Regional Heterogeneity and China's International Trade:

Sufficient Lumpiness or Not?

Meng Lu, Chris Milner and Zhihong Yu

(GEP and School of Economics,

University of Nottingham)

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1. Introduction

Traditional H-O trade modeling represents countries as dimensionless points rather than heterogeneous, geographical spaces. The regional distribution of factor endowments is even by implication in these models, and has as a result no relevance for countries' trade patterns. Recognition of the possible influence of regional heterogeneity or 'lumpiness' in the distribution of factor endowments on intra-national production and trade and on international trade can, however, be traced back to the seminal contribution of Courant and Deadorff (1992). They show that sufficient 'lumpiness' in the distribution of factors across regions can induce international trade for a country which in the absence of this regional heterogeneity would not have an incentive to trade internationally. By implication 'lumpiness' can alter the commodity composition of a country's trade relative to that which would apply if factors were more evenly distributed; a country tending to export (or to export more of) the products that use its lumpier factor more intensively.

Courant and Deadorff (1992) impose lumpiness exogenously in their theoretical model, and by implication rule out the possibility of factor mobility eliminating regional heterogeneity and its induced trade effects. One would anticipate factors to be sufficiently mobile within many countries to reduce the practical relevance of the 'lumpiness' concept. However, Courant and Deadorff (1993) show that factor prices can remain unequal across regions even in the presence of labour mobility due to differences in consumer amenities across regions. In which case, 'lumpiness' may be an endogenous and equilibrium feature of national, economic conditions. In a country like China one may anticipate both endogenous (e.g. regional variations in amenities) and exogenous (e.g. cultural, linguistic, distance and administrative barrier) sources of heterogeneity to give rise to marked and sustained differences in factor prices and endowments. The quality of the infrastructure (transport, communications etc.) in certain regions may well be in line with that of the highly integrated, industrial countries, but this is present also with marked heterogeneity in infrastructure quality across China's regions. China offers therefore an interesting testing ground for the effects of lumpiness, with distinctive data also on endowments, production and trade on a regional basis.

There has been limited empirical exploration of the impact of lumpiness on trade patterns, in part because it is an unlikely feature of many small economies but also because appropriate regional data is often not available for larger and less developed economies. Debaere (2003) investigates the incidence of lumpiness across the regions of Japan, UK and India, but finds no evidence of it even in the geographically larger and less developed Indian economy. As a result, and despite recognized concerns about data quality, he concludes that regional heterogeneity and associated specialization is not a major influence on international trade. However, Bernard et al. (2004) conclude that lumpiness is likely to be of greater relevance in the case of developing countries. They show that Mexico's regions exhibit substantial variation in skill abundance and relative factor rewards. Similarly, Silventa et al. (2008) show that, although no longer an influence on Spain's trade, there is some evidence of lumpiness in the past when Spain was less developed and integrated. The regional heterogeneity of China, combined with its importance in world trade, offers therefore an opportunity to revisit the question of whether heterogeneity of factor endowments across regions is an influence on international trade.

The present paper, using alternative empirical methods and rich regional data, finds some evidence of lumpiness for China especially when greater regional disaggregation is used. This latter finding suggests that the phenomenon may not be China-specific, if other studies that have not identified lumpiness have obscured the effects of lumpiness through the use of over-aggregated geographical entities. With over –aggregation there is likely to reduced regional heterogeneity as a result of the smoothing of relative endowments differences and the artificial elimination of barriers (cultural, linguistic and administrative) associated with non-contiguity.

The remainder of the paper is organized as follows. Section 2 explores the pattern of regional heterogeneity in China. Section 3 sets up the conceptual and theoretical framework. Section 4 describes the lens condition methodology for identifying lumpiness. Section 5 reports on the application of this methodology to Chinese regional data and some sensitivity analysis, including of the effects of regional aggregation on the results of the lens condition test. Further robustness checking of the findings is undertaken in section 6, using direct evidence on production specialization and trade patterns across China's regions. Finally, section 7 sets out the summary conclusions and implications of the study.

2. Regional Heterogeneity in China

Regional information on factor endowments is available over time for China for 28 regions (see appendix A for a listing of the regions and section 5 for a description of the data sources). For the present purpose we are interested in identifying the extent of unevenness or lumpiness in the distribution of endowments across the regions. With a perfectly even distribution approximately 3.6% of each factor would be endowed to each region. In table 1 we summarize the extremes of the deviation from this homogenous regions condition, for the years 1997 and 2004. For a capital and labour break down of endowments we have information for both years, and for a high and low skill labour representation of technology for 2004 only. There tends to be more unevenness (as indicated by the ratio of the maximum to minimum factor endowments ratio) in the distribution across regions of capital and high skill labour than of labour and low skill labour.

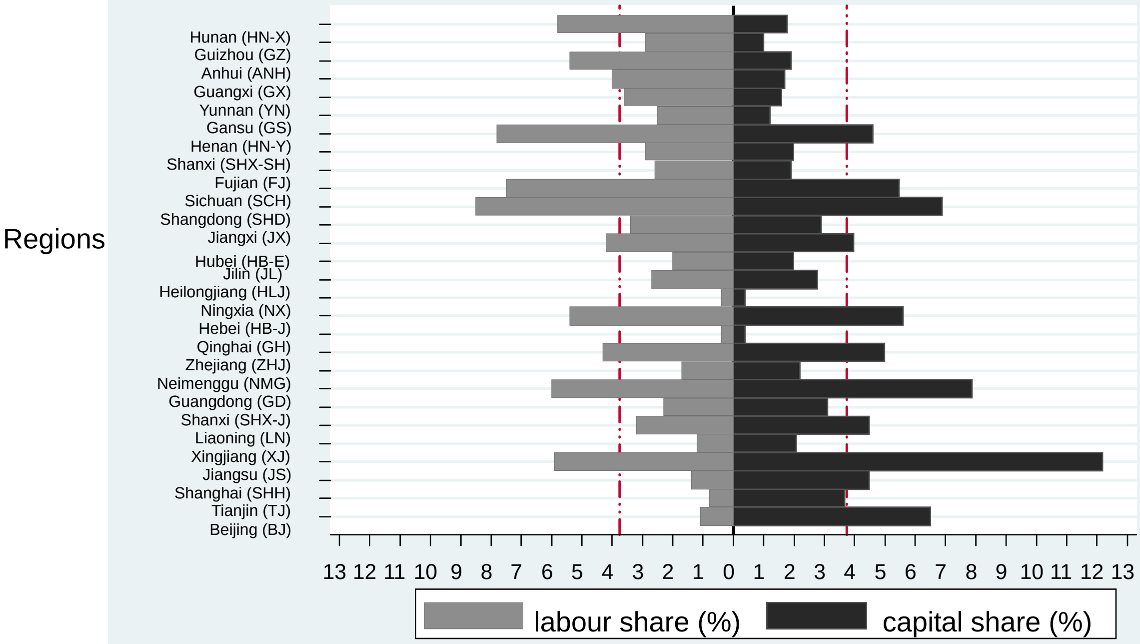
It is clear from table 1 that there are marked deviations from a uniform or even distribution of factors; the maximum share of any one region's share of labour ranging of about 8.5%, with the minimum share constant at 0.4%. In the case of capital the maximum regional share is in the range 10.1% to 12.2%, while a minimum again of 0.4% in both years. Inevitably some of this heterogeneity in regional factor shares is a reflection of differences in the size of regions or in the scale of economic activity across regions and of a range of features of geography affecting the scope for economic activity. It is not necessarily this type of heterogeneity that we are interested in for the present purpose. Take for instance the Shandong (SHD) region in 2004, with 6.7% of China's endowment of high- skilled labour and 7.1% of its low- skilled labour. Shandong accounts for a larger share of manufacturing activity than in China on average, but its relative (high/low skill) endowment is very similar to the economy-wide relative endowment. It is differences in the relative endowment of each factor that indicates the presence of heterogeneity in relative endowments that may give rise to 'lumpiness'. Beijing (BJ) for example accounts fro 4.8% of China's high skill endowment but only 0.9% of its low skill endowment. This differential is associated as a result with a HSL/LSL ratio 5.13 times larger than the national average. By contrast Sichuan (SCH) has 4.3% of China's high skill endowment and 6.9% of its low skill labour, and a HSL/LSL ratio of only 61% of the national average. It is these extremes in the distribution of regional, relative endowments that gives rise to the possibility of lumpiness sufficient to induce trade and specialization differences across China's regions.

Table 1: Overall Degree of Regional Heterogeneity in China

Specific Regions	1997	2004	2004
Labour (L) Share (%)			**Low-skill Labour (LSL)**
a) Max	8.5	8.4	7.6
b) Min	0.4	0.4	0.4
c) Ratio (a/b)	21.3	21.0	19.0
Capital (K) Share (%)			**High-skill Labour (HSL)**
a) Max	12.2	10.1	6.7
b) Min	0.4	0.4	0.3
c) Ratio (a/b)	30.5	25.3	22.3
Absolute Differences in K and L Shares			**(HLS/LSL)**
a) Max	5.4	3.6	3.9
b) Min	0.0	0.0	0.0
c) Ratio (a/b)	∞	∞	∞
Capital-Labour Ratio (K/L)			**(HSL/LSL)**
a) Max	6.09	3.59	5.13
b) Min	0.31	0.38	0.61
c) Ratio (a/b)	19.6	9.4	8.4

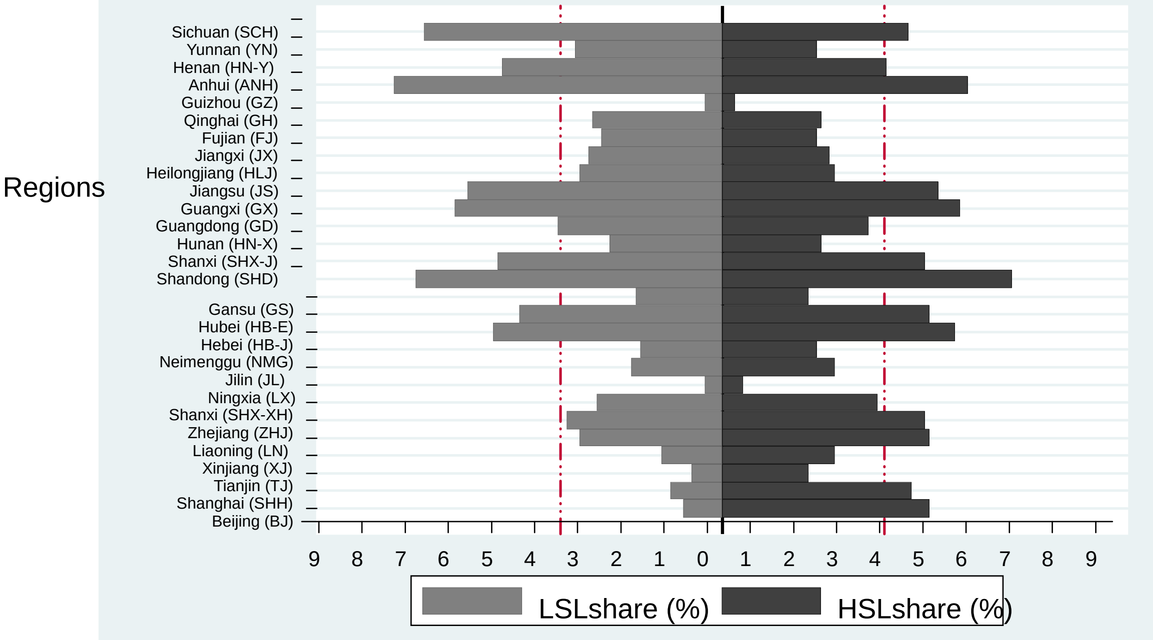
It is interesting to note from table 1 that, in terms of differences in capital and labour shares and in capital-labour ratios, heterogeneity is less in 2004 than in 1997. On the basis of capital and labour endowments, therefore, one would expect lumpiness to be more likely to evident in 1997 than 2004. Indeed the maximum capital-labour (K/L) ratio for a specific region is over six times the national average in 1997, with the ratio of the maximum to minimum regional K/L ratio being 19.6. Fig 1a(b) shows the shares of K and L (high-low skill) for all the regions in this year, and illustrates the relationship between differences in individual factor shares and relative factor endowments.

Fig 1(a): Regional Share of Labour and Capital Endowment in 1997



Source: China Industry Yearbook 2004

Fig 1(b): Regional Share of High (HSL) and Low Skill (LSL) Endowment in 2004



Source: China Industry Yearbook 2004

3. Conceptual and Theoretical Framework

Lumpiness as a source of trade

In Courant and Deardorff's (1992) model of lumpiness, a small open economy produces two goods (good 1 and good 2), using two factors (labour and capital) and the country consists of two regions (regions A and B). We use the Edgeworth box (fig. 2) to elaborate how the distribution of factor endowments between regions may affect a country's trade pattern. The horizontal and vertical dimensions of the box represent the labour and capital endowment of the country as a whole. Any point in the box indicates a particular distribution of factors between the two regions, with the endowment of region A measured from the lower left origin (O_A) and the endowment of region B from upper right (O_B). The factor intensity rays (r_1 and r_2) show the ratios of capital to labour employed in industries 1 (capital-intensive) and 2 (labour-intensive).

We assume initially that factors are equally distributed between the two regions, and that there is no incentive for the country to trade internationally because the country and the world have identical relative factor endowments[1]. In the Edgeworth box, this equal distribution of factors across regions is shown at point *O*. Interregional trade occurs when relative endowments of the two regions are unequal, but international trade only occurs when the regional allocation of factors is sufficiently unequal. Consider a reallocation of labour from region A to region B, shown by a move from points *O* to *Z*. Point Z is still within the factor price equalization (FPE) parallelogram O_ABO_BA, and there is incomplete specialization. The reallocation causes region A (B) to reduce (increase) its production of both goods, but to reduce (increase) it proportionately more for the now relatively less (more) abundant, labour- (capital) intensive good 2 (1). With common preferences across regions, there is intra-regional trade (with region B exporting good 2 to region A) but no international trade.

The international trade occurs only when there is a sufficiently uneven distribution of factors, i.e. sufficient lumpiness within the country. At point *M*, for example, the distribution of labour is sufficiently lumpy to induce international trade. The capital to labour endowment ratios of region A is even greater than the factor intensity ratios of the two industries and region B's ratio is between the two intensity ratios ($K_A/L_A > K_1/L_1 > K_B/L_B > K_2/L_2$). There is now complete specialization in the capital-intensive good (good 1) in region A and partial specialization in the labour-intensive good (good 2) in region B. As a result there is an incentive for the country to trade internationally, exporting good 2 (intensive in labour) in exchange for imports embodying now relatively scarce capital.

In general, the theorem of lumpiness predicts that a lumpy country will tend to export the good that uses its lumpier factor intensively. As long as the factor allocation point lies inside the Factor Price Equalization (FPE) parallelogram O_ABO_BA which is constructed by industrial factor intensities (r_1 and r_2), that is, the factor endowments differ across regions less than factor

[1] Given the world prices and preferences, we assume the country's initial trade with others is zero. The model also assumes that there is a common technology across and within countries. For the present purposes we are particularly concerned with maintaining this assumption within the country in which we introduce lumpiness. In the case of China (and other developing countries) this may be a strong assumption, especially where FDI is geographically concentrated. We find, however, that there is lumpiness within the Chinese western or coastal areas (where FDI is concentrated) as well as between eastern and western regions.

intensities differ across industries, the degree of lumpiness is not sufficiently large to cause (complete) intra-country specialization, different regional factor prices and international trade. A necessary condition for lumpiness to be a source of international trade is also identified by Deardorff (1994) for extended models with more regions and goods. (We return to the so-called ‘lens condition’ in the next section.)

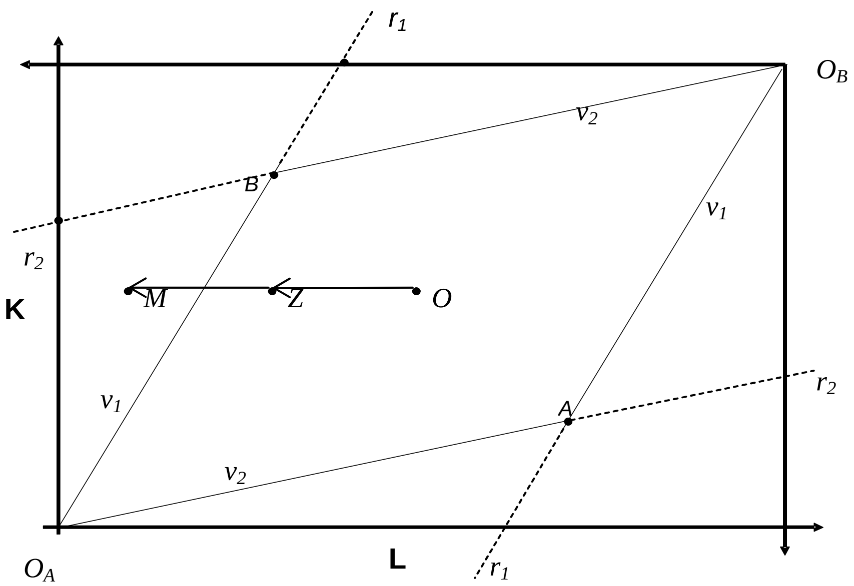


Figure 2: A Model of Lumpiness with Two Regions and Two Goods

Lumpiness altering trade patterns

The model above describes an outcome that contradicts the predictions of comparative advantage based on aggregate, relative factor endowments; international trade taking place where none would without ‘lumpiness’. The practical relevance of Courant and Deardorff’s idea is more likely to lie in how the trading pattern of a country that has a motive to trade in the absence of lumpiness may be affected by lumpiness. In the case of China, for example, with a possible abundance overall in low skill labour, there is in standard H-O terms an incentive for specialization in relatively low skill-intensive production. With sufficient concentration of high skill labour in specific regions in China, the relative wage of skilled labour may be sufficiently low to induce greater specialization in high skill-intensive production than there would be without this regional concentration of skill endowments. The set of products (skill and unskill labour-intensive) that China produces is expanded, potentially extending the overlap of the product mix with more trading partners (including possibly ones with greater and lesser relative, national endowments than those of China). This may as a result give rise to what Deardorff (1993) calls 'cross-over-trade'; China exporting more skill-intensive products to less skill abundant countries and less skill-intensive products to more skill abundant countries.

4. Methodology

Lens condition approach

Debaere (2003) explores data on the labour (L) and land (T) used in each sector (*i*) and each region (*r*), T_{ir} and L_{ir}. A regional lens is constructed by summing the land and labour inputs across sectors (equation (1)) and a sector lens by summing these inputs across regions (equation (2)). v_r and z_i are the regional factor-employed vector and sectoral factor use vector respectively.

$$v_r = \begin{bmatrix} T_r & L_r \end{bmatrix} \qquad z_i = \begin{bmatrix} T_i & L_i \end{bmatrix}$$

$$T_r = \sum_i T_{ir}, \qquad L_r = \sum_i L_{ir} \qquad (1)$$

$$T_i = \sum_r T_{ir}, \qquad L_i = \sum_r L_{ir} \qquad (2)$$

To construct the regional lens, T_r and L_r are ranked by the land/labour ratio and connected to the corresponding factor input vectors $v_r\left[T_r, L_r\right]$ from the origin *O* at the lower left of the Edgeworth box (see figure 3) by increasing and decreasing the land/labour ratio. Similarly for the goods lens, T_i and L_i are ranked by the land/labour ratio and the corresponding vectors $z_i\left[T_i, L_i\right]$ connected in increasing and decreasing order of the land/labour ratio starting from the origin. If the regional lens is fully located inside the goods lens, the lens condition is satisfied. "*…a necessary condition for FPE is that the lens formed by the factor-endowment vectors must be a subset of the lens formed by the factor-use vectors...*" (Deardorff, 1994). The intuition for the condition is that all regions will produce the same set of goods and at the same relative factor prices if the factor use (goods) lens envelops the factor endowment (regional) lens. It is only if this condition is violated that there is an incentive for specialization within some regions.

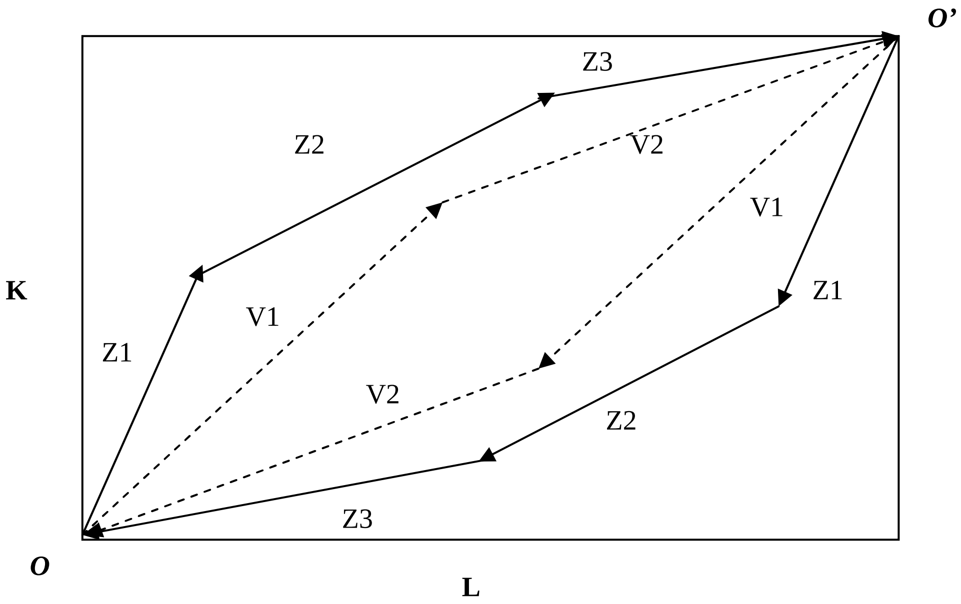


Figure 3: Lens Condition Satisfied with 2 Regions and 3 Goods Model

Rather than inspect the lens condition visually, a "distance" measurement can be used to indicate whether or not the regional lens lies inside the goods lens. This measure was introduced in Debaere and Demiroglu (2003) and also applied by Silventa's et al. (2007). The measure is defined as

$$\min\left\{1-\frac{d(x,r(x))}{d(x,s(x))}\right\}$$

In figure 4, *x* is any point on the diagonal of the endowment box between the two origins (0,0) and (1,1). The perpendicular lines are drawn through point x and intersects the regional lens and goods lens at points *r(x)* and *s(x)*. *d(x,r(x))* and *d(x, s(x))* are the distances between point *x* and the two intersections. The relative locations of the two lenses are identified by comparing the two distances. A positive value of the expression indicates that the lens condition is satisfied and a negative value means a violation.

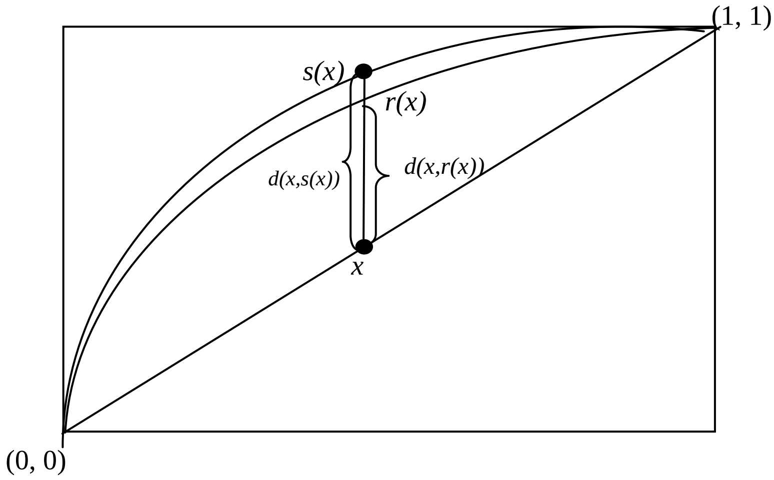


Figure 4: Distance Measure

5. Empirical Application of the Lens Condition

Data

We use Chinese endowment data for 1997 and 2004 in this study. The 1997 data which is from *1987-1997 Chinese Industry Dataset*[2] provides factor endowment, production and trade (exports only) data for up to 29 manufacturing industries and 28 (of the 31) Chinese regions. This gives information for a two factor breakdown: capital and labour. The classification of industries is based on the Industrial Classification and Codes for National Economic Activities (GB/T 4754-94). The measure of the capital stock is taken from data on estimated net fixed assets and expressed in real terms based on 1978 values using the investment price index.

The 2004 data is taken from *China Industry Yearbook 2004,* which provides information on factor endowments (capital and labour), output and exports for 389 industries (4-digit) in 31 Chinese regions. Further we can now divide labour endowments into high-skilled labour (HSL) and low-skilled labour (LSL) according to the level of education attainment. The HSL consists of labour with tertiary education: college qualification, university degree or above[3]. The 2004

[2] We wish to thank Dr. Mingxing Liu from School of Government, Peking University who provided the *1987-1997 China Industry Data*. The dataset are sourced from *China Compendium of Statistics 1949-2004, China's Gross Domestic Product Estimation: 1952-1995, China Statistical Yearbook, Collection of Industry, Transportation and Energy in China 1949-1999, China Industry Economy Statistical Yearbook, China Population Yearbook* and *China Population Statistics Yearbook*, etc.

[3] The corresponding levels from International Standard Classification of Education (ISCED) are levels 5, 6 and 7.

data uses the International Standard Industry Classification (ISIC) at a more disaggregate level (4-digit) than for 1997.

We standardize the classification, using the Chinese Industry Classification (GB/T 4754-94) for all the three datasets, to give us the 28 regions (3 municipalities, 4 autonomous regions and 21 provinces) and 28 or 29 manufacturing industries[4]. (See Appendix A for further details).

If the regional factor endowments were generated by summing actual factor inputs employed by region and sector, as in Debaere (2003), the measure of regional endowment would be restricted in the sense that the sectors which are counted for measuring regional endowment may not cover all the sectors in the region[5]. Further the measure would not account for unemployed factors. These sources of measurement error are both issues in the present context. In Debaere's study (Debaere, 2003) of lumpiness in Japan and the UK, the sample sectoral dataset covers all the sectors, while the Chinese data used above only covers 30 plus sectors out of 99 2-digit sectors. Tradable sectors such as agriculture which employ large numbers of workers are excluded. The large scale of unemployment of labour, in some inland regions in particular, would also be an important source of measurement error. This may also have affected Debaere's analysis and results for India.

To deal with this problem, we use direct regional endowment data from *China Statistic Yearbook*. This is a more comprehensive measure of regional endowments as the data covers all the factor supplies that are available for production in the region. Regional labour, for example, is the amount of labour that is employed in all the sectors plus the unemployment population. Table B.1 in Appendix B reports the fraction of total Chinese endowment in each of the 28 regions. The rankings of region accords quite well with prior expectations about the rankings of regional endowments: Eastern regions like Beijing (BJ), Shanghai (SHH) and Tianjin (TJ) are revealed to be relatively capital or high-skilled labour abundant, while western

[4] Of the maximum of 30 manufacturing industries there was only data for weapons and ammunitions manufacture in 2004, and petroleum processing and coking was dropped throughout.
[5] Given the Chinese data this method would underestimate the regional endowment, as there are a big number of labour forces from other sectors that are excluded from the 30 plus sectors in each region.

regions such as Yunnan (YN), Guangxi (GX), Sichuan (SCH) and Guizhou (GZ) are shown to be relatively labour or low-skilled labour abundant regions.

Next, the regional and goods lenses are constructed by arranging these regional endowment vectors from Tables B.1 ($\left[\frac{L_r}{L_c}, \frac{K_r}{K_c}\right]$ or $\left[\frac{LSL_r}{LSL_c}, \frac{HSL_r}{HSL_c}\right]$) in increasing orders of the normalized factor endowment ratios, starting from the origin. Similarly, the goods lens is obtained by ordering the industry factor use vectors from Tables B.2 ($\left[\frac{L_i}{L_m}, \frac{K_i}{K_m}\right]$ or $\left[\frac{LSL_i}{LSL_m}, \frac{HSL_i}{HSL_m}\right]$) from the origin in terms of increasing (normalized) factor intensity ratios. Figure 5 shows these lens based capital and labour for 1997 and 2004, and alternatively for 2004 on a skill endowment basis. The orders of the points on the lenses are consistent with the ranks of regions and sectors in Tables B.1 and B.2.

The lens condition is violated for two of the three applications, the exception being for the 2004 lenses based on a capital-labour representation.[6] The distance measures (Table 2) are negative in 1997 and for skill endowment representation for the 2004. The violation of the lens condition is more pronounced for the high-low skill representation in 2004 than for the capital-labour one for 1997.

[6] There is one regional capital-labour ratio (Shanghai, SHH) that is marginally greater than that of the most capital-intensive industry (tobacco) in 2004, but the distance measure has been rounded to zero.

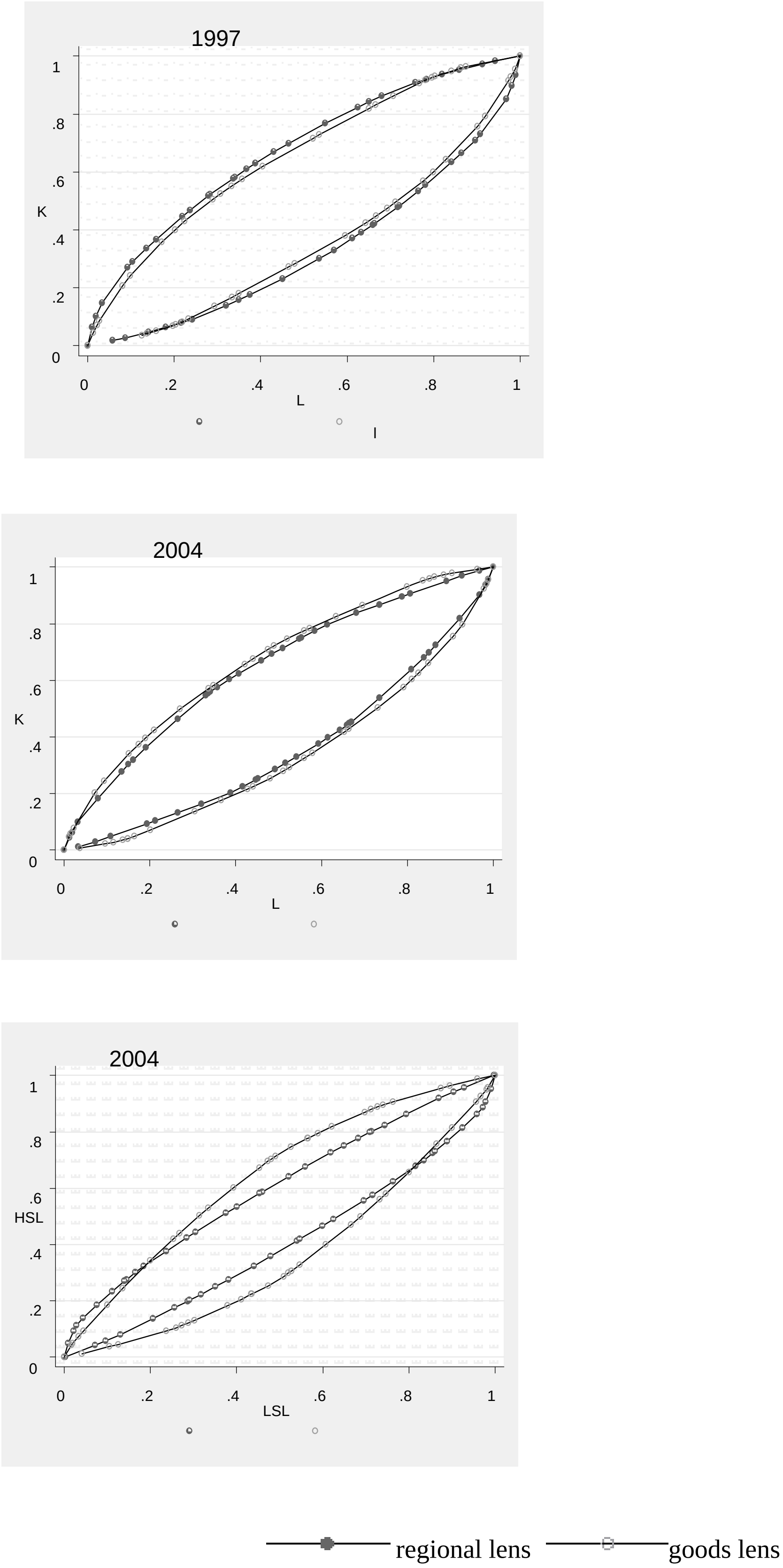


Figure 5: Capital (K) vs. Labour (L) for 1997 and 2004, High-Skilled Labour (HSL) vs. Low-Skilled Labour (LSL) for 2004. 28 Regions and 29 Manufacturing Industries

Sensitivity analysis

The analysis above shows that there is sufficient lumpiness in factor supplies within China to induce regional specialization and non-equalization of factor prices across regions. The result, however, is based upon an imposed aggregation of regions and industries. It may be sensitive to variation in the level of aggregation sectors and regions used to construct the goods and regional lenses. More (less) aggregation makes both the goods and regional lenses narrower (wider). If industries are over (under) aggregated and regions under (over) aggregated, the condition is more likely to be violated (satisfied). Therefore the result will be fashioned, therefore, by the relative aggregation of industries and regions.

Bernard, Robertson and Schott (2005) explore this specific issue in the implementation of lens condition and demonstrate how the degree of data aggregation influences the relative size (area) of goods and regional lenses. They argue that if the "true" number of either goods or regions is unknown, the outcome achieved by any particular level of aggregation is ambiguous. Their empirical implementation shows how varying the degree of industry aggregation results in both violation and satisfaction of the lens condition in Mexico.

In order to investigate the sensitivity of the results based on the capital-labour representation, we reconstruct the regional lenses at various levels of greater aggregation, while keeping the degree of sectoral or goods aggregation fixed.[7] The likelihood of observing violation of the lens condition must decrease and violation will disappear at some point as the number of regions is reduced.

Having disaggregated down from 2 regions (coastal and inland regions), we find in fact that the lens condition for insufficient lumpiness is still just satisfied with an imposed aggregation of 12 regions: Heilongjiang (HLJ), rest of North East, North Coast, Jiangsu (JS), rest of East Coast, South Coast, Shanxi and Henan (SHX-J and HN-Y) Yellow River Middle, Yangtze River Middle, South West, North West, Xinjiang and Ningxia (XS and NX) regions (see appendix C for details of the grouping of initial regions involved in moving from 31 to 12

[7] The aggregation level of industry data is fixed due to the availability of dataset.

regions and the associated adjustment to average relative endowments induced). Table 2 reports the distance measures for a 12 region arrangement, and also for an even more aggregated 8 region configuration used in Li and Hou (2004).

Table 2: Distance Measures

	Base Aggregation	Sensitivity Analysis
Capital and Labour		
1997	-0.1	0.03 (8)
2004	0.0	0.37 (8)
High and Low Skill		
2004	-0.05	0.45 (8)
		0.01 (12)

Note: the number in brackets indicates the number of regions that are included in the regional lenses

Although the sensitivity analysis serves to caste some doubts upon the robustness of the evidence of violation of the lens condition based on a 31 region disaggregation of China, we do not have strong priors that a 12 region representation is better in terms of the capture of barriers to factor mobility and of persistent factor price differences within China. Indeed, a comparison of the information on relative factor endowments in the more disaggregated regions (Appendix B) with that for the more aggregated regions (Appendix C) indicates that there are marked variations in relative endowments within the more aggregated representations of a region. The possibility of regional specialization cannot be ruled out by this sensitivity analysis, and further exploration of regional specialization is undertaken in section 6

Another issue that merits some robustness testing is the use thus far in the analysis of normalized factor endowment and intensity ratios to identify the violation of the lens condition, in a context where the overall or average factor endowment and intensity ratios are not necessarily identical in absolute terms. This issue would not arise if regional endowments were measured by aggregating by factor usage across all industries within each region. They were not measured in this manner because of incomplete industry coverage at the regional level, and because of the potential absence of full employment conditions in some regions at least. If the overall endowments ratio (Kc/Lc or HSLc/LSLc) is equal to or approximately equal to the overall factor intensity ratio in manufacturing (Km/Lm or HSLm/LSLm,) then the lens condition based on normalized ratios is an undistorted indicator. To the extent that Kc/Lc (or HSLc/LSLc) is greater (less) than Km/Lm (or HSLm/LSLm) then we risk over- (under-) identifying violation of the lens condition. Table 3 below lists the regions that induce violation of the lens condition, both using the initial values of the normalized factor endowment and intensity ratios (as set out in Appendix B) and adjusted ratios (with the normalized factor endowment ratios multiplied by the ratio of Km/Lm (or HSLm/LSLm) to Kc/Lc (or HSLc/LSLc). Encouragingly this adjustment does not alter the results for 1997 at all, and makes only marginal changes to those for 2004; creating now violation by one region only (Shanghai, SHH) when using a capital-labour representation, and removing Tianjin from the small group of regions inducing violation when using a labour skills representation.

Table 3 Regions[1] Inducing Violation of Lens Condition

Capital-Labour Representation				**Skills Representation**	
1997		2004		2004	
Unadjusted Factor Endowments	Adjusted Factor Endowments[2]	Unadjusted Factor Endowments	Adjusted Factor Endowments[3]	Unadjusted Factor Endowments	Adjusted Factor Endowments[4]
SHH (Shanghai)	SHH		SHH	TJ	SHH
TJ (Tianjin)	TJ			SHH	BJ
BJ (Beijing)	BJ			BJ	

[1] Regions with higher normalized factor endowments ratio than the factor intensity ratio of the most capital or high-skill intensive industry
[2] Unadjusted factor endowments ratio multiplied by the ratio $(K_M / L_M)/(K_C / L_C)$ (1.08)
[3]Unadjusted factor endowments ratio multiplied by the ratio $(K_M / L_M)/(K_C / L_C)$ (0.9)
[4] Unadjusted factor endowments ratio multiplied by the ratio $(HSL_M / LSL_M)/(HSL_C / LSL_C)$ (1.27)

Interestingly it is the same three regions – Shanghai, Beijing and Tianjin - that consistently induce violation of the lens condition. Given that all are city regions, we explored also whether the merging of these specific regions with their neighbouring regions alters the findings. We compared the endowment ratios for a merged Shanghai and Zhejiang (SHH+ZHJ) and for three possible combinations of Beijing, Tianjin and Hebei (BJ+HB-J, TJ+HB-J, and BJ+TJ+HB-J). Although the Shh+ZHJ merged regions no longer violate the lens condition, all the BJ, TJ and HB-J combinations continue to induce violations. The finding of some lumpiness is robust therefore to a range of sensitivity tests.

6. Direct Evidence on Regional Specialization

As outlined in section 2, sufficient lumpiness in the distribution of factors across regions gives rise to specialization in production in some regions, resulting in some regions at least specializing in different products to the country as a whole. This in turn will give rise to differences in the patterns of international trade across regions, and possibly to differences in the country's pattern of trade relative to that which would apply in the absence of lumpiness. In the present context we have the possibility to explore this directly because, unusually for a developing country, information on production and international trade is available for China by region. We are able therefore to investigate whether those regions for which there is an indication from the lens condition analysis of lumpiness do in fact have different patterns of production specialization and international trade to those for which there is no indication of violation of the lens condition.

Production Specialization by Region

In order to identify the regional specialization in production, *Production Specialization Indices* (PSI) are calculated for regions as follows:

$$PSI_{ir} = \frac{\frac{Q_{ir}}{Q_r}}{\frac{Q_{ic}}{Q_c}}$$

where

Q_{ir} = production of good *i* in region *r*

Q_r = total industry production in region *r*

Q_{ic} = production of good *i* in country *c*

Q_c = total industry production of good *i* in country *c*.

We set *i*= capital-intensive industries or high-skilled intensive industries according to whether they have a normalized factor endowments ratio greater than unity (see Appendix B). If PSI_i for the set of industries *i* is greater than 1, region *r* is more specialized in the production of capital or high skill intensive industries than the country as a whole.

Table 4 reports the results of a comparison of relative specialization in 'violating' and 'non-violating' regions. The table lists the regions that do and do not violate the lens condition in 1997 for the capital-labour representation and in 2004 for the high-low skill case. A production specialization index (PSI) is reported for each region for the relevant set of industries which are relatively capital or high skill intensive (i.e. more capital or high skill intensive than the average for manufacturing as a whole).

For both years we find more specialization on average in more capital (1997) and high skill (2004) –intensive industries in the 'violating' than 'non-violating' regions. All of the violating regions in both years have PSI indices in excess of unity (and clearly so) in both years. Although there are some anomalies (i.e. non-violating regions more specialized in capital intensive production and with higher PSI indices than all of the violating regions), 18 (21) out of the 25 non-violating regions have lower PSI indices than any of the violating regions in 1997 (2004). Some of the anomalies may be associated with the concentration of production in specific regions arising from aspects of geography (e.g. supplies of raw materials from the agricultural sector in to food, beverage and tobacco production or of mineral products in to metals production), which are not captured by the present representation of technology. Further, it should be noted that relative factor intensity is defined in the present analysis within the manufacturing sector only. This may upwardly or downwardly bias the measurement, depending on factor intensities in excluded tradables industries in the primary and secondary sectors. The evidence on production specialization offers some support, however, for the idea that regional heterogeneity in factor endowments affects the pattern of region specialization, which in turn affects the pattern of international trade by region.

Table 4: Production Specialization in Violating and Non-violating Regions

1997[1]				2004[2]			
a)Non-Violated Regions		b)Violated Regions		a)Non-violated Regions		b)Violated Regions	
HN-X	1.03	SHH	1.25	SCH	1.10	TJ	1.21
GZ	1.43	TJ	1.34	YN	1.23	SHH	1.15
ANH	0.73	BJ	1.43	HN-Y	0.88	BJ	1.25
GX	0.94			ANH	1.03		
YN	1.21			GZH	1.30		
GS	1.56			QH	1.30		
HN-Y	0.82			FJ	0.82		
SHX-SH	1.21			JX	1.03		
FJ	0.78			HLJ	0.79		
SCH	1.30			JS	1.05		
SHD	0.76			GX	1.02		
JX	1.06			GD	1.04		
HB-E	1.04			HN-X	1.01		
JL	1.60			SHX-J	1.08		
HLJ	1.04			SHD	0.81		
NX	1.18			GS	0.87		
HB-J	1.00			HB-E	1.10		
QH	1.56			HB-J	1.04		
ZHJ	0.70			NMG	1.09		
NMG	1.15			JL	1.28		
GD	0.90			NX	0.94		
SHX-J	1.43			SHX-SH	1.08		
LN	1.36			ZHJ	0.82		
XJ	0.86			LN	0.97		
JS	0.82			XJ	0.53		
Average	**1.10**	**Average**	**1.34**	**Average**	**1.00**	**Average**	**1.21**

[1] *PSI* for capital intensive industries excluding tobacco industry with K/L greater than 1.0 (normalized)
[2] *PSI* for HSL intensive industries excluding tobacco industry with HSL/LSL greater than 1.0 (normalized)

In table 5 we compare the pattern of exporting by violating and non-violating regions and type of product by factor intensity, using the same criteria to identify capital (and labour) and high skill (and low skill) intensive products as used to comment on the pattern of specialization. For both years and cases of violation of the lens condition the violating regions export absolutely more capital than labour intensive products (1997) or of high skill than low skill intensive products (2004). By contrast, in 1997 the non-violating regions export absolutely more labour than capital intensive products. In 2004 the contrast is less evident; the non-violating regions actually exporting absolutely more high skill than low skill-intensive products, though they exported relatively more low skill-intensive products than the violating regions. We find some evidence, therefore, consistent with 'lumpiness' affecting the trade pattern by region, but as may be expected actual trade patterns may be affected by other factors (taste, policy and non-endowment supply factors) as well as the regional distribution of endowments.

Table 5: Shares of Exports of Violating and Non-violating Regions (%)

i) 1997

	Violating Regions (SHH, TJ, BJ)	**Non-violating Regions**
(a) Capital-intensive exports	4.5	17.1
(b) Labour-intensive exports	1.4	77.0
(a)/(b)	3.2	0.22

ii) 2004

	Violating Regions (SHH, TJ, BJ)	**Non-violating Regions**
(a) High Skill-intensive exports	12.4	45.7
(b) Low Skill-intensive exports	3.8	38.1
(a)/(b)	3.3	1.2

7. Conclusions

This paper has explored whether 'lumpiness', in the sense identified by Courant and Deardorff (1992) is evident for China in two relative recent years (1997 and 2004). We show in section 2 that there is considerable heterogeneity of factor endowments across the regions of China. This is both where relative endowments are expressed in terms of capital and labour or in terms of high and low skilled labour, though on the former basis the degree of regional heterogeneity declined between 1997 and 2004. The critical issue for the present study, however, is not whether there is regional heterogeneity, but whether there is sufficient regional heterogeneity or lumpiness to affect China's specialization and international trade.

We first use a lens condition methodology, similar to that used by Debaere (2003), to identify whether there is evidence of violation of factor price equalization across regions. For a categorization based on 28 regions and 28 or 29 manufacturing industries we do find violation of the lens condition for 1997, but not 2004, when capital and labour endowments are used, and for 2004 when high and low labour skill endowments are used. This finding is shown, however, to be sensitive to the level of regional aggregation used. As shown by Bernard, Robertson and Schott (2005), satisfaction or not of the lens condition of factor price equalization is sensitive to relative degree of aggregation of regions and industries used. Holding the number of industries constant, we tested the lens condition for smaller numbers of regions (by grouping the initial regions). Violation of the lens condition disappears with a representation of China based on 12 regions. It is difficult, a priori, to assert the appropriateness of either the more or less aggregated regional representation, though it should be recognized that there is smoothing of regional differences in relative endowments as more aggregated regions are used.

Given the ambiguity arising from the lens condition analysis, we explore also direct evidence on patterns of production specialization and international trade across the regions of China. We find from this analysis that the violation of the lens condition for the 28 region representation is in general associated with patterns of production specialization and trade by regions that is consistent with the presence of 'lumpiness'. We conclude therefore that China at specific times, including as recently as 2004, has been sufficiently lumpy or regionally heterogeneous for this to affect its pattern of specialization and international trade.

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Appendix A: Data

Table A1: Chinese Regions

28 Chinese Regions	
Eastern Regions (12 regions)	Beijing (BJ), Tianjin (TJ), Hebei (HB-J), Shanghai (SHH), Jiangsu (JS), Zhejiang (ZHJ), Fujian (FJ), Shandong (SHD), Guangdong (GD), Jilin (JL), Liaoning (LN), Heilongjiang (HLJ)
Mid Regions (6 regions)	Anhui (ANH), Shanxi (SHX-J), Jiangxi (JX), Henan (HN-Y), Hubei (HB-E), Hunan (HN-X)
Western Regions (10 regions)	Neimenggu (NMG), Xinjiang (XJ), Guangxi (GX), Sichuan (SCH), Yunan (YN), Guizhou (GZ), Shanxi (SHX-SH), Gansu (GS), Qinghai (QH), Ningxia (NX)

Sectors

The Chinese Industrial Classification is closely linked to ISIC Rev. 3, except for some slight deviations.[8] Table A2 gives the concordance between these classifications in general terms. The concordance file we used for the data processing was complete in the sense that every single 4-digit ISIC code had a corresponding 2-digit GB/T 4754-94 code.

A 5-digit Standard International Trade Classification (SITC) production dataset and 6-digit Harmonized System (HS) trade dataset which was also transferred to 2-digit GB/T dataset using concordances SITC5 to ISIC4 and HS6 to ISIC4[9].

[8] See details from National Classification of China on United Nations Statistics Divisions. http://unstats.un.org/unsd/cr/ctryreg/ctrydetail.asp?id=115

[9] The HS6 to ISIC4 concordance file is provided by Feenstra. Robert.

Table A2: Concordance between Chinese Classification and ISIC

Chinese Code (GB/T 4754-94)	Corresponding ISIC Rev.3 Code	Manufacturing Industry
C13	14	Food Processing
C14	152, 153, 154	Food Manufacturing
C15	155	Beverage Manufacturing
C16	16	Tobacco Processing
C17	17	Textile Industry
C18	181, 192	Garments and Other Fiber Products
C19	182, 191	Leather, Furs, Down and Related Products
C20	20	Timber Processing, Bamboo, Cane, Palm Fiber and Straw Products
C21	361	Furniture Manufacturing
C22	21	Papermaking and Paper Products
C23	22	Printing and Record Medium Reproduction
C24	3692, 3693, 3694	Cultural, Educational and Sports Goods
C25	23	Petroleum Processing and Coking
C26	241, 2421, 2422, 2424, 2429	Raw Chemical Materials and Chemical Products
C27	2423	Medical and Pharmaceutical Products
C28	2430	Chemical Fiber
C29	251	Rubber Products
C30	252	Plastic Products
C31	26	Nonmetal Minerals Products
C32	271	Smelting and Pressing of Ferrous Metals
C33	272	Smelting and Pressing of Nonferrous Metals
C34	28	Metal Products
C35	291	Ordinary Machinery
C36	2921, 2922, 2923, 2924, 2925, 2926	Special Purpose Equipment
C37	34, 35	Transport Equipment
C40	31	Electric Equipment and Machinery
C39	2927	Weapon and Ammunition Manufacturing
C41	32	Electronic and Telecommunications Equipment
C42	3312, 3313, 332, 333	Instruments, Meters, Cultural and Clerical Machinery
C43	3691, 3699	Other Manufacturing

Appendix B

Table B.1: Factor Shares and Relative Factor Endowments By Region

Year 1997				Year 2004							
	Lr/Lc	*Kr/Kc*	*Kr/Lr*		*Lr/Lc*	*Kr/Kc*	*Kr/Lr*		*HSr/HSc*	*LSr/LSc*	*HSr/LSr*
HN-X	0.058	0.018	0.31	GZ	0.033	0.012	0.38	SCH	0.043	0.069	0.61
GZ	0.029	0.010	0.34	GX	0.040	0.018	0.45	YN	0.022	0.034	0.65
ANH	0.054	0.019	0.36	YN	0.036	0.019	0.52	HN-Y	0.057	0.076	0.76
GX	0.040	0.017	0.42	HN-Y	0.084	0.045	0.53	ANH	0.038	0.051	0.76
YN	0.036	0.016	0.45	GS	0.020	0.011	0.53	GZ	0.023	0.030	0.77
GS	0.025	0.012	0.47	ANH	0.052	0.028	0.54	QH	0.003	0.004	0.77
HN-Y	0.078	0.046	0.59	HN-X	0.054	0.030	0.55	FJ	0.022	0.028	0.78
SHX-SH	0.029	0.020	0.68	SCH	0.068	0.041	0.60	JX	0.026	0.033	0.80
FJ	0.026	0.019	0.72	SX	0.028	0.022	0.77	HLJ	0.025	0.031	0.80
SCH	0.075	0.055	0.74	JX	0.031	0.025	0.80	JS	0.050	0.059	0.85
SHD	0.085	0.069	0.81	HB-E	0.039	0.033	0.84	GX	0.034	0.038	0.89
JX	0.034	0.029	0.85	HLJ	0.024	0.021	0.84	GD	0.055	0.062	0.89
HB-E	0.042	0.040	0.95	HB-J	0.052	0.046	0.90	HN-X	0.047	0.052	0.90
JL	0.020	0.020	0.98	SHX-J	0.022	0.021	0.94	SHX-J	0.023	0.026	0.90
HLJ	0.027	0.028	1.03	FJ	0.027	0.027	1.00	SHD	0.067	0.071	0.95
NX	0.004	0.004	1.03	JL	0.017	0.017	1.00	GS	0.020	0.020	0.98
HB-J	0.054	0.056	1.04	QH	0.004	0.004	1.05	HB-E	0.048	0.047	1.00
QH	0.004	0.004	1.09	NX	0.004	0.005	1.21	HB-J	0.054	0.053	1.02
ZHJ	0.043	0.050	1.18	GD	0.065	0.085	1.30	NMG	0.022	0.019	1.16
NMG	0.017	0.022	1.29	SHD	0.074	0.101	1.35	JL	0.026	0.021	1.20
GD	0.060	0.079	1.32	LN	0.029	0.043	1.46	NX	0.005	0.004	1.26
SHX-J	0.023	0.031	1.32	XJ	0.011	0.017	1.47	SHX-SH	0.036	0.029	1.27
LN	0.032	0.045	1.41	NMG	0.015	0.026	1.68	ZHJ	0.047	0.036	1.32
XJ	0.012	0.021	1.79	JS	0.056	0.095	1.69	LN	0.048	0.033	1.48
JS	0.059	0.122	2.06	ZHJ	0.047	0.083	1.79	XJ	0.026	0.014	1.79
SHH	0.014	0.045	3.30	BJ	0.013	0.036	2.70	TJ	0.020	0.007	2.73
TJ	0.008	0.037	4.47	TJ	0.006	0.018	2.83	SHH	0.044	0.012	3.71
BJ	0.011	0.065	6.09	SH	0.012	0.044	3.59	BJ	0.048	0.009	5.13

Note: *Lr/Lc, Kr/Kc, LSr/LSc* and *HSr/HSc* means the share of total factor endowment (labour, capital, low-skilled labour and high-skilled labour) of China *c* in region *r*. *Kr/Lr* and *HSr/LSr* are the relative factor endowment ratio for each region *r*. The regions are listed with ascending order of the ratio in each year.

Table B.2: Shares of Factors and Relative Factor Intensities by Industry

Year 1997

	Li/Lm	*Ki/Km*	*Ki/Li*
Ordinary+special purpose machinery	0.126	0.037	0.29
Cultural, education products	0.011	0.005	0.44
Leather	0.022	0.010	0.46
Garments and Fiber	0.038	0.018	0.47
Furniture	0.007	0.004	0.55
Bamboo, cane and straw	0.015	0.010	0.64
Instruments and cultural machinery	0.014	0.010	0.70
Food	0.061	0.045	0.74
Metal products	0.040	0.031	0.76
Printing	0.016	0.012	0.79
Textile	0.115	0.091	0.79
Rubber	0.014	0.012	0.82
Nonmetal minerals	0.116	0.097	0.83
Electric equipment	0.047	0.045	0.95
Plastic	0.024	0.024	0.98
Paper	0.026	0.026	1.00
Medical products	0.018	0.020	1.12
Transport equipment	0.064	0.073	1.13
Beverage	0.023	0.031	1.36
Electronic and telecommunications	0.030	0.043	1.45
Chemical products	0.073	0.115	1.57
Nonferrous metals	0.019	0.036	1.96
Ferrous metals	0.054	0.121	2.25
Tobacco	0.005	0.014	2.84
Chemical fiber	0.009	0.027	2.84

Continued

Table B.2 (Continued)

Year 2004

	Li/Lm	*Ki/Km*	*Ki/Li*
Leather	0.037	0.008	0.21
Garments and fiber	0.059	0.014	0.24
Cultural, education products	0.019	0.005	0.26
Instruments and cultural machinery	0.022	0.008	0.36
Furniture	0.011	0.005	0.43
Other manufacturing	0.001	0.000	0.44
Electronic and telecommunications	0.015	0.008	0.55
Metal products	0.038	0.022	0.58
Textile	0.104	0.065	0.63
Weapon and ammunition	0.062	0.040	0.65
Ordinary machinery	0.061	0.040	0.67
Bamboo, cane and straw	0.014	0.009	0.67
Special purpose machinery	0.039	0.028	0.72
Plastic	0.031	0.026	0.84
Rubber	0.014	0.013	0.90
Food processing	0.035	0.033	0.95
Food manufacturing	0.020	0.019	0.97
Nonmetal minerals	0.073	0.074	1.01
Printing	0.011	0.012	1.05
Electric equipment	0.067	0.073	1.09
Transport equipment	0.060	0.073	1.21
Medical products	0.020	0.029	1.43
Beverage	0.015	0.022	1.47
Paper	0.023	0.034	1.50
Chemical products	0.058	0.096	1.67
Nonferrous metals	0.022	0.041	1.82
Ferrous metals	0.049	0.126	2.58
Chemical fiber	0.007	0.018	2.67
Tobacco	0.004	0.013	3.57

	HSi/HSm	*LSi/LSm*	*HSi/LSi*
Leather	0.013	0.041	0.31
Garments and fiber	0.025	0.064	0.38
Cultural, education products	0.008	0.020	0.41
Textile	0.047	0.112	0.42
Instruments and cultural machinery	0.012	0.023	0.52
Furniture	0.007	0.013	0.54
Bamboo, cane and straw	0.009	0.015	0.61
Rubber	0.010	0.015	0.68
Nonmetal minerals	0.052	0.076	0.68
Plastic	0.023	0.032	0.73
Paper	0.018	0.024	0.75
Other manufacturing	0.001	0.001	0.77
Metal products	0.030	0.038	0.78
Food processing	0.032	0.036	0.90
Printing	0.012	0.011	1.04
Chemical fiber	0.007	0.007	1.06
Food manufacturing	0.022	0.019	1.16
Weapon and ammunition	0.072	0.060	1.20
Ordinary machinery	0.071	0.059	1.20
Nonferrous metals	0.028	0.022	1.29
Ferrous metals	0.062	0.046	1.36
Beverage	0.020	0.014	1.41
Chemical products	0.076	0.054	1.42
Electric equipment	0.100	0.064	1.56
Special purpose machinery	0.059	0.036	1.63
Transport equipment	0.092	0.055	1.67
Electronic and telecommunications	0.024	0.014	1.76
Tobacco	0.006	0.003	2.13
Medical products	0.044	0.017	2.63

Note: *Li/Lm, Ki/Km, LSi/LSm* and *HSi/HSm* means the share of total factor employment (labour, capital, low-skilled and high-skilled labour) of manufacturing industry *m* in sector *i*. *Ki/Li* and *HSi/LSi* are the relative factor intensity ratio for each manufacturing sector *i*. The sectors are listed with ascending order of the ratio in each year.

Appendix C: Sensitivity Analysis

Table C.1: Factor Shares and Relative Factor Endowments By Region

Capital vs. Labour

Year 1988

8 Regions			
Yangtse River Mid	0.188	0.120	0.64
South West	0.181	0.131	0.73
South Coast	0.082	0.072	0.88
Yellow River Mid	0.145	0.142	0.98
East Coast	0.130	0.158	1.21
North West	0.042	0.051	1.21
North Coast	0.149	0.201	1.35
North East	0.083	0.125	1.51

Year 1997

8 Regions			
South West	0.180	0.098	0.54
Yangtse River Mid	0.188	0.107	0.57
Yellow River Mid	0.148	0.119	0.81
North West	0.045	0.041	0.92
South Coast	0.086	0.098	1.14
North East	0.079	0.092	1.17
North Coast	0.158	0.227	1.44
East Coast	0.116	0.218	1.88

Year 2004

8 Regions			
South West	0.202	0.112	0.55
Yangtse River Mid	0.176	0.115	0.65
Yellow River Mid	0.150	0.113	0.75
North West	0.042	0.039	0.94
North East	0.071	0.080	1.14
South Coast	0.098	0.117	1.19
North Coast	0.146	0.202	1.38
East Coast	0.115	0.222	1.93

High-Skilled Labour vs. Low Skilled Labour

Year 2004

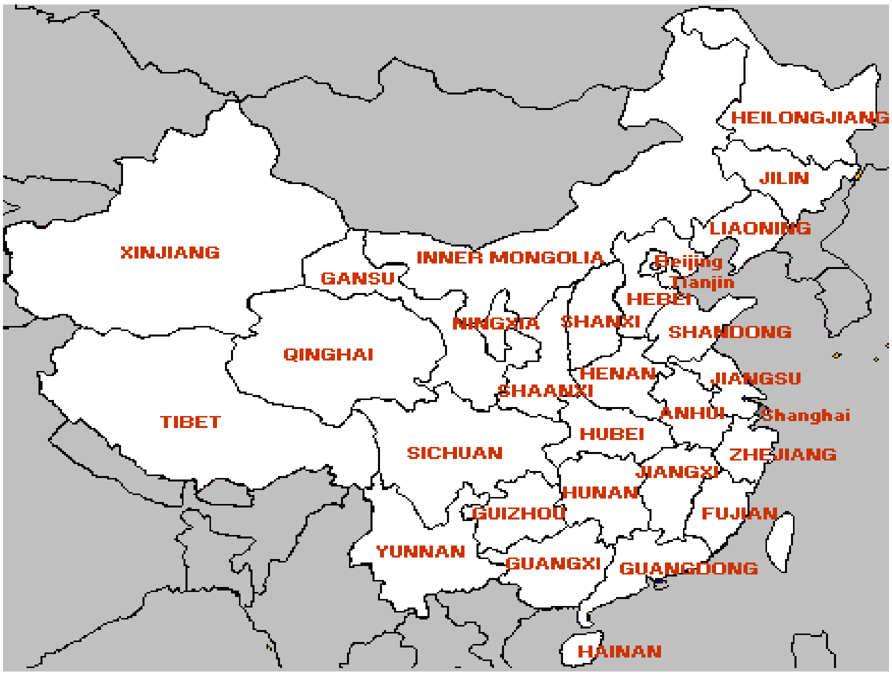
Coast

8 Regions	*HSr/HSc*	*LSr/LSc*	*HSr/LSr*
South West	0.137	0.196	0.70
South Coast	0.082	0.096	0.86
Yangtse River Middle	0.159	0.183	0.87
Yellow River Middle	0.138	0.149	0.93
North East	0.098	0.084	1.16
North West	0.054	0.045	1.21
East Coast	0.142	0.107	1.32
North Coast	0.189	0.147	1.35

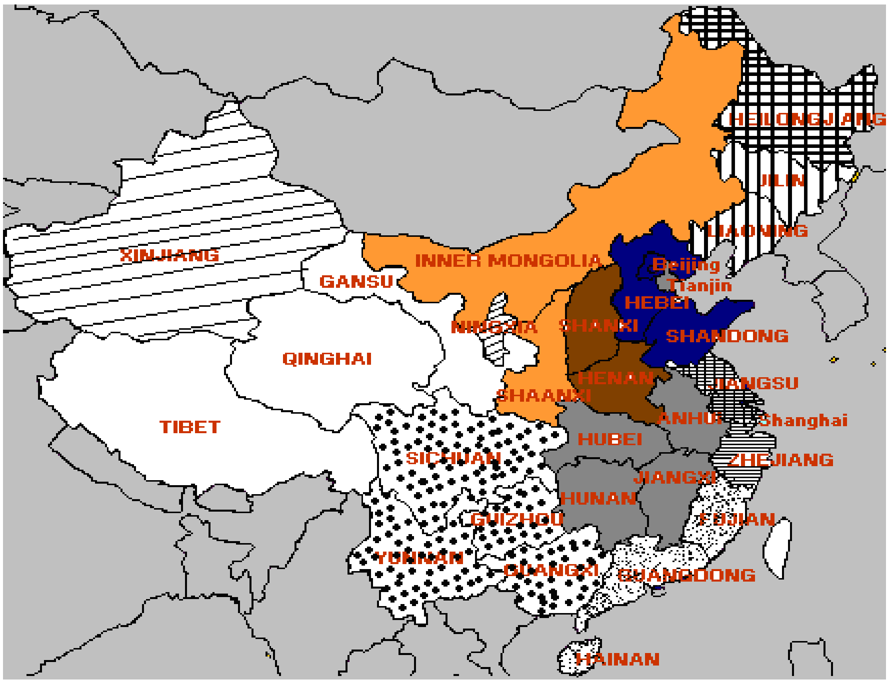
Year 2004

12 Regions	*HSr/HSc*	*LSr/LSc*	*HSr/LSr*
SCH,CQ,YN,GZ,GX (South West region)	0.137	0.196	0.70
SHX-J,HN-Y	0.081	0.102	0.79
HLJ	0.025	0.031	0.80
JS	0.050	0.059	0.85
GD,FJ,HN (South Coast region)	0.082	0.096	0.86
HB-E,ANH,JX,HN-X (Yangtze River region)	0.159	0.183	0.87
XZ,GS,QH	0.023	0.027	0.88
NMG,SHX-SH	0.058	0.047	1.23
HB-J,BJ,TJ,SHD (North Coast region)	0.189	0.140	1.35
JL,LN	0.074	0.054	1.37
XJ,NX	0.031	0.019	1.67
SHH,ZHJ	0.092	0.048	1.91

a)



b)



North East Region North Coast Region Jiangsu (JS) East Coast Region
South Coast Region Yangtze River Middle Region Xinjiang and Ningxia (XJ and NX)
North West Region Heilongjiang (HLJ) South West Region
Shanxi and Henan (SHX-J HN-Y) Yellow River Middle Region

Figure C.1 a) 12 Region Classification of China
b) 12 Region Classification of Region of China