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On the Extent of Economic Integration: A Comparison of EU Countries and US States

Harry P. Bowen[1]
Haris Munandar[2]
Jean-Marie Viaene[3]

[1] *Queens University of Charlotte, Charlotte;*
[2] *Bank of Indonesia;*
[3] *Erasmus University Rotterdam, Tinbergen Institute, and CESifo.*

Tinbergen Institute Amsterdam
Roetersstraat 31
1018 WB Amsterdam
The Netherlands
Tel.: +31(0)20 551 3500
Fax: +31(0)20 551 3555

Tinbergen Institute Rotterdam
Burg. Oudlaan 50
3062 PA Rotterdam
The Netherlands
Tel.: +31(0)10 408 8900
Fax: +31(0)10 408 9031

ARE EU COUNTRIES LESS INTEGRATED THAN US STATES? THEORY AND EVIDENCE*

HARRY P. BOWEN
McColl School of Business, Queens University of Charlotte
1900 Selwyn Avenue, Charlotte, NC 28274
phone: +1 704.688-2707; e-mail: bowenh@queens.edu

HARIS MUNANDAR
Central Bank of Indonesia and University of Indonesia
Jl. M.H. Thamrin No. 2, Jakarta 10350, Indonesia
e-mail: hmunandar@bi.go.id

JEAN-MARIE VIAENE
Erasmus University Rotterdam, Tinbergen Institute and CESifo
Department of Economics, H8-8, Erasmus School of Economics
P.O. Box 1738, 3000 DR Rotterdam, The Netherlands
phone: +31-10-4081397; e-mail: viaene@ese.eur.nl

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Abstract

A belief that EU integration is incomplete is often predicated on a comparison to US states. Yet, with low barriers to trade and factor mobility between EU countries, is this belief correct? To address this question, we develop three theoretical predictions regarding the distribution of output and factors across members of an integrated economic area with harmonized policies and free movement of goods and factors. Empirical tests strongly support these predictions for US states and 14 EU countries. Constructing a measure of integration, we find that EU integration rose from the 1960s to equal that of US states by 2000.

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ARE EU COUNTRIES LESS INTEGRATED THAN US STATES?
THEORY AND EVIDENCE

1. INTRODUCTION

The extent of economic integration among EU member states is commonly believed to be incomplete, and that many reforms are still needed. To many, such reforms would include greater liberalization of domestic labor and product markets, greater cooperation in areas under national control like taxation, social security and infrastructure, the adoption of a (new) constitution, etc. In suggesting that further EU integration is needed, analysts and policymakers often refer explicitly or implicitly to the union of US states as the benchmark of complete integration. Yet, with low barriers to trade and productive factors notionally mobile across EU member states, how valid is the conjecture that EU countries are less integrated than US states? Alternatively, is the extent of EU economic integration really incomplete?

This paper seeks to provide an answer to this question that is grounded in theory and supported by statistical evidence. Toward this end, we derive three theoretical propositions regarding the distribution of output and the stocks of productive factors expected to arise among members of a *fully integrated economic area* (IEA) in which goods and factors are freely mobile and policies are harmonized. Our first proposition states that each member's share of total area output will equal its share of the total area stock of each productive factor. Since this equal-share property applies to each IEA member it does not directly address the important question of the distribution of output and factor shares across members. This question is addressed instead by our second theoretical proposition: the distribution of output and factor shares across IEA members will conform to a rank-share distribution that exhibits Zipf's law. Zipf's law specifies a particular relationship among member shares, namely, that the share of e.g. output of the largest member is twice that of the second largest member, three times that of the third largest member, etc. Our explanation for the emergence of Zipf's law for the distribution of member shares derives from the expected randomness of these shares when policies are fully harmonized across area members. This analysis builds on Gabaix's (1999a) result for the expected distribution of city shares of a nation's population when such shares are assumed to evolve as geometric Brownian motion with a lower bound.

Our third theoretical proposition is that, given Zipf's law, the long-run distribution of output and factors across area members is unique and depends only on the number of IEA members. This latter result is significant, since it means that the relative position of each IEA member only depends on the total number of members.

Having derived our three theoretical propositions, we then examine empirically for their validity using data on the output and stocks of physical capital and human capital of each of 14 EU countries and each of the 50 US states plus the District of Columbia (hereafter, the 51 US states). The data generally cover the period from 1965 to 2000, which includes the European Union's internal market program and the introduction of the European Monetary Union.[1]

Our empirical results with respect to EU countries and US states convincingly support each of our theoretical propositions, implying that the actual distribution of output and factors among EU countries and among US states is close to that expected in a fully integrated economic area. Given this, we calculate for each economic grouping a summary measure of the distance between the actual and theoretically expected distributions of output and factor shares using Theil's (1971) entropy statistic. This analysis reveals that the measured extent of integration of

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[1] The European Monetary Union (EMU) or 'Euro zone' exists since January 1, 1999. It initially comprised 12 countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. The 14 EU countries we examine are these 12 EMU countries excluding Luxembourg, plus Denmark, Sweden, and the United Kingdom. Luxembourg is excluded for lack of data on human capital. This omission is unlikely to affect our results due to the small size of Luxembourg's economy relative to other EU member states.

EU countries rose steadily between 1960 and 2000 and that by 2000 the measured extent of integration of EU countries was essentially the same as that of the US states.

Although our analysis is meant to address the question of the extent of EU integration, it also contributes more broadly to the largely neglected question of how increased trade and factor mobility within integrated economic areas impacts the distribution of output across members, and hence the relative economic position of each member. Two recent studies that fall under this theme are Davis and Ortalo-Magné (2011) and Van Nieuwerburgh and Weill (2010). Focusing on labor mobility between US metropolitan areas (MSAs), Davis and Ortalo-Magné (2011) find that the expenditure share on housing is constant over time and across MSAs. As workers flow in and out of MSAs in response to local wage shocks, this constant expenditure share implies a strong positive correlation between rental prices and shocks to a MSA. Van Nieuwerburgh and Weill (2010) find that house prices movements compensate for cross-sectional productivity differences due to regulatory constraints on housing supply.

Earlier work has also demonstrated the potentially important role of trade and factor mobility as influences on economic growth. For example, Baldwin and Martin (2004) consider the relationship between growth and the agglomeration of economic activity and find that it depends crucially on the extent of capital mobility between regions. This result confirms the empirical findings of Fan and Casetti (1994) that suggest that it is the flows of productive factors that contribute to growth of some regions but not others. Going further, Viaene and Zilcha (2002) show that while complete capital market integration among countries has a positive effect on outputs, it does not raise long-run growth rates above autarky values.[2] More recently, the

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[2] An extensive body of work has explored the role of international trade and knowledge flows as mechanisms generating endogenous economic growth. For example, Grossman and Helpman (1991) show that trade generally enhances growth, particularly when it facilitates the international transmission of knowledge. Similarly, Rivera-Batiz and Romer (1991) show that increased trade due to economic integration may have both level and growth effects depending upon the processes by which R&D and information flow across borders. Devereux and Lapham

distributional consequences of trade and factor mobility within integrated economic areas has received greater attention. In a panel-data analysis of 197 European regions between 1977 and 2003, Bouvet (2010) examined for a relationship between institutional changes within the EU and interregional income inequality and found that income inequality declined after 1997 due to a decline in inter-country inequality. Our analysis contributes to this literature by deriving a number of testable hypotheses regarding the distribution of output and productive factors across area members that can provide a better understanding of the economic forces within integrated economic areas.

Finally, in focusing attention on output and factor shares, our analysis reinforces prior literature that demonstrate that country shares of world or regional output, or shares of world or regional total supplies of productive factors, are constructs that are both theoretically important and empirically useful (e.g., Bowen *et al.*, 1987; Helpman and Krugman, 1985; Leamer, 1984; Viaene and Zilcha, 2002).

The remainder of the paper is as follows. In Section 2 we derive our three theoretical propositions regarding the distribution of output and factors across members of a fully integrated economic area. Section 3 discusses the data underlying the empirical tests of these propositions while Section 4 presents our empirical results. Section 5 presents our measure of integration for EU countries and US states. Section 6 summarizes and discusses our findings.

(1994) extend Rivera-Batiz and Romer's model to show that, even without knowledge flows, the balanced growth rate when there is free trade in goods alone exceeds that in autarky, provided that initial levels of national income differ across countries.

2. THEORETICAL PROPERTIES OF FULLY INTEGRATED ECONOMIC AREAS

In this section we derive and discuss the implications of three theoretical propositions regarding the distribution of output and factor among members of a fully integrated economic area in which goods and factors are freely mobile and policies are fully harmonized.

The Equal-Share Relationship

We consider an integrated economic area (IEA) comprising M economic units. Each IEA member m ($m = 1, \ldots, M$) is assumed to produce a single homogenous good by means of a constant return to scale aggregate production function of the form:

$$(1) \qquad Y_{mt} = F_m(K_{mt}, H_{mt}) \qquad m = 1, \ldots, M$$

In this expression, Y_{mt} is the quantity produced, K_{mt} is the stock of physical capital, and H_{mt} is the stock of human capital of member m at time t. The production function is assumed to satisfy all the neoclassical assumptions including diminishing marginal productivity with respect to each factor. For ease of exposition, we assume the production function is of the Cobb-Douglas form:[3]

$$(2) \qquad Y_{mt} = A_{mt} K_{mt}^{\alpha_m} H_{mt}^{1-\alpha_m} \qquad m = 1, \ldots, M.$$

In this expression, technology is represented by the scale parameter A_{mt} and physical capital's share of total output α_m. With free trade, a single commodity price will prevail. If physical capital and labor (human capital) are perfectly mobile between the M members then the (value) marginal product of each factor will be equal across members. However, barriers to capital mobility (e.g., corporate income tax differentials, capital controls) or to labor mobility (e.g., language, differing pension systems) would create a difference in real factor rates of return between members. To characterize such differences, let λ_{mt}^{k} be the proportional difference in the

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[3] The Cobb-Douglas specification has wide empirical support (e.g., Mankiw *et al*., 1992). By analogy, the analysis can be extended to the case where the production function has the constant elasticity of substitution (CES) form (Bowen *et al.*, 2010).

real rate of return to physical capital between any member *m* and some reference member *i*, so that for $m = i$, $\lambda_{it}^{k} = 1$. The equality of real rates of return to physical capital across the *M* members can then be written:

$$(3) \qquad v_1 \lambda_{1t}^{k} \frac{Y_{1t}}{K_{1t}} = \ldots = \frac{Y_{it}}{K_{it}} = \ldots = v_M \lambda_{Mt}^{k} \frac{Y_{Mt}}{K_{Mt}}$$

In this expression, $v_m = \alpha_m/\alpha_i$, so that $v_m = 1$ when $\alpha_m = \alpha_i$ ($m = 1, \ldots, M$). Similarly, letting λ_{mt}^{h} be the proportional difference in the rates of return to human capital between any member *m* and reference member *i*, the equality of rates of return to human capital across the *M* members can be written:

$$(4) \qquad \omega_1 \lambda_{1t}^{h} \frac{Y_{1t}}{H_{1t}} = \ldots = \frac{Y_{it}}{H_{it}} = \ldots = \omega_M \lambda_{Mt}^{h} \frac{Y_{Mt}}{H_{Mt}}$$

In this expression, $\omega_m = (1-\alpha_m)/(1-\alpha_i)$ so that $\omega_m = 1$ when $\alpha_m = \alpha_i$ ($m = 1, \ldots, M$). Taking the ratio of (3) to (4) gives the following relationships between ratios of human to physical capital:

$$(5) \qquad \eta_1 \lambda_{1t} \frac{H_{1t}}{K_{1t}} = \ldots = \frac{H_{it}}{K_{it}} = \ldots = \eta_M \lambda_{Mt} \frac{H_{Mt}}{K_{Mt}} = \frac{\sum_{m=1}^{M} \eta_m \lambda_{mt} H_{mt}}{\sum_{m=1}^{M} K_{mt}}$$

where $\eta_m = v_m / \omega_m = \alpha_m (1-\alpha_i) / \alpha_i (1-\alpha_m)$, implying $\eta_m = 1$ when $\alpha_m = \alpha_i$;

$\lambda_{mt} = \lambda_{mt}^{k} / \lambda_{mt}^{h}$, implying $\lambda_{mt} = 1$ when $\lambda_{mt}^{k} = \lambda_{mt}^{h}$.

As in (5), expression (3) can be rewritten as:

$$(6) \qquad v_1 \lambda_{1t}^{k} \frac{Y_{1t}}{K_{1t}} = \ldots = \frac{Y_{it}}{K_{it}} = \ldots = v_M \lambda_{Mt}^{k} \frac{Y_{Mt}}{K_{Mt}} = \frac{\sum_{m=1}^{M} v_m \lambda_{mt}^{k} Y_{mt}}{\sum_{m=1}^{M} K_{mt}}$$

Combining (5) and (6) yields the following relationship between output and factor shares of reference member *i*:

(7) $$\frac{Y_{it}}{\sum_{m=1}^{M} \nu_m \lambda_{mt}^{k} Y_{mt}} = \frac{K_{it}}{\sum_{m=1}^{M} K_{mt}} = \frac{H_{it}}{\sum_{m=1}^{M} \eta_m \lambda_{mt} H_{mt}} \qquad i = 1, \ldots, M$$

This relationship, which we label the "equal-share" relationship, indicates the distribution of output and factors across the *M* members of an IEA. Expression (7) contains both observable variables (Y_{mt}, K_{mt}, H_{mt}) and unknown parameters $(\alpha_m, \lambda_m^k, \lambda_m^h)$. As (7) indicates, differences in technology or factor market imperfections lead to a multiplicative scaling of observable variables that is different for each ratio. However, if all members have the same technology $(\eta_m = \nu_m = \omega_m = 1)$, and there is perfect (costless) mobility of factors $(\lambda_{mt}^k = \lambda_{mt}^h = 1)$ between IEA members, the equal-share relationship (7) reduces to the following simple expression:

(8) $$\frac{Y_{it}}{\sum_{m=1}^{M} Y_{mt}} = \frac{K_{it}}{\sum_{m=1}^{M} K_{mt}} = \frac{H_{it}}{\sum_{m=1}^{M} H_{mt}} \qquad i = 1, \ldots, M$$

This expression states that with identical technologies and perfect factor mobility each member's share of total IEA output at any date *t* equals its shares of total IEA stocks of physical and human capital.

The equal-share relationship (8) gives rise to a number of observations, three of which we highlight here. First, while (8) is derived from equalities (3) and (4) that hold across economies, they nonetheless fully recognize the underlying homogeneity of degree 1 of each IEA member's production function via parameters ν_m and ω_m. That is, Euler's theorem for homogenous functions of degree 1 holds for each IEA member since the factor shares α_m and $(1-\alpha_m)$ sum to 1. To ensure consistency with this theoretical relationship our empirical definition of production is GDP for EU countries and Gross State Product for US states.

Second, in establishing a relation between regional dynamics and regional income inequality, Fan and Casetti (1994) stress the importance of domestic versus foreign flows of productive factors, mainly physical capital, as a contributor to the growth of selected regions. This aspect can be illustrated in our framework by considering an exogenous inflow ΔK of physical capital into the i^{th} economic unit that originates from either outside or inside the IEA. An inflow of (foreign) capital from outside the IEA will, at impact, affect relationship (8) for the ith IEA member as follows:

$$\frac{Y_{it}}{\sum_{m=1}^{M} Y_{mt}} = \frac{H_{it}}{\sum_{m=1}^{M} H_{mt}} < \frac{(\Delta K + K_{it})}{(\Delta K + \sum_{m=1}^{M} K_{mt})}$$

If the inflow instead originates from another IEA member then:

$$\frac{Y_{it}}{\sum_{m=1}^{M} Y_{mt}} = \frac{H_{it}}{\sum_{m=1}^{M} H_{mt}} < \frac{(\Delta K + K_{it})}{\sum_{m=1}^{M} K_{mt}}$$

In either case, the increase in member i's stock of physical capital increases its share of the total IEA stock of physical capital, with the share increase smaller if the capital inflow originates from outside the IEA. Since the capital stock increase raises the marginal return to human capital in member i, incentives arise to increase investment in human capital or to generate an inflow of workers from countries/states either outside or inside the IEA. Given the increase in its stocks of human and physical capital, member i's output and share of total IEA output increases. These adjustments in output and factor stocks continue until the equal-share equality is restored, but with member i's shares now higher than before.

Thirdly, (8) arises from the equalization of factor rates of return across IEA members. However, there are many reasons why these returns may not be equalized. One reason, as modeled, can be barriers to factor mobility as well as transport costs. But there are other reasons, including the existence of other (immobile) factors such as land or natural resources. Ultimately, the validity of the simplified equal-share relationship (8) becomes an empirical question.

In Section 4 we conduct formal tests of the empirical validity of the equal-share relationship (8). As a prelude to that analysis, we provide here a first indication of its potential validity by examining a “weak” form of this relationship, namely, the extent of conformity between (pairwise) rankings of output and factor shares across IEA members. Since this analysis uses ranks rather than share values, it allows for deviations in the strict equalities between shares given in (8). This allows the potential multiplicative difference in factor returns (as imbedded in (7)) that can arise from technological differences or barriers to factor mobility to be present in the data. It also allows for nonlinearities in the relationships between shares that could arise from the adding-up property of shares, which implies that few large shares would be followed by many smaller shares.

TABLE 1: Spearman rank correlations for output, physical capital and human capital shares across US states and EU countries

Economic Group	**Year**	**Spearman Rank Correlation between Shares of**		
		Output and Physical Capital	*Output and Human Capital*	*Physical And Human Capital*
51 US states [a]	1990	0.987	0.977	0.980
	1995	0.991	n.a.	n.a.
	2000	0.992	0.981	0.978
14 EU countries [b]	1990	0.956	0.776	0.829
	1995	0.960	0.851	0.837
	2000	0.956	0.820	0.881

[a] N = 51 in each year; coefficients whose absolute value exceeds 0.326 are significantly different from zero at the 1% level; critical values of the spearman rank correlation tests are obtained from Zar (1972).

[b] N = 14 in each year, coefficients whose absolute value exceeds 0.626 are significantly different from zero at the 1% level; critical values of the tests are obtained from Zar (1972).

Table 1 shows Spearman rank correlation coefficients for pairwise rankings of the shares of output, physical capital and human capital across members of the two economic groups: the 51 US states and the 14 EU countries. The analysis is conducted for the years 1990, 1995 and

2000, years for which overlapping data on output, physical capital and human capital are available for each economic group.[4]

As shown in Table 1, all rank correlations are positive and significant, with the rank correlations for EU countries lower than those US states. Overall, these results support a "weak" form of the equal-share relationship; namely, a conformity between (pairwise) rankings of the output and factor shares across members of a given integrated economic area.

Whereas the equal-share relationship is one implication of an integrated economic area, this relationship does not address the important question of what determines the size of any one member's shares relative to those of other members. That is, it does not address the question of what determines the distribution of output and factor shares across members. To provide an answer to this question, the next section considers the implications of the equal-share relationship when all IEA members are assumed to follow completely harmonized (coordinated) economic and social policies.

Rank-Share Distributions and Zipf's Law

An important implication of the equal-share relationship (8) is that it contrasts the effect of unilateral policies pursued by any one IEA member with the effect of coordinated or harmonized policies pursued simultaneously by all IEA members. Harmonized policy coordination often involves the *ex ante* specification of common *ex post* objectives (targets) expressed in percentage terms rather than absolute changes.[5] Establishing common targets simplifies the implementation of harmonized policies and allows for a transparent comparison of

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[4] As detailed in Section 3, our data for US states consists of annual cross-sections covering 1990 to 2000. For EU countries, the cross-sections are instead equally spaced at 5-year intervals between 1965 and 2000.

[5] For example, the Lisbon Strategy for jobs, skills and growth include EU benchmarks expressed in percentages, with, for example, initiatives to coordinate research and development specifying that R&D investment should reach a common target of 3% of GDP (see http://www.europa.eu/index_en.htm). In the US, environmental issues related to energy security and greenhouse reductions are similarly expressed as percentages (see www.epa.com).

outcomes.[6] Given this, consider first a unilateral policy implemented only by the i^{th} economic unit that is intended to increase its *ex post* stock of human capital by $(\delta - 1)$ percent, where $\delta > 1$ is the growth factor. At impact, this policy affects relationship (8) for the i^{th} unit as follows:

$$\frac{Y_{it}}{\sum_{m=1}^{M} Y_{mt}} = \frac{K_{it}}{\sum_{m=1}^{M} K_{mt}} < \frac{\delta H_{it}}{\delta H_{it} + \sum_{m=1, m \neq i}^{M} H_{mt}}$$

This states that the increase in member *i*'s stock of human capital also increases its share of the total IEA stock of human capital. This increase will, in turn, increase the marginal return to physical capital in member *i* which stimulates either domestic investment or engenders an inflow of physical capital from either other IEA members or from non-IEA members. With its stocks of human and physical capital now higher, member *i*'s output and share of total IEA output both increase. These adjustments in output and factor stocks continue until the equal-share equality is restored, but with member *i*'s shares now higher than before. In contrast, this change in the distribution of output and factors among IEA members will not take place if a coordinated (harmonized) education policy results in an equi-proportionate increase in the human capital of every IEA member since, by (8), if each member's human capital increases by the same proportion δ then the human capital shares of all members are unchanged.[7]

The case of Ireland is one example of the differential impact of harmonized versus non-harmonized policies. Although an EU member, Ireland independently undertook a number of policies (e.g., lower corporate tax rate, education reforms, etc.) in the 1980s and 1990s that differed significantly from the policies followed by other EU member states. Ireland's policies

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[6] Not much is said about resources needed to achieve these targets but countries/states are not equally effective in implementing harmonized outcomes. The heterogeneity in effectiveness arises from the heterogeneity of the culture, endowments and other attributes of countries/states.

[7] Such a policy could induce an inflow of physical capital from non-IEA members which would raise the levels of output and factor stocks of all IEA members. However, expression (8) indicates that the resulting distribution of output and factors across IEA members would be unchanged.

attracted foreign multinationals to Ireland, particularly from the US, and also led some EU firms to relocate to Ireland. In 1980, Ireland's share of EU-15 GDP was 0.6% In 2000, Ireland's share was 1.2% Given Ireland's unusual success, EU (and OECD) members pressured Ireland to adjust its policies, particularly its tax regime, closer to the EU average.

As indicated, the equal-share relationship implies that the relative performance of any one member of an IEA is unaffected when all area members undertake harmonized economic and social policies (e.g., fiscal, educational, industrial policies). Since complete policy harmonization implies no change in member shares, any changes that do arise can be considered to have done so randomly, and to therefore reflect the realization of some particular state of nature. Such randomness can be thought to arise from various kinds of random shocks, like discoveries, weather, or natural disasters, including some that are specific to a particular member, that would then give rise to a new set of member shares.[8] As we now discuss, if member shares do evolve randomly then the distribution of shares can be characterized as a rank-share distribution that exhibits Zipf's law.

A rank-share distribution specifies a particular relationship between a given share and its rank across a set of observational units. Formally, let S_{mj} denote member *m*'s share of the total IEA amount of variable *j* (i.e., *j* = output (*y*), physical capital (*k*) or human capital (*h*)) and let R_{mj} denote the rank of member *m* in the ranking of shares of variable *j* across all members ($m = 1,\ldots, M$). Let $R_{mj} = 1$ for the member with the largest share value of variable *j* and $R_{mj} = M$ for the member with the lowest share value of variable *j*. If variable *j* has a rank-share or "power-law" distribution then we can write:

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[8] A common perception is that fiscal/financial crises are policy induced. A recent example is perhaps Greece, whose fiscal crisis seems to have arisen from fiscal mismanagement and misrepresentation of the extent of past government deficits. Although our model does not include a monetary sector and an explicit government balance, a crisis like the Greek fiscal crisis can be considered in the first instance an unexpected negative shock to output and physical capital. Our model would then predict a drop in Greece's share of EU output and EU factor stocks. If persistent, such share declines eventually mean a decline in Greece's ranking in the distribution of EU shares.

(9) $S_{mj} = \gamma_j \left(R_{mj}\right)^{\beta_j}$ $m = 1, \ldots, M;\ j = y, k, h.$

In this expression, $\beta_j < 0$ is the power-law exponent and $0 < \gamma_j < 1$ is by definition the share of variable j for the highest ranked member (i.e., when $R_{mj} = 1$). Relationship (9) implies a specific set of relationships among shares:

(10) $S_{1j} / S_{2j} = 2^{-\beta_j}, S_{1j} / S_{3j} = 3^{-\beta_j}, \ldots, S_{1j} / S_{Mj} = \mathrm{M}^{-\beta_j}$.

The expressions in (10) indicate that the entire distribution of shares S_{mj} can be determined once a value of β_j and a value of M (the number of IEA members) is specified.

As to a value for β_j, one particular case is Zipf's law, for which $\beta_j = -1$. For this case, the relationship among member shares (10) simplifies to $S_{1j} = 2S_{2j} = 3S_{3j} = \ldots = M \times S_{Mj}$, which states that the share of the highest ranked country is twice the share of the second ranked country, three times the share of the third ranked country, etc. Zipf's law is a widely documented empirical regularity for city sizes (e.g., Brakman *et al.*, 2001; Fujita *et al.,* 1999; Gabaix, 1999b; Gabaix and Ioannides, 2004; and Eeckhout, 2004). Several explanations have been advanced for the observed regularity of Zipf's law with respect to the distribution of city sizes. Some argue it constitutes an optimal spatial pattern that arises when congestion and urbanization externalities interact as part of the process of development and growth of cities. Such forces are usually found in core models of urban and regional growth (e.g., see Eaton and Eckstein, 1997; Black and Henderson, 1999; Brakman *et al.*, 1999). Others have stressed more mechanical forces that often involve a random growth process for city size. A notable example is Gabaix (1999a), who draws on Gibrat's law[9] to assume that cities follow a random but common growth process. Normalizing city population by a country's total population, Gabaix (1999a) shows (his Proposition 1) that if these city population shares evolve as geometric Brownian motion with an

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[9] Gibrat's law (Gibrat, 1931) states that firm growth is independent of firm size.

infinitesimal lower bound then the steady state distribution of these shares will be a rank-size distribution that exhibits Zipf's law.

As previously discussed, if the policies of IEA members are completely harmonized then the equal-share relationship implies that output and factors shares of IEA members are expected to evolve randomly. To characterize such randomness, one can assume that the share for variable *j* (e.g., *j* = output) evolves as geometric Brownian motion with a lower bound.[10] Assuming also that the distribution of the growth rates of shares is common to all IEA members (i.e., Gibrat's law), the results of Gabaix (1999a) then imply that the limiting distribution of the shares of variable *j* across IEA members will be a rank-share distribution that exhibits Zipf's law.

We conclude this section by reporting the results of simulations intended to gain insight into how a rank-share distribution that exhibits Zipf's law emerges. For this analysis, we simulated the evolution of the distribution of output shares across the 51 US states, allowing the number of years simulated to be 20, 50, 75, 100, 150, 200, 250 and 300. Each US state was initially assigned the same starting output share S_{my} (i.e. $S_{my} = 0.0196 = 1/51$). The output shares were then specified to evolve randomly over time as geometric Brownian motion with a lower bound.[11] At annual intervals during a simulation period, the computed output shares were used as data to estimate the rank-share equation (9) and to then test if the estimated β_y was statistically different from -1.[12] This allowed us to determine the point in time at which the rank-share distribution of output shares exhibited (statistically) Zipf's law.

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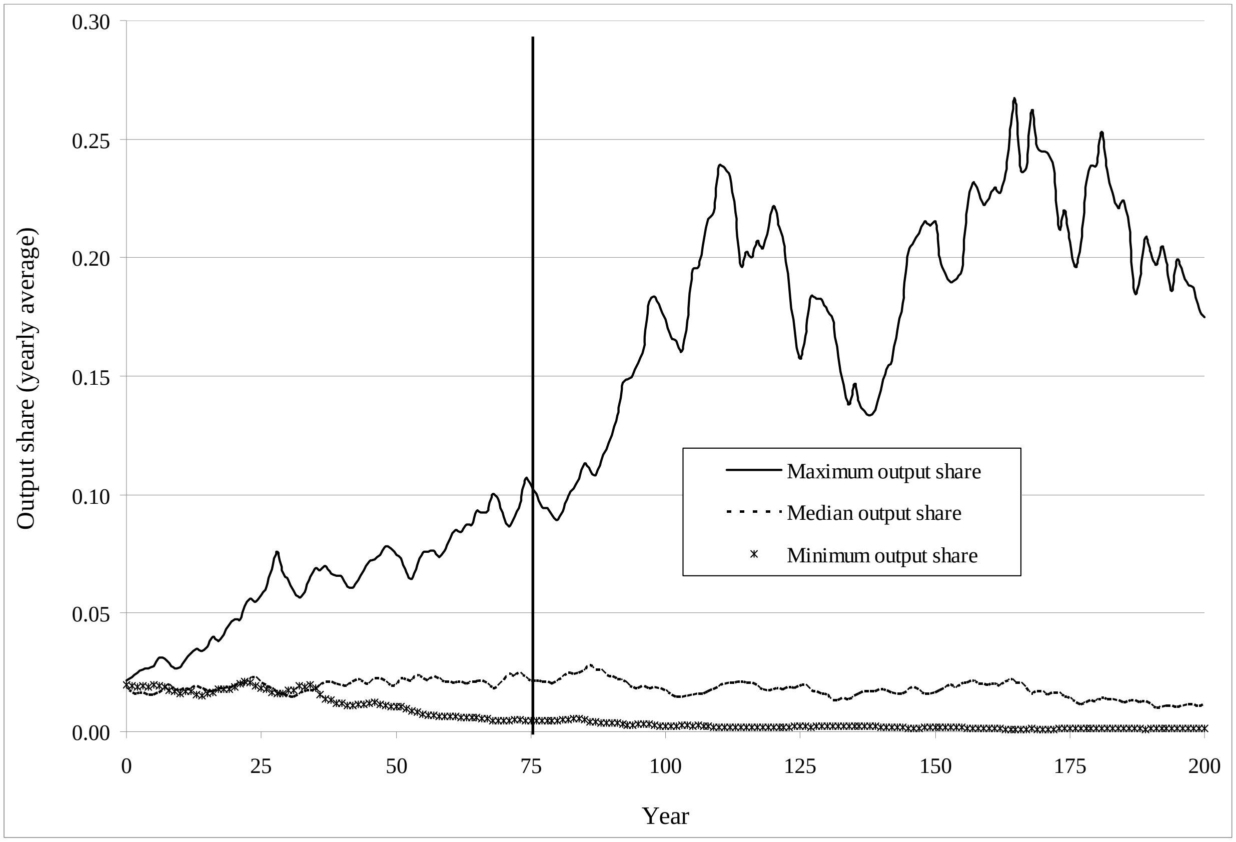
[10] Without a lower bound the limiting share distribution would be lognormal.

[11] Following Gabaix (1999a), each share evolves as $dS_{myt}/S_{myt} = \max[\mu dt + \sigma dB_t, 0]$ for $S_{myt} \leq \min(S_{myt})$ where $\min(S_{myt})$ is the lower bound. Here, μ is the drift, σ is the standard deviation (volatility), B_t is a Wiener process. The increment dB_t of the process is defined in continuous time as $dB_t = \varepsilon_t(dt)^{1/2}$ where ε_t has zero mean and unit standard deviation. Given this, $E[dB_t] = 0$ and $\mathrm{Var}(dB_t) = dt$. Each simulation assumes a calendar year is 365 days ($dt = 1/365$) and that there are two random shocks (two draws of ε_t) each day. Hence, the increment dB_t is approximated by a running sum of 730 discrete increments ("shocks"). We set $\mu = -0.01$, $\min(S_{myt}) = 0.001$, and variously, $\sigma = 0.04$, 0.05 and 0.07.

[12] The estimation procedures used are those detailed in Section 4 below.

Depending on the assumed volatility of the growth rate of the shares, the simulations for US states indicated the emergence of Zipf's law after 75 to 150 years, with convergence to Zipf's law faster the higher the assumed volatility.[13] Figure 1 shows the evolution of the yearly average maximum, median and minimum output share for the 200 year simulation. As indicated in Figure 1, the distribution of the output shares is found to statistically exhibit Zipf's law after about 75 years.

FIGURE 1: Simulated Maximum, Median and Minimum Output Share across 51 US States [a]



[a] Simulation assumes each US state begins with the same output share (= 1/51) and that shares evolve as geometric Brownian motion with a lower bound. For this simulation, drift μ = -0.01, lower bound min(S_{myt}) = 0.001, volatility σ = 0.07. The vertical line indicates the year when the exponent (β_{yt}) is no longer significantly different from –1 (i.e., Zipf's law holds). If Zipf's law holds exactly the maximum share value would be 0.2213.

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[13] On the other hand, with lower volatilities (i.e., 0.01, 0.02 and 0.03) convergence is not obtained even after 300 years.

Limiting Distribution of Shares

As indicated by (10), once a value of β_j is specified the share values S_{mj} in (9) depend only on the number of IEA members (M). In this section, we utilize this result to derive the unique shares values expected in an IEA of given size when the distribution of shares exhibits Zipf's law.

Let V_{mj} denote the level of variable j for IEA member m. Assume without loss of generality that member 1 has the highest value of variable j and let δ_{mj} be member m's value of variable j relative to that of member 1 (i.e., $\delta_{mj} = V_{mj} / V_{1j}$), so that $\delta_{1j} = 1$. Now order the values of variable j in descending order. This ordering of the values of variable j across the $m = 1, \ldots, M$ members can be written:

(11) $V_{1j} > \delta_{2j} V_{1j} > \delta_{3j} V_{1j} > \ldots > \delta_{Mj} V_{1j}$.

Since the total IEA amount of variable j is $V_{1j}(1 + \delta_{2j} + \delta_{3j} + \ldots + \delta_{Mj})$, expression (11) implies a relation between member ranks and shares. For example, dividing the amount of variable j in the first-ranked economy (V_{1j}) by the total IEA amount of variable j gives the share of variable j of the first-ranked (largest) economy (S_{1j}):

(12) $$S_{1j} = \frac{1}{1 + \delta_{2j} + \delta_{3j} + \ldots + \delta_{Mj}}.$$

Likewise, dividing the amount of variable j in the second-ranked economy ($\delta_{2j} V_{1j}$) by the total IEA amount of variable j gives the share of variable j for the second-ranked economy:

(13) $$S_{2j} = \frac{\delta_{2j}}{1 + \delta_{2j} + \delta_{3j} + \ldots + \delta_{Mj}}$$

After repeating the same steps for all subsequent IEA members we arrive at the share of the last and lowest-ranked (smallest) economy M:

(14) $$S_{Mj} = \frac{\delta_{Mj}}{1 + \delta_{2j} + \delta_{3j} + \ldots + \delta_{Mj}}$$

The preceding indicates that the entire sequence of shares S_{mj} starting with (12) and ending with (14) is a Harmonic series, with each share value S_{mj} depending on the values of the δs and the number of members M. Given this, if the distribution of shares exhibits Zipf's law then the values of the δ_{mj} (m = 1, …, M) are determined by setting $\beta_j = -1$ in expressions (10) to obtain: $\delta_{2j} = S_{2j}/S_{1j} = 1/2$, $\delta_{3j} = S_{3j}/S_{1j} = 1/3$, …, $\delta_{Mj} = S_{Mj}/S_{1j} = 1/M$, where the last term for δ_{Mj} indicates that the theoretical share values depend only on M, the total number of IEA members. Hence, once a value of M is specified, the sequence of share values beginning with (12) and ending with (14) are easily computed using the known values of the δs. Moreover, if M is constant over time, then the theoretical shares are also constant over time.

TABLE 2: Theoretical share values assuming distribution of shares exhibits Zipf's law

Economic Group	**Theoretical Share Values (Descending)**
51 US states	0.2213, 0.1106, 0.0738, 0.0553, 0.0443, 0.0369, 0.0316, 0.0277, 0.0246, 0.0221, 0.0201, 0.0184, 0.0170, 0.0158, 0.0148, 0.0138, 0.0130, 0.0123, 0.0116, 0.0111, 0.0105, 0.0101, 0.0096, 0.0092, 0.0089, 0.0085, 0.0082, 0.0079, 0.0076, 0.0074, 0.0071, 0.0069, 0.0067, 0.0065, 0.0063, 0.0061, 0.0060, 0.0058, 0.0057, 0.0055, 0.0054, 0.0053, 0.0051, 0.0050, 0.0049, 0.0048, 0.0047, 0.0046, 0.0045, 0.0044, 0.0043
14 EU countries	0.3075, 0.1538, 0.1025, 0.0769, 0.0615, 0.0513, 0.0439, 0.0384, 0.0342, 0.0308, 0.0280, 0.0256, 0.0237, 0.0220

Given this, Table 2 lists the theoretical share values expected for each of the M = 51 US states and each of the M = 14 EU countries. We now turn to a description of the data used to perform empirical assessments of our three theoretical propositions.

3. DATA

Our data set comprises yearly data on the output and stocks of human and physical capital for the 51 US states and 14 EU countries (see endnote 1). Due to limitations on sourcing data for human capital, our data for US states is restricted to annual observations from 1990 to 2000, while our data for EU countries is restricted to observations at equally spaced 5 year intervals from 1960 to 2000.

For US states, output is measured by real gross state product as reported annually by the US Bureau of Economic Analysis.[14] For EU countries, output is measured by real gross domestic product (GDP), derived from the data on real GDP per capita and population given in Penn World Tables 6.1 (Heston *et al*., 2002).

For both US states and EU countries, the stock of human capital is measured by the number of persons with at least secondary level of education. For US states, data on educational attainment by state are taken from the US Bureau of the Census.[15] These data are available only every 10 years, which restricted the data on human capital for US states to two years: 1990 and 2000.

For each EU country, its stock of human capital is measured by multiplying the percentage of its population with at least a secondary level of education times its total population. Data on rates of educational attainment are from Barro and Lee (1993, 1996, and 2000); country population data are from Heston *et al*. (2002).[16] The educational attainment data are only available every 5 years, limiting the EU data on human capital to five-year intervals from 1960 to 2000.

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[14] Gross state product data available at http://www.bea.doc.gov/bea/regional/gsp

[15] Decennial census data available at http://factfinder.census.gov

[16] Other studies using the Barro-Lee data include Rajan and Zingales (1998), Ramey and Ramey (1995), Barro (1999), Easterly and Levine (1998), Hall and Jones (1999) and Sachs and Warner (1995).

Annual estimates of US state physical capital stocks from 1990 to 2000 are derived from BEA (2002) estimates of the total US physical capital stock in each of nine one-digit industrial sectors that together comprise all economic activity.[17] The total US physical capital stock in each industry is allocated to each state by multiplying an industry's total capital stock[18] by the industry's contribution to a state's total income.[19] For each state, these industry capital stock estimates are then summed to obtain an estimate of a state's total stock of physical capital.[20] The calculation performed for each state m at time t can be expressed as:

$$k_{mt} = \sum_{j=1}^{9} \left[K_{jt} \left(\frac{y_{mjt}}{Y_{mt}} \right) \right] \qquad m = 1, \ldots, 51$$

In this equation, k_{mt} is the stock of physical capital in US state m, y_{mjt} is industry j's value added in US state m, Y_{mt} is total value added in US state m, and K_{jt} is the total US physical capital stock in industry j ($j = 1, \ldots, 9$). This procedure assumes that the capital-to-output ratio in industry j (i.e., k_{mjt}/y_{mjt}) is the same across US states, that is, $k_{mjt}/y_{mjt} = K_{mt}/Y_{mt}$.

Estimates of EU country physical capital stocks for the period 1965 to 1990 are constructed by multiplying the Penn World Tables 5.6 (Heston and Summers, 1991a and 1991b) data on population, physical capital stock per worker and real GDP per capita and then dividing the result by real GDP per worker. Timmer *et al.* (2003) also provide data on EU country physical capital stocks for 1980-2000.[21] These data for 1995 and 2000 are combined with the

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[17] The BEA sectors are Farming (81), Agricultural services, forestry, fishing & other (100); Mining (200); Construction (300); Manufacturing (400); Transportation(500); Wholesale and retail trade (610); Finance, insurance and real estate (700); and Services (800).

[18] Data on state physical capital stock by industry taken from US Fixed Assets Tables available at http://www.bea.doc.gov/bea/dn/faweb

[19] Data on state value added taken from http://www.bea.doc.gov/bea/regional/spi

[20] This procedure follows that used by Munnel (1990) and Garofalo and Yamarik (2002).

[21] Data on physical capital available at http://www.ggdc.net/dseries/growth-accounting.shtml

Penn World Tables derived estimates for 1965-1990 to yield data on EU country physical capital stocks at five year intervals between 1965 and 2000, inclusive.[22]

Tables 3 and 4 describe part of the above raw data by presenting the evolution of the distribution of output shares and their ranking for EU countries and US states. In particular, Table 3 shows the ranking and output share value for the 14 EU member states in 1960, 1985 and 2000 along with the changes in rank and share values between these years. Table 4 shows similar information for the 51 US states for 1990 and 2000.

Table 3 indicates a steady decline of Germany's share of EU-14 output over the 1960 to 2000 period in spite of German re-unification. However, this decline was not enough to knock Germany from its position as number one in the ranking across EU member states. Between 1960 and 2000, the UK and France swapped the number two and three positions in the ranking, with the UK showing a decline in rank. Note that the UK declined two positions (from 2 to 4) in the ranking over the 1960 to 1985 period but regained one position (from 4 to 3) between 1985 and 2000. This turnaround coincides with the Thatcher era that saw important policy changes in the UK that deviated from the EU policy norm, and hence represents the type of unilateral policy change that our model suggests would be needed to have a lasting impact on a country's share of IEA output. In this respect, we earlier noted Ireland as example of the impact of unilateral policy changes. Table 3 indicates that Ireland's output share rose slightly between 1960 and 1985, but doubled between 1985 and 2000, a period that includes Ireland's departure from the EU norm regarding policies such as corporate tax rates. Yet, despite the large increase in its output share between 1985 and 2000, Ireland's ranking was unchanged over the 1960 to 2000 period. Finally, two notable changes in the ranking are (1) Portugal, which gained three positions between 1960

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[22] Estimation was conducted using both sets of data for EU countries. No qualitative difference in results was found for the three years for which data were available from both sources (i.e., 1980, 1985 and 1990). Hence, for these three years, we report only results using the Timmer et al. (2003) capital stock data.

and 2000, with two of these positions gains coming during the 1985-2000 period and (2) Denmark, which slipped two positions in the ranking, with one position lost during each of the sub-periods. Portugal's rise in the ranking likely reflects large inflows of EU structural funds during the 1990s that were invested in infrastructure, human resources and R&D (Magone, 2004, p. 18),[23] while Denmark's decline in rank reflects its own unilateral fiscal policies that begun in the late 1980s to reign in fiscal deficits and to correct persistent balance of payments deficits. These actions produced significant unemployment during the early 1990s that was later reversed in the latter 1990s. During the second half of the 1990s, Denmark also undertook significant labor market reforms that significantly expanded its public sector.

TABLE 3: Evolution of distribution and rank of EU-14 output shares, 1960, 1985 and 2000

Country [a]	Share Rank (1 = largest share)					Share Value [b]					
	1985	2000	Change [c]			1960	1985	2000	Change [d]		
			1960 -1985	1985 - 2000	1960 - 2000				1960 - 1985	1985 - 2000	1960 - 2000
1) Germany	1	1				26.688	23.411	22.779	-3.277	-0.631	-3.908
2) UK	4	3	-2	1	-1	20.323	15.655	16.084	-4.668	0.429	-4.239
3) France	2	2	1		1	14.696	17.088	16.388	2.392	-0.699	1.692
4) Italy	3	4	1	-1		13.872	16.222	15.251	2.350	-0.971	1.379
5) Spain	5	5				5.680	7.911	8.740	2.230	0.830	3.060
6) Netherlands	6	6				4.258	4.261	4.695	0.003	0.434	0.437
7) Sweden	8	8	-1		-1	3.051	2.733	2.543	-0.318	-0.190	-0.508
8) Belgium	7	7	1		1	2.841	2.921	2.958	0.080	0.037	0.117
9) Austria	9	9				2.080	2.216	2.329	0.136	0.113	0.249
10) Denmark	11	12	-1	-1	-2	2.019	1.807	1.723	-0.212	-0.084	-0.296
11) Greece	10	11	1	-1		1.392	1.997	1.872	0.606	-0.126	0.480
12) Finland	13	13	-1		-1	1.331	1.491	1.494	0.160	0.003	0.163
13) Portugal	12	10	1	2	3	1.186	1.613	1.932	0.427	0.319	0.746
14) Ireland	14	14				0.583	0.675	1.212	0.091	0.537	0.628

[a] Sorted by rank in 1960; [b] Share values in percent; [c] A positive change indicates a higher rank in end year relative to start year; [d] A positive value indicates a higher share value in end year relative to start year.

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[23] Greece, Ireland and Spain were also targeted recipients of structural funds during the 1990s. Except for Greece, each of these countries increased in their output share over the 1985-2000 period (Table 3),

Table 4 shows output shares, ranks and their change for the 51 US states between 1990 and 2000. As indicated, the ranking among the top nine states was unchanged over this period. Major gains in rank were achieved by Nevada, Idaho, New Hampshire and Utah, followed by Oregon and Minnesota. It is tempting to attribute the gains by Nevada, Idaho, Oregon, and Utah to inflows of retired and semi-retired persons from California, coupled with an investment boom in Nevada associated with its gambling sector. States with a relative large drop in rank include Connecticut, District of Columbia and Hawaii. Interestingly, Connecticut enacted its first state personal income tax in 1991 – a substantial and unilateral change in tax policy. Hawaii's drop reflects the busting of Japan's property bubble in the early 1990s and subsequent retreat from Hawaii of Japanese tourists and property investors, all of which represent idiosyncratic and long lasting shocks to Hawaii's economy. Exacerbating the effects of this negative shock where tax and employment policy changes enacted in the 1980s, supported by the then ongoing tourism and investment boom. This included substantial increases in business taxes and enactment of union sponsored legislation that, for example, mandated universal health care for employees (Chambers 2006, pp. 262-263). The Japanese retreat and subsequent tourism implosion of the early 1990s was further impacted by the 1991-92 U.S. recession and an additional drop in tourism which eventually induced tens of thousands of Hawaiian residents to seek job opportunities on the US mainland, with many moving to Nevada to support that state's booming tourism/gambling sectors (Chambers, 2006, p. 264). For the District of Columbia, the major fiscal policy change in the 1990s was a substantial increase in the hotel and restaurant meal tax. Apart from these notable gainers and losers, the smaller changes in ranks indicated in Table 10 are suggestive of an ebb and flow of state economic activity associated with transitory shocks, which is consistent with the expectation, as discussed in Section 2 when developing our arguments for the expected randomness of output shares when IEA members pursue harmonized policies, that the evolution of shares would be largely random.

TABLE 4: Evolution of distribution and rank of U.S. state output shares, 1990 and 2000

State [a]	**Share Rank (1 = largest share)**		**Share Value [c]**	
	2000	**Change [b] 1990-2000**	**1990**	**Change 1990-2000**
1) California	1		13.984	-0.452
2) New York	2		8.947	-0.811
3) Texas	3		6.627	0.776
4) Illinois	4		4.792	-0.040
5) Florida	5		4.579	0.138
6) Pennsylvania	6		4.394	-0.373
7) Ohio	7		4.009	-0.217
8) New Jersey	8		3.823	-0.243
9) Michigan	9		3.393	-0.098
10) Massachusetts	11	-1	2.822	0.048
11) Virginia	13	-2	2.631	-0.083
12) Georgia	10	2	2.485	0.471
13) North Carolina	12	1	2.452	0.234
14) Maryland	17	-3	2.066	-0.230
15) Washington	14	1	2.060	0.121
16) Indiana	15	1	1.914	0.038
17) Missouri	18	-1	1.851	-0.059
18) Connecticut	22	-4	1.768	-0.134
19) Minnesota	16	3	1.758	0.143
20) Wisconsin	20		1.738	0.048
21) Tennessee	19	2	1.666	0.126
22) Louisiana	24	-2	1.628	-0.276
23) Colorado	21	2	1.311	0.390
24) Alabama	26	-2	1.254	-0.046
25) Arizona	23	2	1.191	0.409
26) Kentucky	27	-1	1.169	0.009
27) South Carolina	28	-1	1.146	-0.005
28) Oregon	25	3	1.003	0.339
29) Oklahoma	30	-1	0.997	-0.082
30) Iowa	29	1	0.956	-0.016
31) Kansas	31		0.902	-0.043
32) District of Columbia	36	-4	0.767	-0.186
33) Mississippi	35	-2	0.677	-0.007
34) Arkansas	33	1	0.665	0.024
35) Nebraska	37	-2	0.583	-0.007
36) Hawaii	40	-4	0.575	-0.157
37) Nevada	32	5	0.559	0.174
38) Utah	34	4	0.547	0.136

State [a]	**Share Rank (1 = largest share)**		**Share Value** [c]	
	2000	**Change** [b] **1990-2000**	**1990**	**Change 1990-2000**
39) West Virginia	41	-2	0.479	-0.063
40) New Mexico	38	2	0.444	0.119
41) Maine	43	-2	0.419	-0.056
42) Alaska	46	-4	0.419	-0.153
43) New Hampshire	39	4	0.411	0.084
44) Rhode Island	45	-1	0.385	-0.026
45) Delaware	44	1	0.376	-0.018
46) Idaho	42	4	0.301	0.097
47) Montana	48	-1	0.233	-0.013
48) South Dakota	47	1	0.228	0.019
49) Wyoming	50	-1	0.216	-0.027
50) Vermont	51	-1	0.202	-0.015
51) North Dakota	49	2	0.199	-0.007

[a] Sorted by rank in 1990; [b] A positive change indicates a higher rank in 2000 than in 1960;
[c] Share value in percent. A positive value indicates a higher share value in end year relative to start year.

4. EMPIRICAL ANALYSIS

In this section we evaluate empirically our three theoretical propositions regarding the distribution of output and factor shares across members of an integrated economic area. We first examine the hypothesis that output and factor shares conform to a rank-share distribution that exhibits Zipf's law. We then examine for the empirical validity of the equal-share relationship. Finally, we consider the extent to which observed shares conform to the theoretical share distribution given in Table 2.

Rank-Share Distributions and Zipf's Law

To formally assess the hypothesis that output and factor shares conform to a rank-share distribution that exhibits Zipf's law we can take the natural logarithm of each side of expression (9) to obtain:

$$(15) \qquad ln\left(S_{mj}\right) = \theta_j + \beta_j \, ln\left(R_{mj}\right) + u_{mj} \qquad\qquad m = 1, \ldots, M; j = y, k, h$$

where $\theta_j = ln(\gamma_j) < 0$ and u_{mj} is an error term. Estimates of the intercept and slope parameters in (15) for each variable j are obtained by regressing the share values on their rank values across members of a given economic group. This results in separate estimates of the intercept and slope parameters for the output share, physical capital share and human capital share for the 51 US states and 14 EU countries. Given these estimates, evidence against Zipf's law is then assessed by testing if an estimated slope coefficient is significantly different from -1. However, it has been shown that the OLS estimate of β_j in (15) and its associated standard error are biased downward, with the bias diminishing as the number of observational units (M) increases (Gabaix and Ioannides, 2004; Nishiyama and Osada, 2004; Nishiyama, Osada, and Sato, 2008). Hence, failure to correct for these biases means one would more often reject Zipf's law when it is in fact true.

To correct for the downward bias in the OLS slope estimate we follow Gabaix and Ioannides (2004, p. 10) and conduct, for the M = 14 EU countries and M = 51 US States, a Monte Carlo simulation of the OLS slope estimates derived from (15) under the assumption that Zipf's law holds.[24] An estimate of the bias in the OLS slope estimate is then computed by subtracting the slope value under Zipf's law (i.e., -1) from the average of the OLS slope estimates obtained from the Monte Carlo analysis. The resulting value of the estimated bias is 0.172 for M = 14 and 0.081 for M = 51. Given this, an estimate of the true slope coefficient for each M is obtained by adding the estimated bias to the OLS estimate derived from (15).

To obtain a bias adjusted estimate of the standard error we follow Nishiyama and Osada (2004) and use the asymptotic approximation to the true standard error of the OLS slope estimate

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[24] Briefly, for a given sample size M (= 14 or = 51), 100,000 Monte Carlo simulations were performed drawing from the exact power law (9) with coefficient –1 (Zipf's Law). This involved drawing M i.i.d. variables $v_{m,}$ uniformly distributed in the interval [0, 1] and then constructing sizes $L_m = 1/v_m$. The sizes L_m were then normalized into shares S_m which were then ordered and assigned a rank value R_m. We then computed 100,000 OLS regressions using specification (15). The complete results are available from the authors upon request.

given as $-\hat{\beta}_j\sqrt{2/M}$, where $\hat{\beta}_j$ is the OLS estimate of the slope in (15).[25] The test statistic formed using these bias corrected values has asymptotically a normal distribution (Nishiyama and Osada, 2004).

Table 5 reports OLS and bias corrected estimates of the parameters in (15) with respect to the share of output, physical capital and human capital for the sample of 51 US states. Likewise, Table 6 reports these estimates for the sample of 14 EU countries.[26] Over all results, the adjusted *R*-squares range from 0.791 to 0.945, indicating a strong relationship between the rank and share of each variable.

In Table 5 and Table 6, the column labeled “Z-statistic testing bias corrected slope = -1” reports z-statistic values testing the hypothesis that the output and factor share distributions for US states (EU countries) conform to a rank-share distribution that exhibits Zipf’s law. In no instance can this hypothesis be rejected at the 5% level. These results therefore indicate strong support for the hypothesis that each share distribution exhibits Zipf’s law.

These findings for US states and for EU countries are striking empirical results. For comparison, we remark that we preformed the same analysis and tests (results not shown) with respect to a grouping of 30 developing countries and a “world” of 55 countries and found no evidence to support Zipf’s law at the usual level of significance. However, other recent theoretical and empirical contributions do confirm Zipf’s law to be an empirical regularity in international trade. For example, Hinloopen and van Marrewijk (2006) find that the Balassa index of comparative advantage obeys a rank-size rule that often conforms to Zipf’s law. Also, the size distribution of exporters analyzed in Helpman *et al.* (2004) is roughly Zipf’s law.

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[25] The maximum likelihood Hill estimator (Hill, 1975) is another method for estimating the parameters in (9). However, as Gabaix and Ioannides (2004) remark, the properties of the Hill estimator in finite samples can be "very worrisome" and, in particular, their theoretical results predict a large bias in parameter estimates and associated standard errors in small samples. We computed the Hill estimators (results not shown) and indeed found very high downward biases in both parameter estimates and standard errors.

[26] The standard errors are “robust” in the sense of White (1980).

TABLE 5: OLS estimates of rank-share relationship for US states [a]

Share Variable	Year	Intercept [b]	Slope [b]	Bias corrected slope [c]	Z-statistic testing bias corrected slope = -1 [d]	Adj. R^2
Output (M=51)	1990	-1.179 (0.248)	-1.101 (0.081)	-1.020	-0.092	0.887
	1991	-1.194 (0.248)	-1.093 (0.081)	-1.012	-0.055	0.884
	1992	-1.199 (0.252)	-1.090 (0.082)	-1.009	-0.042	0.883
	1993	-1.207 (0.258)	-1.085 (0.084)	-1.004	-0.019	0.881
	1994	-1.208 (0.265)	-1.084 (0.086)	-1.003	-0.014	0.876
	1995	-1.209 (0.265)	-1.083 (0.086)	-1.002	-0.009	0.874
	1996	-1.205 (0.267)	-1.085 (0.087)	-1.004	-0.019	0.872
	1997	-1.192 (0.271)	-1.091 (0.088)	-1.010	-0.046	0.868
	1998	-1.173 (0.272)	-1.100 (0.088)	-1.019	-0.087	0.868
	1999	-1.168 (0.271)	-1.103 (0.088)	-1.022	-0.101	0.866
	2000	-1.164 (0.266)	-1.106 (0.087)	-1.025	-0.114	0.868
Physical Capital (M=51)	1990	-1.199 (0.246)	-1.092 (0.080)	-1.011	-0.051	0.892
	1991	-1.207 (0.247)	-1.089 (0.080)	-1.008	-0.037	0.891
	1992	-1.200 (0.251)	-1.092 (0.081)	-1.011	-0.051	0.892
	1993	-1.197 (0.257)	-1.093 (0.083)	-1.012	-0.055	0.890
	1994	-1.196 (0.266)	-1.092 (0.086)	-1.011	-0.051	0.884
	1995	-1.173 (0.275)	-1.102 (0.089)	-1.021	-0.096	0.879
	1996	-1.168 (0.276)	-1.105 (0.089)	-1.024	-0.110	0.878
	1997	-1.126 (0.286)	-1.125 (0.093)	-1.044	-0.198	0.870
	1998	-1.126 (0.283)	-1.126 (0.091)	-1.045	-0.202	0.876
	1999	-1.108 (0.283)	-1.135 (0.092)	-1.054	-0.240	0.875
	2000	-1.093 (0.282)	-1.143 (0.091)	-1.062	-0.274	0.880
Human Capital (M=51)	1990	-1.244 (0.280)	-1.064 (0.091)	-0.983	0.081	0.854
	2000	-1.264 (0.293)	-1.054 (0.096)	-0.973	0.129	0.839

[a] Standard error in parentheses;[b] All estimates significantly different from zero at the 1% level; [c] Computed as slope estimate plus 0.081 (the bias); [d] Computed as biased corrected slope estimate minus –1 divided by the asymptotic approximation of true standard error (given as minus the OLS slope estimate times 0.198 = $(2/51)^{0.5}$). In no case is the biased corrected slope estimate significantly different from –1 at the 5% level.

TABLE 6: OLS estimates of rank-share relationship for EU countries [a]

Share Variable	Year	Intercept [b]	Slope [b]	Bias corrected slope [c]	Z-statistic testing bias corrected slope = -1 [d]	Adj. R^2
Output (M=14)	1960	-0.645 (0.397)	-1.461 (0.192)	-1.289	-0.523	0.908
	1965	-0.665 (0.416)	-1.435 (0.204)	-1.263	-0.485	0.889
	1970	-0.699 (0.433)	-1.406 (0.212)	-1.234	-0.440	0.867
	1975	-0.742 (0.435)	-1.366 (0.211)	-1.194	-0.376	0.859
	1980	-0.755 (0.419)	-1.357 (0.202)	-1.185	-0.361	0.870
	1985	-0.763 (0.417)	-1.354 (0.199)	-1.182	-0.356	0.872
	1990	-0.772 (0.420)	-1.346 (0.198)	-1.174	-0.342	0.872
	1995	-0.777 (0.405)	-1.343 (0.187)	-1.171	-0.337	0.878
	2000	-0.857 (0.376)*	-1.272 (0.170)	-1.100	-0.208	0.885
Physical Capital (M=14)	1965	-0.816 (0.417)	-1.293 (0.217)	-1.121	-0.248	0.851
	1970	-0.825 (0.396)	-1.275 (0.208)	-1.103	-0.214	0.858
	1975	-0.836 (0.388)*	-1.262 (0.203)	-1.090	-0.189	0.858
	1980	-0.760 (0.484)	-1.332 (0.245)	-1.160	-0.318	0.828
	1985	-0.732 (0.404)*	-1.358 (0.205)	-1.186	-0.362	0.870
	1990	-0.670 (0.398)	-1.418 (0.206)	-1.246	-0.459	0.873
	1995	-0.632 (0.330)	-1.457 (0.174)	-1.285	-0.518	0.908
	2000	-0.658 (0.382)	-1.431 (0.186)	-1.259	-0.479	0.904
Human Capital (M=14)	1960	-0.147 (0.448)	-2.103 (0.287)	-1.931	-1.171	0.791
	1965	-0.343 (0.341)	-1.890 (0.184)	-1.718	-1.005	0.880
	1970	-0.529 (0.280)*	-1.639 (0.176)	-1.467	-0.754	0.865
	1975	-0.642 (0.236)**	-1.518 (0.126)	-1.346	-0.603	0.928
	1980	-0.683 (0.239)**	-1.433 (0.122)	-1.261	-0.482	0.933
	1985	-0.747 (0.185)**	-1.409 (0.092)	-1.237	-0.445	0.945
	1990	-0.895 (0.191)**	-1.241 (0.112)	-1.069	-0.147	0.912
	1995	-0.897 (0.201)**	-1.225 (0.115)	-1.053	-0.114	0.912
	2000	-0.905 (0.196)**	-1.215 (0.110)	-1.043	-0.094	0.919

[a] Standard error in parentheses; [b] All estimates significantly different from zero at the 1% level; [c] Computed as slope estimate plus 0.172 (the bias); [d] Computed as biased corrected slope estimate minus –1 divided by asymptotic approximation of the true standard error (given as minus the OLS slope estimate times 0.3779 = $(2/14)^{0.5}$). In no case is the biased corrected slope estimate significantly different from –1 at the 5% level.

The Equal-Share Relationship

To assess the empirical validity of the equal-share relationship, we estimate equation (15) separately for the output share, physical capital share and human capital share with respect to the 51 US states and 14 EU countries. For each economic group, evidence in favor of the equal-share relationship (8) is obtained in two steps. First, we test for homogeneity of the OLS slope estimates (i.e., whether $\beta_y = \beta_k = \beta_h$) to verify that the share distributions come from a common power-law distribution.[27] Second, we test for intercept homogeneity across the three share equations (i.e., whether $\theta_y = \theta_k = \theta_h$) to examine if the equal-share relationship holds with respect to the highest ranked member of each IEA (i.e., California for US states and Germany for EU countries). Failure to reject these hypotheses of coefficient homogeneity would imply that technological differences and factor market imperfections are not strong enough to prevent the equal-share relationship (8) from holding in a statistical sense.[28]

Table 7 reports *p*-values for testing the hypotheses of slope and intercept homogeneity across the three share distributions in each sample year. We cannot reject these hypotheses for US states in either of the two years (1990 and 2000) for which data were available on all three shares. This result supports the equal-share relationship for US states. The results for EU countries indicate similar support for the equal-share relationship.[29]

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[27] These tests were performed by establishing, in each year, a system comprising the three share equations but without initially imposing any cross-equation parameter restrictions.

[28] It can be shown that since we work with shares (which sum to 1), the first step ($\beta_y = \beta_k = \beta_h$) of this testing sequence implies the second step ($\theta_y = \theta_k = \theta_h$), but not the other way around.

[29] This analysis does not control for the expected downward bias in the estimated value of the slope coefficients since doing so would only strengthens evidence in favor of the equal-share relationship.

TABLE 7: Results testing equal-share relationship for US states and EU countries

Economic Group	**Year**	***p*-value testing coefficient equality across share equations**	
		Intercept	*Slope*
51 US states	1990	0.968	0.901
	2000	0.824	0.596
14 EU countries	1965	0.606	0.045*
	1970	0.801	0.280
	1975	0.862	0.366
	1980	0.969	0.846
	1985	0.997	0.931
	1990	0.811	0.603
	1995	0.712	0.370
	2000	0.729	0.407

** Cross-equation homogeneity rejected at 5% level.*

We now examine the proposition that the limiting distribution of output or factor shares across IEA members is unique and depends only on the number of IEA members. On the one hand, this proposition is partly supported by the earlier findings that support the proposition that member shares conform to a rank-share distribution that exhibits Zipf's law. However, these results do not indicate how close observed shares are to the theoretically expected shares given in Table 2. Such an analysis is undertaken below.

To gauge the extent to which actual observed shares conform to the theoretically expected values as given in Table 2, Table 8 reports simple correlations between the natural logarithms of actual and expected shares for US states and EU countries in 1990 and 2000. The correlations range from 0.918 to 0.962 and all are highly significant, indicating a strong positive relationship between actual and theoretical shares.

TABLE 8: Correlation between logarithm of actual and theoretical output and factor shares for US States and EU Countries, 1990 and 2000

Economic Group	**Year**	**Correlation coefficient**		
		Output	*Physical Capital*	*Human Capital*
51 US states	1990	0.943	0.946	0.926
	2000	0.933	0.939	0.918
14 EU countries	1990	0.939	0.940	0.940
	2000	0.945	0.955	0.962

TABLE 9: Results of two-sample Kolmogorov-Smirnov test for equality of actual and theoretical distributions of output and factor shares, 1990 and 2000

Economic Group	**Year**	**Kolmogorov-Smirnov *D*-statistic between actual shares and theoretical shares** [a]		
		Output	*Physical Capital*	*Human Capital*
51 US states	1990	0.216†	0.216†	0.235†
	2000	0.235†	0.275†	0.216†
14 EU countries	1990	0.357†	0.357†	0.357†
	2000	0.357†	0.357†	0.214†

† Cannot reject the hypothesis that actual and theoretical shares come from a common distribution at the 5% level.

[a] Critical values for the *D*-statistic are: for US states 0.3228 (1% level) and 0.2693 (5% level); for EU countries, 0.6161 (1% level) and 0.5140 (5% level). A *D*-statistic value exceeding a chosen critical value indicates rejection of the hypothesis at the given level of significance.

Whereas these simple correlations indicate a significant linear association among shares, but they do not indicate overall conformity between the actual and theoretical share distributions, that is, whether the actual and expected shares come from the same distribution. To test this, we use the non-parametric two-sample Kolmogorov-Smirnov test. In this test, the null hypothesis is that both sets of shares come from a common distribution against the alternative hypothesis that they do not. The results, shown in Table 9, convincingly indicate a failure to reject the null hypothesis, suggesting that actual and theoretical shares arise from the same distribution.

5. A MEASURE OF THE EXTENT OF ECONOMIC INTEGRATION

Given empirical support for our three theoretical propositions, we compute in this section a summary measure of the extent of integration among members of a given economic group. Ideally, such a measure should summarize in a single value all information conveyed by the distributions of actual and theoretical shares and indicate the extent to which actual shares deviate from those expected theoretically. Our approach is to use the entropy statistic developed by Theil (1971). In our context, this statistic specifies the distribution of actual shares across members of a given economic group of size *M* as the prior distribution and the distribution of theoretical shares for an integrated economic area with *M* members as the posterior distribution. It then calculates the distance to full integration for the given economic group at time *t* as:

$$E(\overline{S}, S_t) = \frac{1}{3} \sum_{j=y,k,h} \left(\sum_{m=1}^{M} \overline{S}_{mj} \ln\left(\frac{\overline{S}_{mj}}{S_{mjt}}\right) \right) \tag{16}$$

In this expression, the time invariant long-run theoretical shares are denoted $\overline{S}_{mj}$ whereas the actual shares at time *t* are denoted S_{mjt}. Measure (16) is the arithmetic average of three terms, one for each of our three variables *j* (*j* = *y*, *k*, *h*). Each term measures the distance between theoretical and actual shares across the *M* members of a given economic group. The measure takes the value zero under complete integration, which arises when the shares are pairwise equal (i.e., $\overline{S}_{mj} = S_{mjt}$ for *m =1, 2,…, M* and *j = y, k, h).* Otherwise, deviations in observed from theoretical shares indicate how far member shares deviate from those expected under complete integration. Since the values of (16) range from zero and infinity, with a higher value indicating less integration (i.e., poorer fit), it is convenient to transform the values of (16) as follows:

$$(17) \qquad I(\overline{S}, S_t) = \frac{1}{e^{E(\overline{S}, S_t)}} = e^{-E(\overline{S}, S_t)}$$

The index $I(\overline{S}, S_t)$ equals 1 under complete integration and its value approaches 0 as the fit between actual and theoretical shares worsens. Hence, increasing departures of actual from theoretical shares lower the value of $I(\overline{S}, S_t)$, indicating less economic integration among members of a given economic group.

Table 10 reports the values of (17) computed for US states and EU countries for as many time periods as possible in order to detect any trend in integration. Columns (1) to (3) of Table 10 indicate the component values for output, physical capital and human capital which are summed to arrive at the value of integration (16) as given in column (4); column (5) reports the (inverted) integration index (17). An important result indicated in column (5) is the steady increase over time in the measured extent of integration among the 14 EU countries, with the value of integration index (17) rising steadily from 0.887 in 1965 to 0.951 in 2000. In contrast, the index values (17) for US states dropped slightly between 1990 and 2000. What seems clear from column (5) is that a lower extent of integration among EU countries relative to US states has evolved over a long period into essentially a slightly higher extent of integration among EU countries relative to US states. Computationally, the main source of the measured evolution toward greater EU integration has been a rising conformity between the actual and theoretical share distributions for human capital, as indicated by the steady decline over time in the values of the human capital component (column (3)) of the entropy measure.

TABLE 10: Entropy measure of extent of economic integration

Economic Group	**Year**	**Integration Index Values** [a]				
		Output *(1)*	*Physical Capital (2)*	*Human Capital (3)*	*Entropy Statistic (4)*	*Inverse Entropy (5)*
51 US states	1990	0.017	0.016	0.027	0.060	0.942
	2000	0.020	0.014	0.030	0.065	0.937
14 EU countries	1965	0.024	0.023	0.072	0.120	0.887
	1970	0.027	0.019	0.039	0.084	0.919
	1975	0.027	0.017	0.027	0.072	0.931
	1980	0.026	0.027	0.015	0.068	0.934
	1985	0.027	0.020	0.018	0.065	0.937
	1990	0.027	0.020	0.009	0.056	0.946
	1995	0.027	0.016	0.007	0.049	0.952
	2000	0.024	0.020	0.006	0.050	0.951

[a] Columns (1) to (3) indicate contribution of output, physical capital and human capital to the value of (14) in column (4), the latter computed as the sum of columns (1) to (3), where a value of zero means complete integration; column (5) reports values of (15), where a value of 1 means complete integration.

Two remarks are warranted regarding the conclusions that can be drawn from the results in Table 10. First, no statistical assessment of the observed difference in index values either over time or between EU countries and US states is possible since the statistical properties of (16) are unknown. Hence, whether the higher level of EU integration relative to US states in later years is statistically meaningful cannot be determined. Second, our analysis is sensitive to the weights given to each variable (i.e., output, physical capital and human capital) in the index. For example, had we computed (16) using only the component values for output and physical capital (each with weight 0.5) the resulting values of index (17) would be 0.950 for US states versus

0.936 for EU countries, indicating a lower extent of economic integration among EU countries relative to US states.[30]

6. SUMMARY AND DISCUSSION

In response to the perception that the process of European integration is lagging or is incomplete, this paper derived three theoretical predictions about the distribution of output and factors expected to arise among members of a fully integrated economic area in which goods and factors are mobile and member polices are harmonized. These predictions were then tested empirically with respect to the members of two economic groups: the 51 US states and 14 EU countries. The data used generally covered the period from 1965 to 2000. In all cases, the empirical results strongly supported the theoretical prediction of an equal-share relationship for each group member, as well as the prediction that the distribution of output and factor shares across members conforms to a rank-share distribution that exhibits Zipf's law. For each economic group, no statistically significant difference was found between the actual and theoretically expected long-run distribution of the output and of factor shares. Also, for the most recent data in our sample, our measure of the extent of integration indicated that, contrary to popular perception, the extent of integration among 14 EU countries is about the same as that for US states. These results indicate that both EU countries and US states can be regarded as equally integrated when measured against the theoretical benchmark of a fully integrated economic area.

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[30] For EU counties, we also investigated if different measures of labor input (civilian employment (CE) and full employment labor force (FELF)) impacted our analyses of prior sections and the extent of integration results shown in Table 10. Our results for EU countries, as reported in Tables 7-9, were unchanged. However, for the integration results reported in Table 10, the values of our integration measure (17) were smaller than those reported in Table 10, and the relative increase in measured EU integration between 1960 and 2000 was also smaller than reported in Table 10. For comparison, the value of (17) reported in Table 10 rose 7.5% between 1960 and 2000; the value of (17) rose just less than 1% over the same period using either the CE or the FELF. This underscores caution when interpreting the measured extent of integration over time or its level when compared between economic groups.

Overall, our results indicate that the extent of economic integration among EU member states is greater than commonly perceived. This suggests that past EU commitments to the freer movement of goods and factors, major transformations like the 1992 internal market program, and the introduction of the European Monetary Union have been effective in reallocating resources both within and between EU members. If so, the results also indicate that perceptions of lagging or incomplete EU integration may instead reflect that resource allocation within the EU is non-optimal from the perspective of world resource allocation (e.g., Bowen and Sleuwaegen, 2007) due to policies such as the Common Agricultural Policy.

The empirical significance of the equal-share relationship and of Zipf's law stresses that policy harmonization is consistent with the proposition that the relative growth performance of individual members of an integrated economic area (IEA) is largely random. Hence, it is random shocks like innovations, discoveries, weather, or natural disasters, including some that are specific to a particular member, that largely affect share values and hence the relative position of IEA members over time. Such randomness is more likely the greater the extent of policy harmonization, and hence more likely if members do not run independent monetary or exchange rate policies, when fiscal policies are constrained by institutions, when education systems are harmonized, and when successful local industrial policies are rapidly imitated. All this points to the need to recognize the potential constraint that greater EU policy harmonization imposes on EU member states: no member state can or should expect to improve its relative position unless it undertakes independent, inharmonious policies (e.g., Ireland).

Finally, in addition to quantifying the extent of integration, our analysis has contributed importantly to the literature that concerns more generally the implications of increased trade and factor mobility for the characterization of integrated economic areas. For example, if the equal-share relationship holds, then all members of an economic group will have the same output per efficiency unit of labor (i.e., human capital). This implication is the essence of the absolute convergence hypothesis (Barro and Sala-i-Martin, 2004; Papyrakis and Gerlah, 2007), here interpreted in terms of efficiency units of labor, and not in per capita terms. Finally, the equal-share relationship highlighted in this paper suggests an answer to Lucas' (1990) question as to why capital does not flow from rich to poor countries: economies with a low level (and hence low share) of human capital are expected to have also a low share of physical capital, and also a low share of output.

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