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THE LIMITING DISTRIBUTION OF PRODUCTION IN INTEGRATED ECONOMIES: EVIDENCE FROM US STATES AND EU COUNTRIES

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Abstract

We show that in a fully integrated economy, in which there is free mobility of goods and factors, each member's share of total output will equal its shares of total stocks of productive factors (i.e., physical and human capital). We label this result the equal-share relationship. This relationship also holds in the presence of technological differences or costs of factor mobility among members if outputs or inputs are properly measured to reflect such differences or costs. The equal-share relationship is the limiting distribution of output and factors among members of a fully integrated economy, and it constraints the set of policies that can affect each member's relative growth within an integrated economy. We empirically examine for the equal-share relationship for alternative economic groups (i.e., US states, EU countries, Developing Countries and a World comprising 55 countries). Our findings indicate that the equal-share relationship holds strongly for US states, holds weakly for EU countries, but does not hold for Developing Countries or the World.

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The Limiting Distribution of Production in Integrated Economies: Evidence from US States and EU Countries

A surge of regional integration agreements over the past two decades have sought to reduce barriers to the exchange of goods, services and, in the extreme, factors of production among subsets of countries.[1] Examples include the NAFTA (United States, Canada and Mexico), the European Union's "Europe 1992" internal market program, the recent accession of 10 additional countries into the European Union (EU), and ongoing efforts to initiate or renew agreements among a variety of nations (e.g., the Free Trade for the Americas, MERCOSUR and ASEAN free trade agreements). The literature dealing with the economic implications of regional integration has mostly dealt with the effects of reducing barriers to the movement of goods. Less attention has been given to the implications of also allowing greater mobility of productive factors within an integrated economy. This omission from the literature is important not only because cross-border factor flows are becoming increasingly important,[2] but also the international trade literature has long recognized that goods trade and cross-border factor flows can evidence a substitute or complement relationship. Hence, reducing barriers to the movement of productive factors within an integrated area would be expected to affect the final distribution of production across members of an integrated economy.

In this paper we investigate the implications of allowing factor mobility within an integrated economy for the distribution of production across members. Employing factor price equalization as a driving force, we show that factor mobility among

[1] Sachs and Warner (1995) chronicle these liberalization efforts.
[2] The importance of factor mobility in many parts of the world is evidenced by the growing importance in many nations' balance of payments of remittances from abroad (e.g., International Monetary Fund, 2004). Capital flows in the form of foreign direct investment continue to be important among industrialized countries and they are increasingly also being directed toward developing countries.

members of an integrated economy (IE) implies that each member's share of total IE output will equal its shares of the total IE stock of each productive factor (i.e., its shares of total physical and human capital). We term this theoretical prediction the "equal-share" relationship.

An important implication of the equal-share relationship is that it sets a constraint on the long-run relative growth performance of IE members. In particular, since the sum of output shares across IE members equals unity, the long-run expected growth rate of output shares must be zero. Therefore, it is not possible for every member of an IE to sustain a positive rate of growth of its output share in the long-run. Moreover, the constraint imposed by the equal-share relationship implies that in any given time period, the relative growth performance of IE members can be taken to be a random outcome contingent on alternative states of nature. The random behavior of member's relative growth is more true the greater the extent of economic integration among members. For example, it is truer 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.

The implications of our analysis for growth relates to the existing growth literature in several respects. First, our analysis has a direct implication for the question of convergence in national outputs that has been extensively investigated in the growth literature (see e.g. Durlauf and Quah, 1999). Empirically, Evans and Karras (1996) and Evans (1997) find higher speeds of income convergence among US states than for countries. These findings are consistent with the theoretical predictions of Barro *et al.* (1995) who show that an open economy with partial capital mobility has a higher rate of convergence than does a closed economy. Similarly, Rappaport (2005) introduces labor mobility in the neoclassical growth model to show that emigration creates a disincentive for gross capital investment. This disincentive partly offsets the positive contribution of labor mobility to faster income convergence. In our framework, the equal-share relationship implies that IE members will have the same output per efficiency unit of labor. This implication is the essence of the convergence hypothesis investigated by the growth literature, here interpreted in terms of efficiency units of labor and not per capita.

A different view of the processes generating economic converge is contained in the literature that relates financial services and growth. Financial intermediation pools funds and allocates these to those activities expected to produce the highest reward. A more efficient allocation of savings tends to increase rates of growth (Bencivenga and Smith, 1991). Internationally, greater integration of financial markets is expected to both lower the cost of financial capital and to foster a reallocation of capital from capital abundant to capital scarce countries. One effect of such a reallocation of capital resources may be to promote technological progress (e.g., venture capital) that can offset decreasing returns to physical capital and may generate endogenous growth (Greenwood and Jovanovic, 1990). Empirically, Levine (1997) found evidence of a cross-country pattern linking growth and domestic finance. However, Edison *et al*. (2002) and Eschenbach (2004), who also review the more recent literature, find weak evidence of a link between capital mobility and per capita income growth. A key contribution of our analysis is to show that capital market integration, and factor mobility in general, will lead to the emergence of the equal-share relationship that then introduces a constraint on the relative growth performance of members of an integrated area.

Finally, the equal-share relationship also addresses Lucas' (1990) question as to why more capital does not flow from rich to poor countries. Namely, an economy with a low level (and hence a low share) of human capital will also have a low share of physical capital, and also a low share of output.

Given the potential theoretical importance of the equal-share relationship, we examine empirically for its presence for different groupings of economic units (i.e., US states, EU countries, Developing Countries, and the World). Our empirical results, based on panel data spanning the period from 1965 to 2000, indicate that the data fit the theoretical equal-share prediction the higher the degree of factor mobility among a defined set of IE members.

1 Output and Factor Shares in Integrated Economies

We consider an economy (or economic unit) that produces a single good by means of a constant return to scale production function:

(1) $$Y_t = F(K_t, H_t).$$

where Y_t is the level of output, K_t is the level of physical capital stock and H_t is the level of human capital stock, all at time t. To facilitate interpretation we assume the production function takes the Constant Elasticity of Substitution (CES) form:

(2) $$Y_t = g\left\{d K_t^{-r} + (1-d) H_t^{-r}\right\}^{-1/r}$$

where g is an efficiency parameter, d the degree of physical capital usage, and r is a substitution parameter such that the elasticity of substitution between the two inputs is $s = 1/(1+r)$. Given (2), the marginal product of physical capital is:

(3) $$(F_K)_t = gd\left\{d + (1-d)\left(\frac{K_t}{H_t}\right)^{r}\right\}^{-(1+r)/r}$$

Combining (2) and (3) one can write:

(4) $$(F_K)_t = g^{-r} d \left(\frac{Y_t}{K_t}\right)^{1+r}.$$

Similarly, the expression for the marginal product of effective labor (human capital) is:

$$(5) \qquad (F_H)_t = g\,(1-d)\left\{(1-d)+d\left(\frac{K_t}{H_t}\right)^{r}\right\}^{-(1+r)/r}$$

or

$$(6) \qquad (F_H)_t = g^{-r}(1-d)\left(\frac{Y_t}{H_t}\right)^{1+r}.$$

We now introduce a second economy and consider the implications of allowing factor mobility between the two economies. If physical capital and human capital are perfectly mobile between the two economies then we would expect each factor to flow from the low to high rate of return country until each factor's rate of return (marginal product) is equalized between the two economies. However, if there are barriers to factor mobility then rates of return will only be partially equalized.[3] For simplicity, we can represent such barriers by a time-varying proportional wedge in rates of return to physical capital ($l_t(k) > 0$) and rates of return to human capital ($l_t(h) > 0$). Given this, the relation between the rates of return between the two economies can be written:

$$(7) \qquad g^{-r}d\left(\frac{Y_t}{K_t}\right)^{1+r} = l_t(k)(g^*)^{-r^*}d^*\left(\frac{Y_t^*}{K_t^*}\right)^{1+r^*}$$

$$(8) \qquad g^{-r}(1-d)\left(\frac{Y_t}{H_t}\right)^{1+r} = l_t(h)(g^*)^{-r^*}(1-d^*)\left(\frac{Y_t^*}{H_t^*}\right)^{1+r^*}$$

where '*' indicates second economy variables. The ratio of (7) to (8) gives the ratio of human to physical capital:

$$(9) \qquad \frac{H_t}{K_t} = h(l_t)^{1/(1+r)}\left(\frac{H_t^*}{K_t^*}\right)^{q}$$

[3] Barriers to capital mobility can include sovereign and political risk, capital controls, and tax differences that can hinder cross-border investments. Barriers to human capital mobility include government regulations on immigration and work permits, differences in pension systems and languages between countries.

where:

$h = [d^*(1-d)/(1-d^*)d]^{1/(1+r)}$, implying $h = 1$ when $d = d^*$;

$q = (1+r^*)/(1+r)$, implying $q = 1$ when $r = r^*$;

$l_t = l_t(k) / l_t(h)$, implying $l_t = 1$ when $l_t(k) = l_t(h)$.

Using these definitions we can write (7) as:

$$\text{(10)} \qquad \frac{Y_t}{K_t} = nw(l_t(k))^{1/(1+r)} \left(\frac{Y_t^*}{K_t^*} \right)^q$$

where:

$$v = (d^*/d)^{1/(1+r)}$$

$$w = \left[(g^*)^{-r^*} g^r \right]^{1/(1+r)}$$

We are now fully equipped to illustrate the implications of the model for the distribution of output and factors between the two economies. To show the role of human capital, rewrite (8) as:

$$\text{(11)} \qquad \frac{Y_t}{H_t} = \frac{wh}{n} (l_t(h))^{1/(1+r)} \left(\frac{Y_t^*}{H_t^*} \right)^q$$

Traditionally, (11) serves as a basis for productivity calculations and comparisons across countries. However, unlike the existing literature (e.g., Hall and Jones, 1999) where productivity is measured by output per worker, equation (11) expresses (like the endogenous growth literature) productivity in terms of output per effective unit of labor. For the sake of comparison, consider Hall and Jones' (1999) example of the United States and Niger. In 2000, US output per worker was 38 times higher than output per worker in Niger. Using as a measure of human capital the number of persons with at least a secondary education, output per unit of human capital in Niger is instead measured to be 1.3 times higher than in the United States for the same period. This indicates the sensitivity of productivity comparisons to the measurement of human capital.

To obtain a first expression of the equal-share relationship, note that (9) and (10) can be written as follows:

$$\frac{H_t}{K_t} = h(l_t)^{1/(1+r)} \left(\frac{H_t *}{K_t *} \right)^q = \frac{H_t + (H_t *)^q \, h(l_t)^{1/(1+r)}}{K_t + (K_t *)^q}$$

$$\frac{Y_t}{K_t} = nw(l_t(k))^{1/(1+r)} \left(\frac{Y_t *}{K_t *} \right)^q = \frac{Y_t + (Y_t *)^q \, nw(l_t(k))^{1/(1+r)}}{K_t + (K_t *)^q}$$

Combining these two expressions gives:

(12) $$\frac{H_t}{H_t + (H_t *)^q h l_t^{1/(1+r)}} = \frac{Y_t}{Y_t + (Y_t *)^q nw l_t(k)^{1/(1+r)}} = \frac{K_t}{K_t + (K_t *)^q}$$

Equation (12) establishes a link between the first economy's shares of the total output, physical capital, and human capital across the two economies. Differences in technology between the two economies imply only a rescaling of the original variables. A difference between $g*$ and g indicates a neutral difference in technologies that has no effect on the optimal selection of physical capital and human capital, but it does have an effect on the distribution of output through ω in (12). A difference between the substitution elasticities introduces the power q whereas differences between the other parameters lead to a multiple rescaling of variables.

Equation (12) nests several share relationships that relate to different assumptions about technology and factor mobility. If technology is identical between the two economies then (12) simplifies to:

(13) $$\frac{H_t}{H_t + H_t * \, l_t^{1/(1+r)}} = \frac{Y_t}{Y_t + Y_t * \, l_t(k)^{1/(1+r)}} = \frac{K_t}{K_t + K_t *}.$$

In this new form of the equal-share relationship, some variables for the second economy are rescaled by the proportional differences in rates of return. For example, from (13), an absence of barriers to physical capital mobility ($l_t(k) = 1$) implies equal output and physical capital shares that, however, differ from the human capital share. If we assume that both $l_t(k) = 1$ and $l_t(h) = 1$ then the equal-share relationship takes the simple form:

(14) $$\frac{H_t}{H_t + H_t*} = \frac{Y_t}{Y_t + Y_t*} = \frac{K_t}{K_t + K_t*}$$

This states that when there are no barriers to factor mobility and technologies are identical, each economy's shares of total output, total physical capital and total human capital will be identical.

The equal-share relationship (14) has three main implications. First, a reallocation of physical capital between IE economies, that is, $dK_t = -dK_t$, must be accompanied by an increase in output and either an inflow of foreign human capital or an accumulation of domestic human capital to rebalance the equality of world shares. Similarly, a policy that increases a country's share of total IE human capital will raise both the country's share of total IE output and its share of total IE physical capital (via either an inflow of foreign physical capital or accumulation of domestic capital).

Second, our framework can be related to the broad topic of output convergence by noting that if (14) holds then the following two equalities will also hold:

(15) $$\frac{Y_t}{H_t} = \frac{Y_t + Y_t*}{H_t + H_t*}$$

(16) $$\frac{Y_t}{H_t} = \frac{Y_t*}{H_t*}$$

From (16) it is clear that, if the equal-share relationship holds, the two economies will have the same output per efficiency unit of labor. This implication is the essence of the productivity convergence hypothesis (Baumol, 1986), here interpreted in terms of efficiency units of labor and not per capita.

Third, the equal-share relationship (14) can be extended to the case of an integrated economy that comprises $j = 1,...,N$ members. If all members have the same technology, and there is perfect mobility of either physical or human capital among members, then the equalization of factor rates of return implies:

(17) $$\frac{H_{it}}{\sum_{j=1}^{N} H_{jt}} = \frac{Y_{it}}{\sum_{j=1}^{N} Y_{jt}} = \frac{K_{it}}{\sum_{j=1}^{N} K_{it}} \qquad \text{for } i = 1, \ldots, \text{N}$$

This set of equalities express the distribution of output and factors among N members of a fully integrated economy. Like (12), expression (17) can be extended to allow for differences in technology and factor market imperfections among members.

2 Empirics

In this section we examine empirically for the equal-share relationship with respect to alternative economic groups that may or may not meet the condition that they form a fully integrated economy. We consider four groupings: the 51 US states, 14 EU countries, 30 Developing Countries and a World consisting of 55 countries.

Specification

The equal-share relationship (e.g., (12)) implies three bivariate relationships that link member i's shares of total IE output ($\tilde{y}_i$), of total IE physical capital ($\tilde{k}_i$) and of total IE human capital ($\tilde{h}_i$):

(18) $$\tilde{y}_i = \tilde{k}_i$$

(19) $$\tilde{y}_i = \tilde{h}_i$$

(20) $$\tilde{h}_i = \tilde{k}_i$$

Expressions (18) - (20) hold when outputs and factors are adjusted for any barriers to factor mobility or technological differences. However these adjustment factors, and hence the theoretical shares, are not observable. However it can be seen from (12) that these adjustment factors only affect measurement of the denominator of each share. This allows us to transform expressions (18) - (20) into testable propositions involving observed output and factor shares.

Let y_i, k_i and h_i denote member i's observed shares of output, physical capital and human capital. Similarly, let Y_i, K_i and H_i denote the observed *level* of each variable, and continue to let a "~" over a variable denote its (unobserved) value when adjusted for any technological differences or factor mobility costs. Given this, we can, for example, transform (18) as follows:

$$\tilde{y}_i = \tilde{k}_i$$

$$Y_i \Big/ \sum_{j=1}^{N} \tilde{Y}_j = K_i \Big/ \sum_{j=1}^{N} \tilde{K}_j$$

$$Y_j = \left(\sum_{j=1}^{N} \tilde{Y}_j \Big/ \sum_{j=1}^{N} \tilde{K}_j \right) K_i$$

$$Y_i \Big/ \sum_{j=1}^{N} Y_j = \left[\left(\sum_{j=1}^{N} K_j \Big/ \sum_{j=1}^{N} \tilde{K}_j \right) \left(\sum_{j=1}^{N} Y_j \Big/ \sum_{j=1}^{N} \tilde{Y}_j \right) \right] K_i \Big/ \sum_{j=1}^{N} K_j$$

(21) $\quad y_i = b_{yk} k_i$

where $b_{yk} = \left(\sum_{j=1}^{N} K_j \Big/ \sum_{j=1}^{N} \tilde{K}_j \right) \left(\sum_{j=1}^{N} Y_j \Big/ \sum_{j=1}^{N} \tilde{Y}_j \right)$. If there are identical technologies and no barriers to capital mobility then $\sum_{j=1}^{N} \tilde{Y}_j = \sum_{j=1}^{N} Y_j$ and $\sum_{j=1}^{N} K_j = \sum_{j=1}^{N} \tilde{K}_j$ so that $b_{yk} = 1$.[4]

Similar transformations of (19) and (20) yield the following expressions between observed output shares and observed factor shares:

(22) $\quad y_i = b_{yh} h_i$

[4] This would also be true in the singular case where technology differences exactly offset barriers to factor mobility.

(23) $h_i = b_{hk} k_i$.

Again, in (22), b_{yh} = 1 if there are no differences in technology or no barriers to human capital mobility. Treated as a system, equations (21) - (23) imply the restriction b_{hk} = b_{yk} /b_{yh}, so that b_{hk} = 1 when $b_{yk} = b_{yh}$.

We conduct several tests of the equal-share relationship based on equations (21) to (23). The first is a "weak" test that considers pair-wise rankings of the output and factor shares across members of a given integrated economy without regard to the strict equalities among share values as stated in (21) to (23). A second set of tests is based on regression estimates of the coefficients that link the output and factor shares. To conduct this second set of tests it is convenient to express (21) to (23) in the equivalent form:

(24) $\ln(y_i) = q_{yk} + g_{yk} \ln(k_i) + u_{iyk}$

(25) $\ln(y_i) = q_{yh} + g_{yh} \ln(h_i) + u_{iyh}$

(26) $\ln(h_i) = q_{hk} + g_{hk} \ln(k_i) + u_{ihk}$

where $q_{yk} = \ln(b_{yk})$, $q_{yh} = \ln(b_{yh})$ and $q_{hk} = \ln(b_{hk})$. The disturbance term (u) added to each equation is assumed to have the standard properties (i.e., i.i.d., with mean zero and constant variance). However, it is clear (particularly from (24) and (25)) that these disturbances will be contemporaneously correlated.[5] To account for this we obtain parameter estimates using the Seemingly Unrelated Regression (SUR) procedure.

Except for US states, our data on countries' output and factor shares comprise a series of cross-sections at five-year intervals between 1965 and 2000. For US States, the data are only available for 1990 and 2000. Given the time period spanned by the data, we might expect that for some groups (e.g., the EU) the equal-share relationship

[5] One would also expect the disturbances in (24) and (25) to be serially correlated in a panel data setting.

may hold in later periods but not in earlier periods. That is, there may be convergence toward the equal-share relationship over time due to increased integration among the members of a given group. To account for this possibility we estimate the equation system (24) to (26) separately using the cross-section data in each year. Subsequent analysis then examines hypotheses regarding coefficient homogeneity over time in order to assess the extent to which the data can instead be pooled over time.[6]

Given estimates of the parameters in (24) to (26), we conduct tests to examine for evidence of the equal-share relationship in each year. Each test, except one, involves a hypothesis that the intercept term in each equation is significantly different from zero. This follows since if any beta coefficient (b_{ij}) in (21) to (23) equals one (i.e., the equal-share relationship holds) then the corresponding intercept in (24) - (26) equals zero (i.e., if $b_{ij} = 1$ then $q_{ij} = \ln(b_{ij}) = 0$).

We first test the simple hypothesis that the intercept term in a given equation equals zero. Failure to reject this hypothesis would support the equal-share relationship with respect to a particular pair of shares. A second test examines if the intercepts across the three equations are jointly equal to zero in a each year. In addition to these tests for a zero intercepts, we also test if the pseudo slope parameters (g_{ij}) equal unity, both individually for each equation and jointly across the 3 equations, in a each year. Finally, as a check on the integrity of equation system (21) - (23), we test the validity of the cross-equation parameter restriction $b_{hk} = b_{yk} / b_{yh}$.. In terms of system (24) - (26), this involves testing the restriction that $\exp(q_{hk}) = \exp(q_{yk}) / \exp(q_{yh})$ or equivalently, that $q_{hk} = q_{yk} - q_{yh}$. Both forms of this cross-equation restriction are tested.[7]

[6] Hence, we do not impose any *a prior* constraint on the parameter values between time periods, as would be the case if we instead estimated the equation system using the entire panel across years and countries .
[7] We test this restriction using a Wald test. We test both forms of the restriction since equivalent forms of a restriction can give different results when using a Wald test (Greene, 2004).

Data

Here we provide only a brief description of the data used. The Appendix provides a more complete description. For each of the 51 US states, output is measured by real gross state product (GSP). State physical capital stocks are estimated by multiplying estimates of the total US physical capital stock per industry with an industry's contribution to the state's total income and then summing them across industries. State human capital stocks are measured by the number of persons in the state with at least a secondary education. Due to missing data, complete data for US states on all three variables (output, physical and human capital) are available only for 1990 and 2000, when US Decennial Census were conducted. However, output and physical capital data are available for other years. Where appropriate (e.g., when computing rank correlations) we use these additional years of data.

We also consider three other economic groupings: (1) the EU, consisting of 14 EU member countries (Luxembourg is excluded due to lack of data), (2) Developing Countries, consisting of 30 lower income countries and (3) the World, consisting of 55 countries for which the necessary data are available. Output of each country is measured by its real gross domestic product as reported in the Penn World Tables 6.1 (Heston, Summers and Aten, 2002). Country physical capital stocks from 1965 to 1990 are those reported in the Penn World Tables 5.6 (Heston and Summers, 1991a; 1991b).[8] However, data on EU country physical capital stocks for the period 1980 to 2000 are

[8] At the time this paper was written the Penn World Tables Version 6.1 did not report country physical capital stocks.

also available from Timmer, *et al.* (2003).[9] We combined these two data sources in order to obtain a capital stock series for EU countries covering 1965 to 2000.[10]

Country human capital stocks are measured as the number of persons with at least a secondary education, as reported in Barro and Lee (1993, 1996, and 2000). Since data on rates of educational attainment are only available every 5 years, the data sample was limited to five-year intervals from 1960 to 2000. Following this constraint, data on output and physical capital stocks are also restricted to the five-year intervals.

Results

Tables 1 and 2 report Spearman rank correlation coefficients between pairings of the output and factor shares for each of the four groups representing alternative integrated economies. These correlations offer a first indication of any tendency for output and factor shares to be related. All rank correlations are positive and highly significant for US states (Table 1) and the three other economic groupings (Table 2). These results offer strong evidence in favor of the "weak" form of the equal-share relationship: that there will be conformity between (pair-wise) rankings of the output and factor shares across members of a given IE.

[Insert Tables 1 and 2 about here]

Tables 3 to 6 report SUR estimates of the three-equation system (24) - (26) for each group in each sample year, and for the data pooled over all years. The results for US states (Table 3) indicate a high degree of fit between output and factor shares: the minimum value of the adjusted R-square over all equations is 0.946. The results further indicate strong support for the equal-share relationship in each year and for the pooled

[9] The series forms the source of the OECD productivity database. See e.g., Schreyer *et al.* (2003)

[10] We performed estimation using both sets of data for EU countries and found no qualitative difference in results when data are available from both sources (1980, 1985 and 1990). We will therefore report only the results using capital stock data from Timmer *et al.* (2003) during these three years.

sample.[11] Specifically, we cannot reject the hypothesis that the intercepts are different from zero, whether this hypothesis is tested individually for each equation, or when tested jointly across the three equations, in each year. We also cannot reject the equal-share hypothesis when using the pooled sample. In addition, in no case can we reject the cross-equation coefficient restriction. This indicates the overall integrity of the equation system relating output and factor shares. These results indicate strong support for the equal-share hypothesis among US states.

[Insert Tables 3 to 6 about here]

For the EU, the yearly cross-section results in Table 4 suggest that the equal-share relationship cannot be rejected, whether by testing that the intercepts are zero in each equation in each year, or testing that the intercepts are jointly equal to zero across the three equations in a given year. However, as indicated in the last part of Table 3, when the equations are estimated using the data pooled over all sample years, or pooled for subsets of the sample years, the equal-share relationship is rejected.[12] The different conclusion from the annual versus the pooled sample results likely reflects the small sample size (14 observations) of each cross-section.[13] While the equal-share relationship for EU countries is rejected in terms of the joint test that the intercepts are zero, the cross-equation coefficient restriction $\exp(q_{hk}) = \exp(q_{yk}) / \exp(q_{yh})$ is not rejected, again indicating the overall integrity of the equation system relating output and factor shares. We conclude that technological differences or barriers to factor mobility

[11] For each equation we could not reject the hypotheses of homogeneity of the intercepts and of the slopes across years. This means it is legitimate to estimate the three-equation system using the data pooled over time.

[12] As for the US, for each equation we could not reject the hypotheses of homogeneity of the intercepts and of the slopes across years. Hence, it is legitimate to estimate the three-equation system using the data pooled over time.

[13] To examine this, we estimated the equation system using data pooled across different subsets of years. Even for the minimal case of combining two years of data, a pooled sample of 28 observations, was sufficient to reject the equal-share relationship.

remain important obstacles preventing EU countries from comprising, unlike US states, a fully integrated economy. Notable is that the equal-share relationship is rejected for EU countries even in 2000, a period following more than a decade of EU reforms (that included implementation of complete labor mobility) intended to further integrate EU countries.

Finally, the results for Developing Countries (Table 5) and the World (Table 6) indicate no support for the equal-share relationship. For each group, the hypothesis that the intercepts equal zero is strongly rejected, for both the individual cross-sections and pooled samples,[14] whether the hypothesis is tested individually for each equation or tested jointly across the set of equations. However, in almost all cases the cross-equation coefficient restriction cannot be rejected, again indicating support for the basic structure of the equal-share equations. These results cast doubt on the importance of factors such as increasing flows of capital across countries (i.e., greater capital market integration) for creating convergence toward the equal-share relationship for these groups of countries. Instead, the results suggest that there remain significant barriers to technology transfer, factor flows, and goods flows between developing countries as well as in the world as a whole.

3 Discussion

This paper considers the implications for the distribution of output and factors among members of an integrated economy in which there is free exchange of goods and factors, and where members share the same production technology. In this setting, we derived a theoretical result we call the equal-share relationship. This relationship states

[14] For both groups, we could not reject for each equation the hypotheses of homogeneity of the intercepts and of the slopes across years. This means it is legitimate to estimate the three-equation system using the data pooled over time.

that each member's share of total IE output will equal its shares of total IE stocks of productive factors. The equal-share relationship was also shown to hold in the presence of technological differences or costs of factor mobility among IE members if outputs and inputs are properly measured to reflect such differences or costs.

Our empirical analysis examined for the existence of the equal-share relationship among alternative economic groupings: US states, EU countries, Developing Countries and a World comprising 55 countries. Strong evidence for a weak form of the equal-share relationship involving a link between rankings of output and factor shares was found for each of the four groups representing alternative integrated economies. When strong forms of the equal-share relationship were instead examined, the results indicated that the integrated economy of US states exhibits full conformity with the predicted equal-share relationship. US states therefore represent a benchmark that can be used to understand the implications of full economic integration.

The empirical findings give only mixed support for the equal-share relationship among EU countries, and they strongly reject this relationship among Developing Countries and the World. The findings for Developing Countries and the World are perhaps not surprising and, in this sense, the findings serve as a check on the robustness of the empirical methods used to examine for the validity of equal-share relationship. The finding that EU countries do not yet appear to form a fully integrated economy suggests that efforts to more completely integrate EU member states have, as least for the time periods studied, failed to achieve the desired level of integration.

Though the equal-share relationship is a static characterization of integrated economy, it raises questions of a dynamic nature. One implication of the equal-share relationship is that the underlying growth mechanism of members of a fully integrated economy can differ markedly from those assumed by the existing growth literature.

Specifically, it puts a constraint on the set of policies that can affect the economic position of a member relative to other IE members. The more harmonized are the economic policies of IE members the more likely is the relative growth experience of any one member to be a random outcome contingent on particular states of nature. Also, successful investment and education policies by an IE member may not increase its relative position if these policies are rapidly duplicated by other members. Hence, only independent and non-imitated investment and education policies undertaken by one member can increase the returns to that member's local productive factors which can then provide the incentive to accumulate and/or generate inflows of productive factors.

The empirical relevance of the equal-share relationship stresses the importance of foreign direct investment since it increases the host member's share of physical capital and its return to human capital. Also, a country whose funding level of education is relatively high may experience an increase in its share of human capital. Since this rising of human capital share increases the return to physical capital, the resulting inflow of external (foreign and/or from another IE member) physical capital and accumulation of local physical capital can increase the active member's share of output.[15] Of course, much depends on the institutional arrangements that characterize the policy space of IE members. It is hoped that the analysis presented here offers a convenient framework within which further research on such issues can be conducted.

[15] These predictions assume the integrated economy is "closed", so that there are no flows of goods or resources between integrated economy members and economies that are not members of the given integrated economy. These predictions would therefore certainly apply to the integrated economy comprised of all economies (i.e., the World).

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Appendix – Data Methods and Sources

The output for each of the 51 US states is measured by real gross state product as reported by the US Bureau of Economic Analysis (BEA).[16] These data were available yearly from 1990 to 2000.

Estimates of state physical capital stocks were derived from BEA (2002) estimates of the total US physical capital stock in each of nine one-digit industrial sectors comprising all economic activity.[17] These national physical capital stocks in each industry were allocated to each state by multiplying an industry's total capital stock[18] by that industry's contribution to a state's total income.[19] These industry capital stock estimates were then summed, for each state, to obtain an estimate of a state's total stock of physical capital.[20] The calculation performed for each state at each time t can be expressed algebraically as

$$k_i(t) = \sum_{j=1}^{9}\left[K_j(t)\left(y_{ij}(t)/Y_i(t)\right)\right]$$

In this equation, $k_i(t)$ is the stock of physical capital in state i, $y_{ij}(t)$ is value added by industry j in state i (i = 1…51), $Y_i(t)$ is state i's total value added, and $K_j(t)$ is the national level stock of physical capital in industry j (j = 1,…, 9). This procedure assumes that the capital-to-output ratio within an industry j (i.e., $k_{ij}(t) / y_{ij}(t)$) is the same across US states, that is, $k_{ij}(t) / y_{ij}(t) = K_i(t) / Y_i(t)$. In turn, this assumption implies that an industry is in a common steady state across all US states.[21] For example, the

[16] Data on gross state product are available at http://www.bea.doc.gov/bea/regional/gsp
[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 US Fixed Assets Tables, available at http://www.bea.doc.gov/bea/dn/faweb.
[19] Data on annual state personal income are available at http://www.bea.doc.gov/bea/regional/spi.
[20] This procedure follows that used by Munnell (1990) and Garofalo and Yamarik (2002).
[21] If a sector is converging towards its steady state, the output-to-capital ratio would be below its steady-state value. This only poses a problem if the initial output-to-capital ratios vary across US states. If the

agricultural sector in Texas is in the same steady state as its counterpart in Oregon, and the manufacturing sector in Pennsylvania is in the same steady state as its counterpart in Ohio.[22] The constructed physical capital data are from 1990 to 2000, on a yearly basis.

State human capital stocks were derived from data on educational attainment in each state taken from the US Bureau of the Census.[23] Since census data on educational attainment are only available every 10 years, this limits the data on stocks of human capital to the two years 1990 and 2000.

For the countries comprising the EU, Developing Countries and World integrated economic areas, total output is measured by a country's real gross domestic product (GDP) derived from the data on real GDP per capita (base year = 1996) and population in Penn World Tables 6.1 (Heston, Summers and Aten, 2002).[24] The data on output were obtained from 1960 to 2000.

Data on physical capital stocks were derived from Penn World Tables 5.6 (Heston and Summers, 1991a; 1991b) which reports four data series for each country: (1) population, (2) physical capital stock per worker, (3) real GDP per capita and (4) real GDP per worker.[25] The physical capital stocks for each country were constructed as the product of the first three series divided by the last series. These data cover the period 1965-1990. The series for each EU country was updated to 2000 using data from Timmer *et al.* (2003).[26]

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ratios do vary, the procedure would allocate too much to those states further from steady-state and too little to those states closer to their steady state.

[22] If a sector has a different steady state, and hence a different capital-to-output ratio, the procedure will allocate too much to states with lower ratios and too little to states with higher ratios. However, this possibility is unlikely if competition lead firms in all states to adopt the best available production technology.

[23] Decennial Census Dataset are available at http://factfinder.census.gov

[24] Penn World Tables 6.1 is available at http://datacentre2.chass.utoronto.ca/pwt

[25] Penn World Tables 5.6 is available at http://datacentre2.chass.utoronto.ca/pwt56

[26] This physical capital database is available at http://www.ggdc.net/dseries/growth-accounting.shtml

Each country's stock of human capital stock was measured by multiplying the percentage of a country's population having at least a secondary level of education with the country's total population. Data on the rate of educational attainment for each country were taken from Barro and Lee (1993, 1996, and 2000).[27] Data on a country's population were from Heston, Summers and Aten (2002). Since the data on rates of educational attainment were only available every 5 years, the data sample is limited to five-year intervals from 1960 to 2000. Following this constraint, the output and physical capital stocks were also obtained in five-year intervals.

The countries comprising the World integrated economic area are: Argentina, Australia, Austria, Belgium, Bolivia, Botswana, Canada, Chile, Colombia, Denmark, Dominican Republic, Ecuador, Finland, France, Germany, Greece, Guatemala, Honduras, Hong Kong, Iceland, India, Iran, Ireland, Israel, Italy, Jamaica, Japan, Kenya, Republic of Korea, Malawi, Mauritius, Mexico, Netherlands, New Zealand, Norway, Panama, Paraguay, Peru, Philippines, Portugal, Sierra Leone, Spain, Sri Lanka, Swaziland, Sweden, Switzerland, Syria, Taiwan, Thailand, Turkey, United Kingdom, United States, Venezuela, Zambia and Zimbabwe.

The 14 EU countries are: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden and United Kingdom.[28] The set of 30 Developing Countries comprises: Argentina, Bolivia, Botswana, Chile, Colombia, Dominican Republic, Ecuador, Guatemala, Honduras, Hong Kong, India, Iran, Israel, Jamaica, Kenya, Malawi, Mauritius, Panama, Paraguay, Peru, Philippines, Sierra Leone, Sri Lanka, Swaziland, Syria, Taiwan, Thailand, Venezuela, Zambia and Zimbabwe.

[27] Others studies that have used 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).
[28] Luxembourg is excluded for lack of data on human capital. Given the small scale of its economy relative to other EU countries, this omission is unlikely to affect the results for EU countries.

Table 1 - Spearman rank correlations between output (*y*), physical capital (*k*) and human capital (*h*) shares across US states

Year	Spearman Rank Correlation Between*		
	y & k	**y & h**	**k & h**
1990	0.987	0.977	0.980
1991	0.988		
1992	0.988		
1993	0.988		
1994	0.989		
1995	0.991		
1996	0.993		
1997	0.994		
1998	0.994		
1999	0.993		
2000	0.992	0.981	0.978

Notes: y = output share; k = physical capital share; h = human capital share;
[*] 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).

Table 2 - Spearman rank correlations between shares of output (*y*), physical capital (*k*) and human capital (*h*) across EU countries, Developing Countries and World

Year	European Union*			Developing Countries**			The World***		
	y & k	y & h	k & h	y & k	y & h	k & h	y & k	y & h	k & h
1960		0.688			0.828			0.824	
1965	0.934	0.754	0.640	0.944	0.853	0.837	0.964	0.864	0.842
1970	0.912	0.881	0.789	0.955	0.831	0.826	0.966	0.914	0.904
1975	0.921	0.820	0.763	0.952	0.850	0.857	0.972	0.898	0.898
1980	0.921	0.943	0.903	0.944	0.893	0.881	0.973	0.929	0.922
1985	0.952	0.947	0.960	0.940	0.882	0.875	0.974	0.947	0.938
1990	0.956	0.776	0.829	0.951	0.895	0.888	0.975	0.937	0.930
1995	0.960	0.851	0.837		0.860			0.923	
2000	0.956	0.820	0.881		0.857			0.920	

Notes: y = output share; k = physical capital share; h = human capital share;
* n = 14 in each year; coefficients whose absolute value exceeds 0.626 are significantly different from zero at the 1% level
** n = 30 in each year; coefficients whose absolute value exceeds 0.425 are significantly different from zero at the 1% level
*** n = 55 in each year; coefficients whose absolute value exceeds 0.314 are significantly different from zero at the 1% level.

Table 3 - SUR Estimates of Output and Factor Share Equations for US States

Year (obs)	Equation (i on j)	Intercept (q_{ij})	Slope (g_{ij})	Adj. R^2	Joint Hypothesis *p*-value: Intercepts = 0	Joint Hypothesis *p*-value: Slopes = 1	Joint Hypothesis *p*-value: Across Equation Restriction§
1990 (n = 51)	y on k	-0.053 (0.092)	0.989 (0.020)	0.974	0.9368	0.9539	0.9517
	y on h	-0.045 (0.092)	1.000 (0.019)	0.946			
	h on k	-0.010 (0.102)	0.989 (0.022)	0.961			
2000 (n = 51)	y on k	-0.128 (0.076)	0.963 (0.016)$^{+}$	0.985	0.2868	0.0344	0.9065
	y on h	0.052 (0.089)	1.025 (0.019)	0.957			
	h on k	-0.178 (0.101)	0.939 (0.021)$^{++}$	0.956			
1990 & 2000 (n = 102)	y on k	-0.097 (0.062)	0.975 (0.013)	0.979	0.4259	0.1095	0.9842
	y on h	0.003 (0.064)	1.012 (0.014)	0.952			
	h on k	-0.101 (0.073)	0.963 (0.016)$^{+}$	0.957			

Notes: y = output share; k = physical capital share; h = human capital share; standard error in parentheses;
$^{+}$ reject hypothesis that coefficient is unity at 5% level; $^{++}$ reject hypothesis that coefficient is unity at 1% level.
§ Test of across equation restriction $\exp(q_{hk}) = \exp(q_{yk})/\exp(q_{yh})$.

Table 4 - SUR Estimates of Output and Factor Share Equations for EU Countries

Year (obs)	Equation (i on j)	Intercept (q_{ij})	Slope (g_{ij})	Adj. R^2	Joint Hypothesis *p*-value		
					Intercepts = 0	Slopes = 1	Across Equation Restriction§
	y on k	-0.279 (0.200)	0.899 (0.057)	0.941			
1965 (n =14)	y on h	-0.670 (0.464)	0.688 (0.110)$^{+}$	0.421	0.3411	0.0231	0.6813
	h on k	0.177 (0.681)	1.188 (0.189)	0.454			
	y on k	-0.218 (0.185)	0.915 (0.053)	0.949			
1970 (n =14)	y on h	-0.395 (0.363)	0.814 (0.093)	0.647	0.5701	0.1533	0.8552
	h on k	0.126 (0.444)	1.096 (0.123)	0.689			
	y on k	-0.277 (0.173)	0.879 (0.048)$^{+}$	0.945			
1975 (n =14)	y on h	-0.257 (0.382)	0.872 (0.102)	0.636	0.4113	0.0841	0.7998
	h on k	-0.082 (0.353)	0.990 (0.097)	0.754			
	y on k	-0.288 (0.277)	0.921 (0.082)	0.885			
1980 (n =14)	y on h	-0.130 (0.181)	0.940 (0.047)	0.875	0.7161	0.5346	0.8071
	h on k	-0.177 (0.317)	0.977 (0.093)	0.831			
	y on k	-0.206 (0.212)	0.942 (0.063)	0.926			
1985 (n =14)	y on h	-0.044 (0.187)	0.962 (0.049)	0.882	0.8111	0.7684	0.8596
	h on k	-0.174 (0.238)	0.978 (0.070)	0.896			
	y on k	-0.324 (0.186)	0.891 (0.053)	0.929			
1990 (n =14)	y on h	0.083 (0.280)	1.048 (0.081)	0.802	0.1102	0.0242	0.9146
	h on k	-0.396 (0.197)	0.848 (0.056)$^{+}$	0.896			
	y on k	-0.358 (0.213)	0.871 (0.061)	0.919			
1995 (n=14)	y on h	0.073 (0.320)	1.053 (0.093)	0.751	0.2601	0.0648	0.9946
	h on k	-0.433 (0.266)	0.820 (0.075)$^{+}$	0.806			
	y on k	-0.403 (0.173)*	0.848 (0.050)$^{++}$	0.942			
2000 (n=14)	y on h	-0.012 (0.326)	1.014 (0.097)	0.732	0.0851	0.0087	0.8936
	h on k	-0.414 (0.267)	0.828 (0.075)$^{+}$	0.794			
	y on k	-0.312 (0.076)**	0.890 (0.022)$^{++}$	0.932			
1965-00 (n = 112)	y on h	-0.303 (0.126)**	0.876 (0.034)$^{++}$	0.683	0.0003	0.0000	0.3901
	h on k	-0.084 (0.140)	0.993 (0.040)	0.720			
	y on k	-0.323 (0.100)**	0.892 (0.029)$^{++}$	0.922			
1980-00 (n = 70)	y on h	-0.027 (0.117)	0.996 (0.033)	0.818	0.0102	0.0020	0.7436
	h on k	-0.313 (0.123)*	0.891 (0.035)$^{++}$	0.837			
	y on k	-0.364 (0.112)**	0.869 (0.032)$^{++}$	0.932			
1990-00 (n = 42)	y on h	0.048 (0.178)	1.038 (0.052)	0.775	0.0019	0.0000	0.9707
	h on k	-0.415 (0.142)**	0.832 (0.040)$^{++}$	0.841			

Notes: y = output share; k = physical capital share; h = human capital share; standard error in parentheses;
* reject hypothesis that coefficient is zero at 5% level; ** reject hypothesis that coefficient is zero at 1% level;
$^{+}$ reject hypothesis that coefficient is unity at 5% level; $^{++}$ reject hypothesis that coefficient is unity at 1% level.
§ Test of across equation restriction $\exp(q_{hk}) = \exp(q_{yk})/\exp(q_{yh})$.

Table 5 - SUR Estimates of Output and Factor Share Equations for Developing Countries

Year (obs)	Equation (i on j)	Intercept (q_{ij})	Slope (g_{ij})	Adj. R^2	Joint Hypothesis *p*-value		
					Intercepts = 0	Slopes = 1	Across Equation Restriction§
1965 (n = 30)	y on k	-1.634 (0.305)**	0.620 (0.060)$^{++}$	0.778	0.0000	0.0000	0.1523
	y on h	-1.242 (0.252)**	0.707 (0.045)$^{++}$	0.709			
	h on k	-0.680 (0.503)	0.849 (0.097)	0.575			
1970 (n = 30)	y on k	-1.459 (0.308)**	0.670 (0.061)$^{++}$	0.800	0.0000	0.0000	0.3519
	y on h	-1.625 (0.326)**	0.609 (0.057)$^{++}$	0.551			
	h on k	-0.181 (0.690)	1.003 (0.135)	0.419			
1975 (n = 30)	y on k	-1.287 (0.285)**	0.696 (0.058)$^{++}$	0.825	0.0000	0.0000	0.2845
	y on h	-1.022 (0.271)**	0.729 (0.049)$^{++}$	0.700			
	h on k	-0.499 (0.487)	0.926 (0.097)	0.602			
1980 (n = 30)	y on k	-1.155 (0.270)**	0.715 (0.055)$^{++}$	0.846	0.0000	0.0000	0.3019
	y on h	-0.929 (0.226)**	0.678 (0.037)$^{++}$	0.778			
	h on k	-0.419 (0.486)	1.036 (0.097)	0.671			
1985 (n = 30)	y on k	-1.179 (0.250)**	0.707 (0.050)$^{++}$	0.865	0.0000	0.0000	0.1510
	y on h	-0.669 (0.246)*	0.751 (0.043)$^{++}$	0.771			
	h on k	-0.754 (0.418)	0.925 (0.082)	0.690			
1990 (n = 30)	y on k	-1.217 (0.248)**	0.696 (0.049)$^{++}$	0.863	0.0000	0.0000	0.0815
	y on h	-0.557 (0.212)*	0.792 (0.037)$^{++}$	0.818			
	h on k	-0.867 (0.356)*	0.872 (0.069)	0.764			
1965-90 (n = 180)	y on k	-1.337 (0.115)**	0.681 (0.023)$^{++}$	0.832	0.0000	0.0000	0.0045
	y on h	-1.065 (0.111)**	0.700 (0.019)$^{++}$	0.705			
	h on k	-0.536 (0.207)*	0.941 (0.041)	0.606			

Notes: y = output share; k = physical capital share; h = human capital share; standard error in parentheses;
* reject hypothesis that coefficient is zero at 5% level; ** reject hypothesis that coefficient is zero at 1% level;
$^{+}$ reject hypothesis that coefficient is unity at 5% level; $^{++}$ reject hypothesis that coefficient is unity at 1% level.
§ Test of across equation restriction $\exp(q_{hk}) = \exp(q_{yk})/\exp(q_{yh})$.

Table 6 - SUR Estimates of Output and Factor Share Equations for the World

Year (obs)	Equation (i on j)	Intercept (q_{ij})	Slope (g_{ij})	Adj. R^2	Joint Hypothesis *p*-value: Intercepts = 0	Joint Hypothesis *p*-value: Slopes = 1	Joint Hypothesis *p*-value: Across Equation Restriction§
1965 (n = 55)	y on k	-1.171 (0.225)**	0.764 (0.037)++	0.885	0.0000	0.0000	0.2113
	y on h	-0.768 (0.220)**	0.798 (0.032)++	0.793			
	h on k	-0.582 (0.360)	0.944 (0.058)	0.724			
1970 (n = 55)	y on k	-0.951 (0.213)**	0.803 (0.035)++	0.904	0.0000	0.0000	0.5095
	y on h	-0.842 (0.210)**	0.806 (0.031)++	0.808			
	h on k	-0.200 (0.346)	0.986 (0.055)	0.754			
1975 (n = 55)	y on k	-0.905 (0.192)**	0.802 (0.032)++	0.918	0.0000	0.0000	0.4184
	y on h	-0.607 (0.211)**	0.861 (0.033)++	0.815			
	h on k	-0.397 (0.299)	0.923 (0.048)	0.780			
1980 (n = 55)	y on k	-0.879 (0.184)**	0.811 (0.031)++	0.925	0.0000	0.0000	0.4041
	y on h	-0.652 (0.182)**	0.818 (0.027)++	0.852			
	h on k	-0.314 (0.294)	0.985 (0.048)	0.809			
1985 (n = 55)	y on k	-0.909 (0.175)**	0.805 (0.029)++	0.931	0.0000	0.0000	0.3366
	y on h	-0.444 (0.181)*	0.887 (0.028)++	0.863			
	h on k	-0.552 (0.257)*	0.903 (0.042)+	0.826			
1990 (n = 55)	y on k	-0.966 (0.176)**	0.790 (0.029)++	0.927	0.0000	0.0000	0.3929
	y on h	-0.471 (0.168)**	0.916 (0.027)++	0.873			
	h on k	-0.559 (0.231)*	0.859 (0.037)++	0.852			
1965-90 (n = 330)	y on k	-0.965 (0.080)**	0.796 (0.013)++	0.915	0.0000	0.0000	0.0279
	y on h	-0.665 (0.083)**	0.840 (0.013)++	0.792			
	h on k	-0.406 (0.125)**	0.938 (0.020)++	0.742			

Notes: y = output share; k = physical capital share; h = human capital share; standard error in parentheses;
** reject hypothesis that coefficient is zero at 5% level;** reject hypothesis that coefficient is zero at 1% level;
+ reject hypothesis that coefficient is unity at 5% level; ++ reject hypothesis that coefficient is unity at 1% level.
§ Test of across equation restriction $\exp(q_{hk}) = \exp(q_{yk})/\exp(q_{yh})$.