De Economist (2022) 170:305–321
https://doi.org/10.1007/s10645-022-09407-7

ORIGINAL PAPER

Is Holland a Lumpy Country? An application of the Lens-Condition to Dutch Cities

Steven Brakman[1] · **Tijl Hendrich**[2] · **Charles van Marrewijk**[3] · **Jennifer Olsen**[2]

Accepted: 25 May 2022 / Published online: 14 June 2022

Abstract

Traditional trade theory assumes that countries are dimensionless points. Recent research, however, shows that the internal geography of countries is important for the trade structure of a country. One aspect of internal geography is the uneven spatial distribution of factors of production, which especially concentrate in urban locations. The so-called lens-condition (based on the Heckscher-Ohlin model) tests whether the (urban) distribution of factors of production is uneven enough to affect the national structure of trade and welfare. Our analysis, using firm export data and applying the condition to 22 cities and 4 regions within The Netherlands for 2007–2017, shows that the condition is fulfilled. We explain why.

Keywords Comparative Advantage · Cities · Location Characteristics, Lens condition

JEL-Codes F11 · F15 · R12

✉ Steven Brakman
s.brakman@rug.nl

Tijl Hendrich
t.j.m.hendrich@cpb.nl

Charles van Marrewijk
j.g.m.vanMarrewijk@uu.nl

Jennifer Olsen
j.d.olsen@cpb.nl

1 Faculty of Economics & Business, University of Groningen, Groningen, Netherlands

2 CPB Netherlands Bureau of Economic Policy Analysis, The Hague, Netherlands

3 Faculty of Economics, Utrecht University, Utrecht, Netherlands

1 Geography and Comparative Advantage

Traditional trade models assume that countries are just points in space; the internal geography of countries is ignored. This is a strong assumption. Recent research forcefully points out that by ignoring the internal geography of countries important facts about the effects of trade on, for example, regional development or income inequality are overlooked (see, for example, Donaldson 2018, or Hirte et al., 2020). The literature that points out that trade and the internal geography of countries are fundamentally linked is rapidly growing (see Redding, 2021, for a survey).

This research finds inspiration in standard trade models. Coşar and Fajgelbaum (2016), for example, show that in a Ricardian setting the internal trade costs split locations into two types; locations close to international gates are export oriented, whereas more distant locations do not trade. As a consequence the sensitivity of locations to trade shocks can differ considerably; the largest effects are found near borders (see Brülhart et al., 2018). Courant & Deardorff (1992, 1993) show that in a Heckscher-Ohlin setting of factor abundance, the spatial *uneven* distribution of production factors within a country can affect the national structure of trade in complex ways (see Debaere & Demiroglu 2003, Debaere, 2004, and Brakman & Van Marrewijk 2013, for empirical evidence). Models incorporating imperfect competition, for example incorporating production externalities in certain locations combined with trade costs, can explain the export orientation of certain industries in specific locations (Rossi-Hansberg, 2005). This interaction of agglomeration economies and trade costs, which is crucial in New Economic Geography models, can determine trade patterns between core and peripheral regions.[1] The welfare consequences can be substantial. Ramondo et al., (2016) point out that the gains from trade are reduced in large countries because of internal trade frictions between regions. The overall conclusion of this growing body of literature is that the internal geography of countries should be taken on board in trade analyses.

In this contribution we focus on Courant & Deardorff (1992, 1993). Their analysis, based on the Heckscher-Ohlin trade model, stands out because they relate the regional distribution of factors of production to the welfare maximizing national trade structure. The central question is, whether the so-called welfare maximizing integrated equilibrium is affected by regional characteristics. Courant & Deardorff (1992, 1993) provide a simple test to determine if the national trade structure is affected by an uneven, or 'lumpy', distribution of factors of production within a country. This test is the lens-condition. In general, if factors of production are not "too" unevenly distributed the lens-condition is fullfilled. Why factors of production are unevenly distributed is not part of this paper. We take the spatial distribution as given and analyze the trade consequences.

Whether or not the condition is fulfilled can have important policy consequences. If the lens-condition is fulfilled the spatial distribution of factors of production is consistent with the welfare maximizing integrated equilibrium (see Dixit & Norman 1980, for a discussion of the welfare implications. See Appendix B for a reminder of this concept). If, not a policy induced relocation of factors of production might

[1] See also Redding & Rossi-Hansberg (2017) for a discussion of this literature.

be called for to increase welfare. We use detailed firm-level data at the city level to determine whether the lens-condition holds for The Netherlands. Existing evidence on lumpiness is relatively scarce, and the evidence is also mixed. Debaere (2004) uses the lens-condition along with regional data to show that lumpiness is not an issue for the UK, India and Japan. Debaere & Demiroglu (2003) show that for the group of OECD countries the lens-condition is not violated. Bernard et al., (2010), however, argue that for Mexico regional lumpiness of production factors might be a significant factor. Brakman & Van Marrewijk (2013) show that at the city level the lens-condition is violated for most countries in their sample. Differences seem related to the level of aggregation: the province, region or city level. We choose the city level, because on higher levels of aggregation urban and rural areas are lumped together. So, the urban level of aggragation is a more natural spatial unit for an analysis of the lens-condition.

Importantly, if the lens condition holds, the national trade structure is not affected by the regional distribution of factors of production, and the welfare maximizing integrated equilibrium can be reproduced by the regional trade structure. As said, we focus on the city level because concentration of factors of production is most manifest in urban areas (and the city level provides a more strict test of the lens-condition than, for example, the regional level). Our analysis refers to 2007–2017. We use micro-firm export data, factor endowments and factor intensities for 22 Dutch cities, 4 regional areas, and 83 sectors (see Appendix A for a map of Dutch cities-region locations). We find that factors of production are unevenly spread over The Netherlands, but not to the extent that it affects aggregate trade flows: the lens-condition is fulfilled. This implies that the so-called welfare maximizing integrated equilibrium can be reproduced by the current spatial distribution of factors of production. In *this* sense the spatial distribution is optimal and so no policy actions are necessary. A reason for this result could be labor mobility within The Netherlands. Violation of the lens condition would imply factor price inequality, stimulating factor movements until the lens condition is fulfilled again.

The article is structured as follows. Section 2 discusses the lens-condition, Sect. 3 describes the data, Sect. 4 confronts the lens-conditon to Dutch data, Sect. 5 evaluates the main implications, and Sect. 6 concludes.

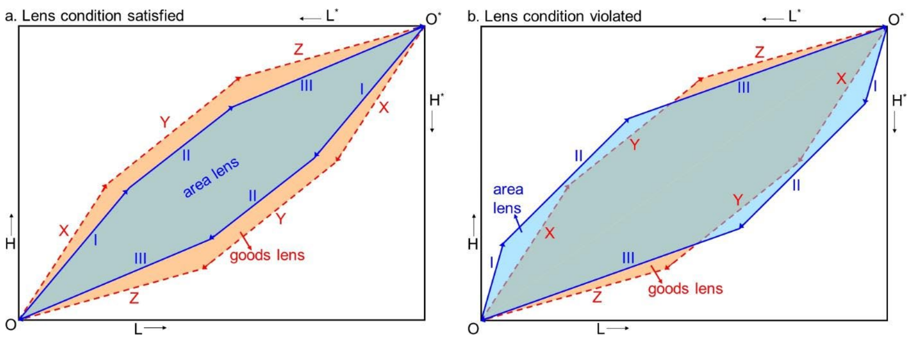


Fig. 1 The Lens-Condition

2 Theory of the Lens-condition[2]

The so-called *lens-condition* determines whether the regional allocation of production factors is within the Factor Price Equalization set in the Edgeworth box (see Courant & Deardorff 1992, for a discussion, and Appendix B for a reminder). If this is the case the welfare maximizing integrated equilibrium can be reproduced by trade flows. If not, this equilibrium cannot be reproduced by trade flows, which suggests that a government might like to relocate factors of production within a country.

The construction is straight forward. We can rank factor intensities of all sectors according to decreasing high skill / low skill intensities above the diagonal (and vice versa below the diagonal) and concatenate the corresponding vectors of factor intensity. Following a similar procedure we can concatenate the vectors of relative factor endowments in each area. If the line of relative factor intensities in the sectors encloses the line of relative factor endowments in the areas, the integrated equilibrium can be reproduced. This is called the *lens-condition* because if we introduce a large number of goods and areas the two concatenations look like lenses (see below).[3]

Figure 1 illustrates the condition for a three goods (X, Y, and Z) and three area (I, II, and III) example. In Fig. 1a the lens-condition is *satisfied*: the factor endowment lens for the areas is a subset of the (factor use) goods lens, indicating that the empirical distribution of the factors of production across the various areas within the country does not influence the country's overall trading position. In Fig. 1b the lens-condition is *violated*: the factor endowment lens for the areas is *not* a subset of the goods lens, indicating that the empirical distribution of the factors of production across the various areas within the country *does* influence the country's overall trading position and the welfare maximizing integrated equilibrium cannot be reproduced.

Note, that the lens-condition is less restrictive than is sometimes assumed. Courant & Deardorff (1993), for example, extent their model by including non-traded goods and amenity differences across locations that can explain factor price differences. Helpman & Krugman (1985) show that it is straightforward to extent the Edgeworth-box analysis with an increasing returns sector (they also discuss non-tradables in the Edgeworth-box setting). Whereas Dixit & Norman (1980) point out that one can include trade costs by redefining one of the goods as a transportation service that is used by the traded good sectors.

3 Data

Statistics Netherlands defines 22 city districts, which consist of municipalities with city-status as well as surrounding municipalities that are determined to be economically dependent on the city. Municipalities that do not form part of any city district are grouped by NUTS 1 region, forming four regions: North, South, West and East (see Appendix A).

[2] Note that this section is partly based on Brakman & Van Marrewijk (2013).

[3] See also Debeare and Demiroglu (2003) for a more detailed discussion of the lens-condition.

In terms of factors of production, our analysis focuses on human capital in terms of skills from schooling for cities-regions as well as sectors.[4] We use annual registry data on the highest attained level of education for Dutch citizens to identify three skill levels for general schooling, labelled high-, medium-, and low-skilled (with sub-indices *high*, *med*, and *low*, respectively).[5] In addition, we differentiate between technical and non-technical types of schooling using the same classification (identified by

Table 1 Skill abundance in cities-regions; ranked by high-skilled, per cent, 2017

City-region	General schooling share		Technical schooling share	
	High-skilled	Low-skilled	High-skilled	Low-skilled
Utrecht	44.5	22.4	7.6	1.8
Nijmegen	39.3	24.1	6.2	2.4
Groningen	38.4	20.1	5.2	2.0
Amsterdam	37.0	26.4	5.0	2.2
Leiden	36.9	25.3	6.3	2.3
Den Bosch	35.5	27.5	5.8	2.9
Eindhoven	34.3	27.3	9.3	3.2
Amersfoort	34.2	27.5	5.7	2.6
Zwolle	33.9	25.3	4.3	2.7
Haarlem	33.8	27.1	5.0	2.5
Maastricht	33.0	27.3	4.7	3.0
Breda	32.2	27.3	5.0	2.9
The Hague	32.1	30.4	7.1	2.5
Arnhem	30.9	29.3	5.3	2.8
Tilburg	30.4	28.9	4.2	3.3
Enschede	27.5	30.0	5.8	3.2
West	26.8	29.9	4.4	3.4
Geleen-Sittard	26.7	31.8	5.1	3.7
Apeldoorn	26.7	30.9	4.4	3.3
Leeuwarden	26.6	27.2	3.4	3.1
Rotterdam	26.1	34.0	4.0	3.0
East	24.2	31.6	4.3	3.9
South	24.1	32.3	4.5	4.5
Dordrecht	23.6	32.5	4.0	3.7
North	20.8	32.0	2.9	4.2
Heerlen	20.5	36.5	3.6	4.6

Source: author calculations; exports as per cent of Dutch total; skill distribution as per cent of working population (15 to 75 years), based on place of residence.

[4] Unfortunately, we have no reliable information on the capital abundance in regions-cities, nor on the capital intensity in sectors, so, like land, this factor of production is excluded from the analysis.

[5] Citizens that have no registered education are excluded from our analysis, as are citizens that are not of working age as defined by Statistics Netherlands (working age is 15–75 years old).

subindices *tec-high*, *tec-med*, and *tec-low*).[6] Note, that the regular skills classification shares add to one, while this is not the case for technical skill shares; we therefore use the sub-index *tech* to refer to the sum of *low*, *medium*, and *high* technical skill.

We analyse differences in human skills from two perspectives: From a cities-regions perspective (we refer to this as the *abundance* of skills in a location), and from a sector perspective (we refer to this as the *intensity* of skills in a sector). Citizens are assigned to cities-regions using their registered home addresses, and to sectors using their work locations from firm-level job data.

Regarding skill abundance, Table 1 provides some information for 2017. The table is ordered by the share of high-skill workers, starting with Utrecht, Nijmegen, and Groningen (which are relatively abundant in high-skill workers) and ending with Dordrecht, North, and Heerlen. The highest share for Utrecht is 44.5 per cent, the lowest share for Heerlen is 20.5 per cent. Obviously, if the share of high-skilled workers is relatively high, the share of low-skilled workers tends to be low (correlation is -0.89). Table 1 also provides information on the abundance of technical skills. Regarding technical high-skilled workers, Eindhoven ranks highest (9.3 per cent), followed by Utrecht and The Hague, while Heerlen, Leeuwarden, and North (2.9 per cent) rank lowest. Although there is substantial variation in the ordering of high-skilled workers and technical high-skilled workers, the correlation between these two variables is strongly positive (0.68). Nonetheless, it is clear that the cities-regions are diverse in terms of the skill abundance of their inhabitants.

Regarding skill intensity, Table 2 provides some information for 2017 for the top and bottom five sectors in terms of high-skill worker shares, where workers are

Table 2 Sector skill intensity; Top 5 and Bottom 5 by high-skilled workers, 2017

		Size	General schooling		Technical schooling	
SBI	Sector	# work	High-skill	Low-skill	High-skill	Low-skill
Top 5 sectors high-skilled intensity						
85	Education	515	80.8	3.3	5.7	1.0
72	R&D	31	78.2	3.1	41.8	0.5
60	Program & broadcasting	8	73.4	2.9	2.5	0.4
64	Financial institutions	86	71.8	3.5	8.6	0.4
70	Holding companies	116	71.1	4.4	16.1	0.7
Bottom 5 sectors high-skilled intensity						
49	Land transport	139	10.5	29.8	1.6	6.2
56	Food services	504	10.4	33.8	0.9	3.1
81	Facility management	172	9.5	46.8	1.7	5.0
96	Wellness; funeral activity	59	9.5	24.0	0.8	2.0
80	Security & investigation	34	8.9	19.0	1.2	2.0

Source: author calculations; size by working population ($\times 1000$); skill distribution as % working population.

[6] For this we use the categorization of education programmes created by Statistic Netherlands. We consider a category 'technical' if it falls within "Natural Sciences, Mathematics, and Statistics", "Information and Communication Technologies" or "Engineering, Manufacturing, and Construction".

counted in full time equivalents (fte). The top-5 sectors employ around 80 per cent of high-skill workers, starting with (not surprisingly) education and R&D. The bottom-5 sectors have around 10 per cent of high-skilled workers, including wellness and security. A large sector in terms of the number of workers at the top is education (515 thousand), whereas the food sector is large at the bottom (504 thousand). There are substantial differences in terms of the technical intensities of the sectors. Education and R&D both require about 80 per cent of high-skill workers, but in terms of technical skills, education requires only 5.7 per cent of technical high-skilled workers compared to 41.8 per cent for R&D (more than seven times as much). When comparing Tables 1 and 2, it is clear that the sectors are more diverse in terms of their skill intensities than the cities-regions are in terms of their skill abundance, see also Sect. 5.

4 The Lens-condition for Dutch Cities

The empirical question we need to answer in light of the above discussion is thus whether the lens-condition is satisfied, or not, for Dutch cities. The concentration of factors of production is the most evident in cities. So, cities are a natural starting point for the analysis. We have information available on factor distributions and factor intensities for different labor skills. We identify three skill levels (low, medium, and high) and two skill types (technical and non-technical). The modest number of $2 \times 3 = 6$ factors of production already presents us with a large number of possible

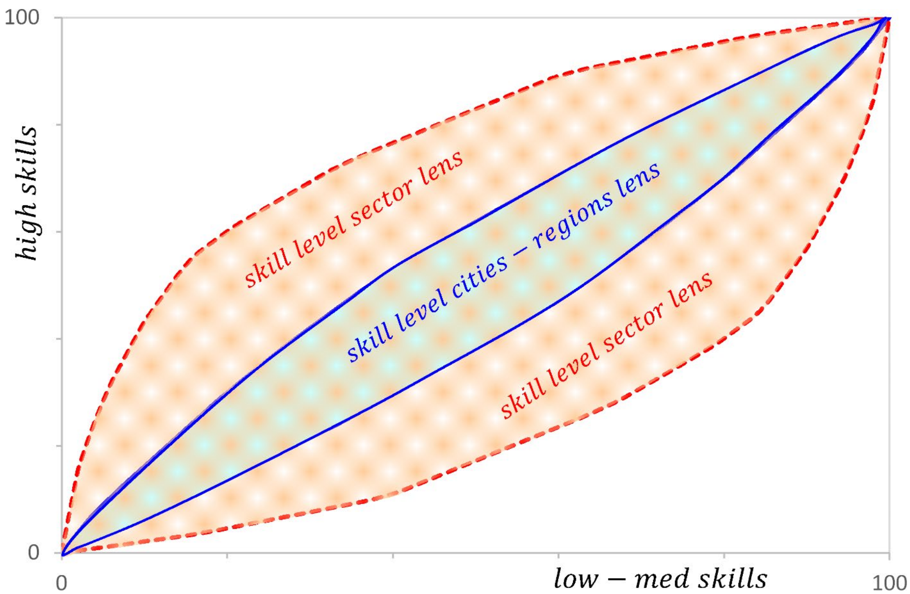


Fig. 2 Dutch General Skills Lens-condition, 2017. (Source: authors; low-med=combination of low and medium skill level; cities-regions represent the 'area'-level, economic sectors represent the 'goods' level)

lens-conditions in 2-dimensional space, in particular if we also combine factors of production.[7] To streamline the analysis, we focus on the lens-condition for 2017 in two steps, by first discussing the general skills and then go into more detail for the different technical skills.[8]

Nationally, in 2017, 29.5 per cent of the Dutch working population had a high skill level, 41.0 per cent had a medium skill level and 29.5 per cent had a low skill level. In the period 2007–2017, the share of the working population with a high skill level has been rising by 2.9% points and with a medium skill level with 2.2% points. This obviously implies that the share with a low skill level has been declining by 5.1% points in this period. For our skill level lens discussion, we combine the low and medium skills and compare with the high skills. For any lens we construct, we normalize each factor of production to range from 0 to 100.

Of the 26 cities-regions, Heerlen has the lowest share of high skill workers (20.5 per cent), while Utrecht has the highest share (44.5 per cent). To create the area / cities-regions lens, we order the locations in terms of high skill relative to low skill abundance (both rising and falling) and create vectors with a length proportional to the number of workers in that location (which ranges from about 93 thousand in Maastricht to more than 1 million in West). The result is illustrated in Fig. 2 under the label 'skill level *cities-regions* lens'. With high skill on the vertical axis and low-med skill on the horizontal axis, the steepest slope of the cities-regions lens (for Utrecht) is 1.91, which is 3.1 times steeper than the flattest slope of 0.61 (for Heerlen). The difference is thus substantial, but not enormous, making the skill level cities-regions lens not too wide (see Fig. 2).

Of the 83 Dutch sectors of production, sector 80 (security and detection) has the lowest share of high skill workers (8.9 per cent), while sector 85 (education) has the highest share (80.8 per cent). To create the goods / sector lens, we order the sectors in terms of high skill relative to low-med skill intensity (both rising and falling) and create vectors with a length proportional to the number of workers in that sector (which ranges from about 805 for sector 12 [tobacco] to about 1.4 million for sector 78 [temporary employment agencies]). The result is illustrated in Fig. 2 under the label 'skill level *sector* lens'. With high skill on the vertical axis and low-med skill on the horizontal axis, the steepest slope of the sector lens (for sector 85) is 7.87, which is 42.9 times steeper than the flattest slope of 0.18 (for sector 80). The difference is thus much larger than for the area lens, which in combination with all the other sectors of production creates a fairly wide sector lens.

Figure 2 depicts both the skill level sector lens and the skill level cities-regions lens. Since the sector lens is much wider than the cities-regions lens, it immediately

[7] There are 15 combinations of the 6 production factors. If we look only at the levels there are 3 more combinations, while if we only look at the types there is 1 more combination. If we combine factors of production, as we do in Figs. 2 and 3, more combinations are possible, but some of these would make no sense. For example, it seems reasonable to compare high skill levels relative to a combination of low & medium skills or low skill levels relative to a combination of high & medium skills, but not to compare medium skill levels relative to a combination of high & low skills. Viewed this way, the combinations provide an additional 6 possibilities (4 at the production factor level and 2 at the education level) for a total of 25 possible combinations for each year.

[8] Results for other years are similar.

follows that the lens-condition is *satisfied*. This is in contrast to the conclusion in Brakman and van Marrewijk (2013). We return to this in the Sect. 5. For now, we go one step deeper by analysing the lens-condition for both the type and level of skill, where we focus on technical workers.

Nationally, 15.4 per cent of the Dutch working population had technical schooling in 2017, a decline by 0.4% points relative to 2007. Of the workers with technical schooling in 2017, about 20.8 per cent had a low skill level, 46.9 per cent had a medium skill level, and 32.3 per cent had a high skill level. Relative to the total Dutch working population, this translates to 3.2 per cent with a low technical skill level, 7.2 per cent with a medium technical skill level, and 5.0 per cent with a high technical skill level. Please keep in mind, therefore, that the sum of low-, medium-, and high technical skill levels does not add up to 100 per cent (but to 15.4 per cent nationally). For our technical skill level lens discussion, we combine (as above) the low and medium technical skill levels and compare with the high technical skill level.

Of the 26 cities-regions, North has the lowest share of technical high skill workers (2.9 per cent), while Eindhoven has the highest share (9.3 per cent). Ordering the locations in terms of rising and falling abundance of technical high skill workers relative to technical low-med skill workers in combination with the number of workers at each location allows us to derive the 'tech skill level *cities-regions* lens' as illustrated in Fig. 3. With technical high skill on the vertical axis and technical low-med skill on the horizontal axis, the steepest slope of the cities-regions lens (for Eindhoven) is 1.96, which is 3.4 times steeper than the flattest slope of 0.58 (for North). This difference is similar to what we found for the cities-regions lens in Fig. 2, although

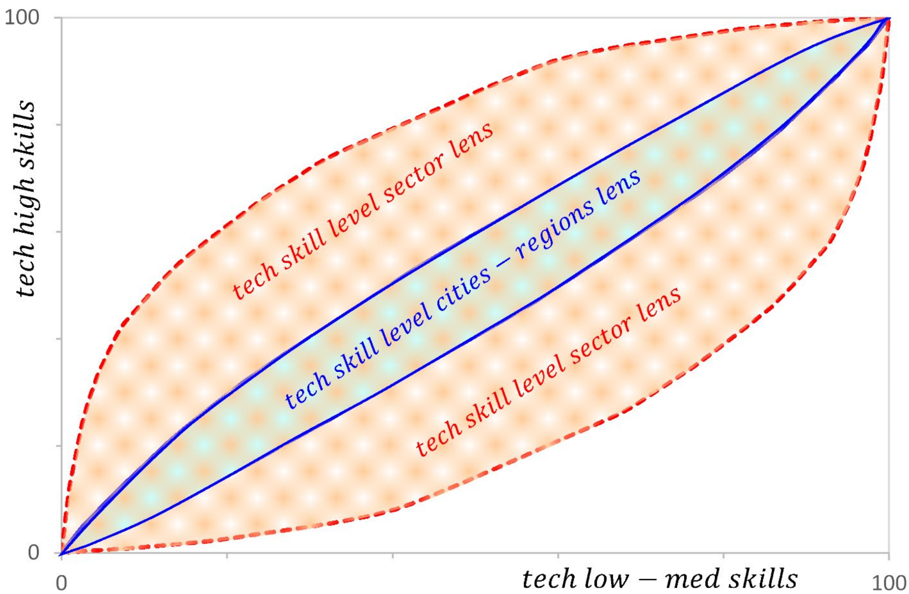


Fig. 3 Dutch Technical Skills Lens-condition, 2017. (Source: authors; tech=technical; low-med=combination of low and medium skills)

in combination with the other locations the resulting cities-regions lens is somewhat smaller (compare Fig. 3 with Fig. 2).

Of the 83 Dutch sectors of production, sector 87 (nursing care with guidance for overnight stay) has the lowest share of technical high skill workers (0.6 per cent) and sector 71 (architects, engineers and technical design & advice) has the highest share (44.9 per cent). Using a similar procedure as before, we create the 'tech skill level *sector* lens' in Fig. 3. With technical high skills on the vertical axis and technical low-med skills on the horizontal axis, the steepest slope of the sector lens (for sector 71) is 13.53, which is 140 times steeper than the flattest slope of 0.10 (for sector 87). As shown in Fig. 3, this is much wider than the cities-regions lens and the lens-condition is again easily *satisfied*.

5 Explanation and Implications

The analysis in Sect. 4 shows that the lens-condition is satisfied for the general skills level and the technical skills level. A similar picture and conclusion arises for all other possible combinations.[9] This section explains from an analytical perspective why this is the case. We conclude by pointing out what the main implications are for our analysis of the comparative advantage of Dutch cities-regions.

From an analytical perspective, the cities-regions lens can only be a subset of the sector lens if this holds close to the respective origins of the Edgeworth-boxes. This requires that the minimum slope of the sector lens is lower than the minimum slope of the cities-regions lens, while the maximum slope of the sector lens is larger than the maximum slope of the cities-regions lens. These slopes are determined by the shares of factor abundance in locations for the cities-regions lens and the shares of factor intensities in sectors for the sector lens, so the slope requirements translate to share requirements.

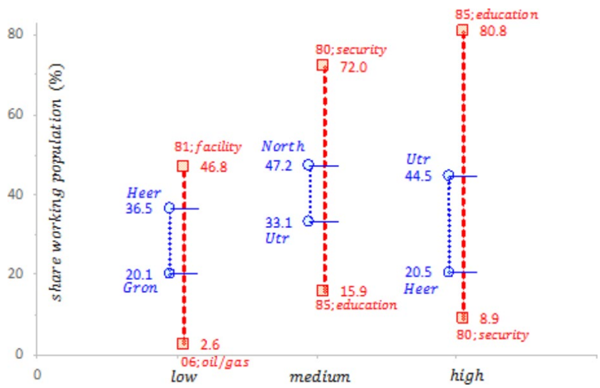


Fig. 4 Skill Level Ranges for Dutch Cities-Regions and Sectors, 2017. (Source: authors; Heer = Heerlen; Utr = Utrecht; Gron = Groningen)

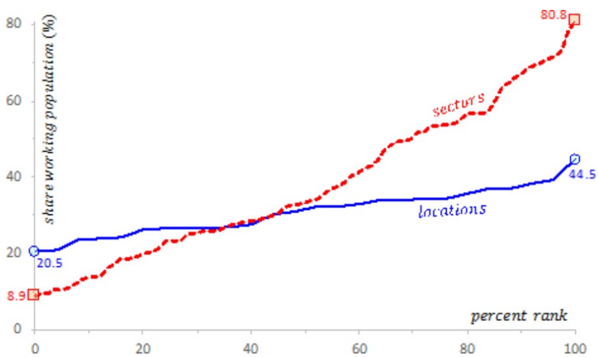
[9] This amounts to 6 combinations in total: 3 skill levels (high, medium, low) x 2 skill types (technical and non-technical).

Figure 4 provides the range of skill level shares (of working population in per cent) for Dutch cities-regions and sectors in 2017 for low, medium, and high skill levels. In all cases, the cities-regions shares are strictly in between the sector shares and the cities-regions range constitutes only a modest fraction of the sector range (about 1/3rd). For the high skill levels, this translates directly to the differences in slopes and slope ratios illustrated in Fig. 2 and discussed in Sect. 4, where the sector lens starts off much wider than the cities-regions lens. Similar remarks hold for the other skill levels. The cities-regions shares are strictly in between the sector shares and the cities-regions range constitutes only a small fraction of the sector range (about 27 per cent for non-technical workers and only 17 per cent for technical workers). In all cases, therefore the sector lens contains the cities-regions lens close to the origins and is much wider, as illustrated in Figs. 2 and 3.

Note that the technical analysis close to the origins is a necessary but not sufficient condition for the lens-condition to be satisfied because the violation could, in principle, also occur more towards the center of the (Edgeworth) box in Fig. 2 or Fig. 3 (see, for example, Fig. 1b). This situation does not arise in our data set because we have detailed factor intensity information available for 83 different sectors wich differ substantially in their factor shares. This is illustrated in Fig. 5 for the high skill share rank distribution for sectors and locations in 2017. There are 26 locations ordered from lowest per cent rank (0) to highest (100) with high skill shares from 20.5 to 44.5 per cent (see also Fig. 5). Similarly, there are 83 sectors ordered from lowest to highest with high skill shares from 8.9 to 80.8 per cent (see again also Fig. 5). The point is that there are many sectors with different sector shares over a wide range. As a consequence, the sector lens gradually moves from high to low slopes (or vice versa), which ensures that the sector lens is fairly wide (as in Figs. 2 and 3) and strictly contains the cities-regions lens over the entire domain.

An economic explanation for the fulfillment of the lens-condition in the Netherlands is labor *mobility*. Violation of the lens-condition implies factor price *in*equality. If factors of production (in this case different types of labor) respond to these factor price differences, the labor distribution and composition adjusts. In other words, the

Fig. 5 High Skill Share Rank Distribution, 2017. (Source: authors)



cities-regions lens is *endogenous* as a result of mobility of factors of production.[10] There are many potential obstacles to mobility within countries, based on distance, cultural-, religious-, language differences, or amenities (such as climate), and legal restrictions. In a small country like the Netherlands there are no legal restrictions to factor mobility, (commuting-) distance plays a minor role, the climate is similar throughout the country, everyone speaks the same language and has a similar culture, while religious obstacles for migration seem to be minor. We should therefore not be surprised if the cities-regions lens adjusts through migration flows to become a subset of the sector lens.

6 Conclusions

Traditional trade models assume that countries are just points in space; the internal geography of countries is ignored. This is a strong assumption. Recent research forcefully points out that by ignoring the internal geography of countries important consequences of regional characteristics on trade are overlooked. The overall conclusion of this recent literature – that finds inspiration in all of the classic trade models such as the Ricardian, Heckscher-Ohlin and imperfect competition models – is that trade and the internal geography of countries are fundamentally linked.

In this contribution we focus on Courant & Deardorff (1992, 1993). Their analysis, based on the Heckscher-Ohlin trade model, stands out because they relate the regional distribution of factors of production to the welfare maximizing national trade structure. The central question they answer is whether the so-called welfare maximizing integrated equilibrium is affected by regional characteristics. This can be tested by the lens-condition. In general, if factors of production are not "too" unevenly distributed the lens-condition is fullfilled and the welfare maximizing equilibrium can be reproduced.

We test the lens-condition for The Netherlands, for the period 2007–2017, using micro-firm export data. We have factor endowments and factor intensities for 22 Dutch cities, 4 regional areas, for 83 sectors. We find that the uneven distribution of factors of production across Dutch cities does not affect aggregate trade flows. This implies that the so-called welfare maximizing integrated equilibrium can be reproduced by the current spatial distribution of factors of production. In *this* sense the spatial distribution is optimal and no policy actions are necessary.

[10] In a long-run perspective, the sector lens is also endogenous as it changes in response to R&D efforts, but these changes are likely to require more time than adjustments of the area lens because of migration.

7 Appendix A: Dutch Cities-Regions Locations

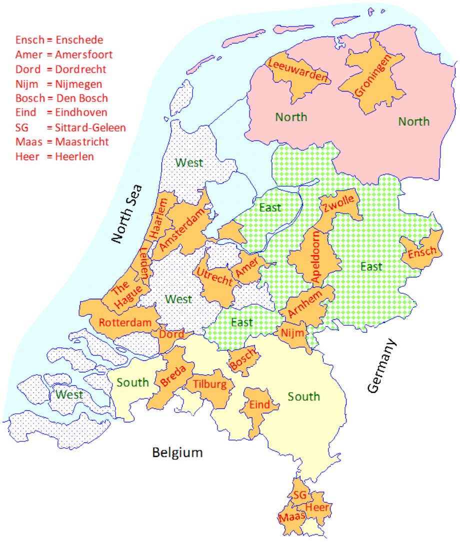


Figure A1 Dutch Locations; 22 Cities and 4 Regions. (Source: constructed by authors. Based on CBS 2005, *Grootstedelijke agglomeraties en stadsgewesten afgebakend)*

8 Appendix B: The Edgeworth box - A reminder

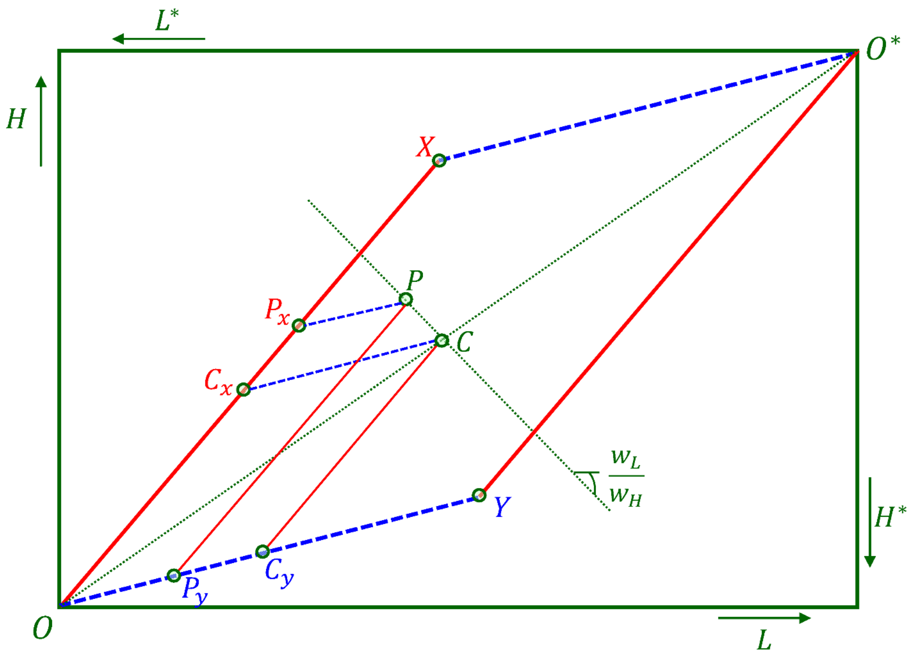


Figure B1 The Integrated Equilibrium

Figure A1 – made popular by Dixit & Norman (1980) – depicts the so-called integrated equilibrium. The idea behind this figure is straightforward. Suppose we start with a perfectly integrated world, in which there are no distortions, with two factors of production – human capital H and labor L – and two goods, X and Y, produced under constant returns to scale. The amounts of capital and labor are given and fixed. The total amount of labor is depicted on the horizontal axis, and the total amount of human capital along the vertical axis. Ignore O^* for the time being. The final, welfare maximizing, equilibrium is characterized by equilibrium goods prices, factor prices, and full employment of factors of production. This equilibrium is welfare maximizing under normal circumstances. Equating demand and supply gives us the equilibrium prices for X and Y, while factor market clearing – together with the prices of X and Y – gives us the factor prices, w_H and w_L, for human capital and labor, respectively.

Figure A1 depicts this equilibrium. Suppose the origin is indicated by O, then the equilibrium for the integrated equilibrium is characterized by OX of good X, and OY of good Y (with an adequate unit of measurement). The slope of the vectors indicate that we have assumed that X is human capital intensive and Y is labor intensive.[11] If we perform a vector summation on OX and OY, total factor usage in both

[11] In order to avoid cluttering of the figure, the isoquants along the rays OX and OY are not drawn. Isoquants are combinations of L and K that produce the same amount of X (or Y). If $X=F(K,L)$ is a production function for X (and similarly for Y), then with Constant returns to scale we have: $\lambda X=F(\lambda K, \lambda L)$.

sectors is exactly equal to the total amount of available factors of production. Note, that this also holds for total consumption (which is obvious because in equilibrium supply equals demand)

The most fundamental question in international economics is: can this welfare maximizing equilibrium be reproduced once this ideal integrated world is split into two separate countries in which factors of production are redistributed over the two countries and no migration is allowed. The surprising answer is, yes, it can, but under certain conditions. We illustrate this for – what is known as – the $2 \times 2 \times 2$ model. That is, we have two countries, two goods and two factors of production. Total world endowment, L measured along the horizontal axis and H measured along the vertical axis, is split between two countries. Home endowments are measured starting from O , and Foreign endowments are measured starting from O^*. This ensures that we have the same total amount of factors of production as before in the integrated equilibrium. Suppose P describes the distribution of factors of production over both countries. The position of P is important. As drawn it is above the diagonal OO^*, indicating that Home is relatively human capital abundant. We can now construct a parallelogram between O and P. This gives, using the same production techniques as in the integrated equilibrium, the production of X and Y that is consistent with full employment in Home: P_x and P_y (vector addition of these two vectors gives P).

Next we turn to consumption. Home's income equals: $I = w_H H + w_L L$, where H and L are the total amounts of the factors of production in Home (corresponding to point P); w_H and w_L are the factor prices, which are the same as in the integrated equilibrium. We can draw this income in Figure *A1* through P and C as: $H = I - \left(\frac{w_L}{w_H}\right) L$. Furthermore, if we assume that preferences are homothetic and identical in both countries, we know that the consumption points are on the diagonal if prices are the same in both countries. An example of such preferences is a Cobb-Douglas utility function: $U = Y^{1-\mu} X^{\mu}$, with $1 - \mu$ as the budget share of Y and μ as the budget share of X . With free trade prices of both commodities are the same in both countries (excluding for the moment the case of complete specialization). With the help of the income line we can find the consumption point; it must be on the income line through P (factor endowments determine income) and on the diagonal (along this line the ratio of X consumption relative to Y consumtion in both countries is identical). This gives consumption point C. Constructing a parallelogram between O and C and comparing the resulting consumption of X and Y with the production of X and Y we immediately conclude from the figure that Home exports $P_x - C_x$ of X , and imports $C_y - P_y$ of Y. This outcome makes sense as human capital abundant Home exports the human capital intensive good X , which is the prediction of the Heckscher-Ohlin model. The difference between the factor content of P and C is the factor content of trade, which is key in empirical tests of the Heckscher-Ohlin model. The Figure shows that Home is a net exporter of human capital (the vertical difference between P and C), and a net importer of labor. It is intuitively clear that Home exports human capital: it is the human capital abundant

Doubling the amount of *K* and *L (*that is, $\lambda=2$*)* we produce twice the amount of *X*. So, the length of the rays correspond to the total production of *X* or *Y*. Because of Euler's theorem the slopes of isoquants intersecting with a ray through the origin are identical.

country, and in autarky the marginal return of human capital is lower than in Foreign (this is why Home has a comparative advantage in X, the human capital intensive good). Through trade in commodities human capital is exported to Foreign (where the marginal return is higher). Trade thus equalizes the returns on production factors. This is why the parallelogram $OXO^{*}Y$ is also know as the Factor Price Equalization set. It is straightforward to repeat the exercise for Foreign. The resulting total production of X and Y and total consumption of both goods, and the production techniques (that is, the slope of OX and OY) is the same as in the integrated equilibrium.

What this construction illustrates is that the integrated equilibrium can be reproduced through trade in goods if factors of production are distributed over two countries instead of being part of a single integrated economy. Only trade in goods is needed to reproduce the welfare maximizing outcome. We can reconstruct the integrated equilibrium for all endowment distributions for the two countries that belong to the parallelogram $OXO^{*}Y$, which is called the factor price equalization set; no matter the distribution of production factors in this set, factor prices, and good prices are the same as in the integrated equilibrium. What happens if we move outside this set, or in the terminology of this paper, if the distribution of factors of production is too lumpy (too different)? Inside the set initial differences between factor prices can be eliminated by trade. Outside this set the differences between factor prices are too large to be completely eliminated through trade. In a qualitative sense the trade prediction of the Heckscher-Ohlin model still holds; the labor abundant country will export the labor intensive commodity. However, total production and consumption in this case will differ from that of the integrated equilibrium. Also welfare will be smaller than in case of the integrated equilibrium (to see this; construct two income lines through a point outside the parallelogram $OXO^{*}Y$, such that labor is relatively less expensive in the labor abundant country, and human capital relatively less expensive in the human capital abundant country. The intersection of these two lines with the diagonal – international prices for X and Y will be identical in the two countries – are such that total world consumption of both goods is smaller than in the integrated equilibrium; the effect of borders is felt in these cases.)

References

Bernard, A. B., Robertson, R., & Schott, P. K. (2010). Is Mexico a Lumpy Country? *Review of International Economics*, *18*, 937–950

Brakman, S., & Van Marrewijk, C. (2013). Lumpy countries, urbanization, and trade. *Journal of International Economics*, *89*(1), 252–261
Brülhart, M., C.Carrere, and, & Robert-Nicoud, F. (2018). Trade and towns: Heterogeneous adjusment to a border shock. *Journal of Urban Economics*, *105*, 162–175
Coşar, A. K. (2016). and P.D.Fajgelbaum Internal Geography, International Trade, and Regional Specialization, American Economic Review:Microeconomics, Vol.8, pp.24–56
Courant, P. N., & Deardorff, A. (1992). International Trade with Lumpy Countries. *Journal of Political Economy*, *100*, 198–210
Courant, P. N., & Deardorff, A. (1993). Amenities, Nontraded goods, and the Trade of Lumpy Countries. *Journal of Urban Economics*, *34*, 299–317
Debaere, P. (2004). Does Lumpiness Matter in an Open Economy? Studying International Economics with Regional Data. *Journal of International Economics*, *64*, 485–501
Debaere, P., & Demiroglu, U. (2003). On the Similarity of Country Endowments. *Journal of International Economics*, *59*, 101–136
Donaldson, D. (2018). Railroads of the Raj: Estimating the Impact of Transportation Infrastructure. *American Economic Review*, *108*, 899–934
Dixit, A., & Norman, V. (1980). *Theory of International Trade: A Dual, General Equilibrium Approach*. Cambridge, U.K: Cambridge University Press
Helpman, E., & Krugman, P. R. (1985). *Market Structure and Foreign Trade: Increasing Returns, Imperfect Competition, and the International Economy*. Cambridge, MA: MIT Press
Hirte, G., C.Lessmann, and A.Seidel (2020). International Trade, Geographic Heterogeneity and interregional inequality. *European Economic Review*, *127*, 1–23
Ramondo, N., Rodriguez-Clare, A., & Saborio-Rodriguez, M. (2016). Trade, domestic frictions, and scale effects. *American Economic Review*, *106*, 3159–3184
Redding, S. J., & Rossi-Hansberg, E. (2017). Quantitative Spatial Economics. *Annual Review of Economics*, *9*, 21–58
Redding, S. J. (2021). Trade and Geography. In Forthcoming (Ed.), G.Gopinath, M.Obstfeld (eds.), *Handbook of International Economics* (5 vol.). Elsevier, Amsterdam: E.Helpman
Rossi-Hansberg, E. (2005). A spatial Theory of Trade. *American Economic Review*, *95*, 1464–1491