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An Application of the Lens-Condition to Dutch Cities

Abstract

Traditional trade theory assumes that countries are dimensionless points. Recent research shows, however, that the internal geography of countries is important for the effects on trade. One aspect of internal geography is the uneven spatial distribution of factors of production. Factors of production especially concentrate in urban locations. The so-called lens-condition tests whether the (urban) distribution of factors of production is uneven enough to affect the national structure of trade. Using detailed 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.

JEL-Codes: F100.

Keywords: lumpiness of countries, HOS model.

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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).

An early contribution in this respect is Courant and Deardorff (1992, 1993). Their analysis, based on the Heckscher-Ohlin trade model, provides a simple test to determine whether the national trade structure is affected by the uneven, or 'lumpy', distribution of factors of production within a country. This is the so-called lens-condition. 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 and Norman, 1980, for a discussion). If, not a policy induced relocation of factors of production might be called for to increase welfare. In this note we use detailed firm-level data at the city level to determine whether the lens-condition holds for The Netherlands.[5] If it holds, the national trade structure is not affected by the regional distribution of factors of production, and the Dutch integrated equilibrium can be reproduced by the regional trade structure. 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 the Appendix for a map of Dutch cities-region locations). We find that the lens-condition is fulfilled for The Netherlands. Section 2 discusses the lens-condition, section 3 confronts the lens-conditon to Dutch data, and section 4 evaluates the main implications. Finally section 5 concludes.

2 Theory of the Lens-condition

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 and Deardorff, 1992, for a discussion). 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

[5] Evidence on lumpiness is relatively scarce, and the existing evidence is 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 and Demiroglu (2003) show that for the group of OECD countries the lens-condition is not violated. Bernard, Robertson, and Schott (2010), however, argue that for Mexico regional lumpiness of production factors might be a significant factor. Brakman and Van Marrewijk (2013) show that at the city level the lens-condition is violated for most countries in their sample.

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).[6]

Figure 1 The Lens-Condition

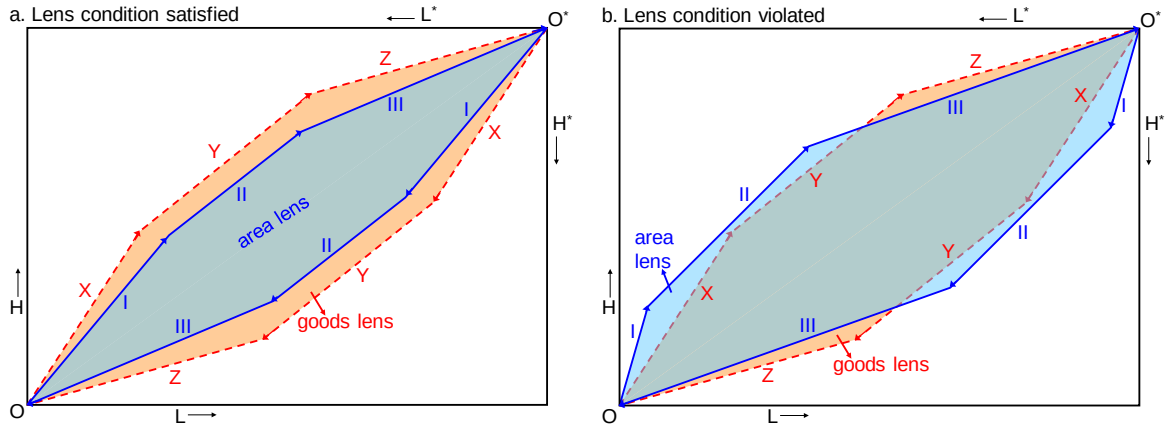


Figure 1 illustrates the condition for a three goods (X, Y, and Z) and three area (I, II, and III) example. In Figure 1a the lens-condition is *satisfied*: the factor endowment lens for the areas is a subset of the (factor use) goods lens, indicating that the empirical distribution of the factors of production across the various areas within the country does not influence the country's overall trading position. In Figure 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 and Deardorff (1993) extent their model by including non-traded goods and amenity differences across locations that can explain factor price differences. Helpman and 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 and Norman (1980) point out that one can include trade costs by redefining one of the goods as a transportation service used by the traded good sectors.

3 The Lens-condition for Dutch Cities[7]

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

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

[7] **Data on 22 cities and 4 regions** are from Statistics Netherlands (in Dutch): https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/gemeente/gemeenten-en-regionale-indelingen/niet-landelijk-dekkende-indelingen **Data on city and firm exports** are constructed using registry data from Statistics Netherlands for the period 2007-2017. For privacy reasons these data are not publicly available. The Netherlands Bureau of Statistics manages these micro data, which can be obtained for research purposes upon request: https://www.cbs.nl/en-gb/our-services/customised-services-microdata/microdata-conducting-your-own-research. Each firm and branch

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 labour 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 lens-conditions in 2-dimensional space, in particular if we also combine factors of production.[8] 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.[9]

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 percentage points and with a medium skill level with 2.2 percentage points. This obviously implies that the share with a low skill level has been declining by 5.1 percentage 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.

is assigned a sector code according to the Dutch coding system (SBI 2008) of which the first two digits correspond to the international NACE rev. 2 classification. SBI = Standaard Bedrijfs Indeling (Standard Firm Classification).

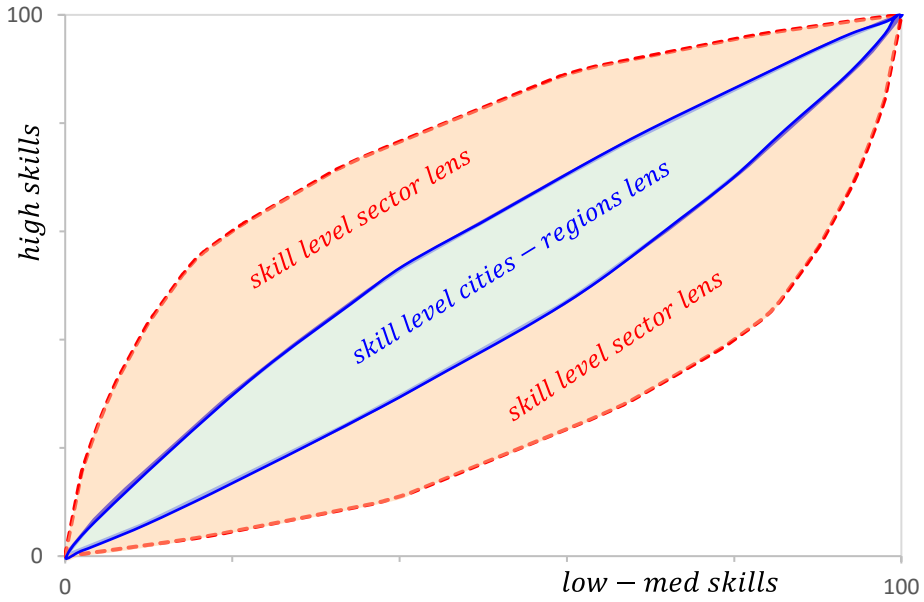
Data on sector skill-intensity/ factor abundance are from annual registry data on the highest attained level of education for Dutch citizens to identify three skill levels for general schooling, labelled high-, medium-, and low-skilled (with sub-indices *high*, *med*, and *low*, respectively.

A detailed data description is available upon request.

[8] 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 Figure 2 and Figure 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.

[9] Results for other years are similar.

Figure 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.

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 Figure 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 Figure 2).

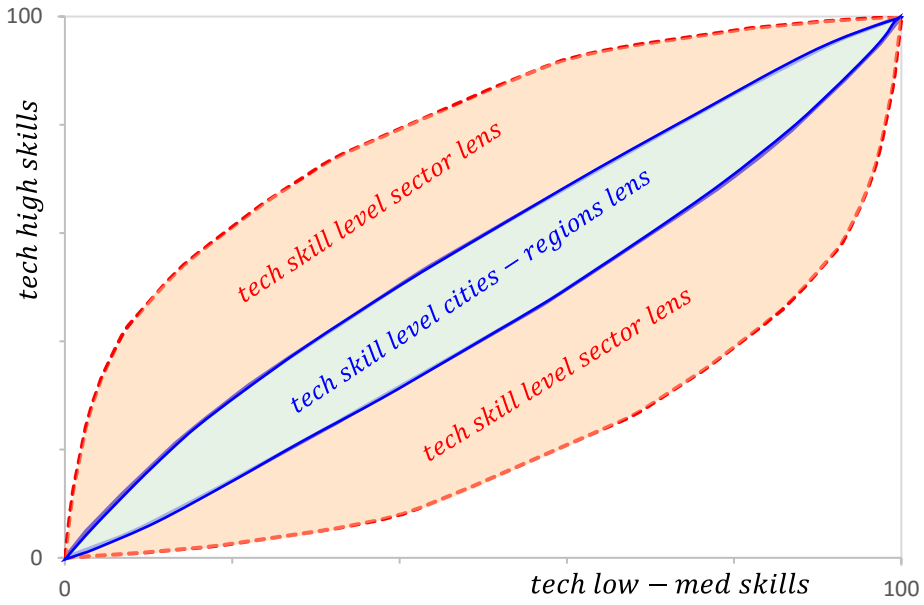
Of the 83 Dutch sectors of production, sector 80 (security and detection) has the lowest share of high skill workers (8.9 per cent), while sector 85 (education) has the highest share (80.8 per cent). To create the goods / sector lens, we order the sectors in terms of high skill relative to low-med skill 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 Figure 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 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 section 3. 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 percentage 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.

Figure 3 Dutch Technical Skills Lens-condition, 2017



Source: authors; tech = technical; low-med = combination of low and medium skills

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

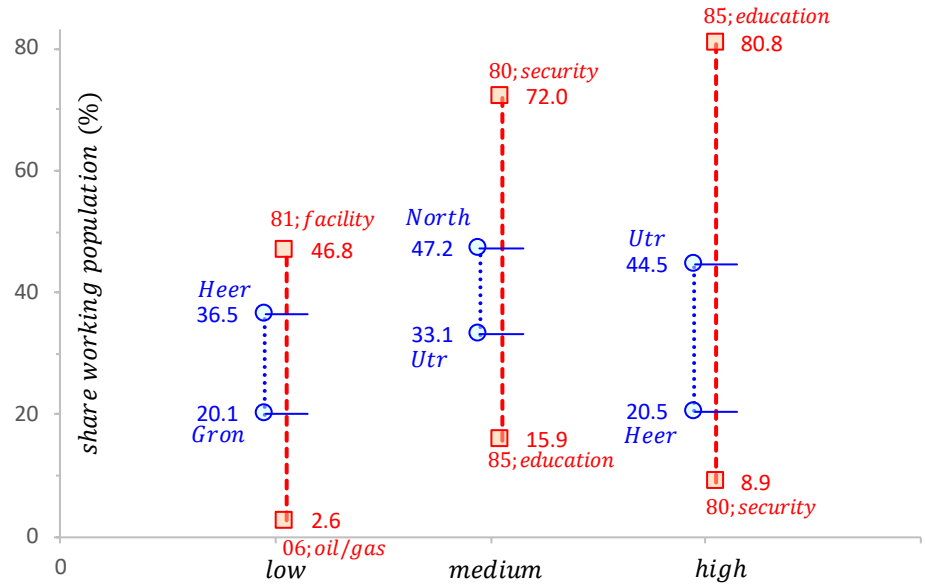
Of the 83 Dutch sectors of production, sector 87 (nursing care with guidance for overnight stay) has the lowest share of technical high skill workers (0.6 per cent) and sector 71 (architects, engineers and technical design & advice) has the highest share (44.9 per cent). Using a similar procedure as before, we create the 'tech skill level *sector* lens' in Figure 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 Figure 3, this is much wider than the cities-regions lens and the lens-condition is again easily *satisfied*.

4 Explanation and Implications

The analysis in section 3 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.[10] 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.

Figure 4 Skill Level Ranges for Dutch Cities-Regions and Sectors, 2017



Source: authors; Heer = Heerlen; Utr = Utrecht; Gron = Groningen.

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.

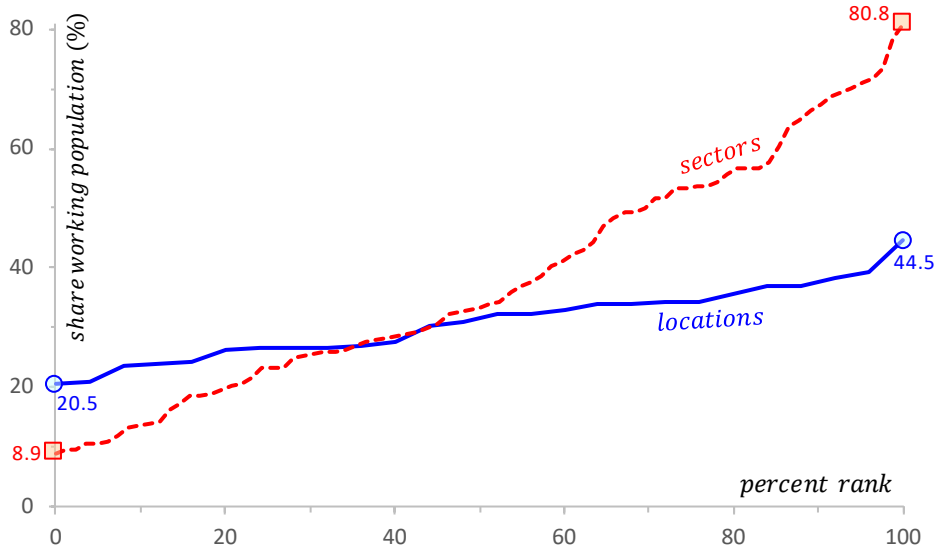
Figure 4 provides the range of skill level shares (of working population in per cent) for Dutch cities-regions and sectors in 2017 for low, medium, and high skill levels. In all cases, the cities-regions shares are strictly in between the sector shares and the cities-regions range constitutes only a 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 Figure 2 and discussed in

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

section 2, 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 Figure 2 and Figure 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 Figure 2 or Figure 3 (see, for example, Figure 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 Figure 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 Figure 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 Figure 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 Figure 2 and Figure 3) and strictly contains the cities-regions lens over the entire domain.

Figure 5 High Skill Share Rank Distribution, 2017



Source: authors.

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

result of mobility of factors of production.[11] 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.

5 Conclusion

An application of the lens-condition to Dutch cities indicates 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.

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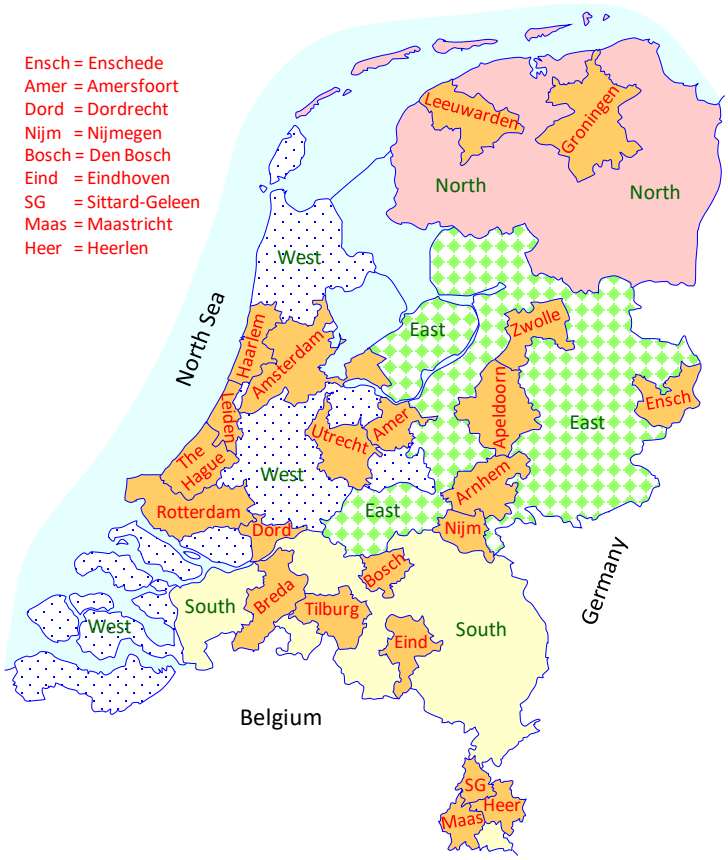
[11] In a long-run perspective, the sector lens is also endogenous as it changes in response to R&D efforts, but these changes are likely to require more time than adjustments of the area lens because of migration.

Appendix: Dutch Cities-Regions Locations

Figure A6 Dutch Locations; 22 Cities and 4 Regions



Source: constructed by authors. Based on CBS 2005, *Grootstedelijke agglomeraties en stadsgewesten afgebakend*