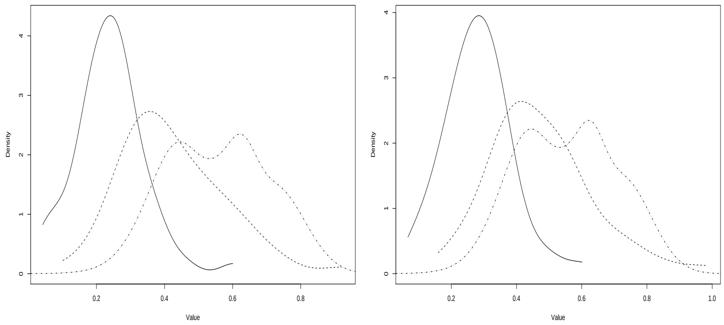


c) Population-weighted

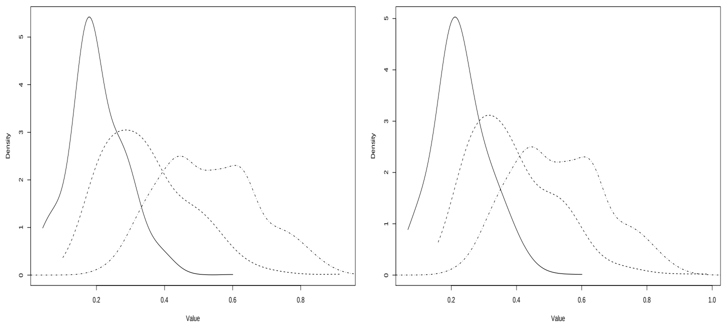
1967 ——— 2004 ------ Ergodic -·-·-·-·-·-

Figure 6: Degree of integration (DI), densities, 1967 vs. 2004 vs. ergodic

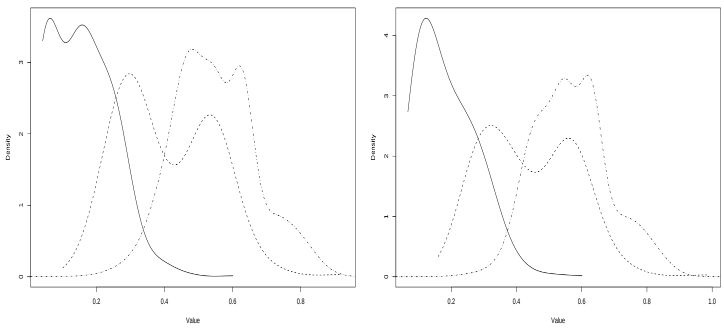
$\boldsymbol{\gamma = 1}$ $\boldsymbol{\gamma = 0.5}$



a) Unweighted



b) GDP-weighted



c) Population-weighted

1967 ——— 2004 ------ Ergodic -·-·-·-·-·-