Measuring Agglomeration Economies–
The Agglomeration Index:

A Regional Classification Based on Agglomeration Economies

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Urban agglomerations are of significant importance for national economies. Although this statement appears to state the obvious, it is nevertheless difficult to test. The influence of urban areas is mainly generated by agglomeration economies, from which not only the inhabitants, but also other participants in the urban process, benefit.

Agglomeration economies are often seen as the driving force behind urban dynamics in all kinds of fields (e.g., rapid economic growth of urbanized regions, spatial concentration of high-tech enterprises). On the other hand agglomeration diseconomies are an explanation for traffic congestion and high crime rates. Agglomeration economies have had worldwide attention in both urban and regional literature. It is probably because of the lack of an operational definition of an agglomeration that little attention has been paid in arriving at a clear quantification of agglomeration economies.

In this article a new regional classification based on agglomeration economies is presented, especially suited for the multi-city systems that are dominating most post-industrial societies. Inter-urban influences are a central topic in this article.

Although the specification of an index strongly depends on the presuppositions made, it is found that the presented agglomeration index is rather insensitive to relatively small adjustments in those presuppositions. This makes the agglomeration index highly suitable for empirical research in which agglomeration economies are used as an explanatory variable. In the conclusion, some results from this kind of research are presented.

AGGLOMERATION ECONOMIES

The amount of agglomeration economies present at a *certain* location are assumed to be dependent on: 1) the distance to the nearest city, 2) the size of that city and 3) inter-urban influences.

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City-located residents and firms benefit more from agglomeration economies than residents and firms located outside the urban area. Residential concentration leads to the development of urban facilities from which city inhabitants benefit most. It is assumed that the use of these facilities decreases with distance. The actual use decline depends on the specific nature of each facility.

Nijkamp and Schubert (1985) argue that city size has to pass a certain threshold level before a city can actually act as a generator of agglomeration spread effects. In this context, we assume that above this level the agglomeration spread effects manifest themselves with varying intensities which depend on the size and the geographic position of the agglomeration concerned. In the present paper a binary scale for these spatial spread effects is used, viz. low spread effects and strong spread effects depending on city size and spatial position in an urban field. This binary scale is only adopted for the sake of simplicity; in principle, a trichotomic scale or even an ordinal scale may also be employed. The low spread effects are mainly a result of the usual type of amenities and facilities to be found in medium-sized cities in a spatial hierarchy. The strong spread effects of large cities can be attributed to city functions of a higher order, namely major service centers containing a large Central Business District and delivering specialized services. A well-developed communication infrastructure between large cities is both a reason and a result of the service function of large cities. Given the Dutch context and the level of amenities in Dutch cities, the threshold level is assumed to be approximately equal to 100,000 inhabitants, while the city size level determining low or strong spread effects is assumed to be approximately equal to 200,000 inhabitants. These threshold levels are often used for government fiscal transfers to Dutch cities.

The relevance and applicability of various—often Anglo-Saxon oriented—urban theories for post-industrial European city system studies (and in particular for the Dutch case) can be questioned on the grounds that the interurban structure of post-industrial European areas differs both in scale and nature with, for instance, the U.S. situation, the latter being characterized by especially large cities each of which has a more isolated location. Pred (1977) has characterized this specific European situation as an urban field. An illustration of this difference can be found in the patterns of innovation diffusion. These patterns were often found to exhibit a spherical pattern for the U.S. situation, as compared to the more complex European patterns, owing to the less isolated position of many European urban areas. Strong interurban influences cause relatively high urbanization economies in those locations that fall within the sphere of influence of more than one large urban area. This observation constitutes one of the corner stones of the agglomeration index developed below.

THE AGGLOMERATION INDEX

To enable a simple interpretation, the three aforementioned factors are united in the one-dimensional agglomeration index AI, formally defined as follows:

AI = f(distance, city size, inter-urban influences).

- The *distance to a main city center* in the vicinity is measured by physical road distance (adjusted for the quality of the infrastructure and communication network).
- *City size* is measured in a non-linear way as a binary function of urban population size by making a distinction into two classes, viz. (a) cities with low spread effects, and (b) cities with strong spread effects. Cities with a size below the threshold level are assumed to generate no significant spread effects.
- The *inter-urban influences* are measured implicitly by including the distance to, and size of, other neighboring cities. A problem in the European context is caused by interurban influences across borders, as most countries are not isolated from their neighbors. It is assumed that foreign urban areas can spread low agglomeration spread effects when there is relatively free access for persons and goods across the borders. The threshold level for foreign city size is assumed to be significantly higher than the inland threshold level. In the Dutch context, the foreign threshold level is set at 200,000 inhabitants. The ultimate expression of the agglomeration index is based on a third order spatial model and is specified as follows:

$$AI = f_I [a_1 * a_2 * a_3 + w * b_1 * b_2 * b_3]$$

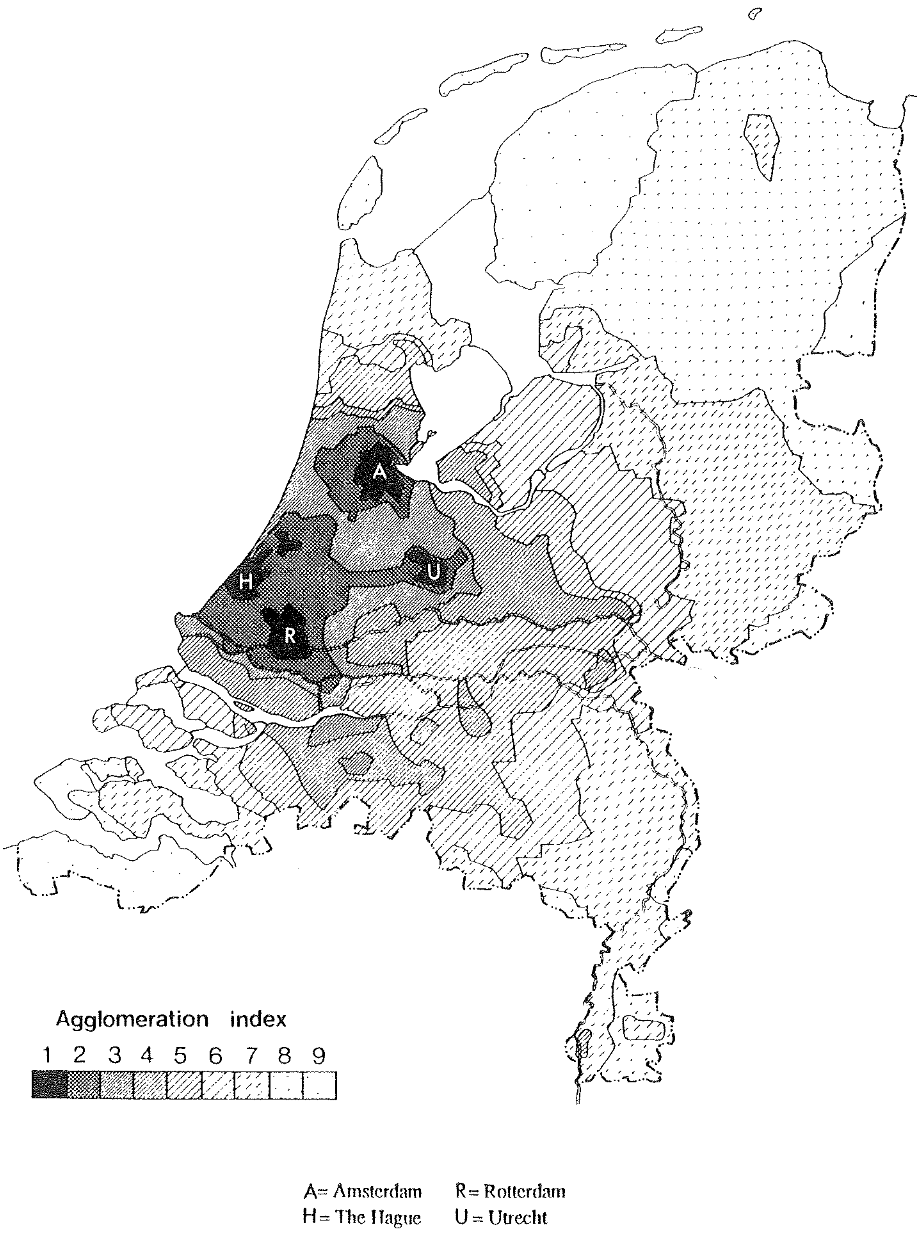
with a_i the distance to the i-th closest city with strong spread effects and b_j the distance to the j-th closest city with low spread effects or foreign city. All distances are measured on a six-interval scale. The actual intervals depend on the psychological perception of distance. Different intervals should, therefore, be used in different contexts. For instance, the following intervals are suggested in the Dutch context:

1 = 0 - 5 km	2 = 5 - 10 km
3 = 10 - 20 km	4 = 20 - 50 km
5 = 50 - 100 km	6 = more than 100 km.

- w is a weighting factor representing the relative importance of the medium–sized cities compared to large–sized cities. Because of the relative nature of w in this dichotomic case, it is not necessary to weigh both size classes separately.
- f_I is an index function that transforms the data input into a measurement scale ranging from 1 to 9 (measured as integers). It is worth noting that the multiplicative terms ensure decreasing marginal interurban influences when the distance increases. An additional inclusion of a fourth– and higher–order impact term would thus only lead to minor changes in some cases and has therefore been omitted here.

Figure 1 gives a visual representation of the agglomeration index for the Netherlands with w = 0.5. The index ranges from 1 (strong agglomeration economies) to 9 (very low agglomeration economies). This map was mainly drawn by means of interpolation taking into account specific physical aspects of the country.

Figure 1: The agglomeration index as applied to the Netherlands.



SENSITIVITY ANALYSIS

An indexation makes sense only when it is relatively stable with regard to (small) changes in the presuppositions. This requirement was tested for the agglomeration index in the Dutch case and was found suitable for both threshold level and parameter w presuppositions. A change in the threshold level up to 20% only had some modest effects on the regional classification. This stability can be explained by the complex structure of the agglomeration index. Only a limited number of cities fall into another category when the threshold level is changed, while the agglomeration index uses a wider complex of cities. Changes in the relativity parameter w have effects on the ultimate classification. These effects however are very limited if $0.25 < w < 0.75$. Table 1 shows the percentage of area that changed to respectively a lower or a higher agglomeration index when the relativity parameter w was changed from 0.5 to another value.

Table 1: Agglomeration index changes as result of deviations from w = 0.50.

w	Lower	Higher
0.25	14.6	13.8
0.40	6.9	5.1
0.60	4.0	4.5
0.75	9.9	11.3

The stability of the agglomeration index with regard to changes in w can also be attributed to the complexity of the index.

AGGLOMERATION INDEX VERSUS DEGREE OF URBANIZATION

Another measure for urban influences is the degree of urbanization as used by the National Census Bureau of the Netherlands, consisting of three different categories and twelve subcategories. The three categories are subdivided according to various criteria:

A *Rural municipalities*:
- A1 over 50 percent agricultural employment
- A2 40 - 50 percent agricultural employment
- A3 30 - 40 percent agricultural employment
- A4 20 - 30 percent agricultural employment

B *Urbanized rural municipalities:*
- B1 Less than 20 percent agricultural employment and the largest residential core has less than 5,000 inhabitants
- B2 Ditto, but largest residential core has 5,000 to 30,000 inhabitants
- B3 Specific commuters municipalities

C *Urban municipalities:*
- C1 Rural towns (residential core with 2,000 to 10,000 inhabitants)
- C2 Small towns (ditto, with 10,000 to 30,000 inhabitants)
- C3 Medium sized towns (ditto, with 30,000 to 50,000 inhabitants)
- C4 Ditto, with 50,000 to 100,000 inhabitants
- C5 Large cities with a residential core with more than 100,000 inhabitants.

First, it should be noted that the degree of urbanization and the agglomeration index are not synonymous. Within each agglomeration index a large range of degrees of urbanization is found in the various municipalities. In regions of type 1 (strong agglomeration spread effects) there is, of course, dominance of C5 municipalities, but A and B municipalities are also present. This variety is much stronger in regions of index type 3, 4 and 5.

Second, the agglomeration index is not meant as a replacement for the degree of urbanization. The degree of urbanization provides much insight into specific population characteristics of the various municipalities. This can vary from social characteristics (e.g., income, housing) to functional characteristics (e.g., commuters, agrarians). Using these characteristics as variables for research purposes, the degree of urbanization is to be preferred over the agglomeration index.

The latter, however, provides more insight into the environment in which a subject (e.g., inhabitant, firm) is located, as well as the provision level of the environment. That environment is particularly important in the decision-making process concerning a subject with a number of key problems, such as locational decisions.

Also a certain degree of similarity exists between the agglomeration index and the market potential models in the sense that both deal with locational interactions (Batten, 1983). It should be stressed, however, that the market potential models treat city size as a continuous variable, while the agglomeration index views city size as a discrete variable depending on the two critical threshold levels. Given this fact, it is clear that the use of market potential models and of the agglomeration index would lead to different spatial divisions.

In summary, the introduction of the agglomeration index leads to a refined and detailed diversification and demarcation of geographic space.

APPLICATIONS OF THE AGGLOMERATION INDEX

Urban influences have been used as explanatory variables in many studies. The agglomeration index provides a simple quantification of these variables. In this section some results of such research are presented as an illustration of possible use of the agglomeration index.

Example 1: Regional dispersion of innovations

The actual motive for the development of the agglomeration index arose out of research concerning location and dispersion of industrial innovations in the Netherlands (Dieperink and Nijkamp, 1987).

Figure 2: The mean number of product innovations per firm.

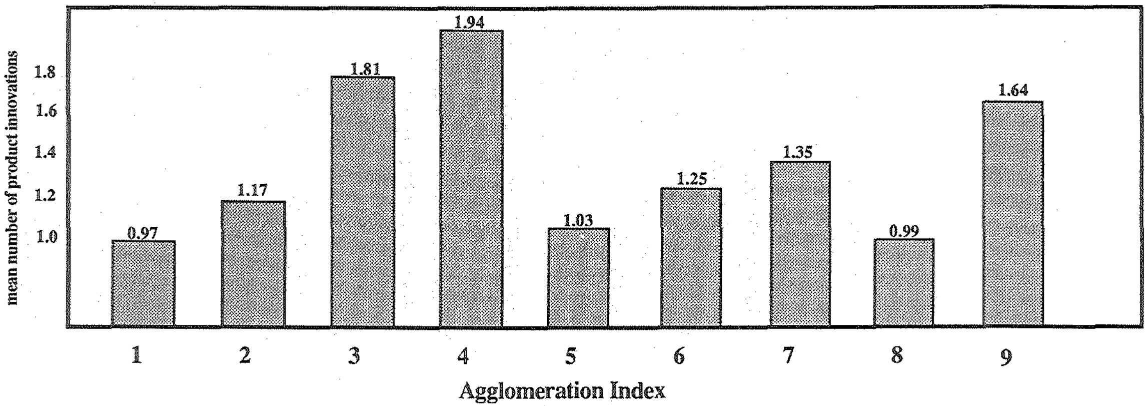


Figure 3: Regional dispersion of knowledge centers.

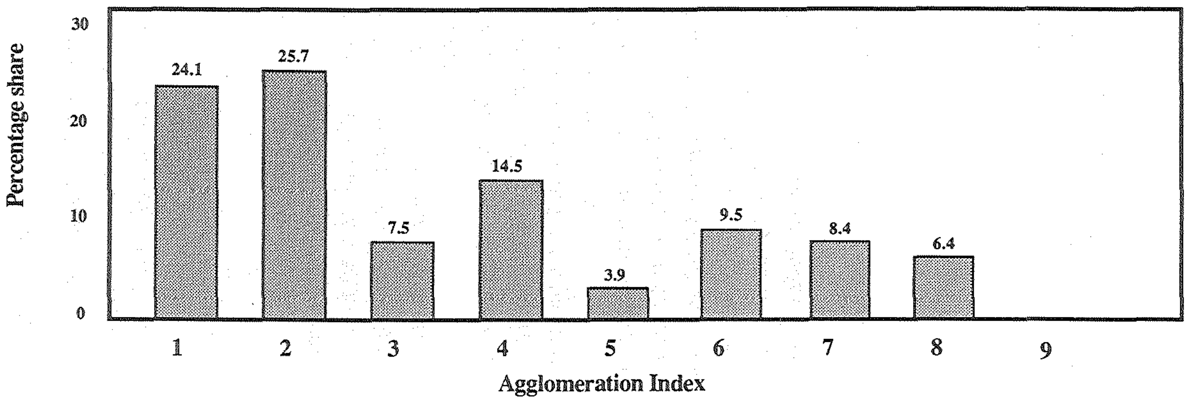
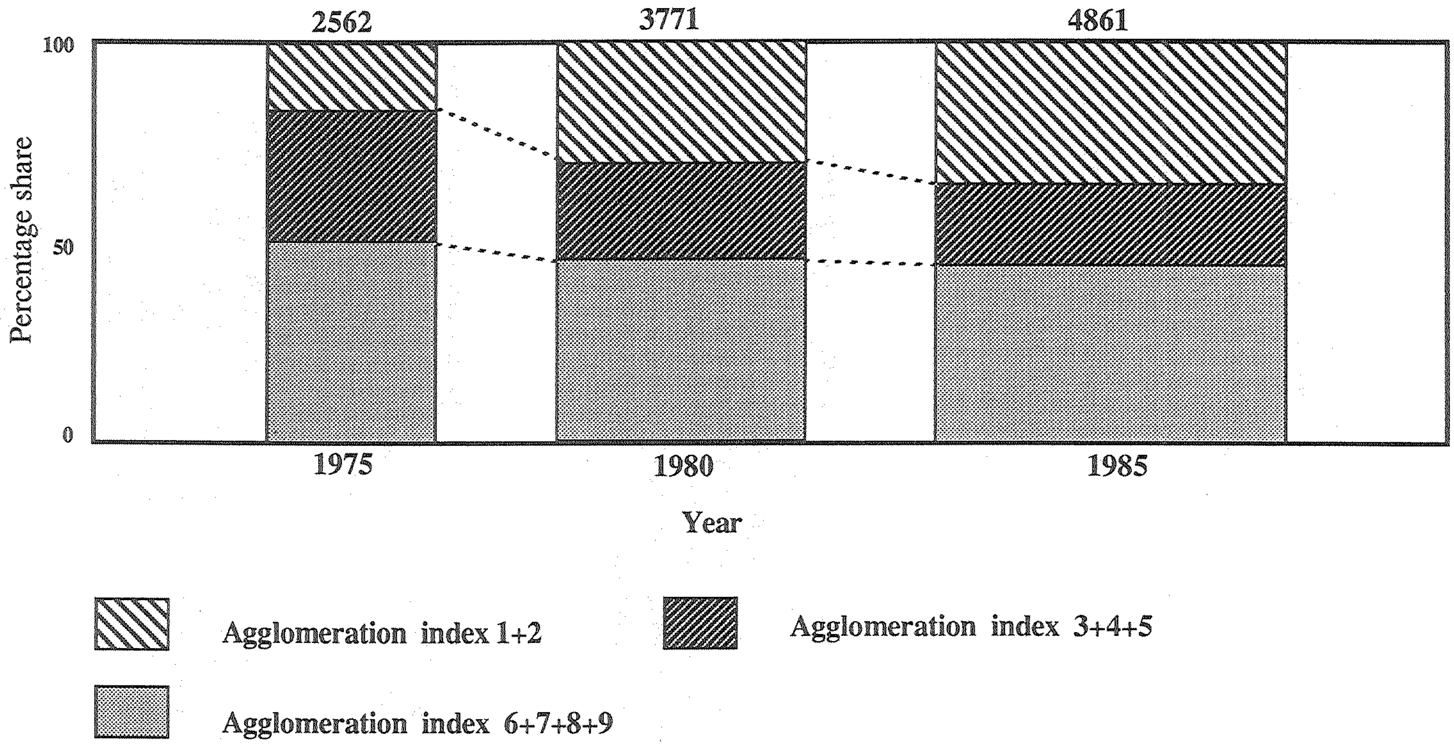


Figure 4: The employment development in high-tech firms (1975-1985).



In contrast with conventional theories it was found that regions of type 1 ("large cities") were the least innovative regions, while the regions of type 4 ("intermediate regions") were the most innovative (Fig. 2).

Example 2: Regional dispersion of knowledge centers

The agglomeration index was used in a research concerning the relations between the location of knowledge centers and regional innovative activities. It was found that there was no significant connection between the two variables in the Netherlands (Mouwen and Nijkamp, 1987). Figure 3 shows the regional dispersion of the various types of knowledge centers.

Example 3: Regional dispersion of high-tech employment

The agglomeration index was also used in research concerning the location of high-tech enterprises in the Netherlands (Bouman and Verhoef, 1985). Figure 4 shows the employment development in high-tech enterprises between 1975 and 1985 in different regions.

CONCLUSION

The agglomeration index would appear to provide a usable quantification of urban influences. This feature is characterized by: (1) simple interpretation, and (2) stability despite parameter variation. Because of these properties, the agglomeration index is highly suitable for applications in empirical studies, in which urban influences or agglomeration economies are used as explanatory variables. Through the compound inter-urban structure of the agglomeration index it is then possible to compare empirical results between multi-nuclei city systems and primate city systems.

REFERENCES

Bouman. H. and A. Verghoef (1985) Ruimtelijke spreiding van high tech werkgelegenheid. Stepro Report Nr. 51. Amsterdam: University of Utrecht and Free University.

Batten, D. F. (1983) *Spatial Analysis of Interacting Economies*. Dordrecht: Martinus Nijhoff.

Dieperink, J. P. H. and Nijkamp, P. (1988) Innovative behaviour, agglomeration economies and R&D infrastructure. *Empirical Economics*, 13:335-57.

Mouwen, A. and Nijkamp, P. (1987) Knowledge centres as strategic tools in a regional development policy. In J. Brotchie, P. Hall, and P. Newton (eds.) *The Spatial Impact of Technological Change*. London: Croom Helm.

Nijkamp, P. and Schubert, U. (1985) Structural change in urban systems. *Sistemi Urbani*, 2:155-176.

Pred, A. (1977) *City Systems in Advanced Economies*. New York: Wiley.