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ON THE EXTENT OF ECONOMIC INTEGRATION: A COMPARISON OF E.U. COUNTRIES AND U.S. STATES*

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Abstract

European economic integration is commonly believed to be incomplete, and that further reforms are needed. In this context, the union of U.S. states is considered the benchmark of complete economic integration and is often the basis for comparison regarding the extent of E.U economic integration. Yet, with low trade barriers and with productive factors at least notionally mobile across E.U. countries, is the belief that U.S. states are more integrated than E.U. member states correct? To address this question, this paper first develops three theoretical predictions about the distribution of output and factors that would arise among members of a fully integrated economic area in which goods, capital and labor are freely mobile and policies are harmonized. These theoretical predictions are then empirically tested using data on the output and factor stocks of 14 E.U. member states and the 51 U.S. states (includes District of Columbia) for the period 1965 to 2000. The empirical results convincingly support each theoretical prediction. Hence, contrary to popular belief, the extent of E.U. economic integration is not statistically different from that among U.S. states.

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On the Extent of Economic Integration: A Comparison of E.U. Countries and U.S. States

The European Union (E.U.) recently turned 50 years of age. Yet, despite its age and recent enlargement to 27 member states, it is commonly believed that the process of European integration is both lagging and incomplete, and that many reforms are still needed. To many, such reforms would include adoption of a (new) constitution, greater liberalization of domestic labor and product markets, and greater cooperation in areas under national control like taxation, social security, infrastructure, etc. In suggesting that further E.U. integration is needed, analysts and policymakers often refer explicitly or implicitly to the union of U.S. states as the benchmark of complete integration. Yet, with low barriers to trade and with productive factors at least notionally mobile across E.U. member states, how valid is the conjecture that U.S. states are more integrated than E.U. countries? Alternatively, is the extent of E.U. economic integration really incomplete?

The purpose of this paper is to address these questions. Using factor price equalization as a driving force, we derive three theoretical predictions about the expected configuration of output and factor stocks among members of a *fully* integrated economic area (IEA) in which goods and factors are freely mobile and policies are harmonized. We then examine empirically for these theoretical predictions with respect to E.U. member states and U.S. states.

We first demonstrate that, within a *fully* integrated economic area, each member's share of total IEA output will equal its shares of the total IEA stock of each productive factor. We label this theoretical result the "equal-share" relationship. Since this equal-share property concerns each IEA member it does not directly address the important question of the distribution of output and factor shares across IEA members. Instead, this question is addressed by our second theoretical proposition: the distribution of output and factor shares across IEA members exhibits Zipf's law. This 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, thrice that of the third largest member, etc. Our explanation for Zipf's law with respect to the distribution of member shares derives from the expected randomness of these shares when policies are fully harmonized across IEA members. In particular, building on Gabaix's (1999a) analysis of city shares of a nation's population, we argue that if the output and factor shares evolve as geometric Brownian motion with a lower bound then the distribution of output and factor shares will exhibit Zipf's law.

Finally, given Zipf's law, we derive our final theoretical proposition: in the long run, the distribution of output and factor shares is unique, and is determined only by the number of IEA members. This latter result is significant, since it means that the relative position of any one IEA member depends only on the total number of IEA members.

While our analysis is meant to address the question of the extent of E.U. (and U.S.) integration relative to the benchmark of a fully integrated economic area, 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 IEA members. That is, while prior work has demonstrated the potentially important role of trade[1] and factor mobility[2] as influences on economic growth, less attention has been given to the distributional consequences of trade

[1] An extensive body of work has explored the role of international trade and of factor mobility 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 (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] For example, Baldwin and Martin (2004) examine the relationship between growth and the agglomeration of economic activity and find that it depends crucially on the extent of capital mobility between regions. Similarly, 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. Instead, these growth rates are affected only by parameters that describe the accumulation of human capital.

and factor mobility within integrated economic areas. Our analysis therefore contributes by investigating properties of integrated economic areas and by deriving a number of testable hypotheses regarding output and factor shares within integrated economic areas.

Finally, in focusing attention on output and factor shares, our analysis also reinforces prior developments in the international economics literature that have demonstrated that country shares of regional output, or shares of a region's total supplies of physical capital and human capital, are both important and useful constructs (e.g., Bowen et al. (1987), Helpman and Krugman (1985), Leamer (1984), Viaene and Zilcha (2002)).

We empirically examine our theoretical propositions using data on the output and factor stocks of each of 14 E.U. countries and each of the 50 U.S. states plus the District of Columbia (hereafter the 51 U.S. states). The data generally covers the period from 1965 to 2000, which includes the European Union's internal market program and the introduction of the European Monetary Union.[3]

For both U.S. states and the E.U. countries, our empirical results convincingly support the theoretical predictions of an equal-share relationship and of Zipf's law, as well as the prediction that the actual distribution of output (and of each factor) across IEA members conforms (in a statistical sense) with the theoretically expected long run distribution. These results therefore indicate that the distribution of output and factors among U.S. states and among E.U. countries conform to that expected in a fully integrated economy. While recognizing that some of the statistical tests for the sample of E.U. countries have low power due to a smaller number of observations, the results do suggest no significant difference in the extent of integration of U.S. states versus E.U. member states.

[3] The European Monetary Union (EMU) or 'Eurozone' exists since January 1, 1999 and comprises 12 countries: Austria, Belgium, France, Finland, Germany, Greece (joined 2001), Ireland, Italy, Luxembourg, The Netherlands, Portugal, and Spain. The 14 E.U. countries we examine are the 12 EMU countries excluding Luxembourg, plus Denmark, Sweden, and the U.K. Luxembourg is excluded for lack of data on human capital. The omission of Luxembourg is unlikely to affect our results due to the small scale of its economy relative to other E.U. countries.

The remainder of the paper is as follows. In Section 1 the theoretical equal-share relationship is derived and initial empirical evidence supporting this relationship is presented. Section 2 explains the emergence of Zipf's law for the distribution of output and factor shares. Section 3 presents empirical tests for the presence of Zipf's law. Section 4 then uses the evidence of Section 3 to further characterize properties of a fully integrated economic area. This includes derivation of the theoretically expected long run distribution of shares, a formal test of the equal-share relationship, and tests of the conformity between the actual and long run distribution of shares. Section 5 summarizes and discusses our findings.

1 Equality of Output and Factor Shares in an Integrated Economic Area

To demonstrate the equality of output and factor shares we consider an IEA that consists of m = 1, …, M members, each producing a single homogenous good by means of a constant return to scale aggregate production function of the form:

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

where Y_{mt} denotes the quantity of the single good produced, K_{mt} the stock of physical capital, and H_{mt} the stock of human capital, all for country 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, the production function is assumed to take the Cobb Douglas form:[4]

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

Here A_{mt} is a scale parameter and α_m is capital's share of total output. With goods arbitrage and free trade a single commodity price will prevail within this IEA. If physical capital and labor are perfectly mobile between the M members then we would expect the (value)

[4] The Cobb-Douglas specification has wide empirical support (e.g., Mankiw et al., 1992). The analysis can be extended to the case where the production function has the constant elasticity of substitution (C.E.S.) form.

marginal product of each factor to be equal. In contrast, barriers to capital mobility (e.g. corporate income tax differentials, capital controls) or labor mobility (e.g. language, different pension systems) would instead create persistent differences in factor rates of returns between members. Consider one reference member of the IEA that, without loss of generality, we take to be country *i*. Let λ_{mt}^{k} and λ_{mt}^{h} define the proportional difference in rates of return to physical capital and to human capital between any country *m* and reference country *i*. The relation between rates of return to physical capital in the IEA can then be written as:

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

where $v_m = \alpha_m / \alpha_i$, implying $v_m = 1$ when $\alpha_m = \alpha_i$ ($m = 1, ..., M$). Note that for $m = i$, $\lambda_{it}^{k} = 1$ and $v_i = 1$. Likewise, the relation between rates of return to human capital can be written:

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

where $\omega_m = (1-\alpha_m)/(1-\alpha_i)$, implying $\omega_m = 1$ when $\alpha_m = \alpha_i$ ($m = 1, ..., M$). Note that for $m = i$, $\omega_i = 1$ and $\lambda_{it}^{h} = 1$. The ratio of (3) to (4) gives the following relationship between ratios of human to physical capital:

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

where

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

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

Like in (5), we can rewrite (3) as:

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

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

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

We term equation (7) the "equal-share relationship." This relationship determines 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 $(\alpha_m, \lambda_m^k, \lambda_m^h)$. Differences in technology or factor market imperfections imply a multiplicative rescaling of the observable variables that is different for each ratio. For example, a difference in α's leaves the observed values (and shares) of physical capital unaffected but transforms the observed values of output and human capital in different ways (through v_m and η_m respectively). If we assume that the *M* members of the IEA share the same technology ($\eta_m = v_m = \omega_m = 1$), and that there is costless (perfect) mobility of factors ($\lambda_{mt}^k = \lambda_{mt}^h = 1$) between members, then we obtain the simplest expression of the equal-share relationship for any member *i*:

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

Hence, with perfect capital mobility and similar technology, each economy's share of total IEA output, and each economy's share of total IEA physical capital stock, at any date t equals its share of the total IEA stock of human capital.

Relationship (8) has an important implication. It contrasts the policies pursued in isolation by any given IEA member with those that are instead pursued jointly (harmonized) across members. For example, (8) does not change when a coordinated education policy by all IEA members increases their human capital by the same proportion. In contrast, the same policy implemented by only one member would increase that member's share of total IEA human capital (as long as this policy is not imitated by other members). For example Ireland, although an E.U member, independently conducted in the 1980s and 1990s a number of policies (e.g., low corporate tax rate, education reforms, etc.) that differed significantly from those followed by other E.U. member states. These policies attracted multinationals in key sectors to Ireland, particularly from the U.S., and led some E.U. firms to relocate to Ireland. At the same time, Ireland's share of E.U.-15 GDP rose from 0.6% in 1980 to 1.2% in 2000. This increase in Ireland's share of E.U. GDP illustrates the differential impact of harmonized versus non-harmonized policies in an integrated economic area on a member country's share of output. Given its unusual success, E.U. (and OECD) members pressured Ireland to move its policies, particularly its tax regime, closer to the E.U. average.

Hence, if IEA members have harmonized economic and social policies (e.g., fiscal, education, industrial policies) then the equal-share property implies that the relative performance of each member remains unaffected by these policies. In this sense, member shares can be considered a random variable whose outcome is dependent on the particular state of nature at time *t*. Such randomness can easily be understood from the fact that various kinds of random shocks, like discoveries, weather, or natural disasters, including some that are specific to a particular member, would give rise to new and different sets of shares for all members.

In Section 3 we report tests of the null hypothesis given by (8) against the alternative hypothesis given by (7). As a prelude to that analysis, we provide here a first indication of the potential validity of the equal-share relationship by examining a "weak" form of this relationship, namely, that there will be conformity between (pair-wise) rankings of the output and factor shares across members of a given integrated area. Table 1 provides evidence of this weaker proposition by reporting Spearman rank correlation coefficients for pair-wise rankings of the shares of output, physical capital and human capital across members of the 51 U.S. states and the 14 E.U. countries in 1990, 1995 and 2000, years for which overlapping data on output, physical capital and human capital are available.[5] All rank correlations are positive and significant for both U.S. states and E.U. countries though correlations are higher for U.S. states. Results support a "weak" form of the equal-share relationship: that there is conformity between (pair-wise) rankings of the output and factor shares across members of both integrated areas.

Table 1. Spearman Rank Correlations for Output, Physical Capital and Human Capital Shares across U.S. States and E.U. Countries

Integrated Economic Area	Year	Spearman Rank Correlation between Shares of		
		Output and Physical Capital	Output and Human Capital	Physical And Human Capital
U.S. States [a]	1990	0.987	0.977	0.980
	1995	0.991	n.a.	n.a.
	2000	0.992	0.981	0.978
E.U. 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).

[5] For U.S. states our data consists of annual cross-sections covering 1990 to 2000. For E.U. countries the cross-sections are instead equally spaced at 5-year intervals and generally cover the period from 1965 to 2000. Section 3 gives a complete description of these data.

2 Rank-Share Distributions and Zipf's Law

Besides the equality of shares for each individual member of a fully integrated economy, there is the important question of what determines the distribution of output and factor shares among all members of this area. To show this, we consider the concept of rank-share distribution that describes a particular relationship between the share and rank of a variable across a set of observational units. It is related to the concept of a rank-size distribution. For instance, a rank-size distribution for city size exists if the relationship between the natural logarithm of city size and of rank based on size is linear and exhibits a negative slope; Zipf's law arises when this slope value equals -1.

The existence of Zipf's law for city sizes is a widely documented empirical regularity (e.g., see 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 recent example is Gabaix (1999a), who draws on Gibrat's law[6] to assume that cities follow a random but common growth process. Normalizing city population by a country's total population, Gabaix shows (his Proposition 1) that if population shares evolve as geometric Brownian motion with an infinitesimal lower bound then the steady state distribution of population shares will be a rank-size distribution that exhibits Zipf's law.

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

As previously noted, the equal-share property for members of an IEA together with an assumed harmonization of IEA members' economic policies implies that the relative performance of any one IEA member can be considered a random variable. Given this, we can assume like in Gabaix (1999a) that the share of variable *j* (e.g., *j* = output) evolves as geometric Brownian motion with a lower bound,[7] and moreover, that the distribution of growth rates of these shares is common to all IEA members (i.e., Gibrat's law).[8] These assumptions 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.

To understand the implications of Zipf's law, consider again an IEA consisting of *M* members. Let S_{mj} denote member *m*'s share of the total IEA amount of variable *j* (*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 ($m = 1, \ldots, M$). Assume $R_{mj} = 1$ for the member with the largest share of variable *j* and $R_{mj} = M$ for the member with the lowest share of variable *j*. If variable *j* has a rank-share distribution then we can write:

$$S_{mj} = \gamma_j \left(R_{mj}\right)^{\beta_j} \tag{9}$$

where $\beta_j < 0$ is the "power-law exponent" and $0 < \gamma_j < 1$ is the share of variable *j* for the IEA member with the highest rank (i.e., when $R_{mj} = 1$). A power law implies a specific relationship among shares: $S_{1j} / S_{2j} = 2^{-\beta_j}, S_{1j} / S_{3j} = 3^{-\beta_j}, \ldots, S_{1j} / S_{Mj} = \mathrm{M}^{-\beta_j}$. Zipf's law corresponds to $\beta_j = -1$, which simplifies the relationship among member shares, namely: $S_{1j} = 2S_{2j} = 3S_{3j} = \ldots = \mathrm{M}S_{Mj}$. This states that the share value of the highest ranked country is twice the share value of the second ranked country, etc.

[7] One needs to prevent output and factors from falling below some lower bound in order to obtain a power law. Otherwise the distribution would be lognormal. A lower bound makes sense in integrated areas as important income transfers are institutionalized to prevent states/regions/countries to vanish. For example, the E.U. maintains a social fund and a regional fund.

[8] The equal-share relationship implies that the common expected rate of growth is zero since the sum over *i* of the output and factor shares in (8) must be one.

To gain insight into how a rank-share distribution that exhibits Zipf's law emerges we simulate the evolution of the distribution of output shares across U.S. states, allowing the number of years simulated to be 20, 50, 75, 100, 150, 200, 250 and 300. For each simulation, each U.S. state is initially assumed to have same level of output and hence the same share S_{my} (i.e. S_{my} = 0.0196 = 1/51). Starting from these common share values, the output shares are then specified to evolve randomly over time as geometric Brownian motion with a lower bound.[9] At annual intervals (t) during a simulation period, the output shares are used as data to estimate rank-share equation (9) and to test if the estimated β_y is statistically different from -1.[10] This allows us to determine the point in time at which the distribution of output shares conforms to a rank-share distribution exhibiting Zipf's law.

Our simulations indicate that Zipf's law emerges after 75 to 150 years depending on the assumed volatility of the growth rate of the shares: the higher the volatility, the faster is convergence to Zipf's law.[11] Figure 1 summarizes the results of the 200 year simulation by showing the evolution of the maximum, median and minimum output share, and the point in time after which the distribution of the output shares exhibits, statistically, Zipf's law.

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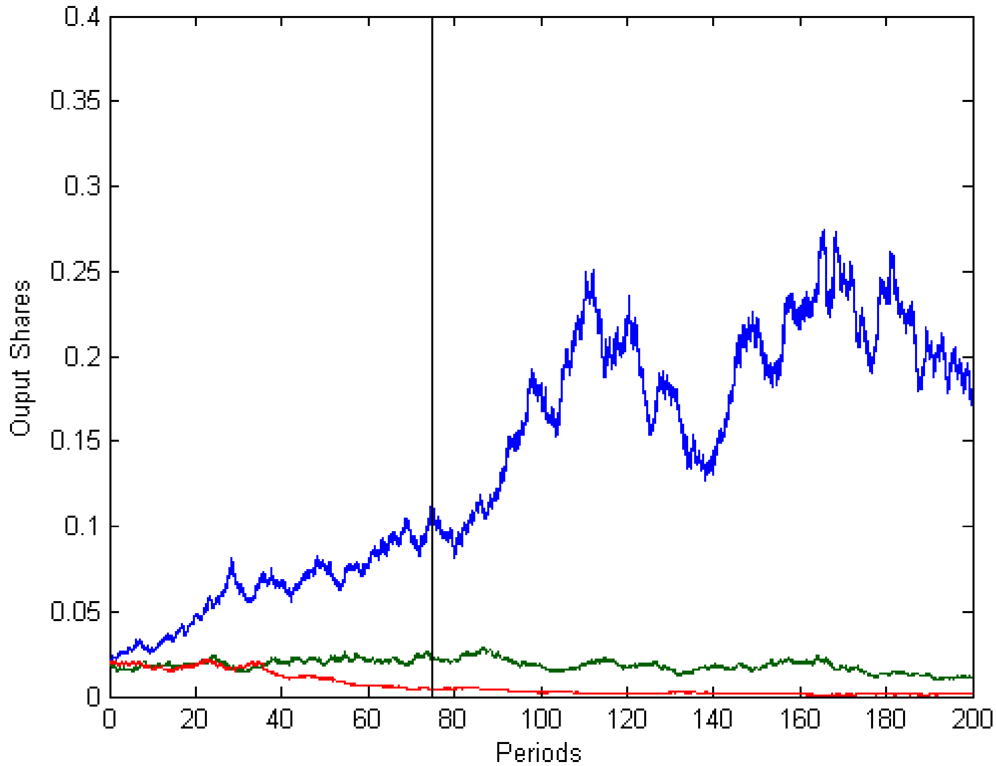
[9] Following Gabaix (1999a), each share evolves as $dS_{myt}/S_{myt} = \mu dt + \sigma dB_t$ if $S_{myt} > \min(S_{myt})$ where $\min(S_{myt})$ is the lower bound. Alternatively, the increment in each share is $dS_{myt}/S_{myt} = \max[\mu dt + \sigma dB_t, 0]$ for $S_{myt} \leq \min(S_{myt})$. Here $\mu < 0$ is a negative drift, σ is the standard deviation (volatility), B_t is a Wiener process. The term dB_t is then the increment of the process, defined in continuous time as $dB_t = \varepsilon_t (dt)^{1/2}$. Since ε_t has zero mean and unit standard deviation, $E[dB_t] = 0$ and $Var(dB_t) = dt$. The increment dB_t is approximated by a running sum of 730 discrete increments ("shocks") since our simulations assume one calendar year is 365 days (dt = 1/365) and we arbitrarily assume two random shocks (two draws of ε_t) on each day. We set μ = -0.01, $\min(S_{myt})$ = 0.001, and variously, σ = 0.04, 0.05 and 0.07.

[10] The estimation procedures used are those detailed in Section 3 below.

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

Figure 1. Simulated Path of the Maximum, Median and Minimum Output Share across 51 U.S. States [a]



[a] Simulation over 200 years assuming that each state begins with the same output share and that the evolution of the shares then follows geometric Brownian motion with a lower bound. For this simulation, drift $\mu = -0.01$, lower bound $\min(S_{myt}) = 0.001$, volatility $\sigma = 0.07$. The vertical line indicates the starting period at which the power law exponent (β_{yt}) is no longer significantly different from –1 (Zipf's law holds).

3 Empirical Analysis

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 (9) to obtain:

$$(10) \qquad \log\left(S_{mj}\right) = \theta_j + \beta_j \log\left(R_{mj}\right) + u_{mj} \qquad m = 1, \ldots, M;\, j = y, k, h$$

where $\theta_j = \log(\gamma_j) < 0$ and u_{mj} is the error term. Estimates of the intercept and slope parameters in (10) are crucial to our analysis and are obtained by regressing the share of variable j on variable j's rank value across a given set of IEA members.

We estimate (10) separately for the output share, physical capital share and human capital share with respect to the 51 U.S. states and 14 E.U. countries. Given estimates of (10), evidence against Zipf's law is assessed by testing if the estimated slope coefficient is significantly different from minus one. However, as Gabaix and Ioannides (2004) and Nishiyama and Osada (2004) recently demonstrate, both the OLS estimate of β_j in (10) and its associated standard error will be biased downward, with these biases diminishing as the number of observational units (M) increases. Hence, without some correction for these inherent biases one is likely to more often reject Zipf's law when it is in fact true.

To correct for these biases, we follow Gabaix and Ioannides (2004, p. 10) and conduct, for the cases M = 14 (E.U. countries) and M = 51 (U.S. States), a Monte Carlo analysis of the OLS slope estimates derived from (10) under the assumption that Zipf's law holds.[12] The difference between the Zipf's law true slope value (-1) and the average of the Zipf's law OLS slope estimates (-1.172 for M = 14 and -1.081 for M = 51) gives an estimate of the downward bias, which is 0.172 for M = 14 and 0.081 for M = 51. Given these estimates of the bias for each M, an estimate of the true slope coefficient is obtained by adding the estimated bias to the OLS estimate derived from (10).

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 given as $-\hat{\beta}_j\sqrt{2/M}$, where $\hat{\beta}_j$ is the OLS estimate of the slope in (10).[13] The

[12] Briefly, for a given sample size M (either M = 14 or M = 51), 100,000 Monte Carlo simulations are performed drawing from an exact power law 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 are then normalized into shares S_m that were then ordered and assigned a rank value R_m. We then perform 100,000 OLS regressions using the specification $\log(S_m) = \theta + \beta \log(R_m) + u_i$. The complete results are available from the authors upon request.

[13] Another method for estimating the parameters of a power law distribution is the maximum likelihood Hill estimator (Hill, 1975). 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.

test statistic formed using these bias corrected values has asymptotically a normal distribution (Nishiyama and Osada, 2004).

Data

Our data set consists of data in a given year on the output and stocks of human and physical capital for the 51 U.S. states and for 14 E.U. countries. Due to limitations on sourcing data for human capital, the data on U.S. states are restricted to annual observations from 1990 to 2000. The data for E.U. countries are restricted to consist of observations equally spaced at 5 year intervals over the period 1960 to 2000. The following provides more details regarding data methods and sources.

For U.S. states, output for the period 1990 to 2000 is measured by real gross state product as reported annually by the U.S. Bureau of Economic Analysis.[14] For E.U. countries, output is measured by real gross domestic product (GDP), derived from data on real GDP per capita and population given in the Penn World Tables 6.1 (Heston, Summers and Aten, 2002).

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

For the E.U. countries, human capital stock is measured by multiplying the percentage of the population having at least a secondary level of education times a country's total population. Data on rates of educational attainment are taken from Barro and Lee (1993,

[14] Data on gross state product available at http://www.bea.doc.gov/bea/regional/gsp
[15] Decennial census dataset are available at http://factfinder.census.gov

1996, and 2000); country population data are from Heston, Summers and Aten (2002).[16] The educational attainment data are only available every 5 years, which limit the E.U. data on human capital to five-year intervals from 1960 to 2000.

Annual estimates of U.S. state physical capital stocks from 1990 to 2000 are derived from BEA (2002) estimates of the total U.S. physical capital stock in each of nine one-digit industrial sectors that together comprise all economic activity.[17] The national industry physical capital stocks are 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

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

In this equation, k_{mt} is the stock of physical capital in state *m*, y_{mjt} is industry *j's* value added in state *m* ($m = 1, \ldots, 51$), Y_{mt} is total value added in state *m*, and K_{jt} is the national physical capital stock in industry *j* ($j = 1,\ldots, 9$). This procedure assumes the capital-to-output ratio within industry *j* (i.e., k_{mjt}/y_{mjt}) is the same across U.S. states, that is, $k_{mjt}/y_{mjt} = K_{mt}/Y_{mt}$.

Estimates of E.U. 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) provides data on E.U.

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[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).

[17] The sectors (BEA code) 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 stocks by industry were taken from U.S. Fixed Assets Tables, available at http://www.bea.doc.gov/bea/dn/faweb

[19] Annual data on state value added available at http://www.bea.doc.gov/bea/regional/spi

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

country physical capital stocks for 1980-2000.[21] These data for 1995 and 2000 are combined with the computed estimates for 1965-1990 to yield data on physical capital stocks at five year intervals between 1965 to 2000, inclusive.[22]

Results

Table 2 reports the OLS and bias corrected estimates of (10) for the share of output, physical capital and human capital for the sample of U.S. states; Table 3 reports OLS and bias corrected estimates for the sample of E.U. countries.[23] Over all results, the adjusted R-squares range from 0.791 to 0.945 indicating a strong relationship between the share and rank of each variable.

For U.S. States, the column labeled "Bias Corrected Slope" in Table 2 reports the estimated slope value corrected for bias expected when OLS is used to estimate (10). Based on this bias corrected slope value, the column labeled "Z-statistic Testing Slope = -1" indicates strong support for the hypotheses that the output and factor shares for U.S. states conform to a rank-share distribution that exhibits Zipf's law; in no instance can we reject (at the 5% level) the hypothesis that the slope coefficient is significantly different from –1. This is strong evidence that, for U.S. States, each of the three share distributions exhibit Zipf's law.

Empirical results for E.U countries are reported in Table 3. As for U.S. States , the column labeled "Bias Corrected Slope" gives the estimated slope value corrected for the bias that arises when we estimate (10) by OLS. Given this, the column labeled "Z-statistic Testing Slope = -1" shows that in no instance can we reject (at 5% level) the hypothesis that the slope coefficient is significantly different from -1. This also strongly supports the hypotheses that

[21] Physical capital database available at http://www.ggdc.net/dseries/growth-accounting.shtml
[22] Estimation was conducted using both sets of data for E.U. countries. No qualitative difference in results was found for the years in which data were available from both sources (i.e., 1980, 1985 and 1990). For these three years we therefore report only the results using the capital stock data from Timmer et al. (2003).
[23] The standard errors associated with the OLS estimates are "robust" in the sense of White (1980).

Table 2. OLS and Bias Corrected Estimates of Rank-Share Relationships for U.S. States

Variable	Year	OLS Intercept [a]	OLS Slope [b]	Bias-corrected Slope [c]	Z-statistic Testing Slope = -1 [d]	OLS Adj. R^2
Output Share (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 Share (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 Share (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] OLS standard errors in parentheses. All intercept coefficients significantly different from zero at 1% level.
[b] OLS standard errors in parentheses. All slope coefficients significantly different from zero at 1% level.
[c] Computed as the OLS slope estimate plus 0.081 (the bias).
[d] Computed as the OLS slope estimate plus 0.081 (the bias) minus –1 divided by the asymptotic approximation of the true standard error (given as minus the OLS slope estimate times 0.198 = $(2/51)^{0.5}$). All slope coefficients are not significantly different from –1 at the 5% level.

Table 3. OLS and Bias Corrected Estimates of Rank-Share Relationships for E.U. Countries

Variable	Year	OLS Intercept [a]	OLS Slope [b]	Bias-corrected Slope [c]	Z-statistic Testing Slope = -1 [d]	OLS Adj. R^2
Output Share (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 Share (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 Share (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] OLS standard errors in parentheses. Significantly different from zero at ** = $p < 0.05$ or * = $p < 0.10$.
[b] OLS standard errors in parentheses. All slope coefficients significantly different from zero at the 1% level.
[c] Computed as the OLS slope estimate plus 0.172 (the bias).
[d] Computed as the OLS slope estimate plus 0.172 (the bias) minus –1 divided by the asymptotic approximation of the true standard error (given as minus the OLS slope estimate times 0.3779 = $(2/14)^{0.5}$). All slope coefficients are not significantly different from –1 at the 5% level.

the output and factor shares for E.U. countries conform to a rank-share distribution that exhibits Zipf's law.

These findings for U.S. states and for E.U. countries are striking empirical results. For comparison, we preformed the same analysis and tests (results not shown) with respect to a grouping of 30 developing countries as well as a "world" of 55 countries and found no evidence to support Zipf's law at the usual levels of significance.

4 Further Characterization of Integrated Economic Areas

The empirical findings of the preceding section support the prediction that the distribution of shares across IEA members will conform to Zipf's law. An important assumption underlying this prediction is the equal-share relationship in (8). In this section, we test the empirical validity of this crucial assumption. In addition, we derive and test the proposition that, when Zipf's law holds, the limiting distribution of output or factor shares across IEA members is determined only by the number of IEA members.

The Equal-Share Relationship

A strong test for the equal-share relationship involves the null hypothesis given by equation (8) against the alternative hypothesis given by (7). Evidence in favor of the equal-share relationship is obtained in two steps. First one tests for homogeneity of the OLS slope estimates (i.e., whether $\beta_y = \beta_k = \beta_h$) to verify that the distributions of shares come from a common power-law distribution. Second, one tests 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 U.S. states and Germany for E.U. countries). Failure to reject the null hypothesis would imply that technological differences and factor market imperfections are not strong enough to prevent the equal-share relationship from holding in a statistical sense.

Table 4 reports *p*-values for testing the hypotheses of slope and intercept homogeneity across the three share distributions in each sample year.[24] For U.S. states we cannot reject the hypotheses of intercept equality and slope equality in either of the two years for which data were available on all three shares (1990 and 2000). This result supports the equal-share relationship for U.S. states. The results for E.U. countries also indicate support for the equal-share relationship. We remark that the slope homogeneity tests use the OLS slope estimates uncorrected for bias. However, correcting for the expected downward bias would only strengthen support for the equal-share relationship found here.

Table 4. Results Testing the Equal-Share Relationship

Region	Year	*p*-values testing coefficient equality across equations	
		Intercept	Slope
U.S. States	1990	0.9680	0.9014
	2000	0.8241	0.5964
E.U. Countries	1965	0.6063	0.0445 [a]
	1970	0.8011	0.2797
	1975	0.8619	0.3655
	1980	0.9689	0.8461
	1985	0.9969	0.9305
	1990	0.8111	0.6034
	1995	0.7124	0.3697
	2000	0.7291	0.4072

[a] Cross-equation homogeneity rejected at 5% level.

[24] 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.

Limiting Distribution of Shares

Let V_{mj} denote the level of variable j for 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:

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

Since the total IEA amount of variable j is then $(1 + \delta_{2j} + \delta_{3j} + \ldots + \delta_{Mj})V_{1j}$, (11) implies the following relations between member ranks and shares:

$$\begin{aligned}
&Rank\ 1: \quad S_{1j} = \frac{1}{1+\delta_{2j}+\delta_{3j}+\ldots+\delta_{Mj}};\\
&Rank\ 2: \quad S_{2j} = \frac{\delta_{2j}}{1+\delta_{2j}+\delta_{3j}+\ldots+\delta_{Mj}};\\
&Rank\ 3: \quad S_{3j} = \frac{\delta_{3j}}{1+\delta_{2j}+\delta_{3j}+\ldots+\delta_{Mj}};\\
&\quad\vdots \qquad\qquad\qquad\qquad \vdots\\
&Rank\ \mathrm{M}: \quad S_{Mj} = \frac{\delta_{Mj}}{1+\delta_{2j}+\delta_{3j}+\ldots+\delta_{Mj}}.
\end{aligned} \tag{12}$$

Expressions (12) indicate that the sequence of shares S_{mj} is a Harmonic series, where each share value S_{mj} depends on the values of the δ's and the number of members M. Accepting our preceding empirical evidence that the distribution of shares exhibits Zipf's law then $\delta_{2j} = 1/2$, $\delta_{3j} = 1/3$, $\delta_{4j} = 1/4$, etc., then the theoretical shares in (12) depend only on the number of IEA members and therefore can be computed once the number of members (M) is specified. For example, the theoretical share values for the M = 51 U.S. states are: 0.2213, 0.1106, 0.0738, 0.0553, …, 0.0043. For the M = 14 E.U. countries the theoretical share values are: 0.3075, 0.1538, 0.1025, 0.0769, …, 0.0220.

To test whether observed shares conform to those theoretically expected using (12), Table 5 reports simple correlations between the natural logarithms of the actual and expected shares for U.S. states and E.U countries in 1990 and 2000. The correlations range from 0.9176 to 0.9619 and all are highly significant, indicating a strong positive relationship between actual and theoretical shares.

Table 5. Correlation between Logarithm of Actual and Theoretical Output and Factor Shares for U.S. States and E.U. Countries, 1990 and 2000

Integrated Economic Area	**Year**	**Correlation between Logarithms of Actual and Theoretical Shares**		
		Output	Physical Capital	Human Capital
U.S. States	1990	0.9429	0.9456	0.9258
	2000	0.9332	0.9393	0.9176
E.U. Countries	1990	0.9392	0.9397	0.9397
	2000	0.9453	0.9548	0.9619

These simple correlations indicate a significant association among shares, but they do not indicate overall conformity of 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 6, convincingly fail to reject the null hypothesis, suggesting that the actual and theoretical shares arise from the same distribution.

Table 6. Two-Sample Kolmogorov-Smirnov Tests between Actual and Theoretical Output and Factor Shares

Integrated Economic Area	Year	Kolmogorov-Smirnov *D*-Statistic between Actual Shares and Theoretical Shares [a]		
		Output	Physical Capital	Human Capital
U.S. States	1990	0.2157**	0.2157**	0.2353**
	2000	0.2353**	0.2745*	0.2157**
E.U. Countries	1990	0.3571**	0.3571**	0.3571**
	2000	0.3571**	0.3571**	0.2143**

** Cannot reject that shares come from a common distribution at 5% level.
[a] Unable to reject that both the actual and theoretical shares come from a common distribution if the *D*-statistic is lower than a critical value; for U.S. states this critical value is 0.3228 at 1% level and 0.2693 at 5% level; for E.U. countries, this critical value is 0.6161 at 1% level and 0.5140 at 5% level.

5 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 among members of a fully integrated economic area in which goods and factors are mobile and member polices are harmonized. These predictions were then empirically tested with respect to the 51 U.S. states and 14 E.U. countries, using data that generally covered the period from 1965 to 2000. In all cases, the data strongly supported the theoretical prediction of an equal-share relationship for each country, and the prediction that the distribution of output and factor shares across countries exhibit's Zipf's law. Moreover, for each bloc, no statistically significant difference was found between the actual distribution of output (and of each factor) and the theoretically predicted long run distribution. Together, these results indicate that E.U. countries and U.S. states can each be regarded as fully integrated economic areas. However, some of the statistical tests based on E.U. data may have lower power due to a lower number of observations.

The results suggest that the extent of economic integration among E.U. member states is greater than commonly believed. They suggest that past E.U. commitments to the freer movement of goods and factors, together with major transformations like the 1992 internal market program and the introduction of the European Monetary Union, have been effective in allocating resources within and between E.U. members. If so, the results also suggest that perceptions of lagging or incomplete E.U. integration may instead reflect that resource allocation within the E.U. is non-optimal from the perspective of world resource allocation (Bowen and Sleuwaegen, 2004) due to policies such as the common agricultural policy.

The empirical significance of the equal-share relationship and of Zipf's law stress that policy harmonization is consistent with the proposition that the relative growth performance of individual IEA members is largely random. Hence, random shocks like innovations, discoveries, weather, or natural disasters, including some that are specific to a particular member, would give rise to different sets of shares and affect the relative position of members. This 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 E.U. policy harmonization imposes on 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 addressing the question of the extent of E.U. economic integration, our analysis has contributed more broadly to the literature on the effects of increased trade and factor mobility that have implications for the characterization of integrated economic areas in general. For example, if the equal-share relationship holds, then all members of an integrated economic area 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, not in per capita terms. The equal-share relationship also addresses Lucas' (1990) question as to why capital does not flow from rich to poor countries. Namely, economies with a low level (and hence low share) of human capital would also be expected to have a low share of physical capital as well as a low output share.

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