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Does lumpiness matter in an open economy? Studying international economics with regional data

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Abstract

This paper addresses the empirical question whether the regional distribution of production factors within countries is ever so uneven that it triggers specialization of production that makes regions produce different sets of goods at different factor prices. Due to the different welfare effects of trade policy in a country with regional specialization, this is an important question. In addition, it is a question about the legitimacy of treating a country as a relatively homogenous unit. In answering these questions, I implement the concept of "lumpiness" as introduced by Courant and Deardorff [J. Polit. Econ. 100 (1992) 198]. I find that lumpiness or an uneven regional distribution of production factors that induces intranational specialization and different regional factor prices is not an issue for Japan, the United Kingdom and maybe not even for India.

Keywords: Heckscher–Ohlin; Multicone production; Factor price equalization; Regional integration; Economic geography

JEL classification: F11; F15; R12

In recent years, economists have rediscovered economic geography. Due to this renewed interest, economic interactions of regions have increasingly been integrated in fields other than regional economics. The latter has been fertile for international economics. As advocated by Krugman (1991), regions in a country have become testing grounds for international trade theories. The focus on regions has challenged what is often a basic presumption of international economics: that a country is a fairly homogeneous,

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undifferentiated unit. It has also challenged the distinction between regional and international economics.

The challenge that I investigate does not come from the "new" geography that is associated with the work of Krugman and others, but rather from the standard perfect competition analysis.[1] In a Heckscher–Ohlin model (HO), international trade is determined by countries' factor endowments: capital-abundant countries export capital-intensive products and labor-abundant countries export labor-intensive goods. Since countries are integrated economies, their regional distribution of production is by assumption irrelevant for their trade pattern. Courant and Deardorff (1992) challenge this view. They study how uneven regional distributions of endowments can be an independent cause for international trade, making regions the preferred unit of analysis in international economics and a country's international trade "a particular aggregation of interregional (...) trade". In their model, very different regional endowments induce specialization between the existing regions; regions produce different goods and their factors are paid different rewards. Moreover, a national trade policy can have different welfare effects across regions and it may impact on factor returns in ways different from the standard predictions of Stolper and Samuelson at the national level (see Melvin, 1985 for a discussion). Courant and Deardorff call a country that is characterized by such an uneven distribution of resources a lumpy country.[2]

I investigate for Japan, the United Kingdom and India whether the distribution of economic activity/resources across their regions is so uneven that it induces specialization and unequal factor prices. I take the agglomeration of resources as given and wonder what it implies for production (and hence trade). We know from empirical studies that there are wage differences within a country.[3] These wage differences are, however, not prima facie evidence of intranational specialization. In particular, since there are many explanations for regional differences, I investigate whether specialization induced by lumpiness is one of them. My findings support the notion that intranational production factors do not vary enough to induce specialization across regions and to trigger different factor prices. I argue that specialization due to lumpiness is not a regional phenomenon and specialization

[1] Krugman and Venables (1995) best summarize the alternative perspective of "new" geography in a programmatic article. They explain agglomeration of economic activity with increasing returns and transportation costs and "talk about international trade without mentioning countries." All trade flows between any two points in space matter, not just those crossing arbitrary lines, called borders. International trade is a special case of regional trade.

[2] Whether differences in *country* endowments generate specialization across countries is a central question in international economics. Leamer (1996) raised the issue in the trade and wages debate since the effect of trade (changing prices) on wages critically depends on whether countries produce the same goods or not. Schott (2003) applying Leamer (1987) and Debaere and Demiroglu (2003) implementing Deardorff (1994) provide evidence that it is impossible that all countries produce the same goods at the same factor prices. (Country endowments do not lie in one diversification cone.) This is corroborated by Evenett and Keller (2002). Note also that the idea of international specialization of production (and non-FPE) was implicitly present in Ohlin's writings from the very beginning onwards (see Flam et al., 2002) The present paper goes one step further and asks whether *regional* endowment differences induce specialization in an open economy.

[3] See Hanson (2000) for a survey of the literature on the regional variation in wages. See Machin (1996) for regional wage inequality in the United Kingdom.

because of endowment differences occurs primarily at the international level where more substantial factor endowment differences between countries exist.

My analysis builds on studies that illustrate how theories with perfect competition and endowment-driven trade still have a role to play next to economic geography. Moroney and Walker (1966) provide an early test of HO across the regions of the United States. In more recent years, Davis et al. (1997) predict Japanese regional production in a Heckscher–Ohlin–Vanek (HOV) setting, a higher-dimensional version of the HO model. Hanson and Slaughter (1999) study the sectoral reallocation across US states in a HOV framework. In addition, Smith (1997) and Kim (1995, 1999) compare the explanatory power of HO with other reasons for agglomeration such as internal and external scale economies. Fairly strong empirical support for the HO (V) model is found in all cases.

1. A criterion for 'lumpiness'

Consider a model with perfect competition, many goods, many countries and many regions per country. There are two factors, labor, L, and land, T, which are not mobile between countries or regions. Within a region, there is labor mobility between the land- and the labor-intensive sector. In addition, the constant-return-to-scale technology and the prices that consumers and producers face are the same everywhere. Countries and regions are open economies that can freely trade without transportation costs. Assume for now that trade equalizes factor returns in the entire world. Trade thus replicates the integrated world economy (IWE)—a hypothetical world in which all factors are perfectly mobile. There is full employment. Fig. 1 illustrates a critical criterion for lumpiness.

The size of the box is determined by one country's land and labor supply. The two solid vectors $\boldsymbol{z}$ represent the factor inputs that satisfy the factor demands *at the world level* in sectors 1, the most capital-intensive sector in the world, and 3, the least capital-intensive sector. For simplicity, I assume there are only two regions in the country that I study. V characterizes the endowments of the two regions. (V's coordinates are measured from o for one region and from o' for the other.) As the dashed lines indicate, one can easily employ the regions' resources in sectors 1 and 3.[4] (Measured from o, the coordinates of a and b indicate the land and labor used in sectors 1 and 3 of one region; measured from o', the coordinates of c and d indicate the same for the other region.) Therefore, regional endowments do not induce specialization within the solid parallelogram; outside that area, they do.

In the empirical implementation I rely on the "lens condition" that is slightly stricter than Fig. 1a and that has been studied by Deardorff (1994) and Debaere and Demiroglu (2003). Fig. 1b depicts the lens condition for our particular country that is part of a world that replicates the IWE. For two production factors, the condition states that regions have equal factor prices and produce the same goods *if and only if* the regional endowment lens (in

[4] As one chooses the country small enough, one can rule out the case in which no such combination of the two sectors with the most extreme factor intensities exists because the country contains more resources than the factor use of the two sectors combined.

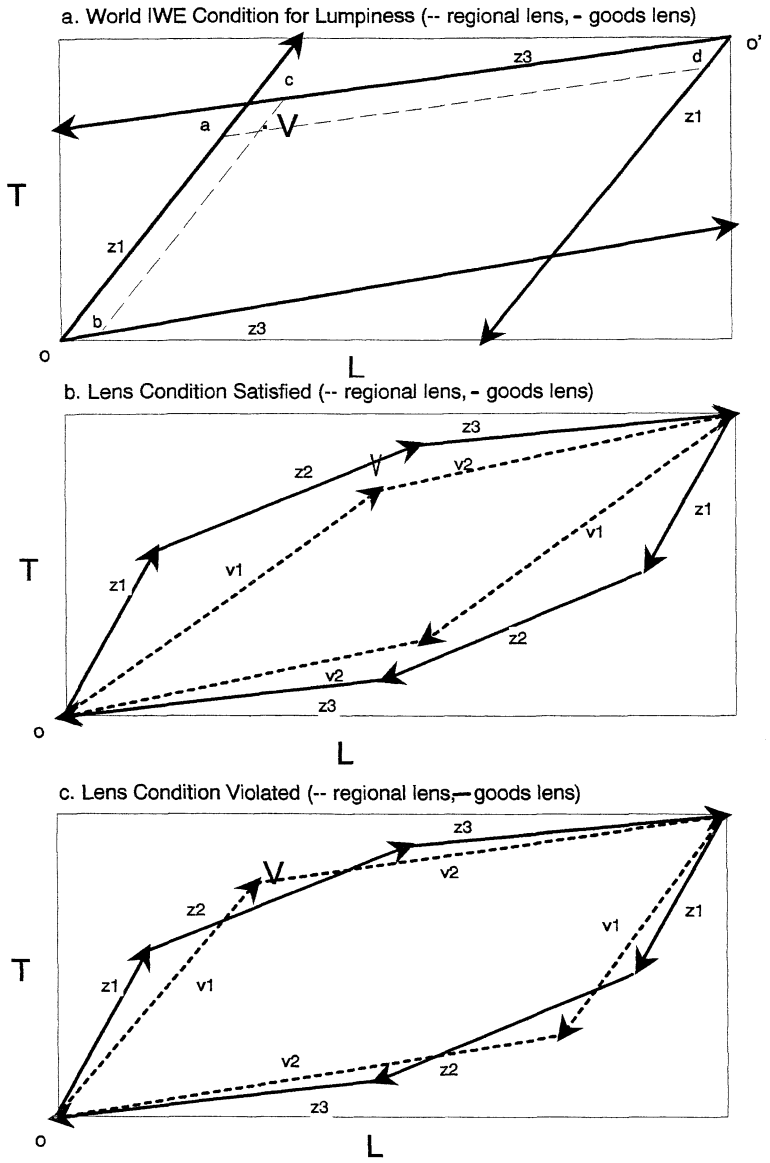

Fig. 1. (a) World IWE condition for lumpiness; (b) lens condition satisfied; (c) lens condition violated.

dashed lines) lies inside the goods lens (in solid lines).[5] Note that Demiroglu and Yun (1999) show that this "lens condition" is only a necessary condition when there are more than two factors. One constructs the regional lens as follows. Rank the endowments for the two

[5] Debaere and Demiroglu (1998) show that the condition can hold for just any group of countries (regions) with FPE.

regions r, T_r and L_r by land/labor ratio and concatenate the corresponding vectors $\boldsymbol{v}_r$, $[T_r, L_r]$, in increasing and decreasing order of their land/labor ratio starting from the origin o. (The height of the box equals our country's land, with the width as its labor.) For any country that experiences FPE, the goods lens is drawn in a similar way. Assume three sectors i and sum their land and labor input across the regions to obtain the total factor use in each, i.e. $T_i = \sum_r T_{ir}$ and $L_i = \sum_r L_{ir}$. Next, rank T_i and L_i again and concatenate the corresponding factor input vectors $\boldsymbol{z}_i$, $[T_i, L_i]$, from the origin by increasing and decreasing land/labor ratio.

In Fig. 1b, the regional lens lies inside the goods lens, which points to FPE and no specialization. Lumpiness does not matter here. With more factors, the goods lens envelops the regional lens for any two of its factors. The lens condition is best illustrated with a violation as in Fig. 1c in which the endowment lens does not entirely lie inside the goods lens. One region has too much land; it could never employ all its resources for a given set of factor prices. Consequently, regions cannot produce the same set of products at the same factor prices; they end up producing different goods.

The condition in Fig. 1b is slightly stricter than Fig. 1a since it depends on the factor inputs of all sectors—not just the most extreme ones. If the condition in Fig. 1b is not violated, then the lumpiness condition of Fig. 1a is automatically satisfied. To study lumpiness empirically, I check condition Fig. 1b with data from Japan, the UK and India. Fig. 1b has the advantage that it does not require knowledge about the entire integrated world economy.[6] So far, I have defined the IWE for all countries of the world. This is by no means necessary. One can have FPE among a group of countries that is far smaller than the entire world. By focusing on the lens condition for one country only, I do not have to take a stand on the entire set of countries, if any, among which there is FPE. I only have to rely on the production pattern of one country as it is found in the data to check whether it is consistent with no specialization.

As presented here, specialization of production hinges on regional factor immobility. Indeed, mobile factors can undo regional differences in factor returns or in relative factor abundance. However, Courant and Deardorff (1993) show in a version of the model with amenities that specialization of production and unequal factor prices can coexist *with* interregional factor mobility. In a country with amenities in various regions, consumers may, for example, be willing to incur a lower wage in order to benefit from amenities, and hence they may decide not to move to higher-wage areas.[7] In other words, assuming regional factor immobility is a convenient, yet not an essential simplification of reality.

2. The case of Japan

In this section, I compare the *distribution* of regional endowments with the *distribution* of sectoral factor use. I draw the lens condition of Fig. 1b as described in the previous

[6] As soon as a country is bigger in size, so that more than two sectors are needed to employ its resources, one has to exactly know the size of the sectors in the integrated world economy (IWE) to be able to judge whether there is a violation or not.

[7] Courant and Deardorff (1993) also consider production amenities, such as, for example, regional variations in climate, and they show how production amenities can reconcile factor mobility with lumpiness on the production side.

section with actual data. I study whether the lens of regional endowments indeed lies inside the goods lens with the actual factor inputs.

To construct the goods and the regional endowment lenses, consider for example high- and low-skilled labor. For the goods lens, one needs national data on the total amount of high- (*HSL*) and low-skilled labor (*LSL*) used in each sector i in Japan. This number by definition amounts to the sum of all factors employed in that sector across the various regions as in Eq. (1). For the regional lens, one also needs the regional endowments that by definition amount to the sum of the regions' high- and low-skilled labor that is used in all sectors.

$$\begin{aligned} z_i &= [\mathrm{HSL}_i\ \mathrm{LSL}_i] \quad \text{and} \quad v_r = [\mathrm{HSL}_r\ \mathrm{LSL}_r]. \\ \mathrm{HSL}_i &= \sum_r \mathrm{HSL}_{ir}, \qquad \mathrm{LSL}_i = \sum_r \mathrm{LSL}_{ir}, \\ \mathrm{HSL}_r &= \sum_i \mathrm{HSL}_{ir}, \qquad \mathrm{LSL}_r = \sum_i \mathrm{LSL}_{ir}, \end{aligned} \tag{1}$$

Next, one ranks factor-input and endowment data in increasing and decreasing order of their high-skilled/low-skilled ratios. To obtain the goods lens, one concatenates the corresponding sectoral factor input vectors in both orderings, starting from origin o; the vectors add up to the total high- and low-skilled endowment of Japan, which is the size of the endowment box. I draw a lens for high- and low-skilled labor, one for capital and low-skilled labor and one for capital and high-skilled labor. A violation in any of these lenses implies specialization no FPE; no violation suggests lumpiness does not matter.

For the empirical analysis, I rely on Davis et al.'s data. They have endowment and production data for 10 Japanese regions that are based on Japan's 47 prefectures.[8] Based on the *Employment Status Survey*, Davis et al. provide factor endowments for high- and low-skilled labor for 10 regions. The regional capital stocks are constructed with the perpetual inventory method with investment flows from the *Annual Report on Prefectural Accounts*. The price deflators are form the *Annual Report on National Accounts* and the depreciation rate is 0.133. As for the sectoral factor use, capital is constructed in the same way as the regional stocks using investment flows for 30 sectors. The investment flows are found in the *Annual Report of Corporation Survey* and the *Census of Manufacturing*. The sectoral employment figures come from the *Employment Status Survey*. Table 1 reports what fraction of the total Japanese endowments is used in the various sectors and what fraction of these endowments is allocated in each of the 10 regions.[9]

[8] The 10 Japanese regions are Hokkaido, Tohoku, Kanto, Hokuriku, Tokai, Kinki, Chugoku, Shikoku, Kyushu and, finally, Okinawa.

[9] In the presence of nontraded goods, one could argue that the lenses should be drawn with data from only the traded good sectors (see Helpman and Krugman, 1985). In my case, drawing the lenses for all sectors or only for manufacturing plus agriculture (to proxy for traded goods) does not affect the results.

Table 1

	Skilled labor	Unskilled labor	Capital
(A) Japan: the regional endowments			
Total endowment of Japan = 1 (fraction of total)			
Hokkaido	0.034	0.041	0.047
Tohoku	0.056	0.070	0.076
Kanot	0.397	0.360	0.343
Hokuriku	0.039	0.043	0.046
Tokai	0.123	0.130	0.127
Kinki	0.180	0.168	0.157
Chugoku	0.058	0.061	0.066
Shigoku	0.025	0.031	0.032
Kyushu	0.081	0.090	0.097
Okinawa	0.005	0.006	0.007
(B) Japan: the sectoral factor use			
Total endowment of Japan = 1 (fraction of total)			
Ag/forestry/fishery	0.001	0.107	0.091
Mining	0.001	0.002	0.004
Const	0.073	0.069	0.036
Food	0.020	0.032	0.021
Textile	0.005	0.017	0.006
Apparel	0.003	0.017	0.002
Lumber	0.002	0.007	0.003
Furniture	0.002	0.006	0.002
Pulp, paper	0.006	0.009	0.009
Printing	0.024	0.015	0.008
Chemicals	0.029	0.016	0.026
Petrol/coal products	0.002	0.001	0.007
Rubber	0.003	0.006	0.004
Leather/leather products	0.003	0.002	0.000
Stone, clay, glass	0.008	0.015	0.013
Iron/steel	0.007	0.013	0.028
Non-fe	0.006	0.006	0.008
Fabricated metal	0.014	0.022	0.011
Machinery	0.032	0.031	0.022
Electrical machinery	0.066	0.062	0.044
Transport equip	0.025	0.033	0.037
Precision instru	0.009	0.009	0.005
Other manufacturing	0.012	0.016	0.011
Transportation/communication	0.044	0.107	0.053
Electricity/gas/water	0.009	0.009	0.072
Wholesale/retail	0.251	0.152	0.075
Finance/insurance	0.104	0.045	0.016
Real estate	0.011	0.005	0.018
Other services	0.219	0.154	0.096
Public administration	0.009	0.015	0.274

Davis et al. (1997).

Fig. 2 shows the lens with high- and low-skilled labor. As the endowments are normalized with the total factor supplies, the sides of the endowment boxes add up to 1. There is more variation in the factor inputs than in the regional factor supplies. The lens

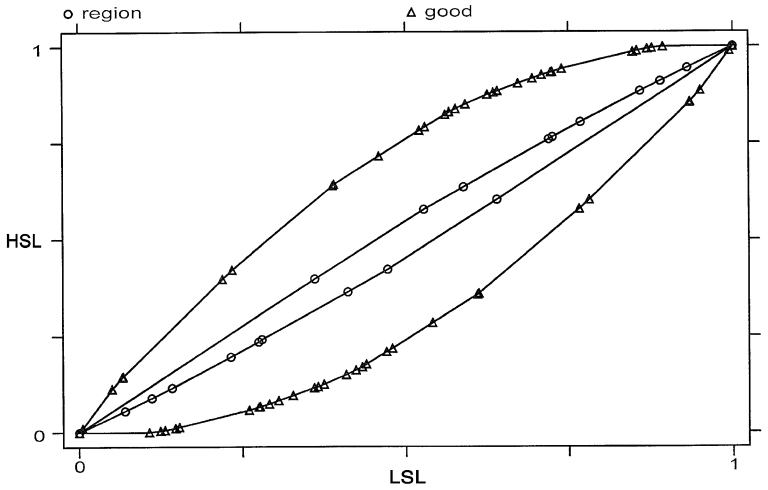

Fig. 2. Japan, high-skilled labor (HSL) versus low-skilled labor (LSL).

condition is not violated. Also, for capital-skilled labor and capital-unskilled labor (not reported) is the regional lens well inside the goods lens. The extent to which regional endowments differ cannot be a source of regional specialization. This supports Davis et al.'s claim that lumpiness should not matter for Japanese production.

3. The case of the United Kingdom

In this section, I extend the empirical analysis of lumpiness to the United Kingdom. I use data of the 11 regions into which the *Central Statistics Office* divides the United Kingdom.[10] The United Kingdom has, like Japan, a fairly pronounced pattern of regional concentration and dispersion of its economic activity. The fairly densely populated string of regions that runs from the South East across the West Midlands through the North West covers a little less than 20% of the entire area of the United Kingdom. Still, in 1988, this area accounted for about 54% of the available jobs in the United Kingdom. Not surprisingly, on a subregional level, the picture is even starker. Out of the 65 subregional units that the *Central Statistics Office* distinguishes for the United Kingdom, the 15 most densely populated subregions account for about 7% of the area of the entire UK. In terms of employment, however, it fills about 48% of the jobs in the UK. In order to draw the goods lens and the regional lens for the United Kingdom, I collect endowment and sector-level factor use data for 1990.[11] The production factors are high- and low-skilled labor. I also construct regional and sectoral capital stocks. Table 2 reports the regional factor

[10] The regions are for England, Yorkshire and Humberside, the North, the East Midlands, East Anglia, the South East, the South West, the West Midlands and the North West plus Wales, Scotland and Northern Ireland.

[11] For the distribution of high- and low skilled labor across the different regions, I have to rely on the 1991 figures.

Table 2

	Skilled labor	Unskilled labor	Capital
(A) United Kingdom: the regional endowments			
Total endowment of the UK = 1 (fractional of total)			
North	0.046	0.057	0.061
Yorkshire and Humberside	0.075	0.090	0.086
East Midlands	0.065	0.072	0.065
East Anglia	0.034	0.037	0.037
South East	0.361	0.284	0.296
South West	0.081	0.084	0.077
West Midlands	0.082	0.095	0.084
North West	0.105	0.112	0.106
Wales	0.043	0.053	0.056
Scotland	0.085	0.090	0.103
Northern Ireland	0.022	0.027	0.028
(B) UK: the sectoral factor use			
Total UK endowment = 1 (fractional of total)			
Agriculture, forestry, fishing	0.019	0.029	0.021
Mining	0.011	0.016	0.018
Food, drinks and tobacco	0.037	0.059	0.046
Textile, leather, footwear	0.013	0.021	0.012
Wood, cork and furniture	0.007	0.011	0.007
Paper, printing and publishing	0.032	0.027	0.029
Basic chemicals	0.024	0.024	0.025
Pharmaceuticals	0.007	0.006	0.006
Petroleum refineries and products	0.006	0.007	0.022
Rubber plastic products	0.011	0.012	0.011
Stone, clay and glass	0.009	0.011	0.012
Ferrous metals	0.012	0.014	0.015
Non-ferrous metals	0.004	0.006	0.004
Fabricated metal products	0.012	0.013	0.012
Other non-electrical machinery	0.024	0.026	0.021
Computers and office equipment	0.011	0.010	0.008
Electrical equipment	0.010	0.011	0.009
Electronic equipment	0.020	0.020	0.016
Ship building	0.002	0.003	0.002
Other transport equipment	0.001	0.002	0.002
Motor vehicles	0.016	0.020	0.017
Aircraft	0.011	0.010	0.008
Instruments	0.004	0.004	0.004
Other manufactures	0.003	0.004	0.003
Electricity, gas	0.020	0.022	0.061
Construction	0.080	0.127	0.072
Wholesale and retail	0.091	0.106	0.108
Hotels and restaurants	0.016	0.017	0.016
Transport and storage	0.044	0.043	0.046
Communications	0.016	0.015	0.017
Finance insurance	0.093	0.074	0.125
Real estate and business services	0.096	0.072	0.120
Community, social services	0.238	0.159	0.106

Regional Trends, OECD, own calculations.

supplies and the factor inputs of the various sectors. Both are reported as shares of the total factor endowments of the UK.

I first describe the data for the goods lens. From an OECD working paper, OECD (1996), I take the employment figures for all the sectors of the United Kingdom for both high- and low-skilled labor. High-skilled labor consists of high-skilled white-collar workers which comprise the following categories of the Industry Standard Classification of Occupations issued by the International Labor Organization: 10 (legislators, senior officials and managers), 20 (professionals) and 30 (technicians and associate professionals). I consider all other workers (the OECD distinguishes low-skilled white-collar workers and high- and low-skilled blue-collar workers) of the low-skill type.[12] The OECD provides labor data for 42 sectors. I regroup the labor data into the 33-sector classification of the OECD *Input–Output Tables* (1995) to make them consistent with the investment data that are needed for the construction of sector-level capital stocks. I rely on the concordance of the OECD *Input–Output Tables* (1995) for this reclassification. The sectoral investment flows with which I construct the sectoral capital stocks of the United Kingdom are drawn from the *OECD National Accounts*, *Detailed Tables*. The investment flows from 1976 to 1990 are transformed into stocks with the perpetual inventory method. The investment deflator is also from the OECD and the depreciation rate is 0.133. To obtain direct plus indirect factor inputs, I combine sectoral factor input data with the UK's Input–output table for 1990, also found in the OECD *Input–Output Tables* (1995).

In order to be able to draw the regional lens, endowment data are needed for the 11 regions. To be consistent with the factor input data that I described above, I sum the OECD high- and low-skilled labor data of the previous paragraph across sectors in order to obtain countrywide endowments. I then apply to these endowment figures the regional distribution of high- and low-skilled labor that is taken from the *Regional Trends* of the Central Statistical Office. *The Regional Trends* provides for the 11 regions of the United Kingdom the total number of people of age 16 years and older that are active in each region. In addition, it breaks down these numbers per region according to occupation (see Table 10.9). These figures allow me to identify what fraction of the total UK-employed labor force is high-skilled or low-skilled in each region. These fractions are then multiplied with the OECD endowments mentioned above.

Estimates of regional capital stocks for the United Kingdom are obtained along similar lines. The aggregate capital stock of the UK is just the sum of the capital stocks that are used in the various industries discussed in the previous paragraph. I derive the regional distribution of capital from *The Regional Trends*. More in particular, I construct regional capital stocks with the private and government gross fixed capital formation figures from *Regional Trends* for the same 15 years, 1976–1990. I rely upon the perpetual inventory method and use the same deflators and the same depreciation rate here. The regional distribution of the thus obtained capital stocks is then applied to the total UK capital stock that is based on OECD investment figures.

Fig. 3 presents for the United Kingdom the lens for low-skilled labor vs. capital. As before, the endowments are normalized with the total factor supplies, so that the sides of

[12] A broader definition of high-skilled labor including low-skilled white-collar workers generates qualitatively similar results.

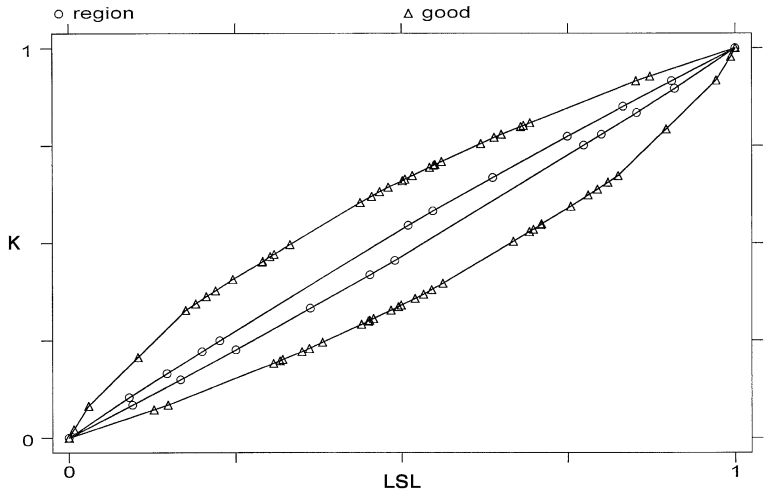

Fig. 3. UK capital (K) versus low-skilled labor (LSL).

the endowment box add up to 1. The high-skilled vs. capital and the high- vs. low-skilled labor lens (not reported) are similar and confirm for the UK the results that were obtained for Japan.[13] The regional endowment lens lies well inside the goods lens.

4. Assessment of results

There is significant variation in economic activity across the regions of a country. My analysis shows, however, that there is not enough regional variation in the factor supplies in the United Kingdom and Japan to induce regional specialization and to make different regions produce different goods at different factor prices. My findings accord well with the empirical trade literature on international specialization. Debaere and Demiroglu (2003) and Schott (2003) show that specialization is especially an international phenomenon. In particular, the substantial difference in endowments, especially between developing and developed countries, prevents all countries from producing the same set of goods. The lens condition is violated for a group of countries that includes both developed and developing countries. For reference, the endowment variations are much more pronounced in an international context. The capital/labor ratio in a developed country such as Germany is easily 15 times higher than the capital/labor ratio in developing countries such as India.[14] Note that the difference between the highest and the lowest regional capital/labor ratio is only around 2 for the United Kingdom and Japan. In this section, I address a few issues

[13] If one aggregates the regions of England and if one draws the lens together with the data from Scotland, Wales and Northern Ireland, one still does not obtain a violation.

[14] Even after correcting labor figures for differences in human capital, developed country ratios are still five times higher than for developing countries.

that often arise in discussions of lenses. They should give an idea of the robustness and generality of the obtained result.

A common concern is that the lenses are constructed while it is assumed that the factor endowments are similar enough not to induce specialization. If we obtain a violation, we know a country is lumpy, but one may wonder what we should conclude if we do not. I show in Fig. 4 that for (two) regions that produce different goods because their endowments are too different, one is likely to obtain a violation of the lens condition if one draws the lenses with actual data the way I do. The top panel of Fig. 4 is a Lerner–Pearce diagram with unit value isoquants for three goods, and the bottom panel represents the corresponding endowment boxes. Region one (with endowment V_1) produces goods 1 and 2, whereas goods 2 and 3 are produced in the second region (with endowment V_2).

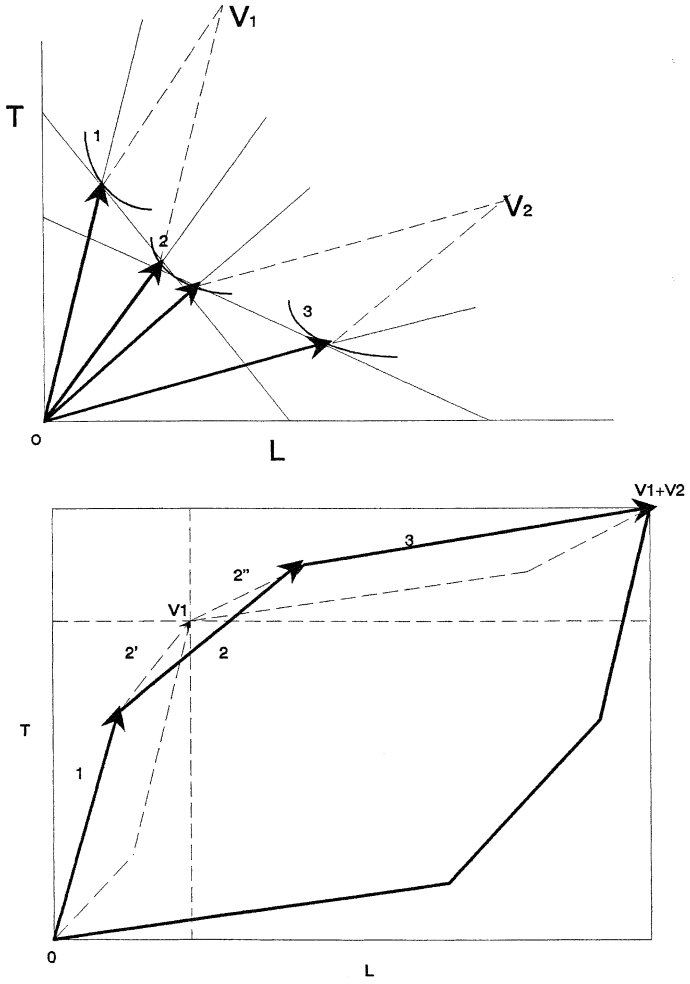

Fig. 4. Specialized production and a violation of the FPE production lens.

Initially, I treat the more land-intensive good 2, 2′, and its less labor-intensive version, 2″, as separate goods and draw for each region a different goods lens (in dashed lines). Next, I draw one goods lens for both regions. [In most cases, the data make one consider 2′ and 2″ the same product and add up the factor inputs of 2′ and 2″ to draw the goods lens (in solid lines)]. One clearly sees how this produces a violation of the goods lens. V_1 lies outside the goods lens. In order to avoid overburdening the graph, I have not explicitly drawn the regional lens connecting o, V_1 and V_1+V_2.

Davis et al. (1997) are right to assume that factor price equalization is more likely within a country than across the globe. Still, one wonders whether factor-augmenting productivity differences (as in Trefler, 1993) across regions, should they occur, would change my result. Factor-augmenting productivity differences are consistent with the basic assumptions of the setup if one reformulates endowments, factor use and factor prices in productivity equivalents. In particular, they require one to draw the lenses in productivity equivalents.[15] It can be proven that Hicks-neutral differences do not produce a violation of the lens condition if there was none without adjustments (see Debaere and Demiroglu, 1998). Also, factor-augmenting technology differences that are not symmetric across factors are unlikely to lead to a violation in our case—just consider how well the endowment lens lies into the goods lens.

One may wonder further how general the obtained results are. It is an open question whether the obtained results are characteristic for developed countries only. If the regional differences in per capita GDP give any indication of the variation in regional endowments, there could be a presumption that a violation of the lens condition might be more likely in developing countries in which there is more variation in per capita GDP across states. The maximum regional per capita GDP of a region is, in the US, about twice the minimum. The same is true for Japan and for the UK. For countries such as Brazil or India, we easily obtain a factor of 4 or 5.

With due reservations about the quality of the data, I report Fig. 5 that can give an indication of what to expect in developing countries. It presents the regional endowment and goods lens for India for the year 1988. The factors are capital and employed labor. The data source for this exercise is the *1998 Industrial Databook* from the Centre for Industrial and Economic Research (1998). It provides estimates of the capital stock for 25 regions and also breaks down an estimate of the countrywide capital stock according to 20 sectors.[16] The *CIER* also provides employment data at the regional level for the same 25 regions and nationwide sectoral employment figures for the corresponding sectors. I report the data in Table 3. The regional lens lies well inside the goods lens. I am cautious with this result since it is likely that there are technological differences across regions (or other

[15] Factor-augmenting productivity differences require that one adjusts the sectoral factor inputs and the regional endowments with a relative productivity measure of region r with respect to a reference region s, π_{rs}. For high-skilled labor, the factor input for a sector i changes to $\mathrm{HSL}_i = \sum_r \pi_{rs}\mathrm{HSL}_{ir}$. The factor endowment figure for a region r changes to $\mathrm{HSL}_r = \pi_{rs} \sum_i \mathrm{HSL}_{ir}$.

[16] The regions of India on which CIER provides data are Jammu and Kashmir, Punjab, Haryana, Himachal Pradesh, Chandigarth, Delhi, Rajasthan, Utra Pradesh, Bihar, Gujarat, Maharashtra, Madhya Pradesh, Goa Daman and Diu, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Pondicherry, Orissa, West Bengal, Assam, Manipur, Tripura, Meghalaya, Andaman and Nicobar.

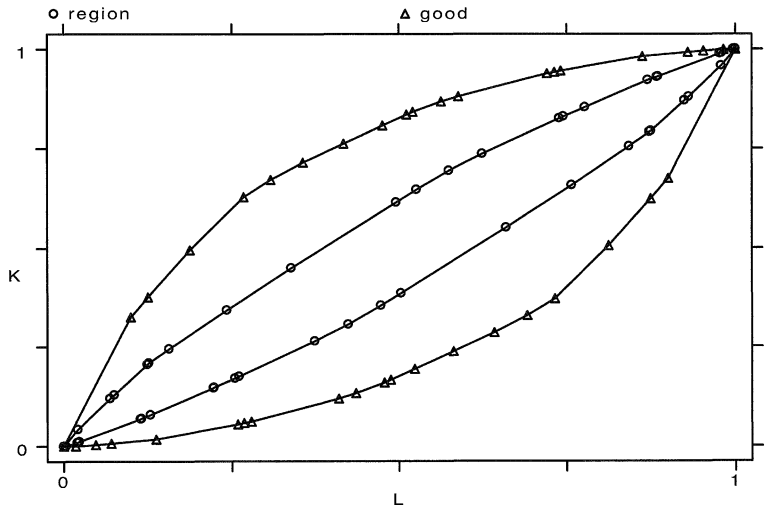

Fig. 5. India, labor (L) versus capital (K).

violations of the model's basic assumptions). I would not interpret the finding as evidence suggesting FPE or FPE in productivity equivalents, however. Rather, I see it as a finding that suggests that even when technology were the same (and if all other assumptions held up) among Indian regions, there would not be enough regional variation in endowments to trigger specialization of production.

Finally, there may be concerns about aggregation and other factors than the ones that I study. I have drawn the lenses for capital, skilled and unskilled labor. Production factors such as mineral deposits or arable land are not considered due to data limitations. It is possible, however, that such other factors could lead to a violation. Then there is aggregation. Indeed, the lenses are drawn for a limited number of sectors only. Each sector is bound to consist of many subsectors. One may wonder how this affects the result. Aggregation is bound to make the goods lens thinner (for reference, adding up all the sectors into one will yield the diagonal of the endowment box.) Hence, with more disaggregation, the goods lens will become even wider, making a violation even less likely.

In addition, one may wonder, whether the endowments should not be disaggregated and whether such disaggregation should not work the other way and make a violation of the lens condition more likely. Consider what would happen if one were to use data at the county level. In a wealthy county with a high concentration of highly skilled labor and virtually no low-skilled labor, the high/low skilled labor ratios would be very high, whereas in a poor one, the opposite should apply. In such a case, one might think that the more disperse disaggregate high/low skilled labor ratios (compared to the average of both counties) should more easily induce a violation of the lens condition for a given goods lens. It is critical to remember, however, that if the people of both counties work in the same firms, the violation would be entirely spurious. In other words, the geographic units of analysis cannot be too small since they should include all people living and working in

Table 3

	Labor	Capital
(A) India: the regional endowments		
Total endowment of India = 1 (fraction of total)		
Jammu and Kashmir	0.006	0.004
Punjab	0.049	0.048
Haryana	0.031	0.03
Hamachal Pradesj	0.006	0.009
Chandigarh	0.001	0.005
Delhi	0.017	0.009
Rajasthan	0.03	0.036
Uttar Pradesh	0.096	0.106
Bihar	0.05	0.076
Gujarat	0.086	0.098
Maharashtra	0.157	0.165
Madhya Pradesh	0.048	0.078
Goa, Daman and Diu	0.002	0.003
Karnataka	0.05	0.042
Andrha Pradesh	0.092	0.058
Tamil Nadu	0.089	0.114
Kerala	0.032	0.023
Pondicherry	0.002	0.001
Orissa	0.021	0.043
West Bengal	0.094	0.043
Assam	0.013	0.09
Manipur	0.000	0.000
Tripura	0.000	0.002
Meghalaya	0.000	0.000
Andaman and Nicobar	0.000	0.000
(B) India: the sectoral factor use (fraction of total)		
Basic metals	0.079	0.138
Metal products	0.025	0.013
Chemical products	0.071	0.118
Transport equipment	0.062	0.060
Machinery and tools	0.056	0.043
Rubber	0.027	0.050
Food products	0.128	0.057
Beverages and tobacco	0.056	0.010
Cotton textiles	0.107	0.037
Woolen textiles	0.040	0.027
Jute, hemp and mesta	0.025	0.004
Paper products	0.037	0.027
Nonmetallic mineral products	0.054	0.045
Textile products	0.017	0.007
Leather and fur products	0.010	0.004
Wood furniture	0.009	0.003
Repair services	0.022	0.003
Electricity	0.111	0.323
Other manufacturing	0.010	0.007

CIER (1988).

the same area.[17] With this criterion in mind, Davis et al. selected the Japanese regions and for the same reason, I used UK regional data from the *Regional Trends*.

5. Conclusion

In this paper, I have investigated whether the uneven distribution of endowments across the regions within a country triggers specialization of production and whether it makes regions produce different sets of goods at different factor prices. To study this question, I operationalized the concept of lumpiness that Courant and Deardorff (1992) developed. For Japan, the United Kingdom and even for India, I found that lumpiness should not give way to specialization and different factor prices across regions. This suggests that specialization due to lumpiness is not a regional phenomenon. This finding accords well with the empirical literature that argues that specialization due to endowment differences is an international phenomenon: All countries cannot produce the same set of goods. The results also suggest that regional specialization is most likely not a major explanation for why trade patterns do not conform to the basic predictions of the Heckscher–Ohlin model.[18]

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[17] From this perspective, I consider it an advantage that Japan and the UK are island economies. One should not be concerned about cross-border employment.

[18] Note that when regions produce different goods at different factor prices, the actual pattern of trade of a lumpy country differs from any prediction based on countrywide data. The latter observation has sometimes been invoked to explain long-standing questions in the trade literature such as the Leontief paradox (see Courant and Deardorff, 1993).

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