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Economic Networks and Urban Complementarities in the Dutch Randstad Region

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Economic networks and urban complementarities in the Dutch Randstad region

Paper prepared for the 46th Congress of the
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Abstract

The network economy is often argued to have a considerable impact on the spatial economic configuration of cities and regions. In the Netherlands, policy makers speak of urban networks, of which the Randstad Holland is considered to be the largest, natural example - a set of larger and medium sized cities that have complementary economic specialisations. This paper tests this hypothesis by means of a questionnaire of 1676 firms in the region. The firms (stratified by size, sector and municipality) provided us with their detailed business network relationships. Using network analysis, entropy measures and negative binominal regression techniques we test to what extent the traditional central place conceptualisation characterised by urban hierarchy in firm relations is replaced by a network model that emphasises criss-cross interdependencies. The central place model is still convincingly dominant and functional complementarities between specialized cities in a Randstad system of places do not come to the fore. This questions the policy emphasis on regional network externalities in the Netherlands, but might have implications for other urban and regional European economies as well.

1 Introduction

The recent literature on spatial development (both social and economic) as well as various policy documents dealing with physical and spatial-economic planning focus on the theme of the 'network society' (Batten 1995, Asbeek *et al.*, 2002, Camagni & Capello 2004). The literature argues that a 'new geography' has been emerging for some time, in which urban networks are seen as imprints of functional linkages on an ever larger scale than that of the city itself (the 'old geography'). Social and economic processes are argued to occur on the larger spatial scale, while at the same time they paradoxical are being restructured within the existing levels of scale. Various processes are increasingly embedded in more and different types of areas (e.g. residential, business and shopping centres). "The 'new geography' offers a combination of scale expansion and differentiation between locations and networks" (Priemus 2005: 10). Because the term 'urban networks' is both new and appealing, the economists, planners and policy-makers have been eager to join in the social debate on the growing interweaving of processes at various scales (Castells 1996; Gereffi & Korzeniewicz 1994). The term 'urban networks' seems to have become the planning field's fashionable answer to

the ‘network economy’, ‘network management’ and ‘network society’ introduced by other disciplines (Hemel 2001). According to the policy documents, the urban network should be most developed in the Randstad – the region of the western Netherlands that comprises the provinces of Utrecht, Noord-Holland and Zuid-Holland. Little is actually known about networked relationships. This paper examines the *economic* networks in this region.

The Randstad for long is the main focus of the Dutch economy. The advantages of agglomeration have attracted many companies who (believe they) can function better here than anywhere else in the country (Lambooy 1998, Witsen 1986). Indeed, the advantages of agglomeration are still seen to outweigh the disadvantages of congestion, high prices for land, real estate and housing, and the various other problems associated with larger cities (Thissen *et al.*, 2006). It is often assumed that the advantages are further enhanced by the better opportunities for network formation in the Randstad (Dieleman *et al.* 1999, Cortie *et al.* 1992). Networks can develop between the companies themselves, between the companies and their staff, between consumers and producers, between companies and knowledge institutions, and between the manufacturing industry and the service industry. In planning terms, a ‘spatial imprint’ of these functional networks within the Randstad is assumed to exist (Van Oort *et al.* 2006, Knol & Manshanden 1990). The Randstad is seen as a prototype for the ‘urban network’ - a readily accessible network of locations having complementary specialisations and an internal differentiation that together create a favourable setting for economic production. Recent policy documents, such as *Pieken in de Delta* (‘Peaks in the Delta’) published by the Ministry of Economic Affairs, and the Ministry of Housing, Spatial Planning and the Environment’s *Nota Ruimte* (‘National Spatial Strategy, creating space for development’) both published in 2004, introduce the term ‘urban networks’ to the vocabulary of the policy-makers. The policy document *Nota Mobiliteit* (‘Policy Document on Mobility’), published by the Ministry of Transport, Public Works and Water Management in the same year, also devotes attention to the concept. All three documents emphasize the structuring effect of *economic* networks (of companies) as the basis that underlies the commuting and recreational networks of people. The *Nota Ruimte* describes the urban network as follows:

“Society is changing in both economic and the socio-cultural spheres. This is reflected by the development of the network society and the network economy, which are in part the result of such factors as ongoing internationalisation and the specialization occurring in many economic sectors, as well as the ongoing expansion of scale in many towns and cities further

to the process of sub urbanization seen in the past. While the urban problems are primarily to be seen at the level of the major cities and their neighbouring municipalities, the longer-term opportunities are to be seen at a higher level of scale: that of the urban networks”.

Ministry of Housing, Spatial Planning and the Environment (VROM 2004: 8)

Nevertheless, it has not yet been established that the existence of (urban) economic networks in the Netherlands can be empirically demonstrated (Zonneveld & Verwest 2005). The shift from a location-based society or economy to a network-based one can be seen as a continuum, while the extent to which urban networks are actually substitutes for towns, or are complementary to them, is far from clear. It is assumed that the networking connections within the network economy will be at ever larger levels of scale than those of the ‘traditional’ city, whereby economic relationships are seen as an important motor of the physical urban extension process, a final phase in suburbanization (Van Oort *et al.* 2006). According to the policy documents, the spatial form of urban networks should take advantage of the assumed economic interrelationships and the spatial up scaling of these. The Randstad is the largest (assumed) urban network in the Netherlands and forms the heart of the Dutch economy. In the Randstad some fifty per cent of the country’s gross domestic product is generated on approximately 25 per cent of the national surface (EZ 2004: 24). A large proportion of the Dutch population lives and works here, spread over a number of cities and smaller towns, some of which are very attractive and all of which seem to display a high degree of mutual involvement and interaction. They offer a large range of public amenities and act as important motors of the national economy (VROM 2004: 133).

The central issue addressed by this paper is the extent to which the economy of the various locations within the Randstad functions as a spatially defined, integrated network. If this is indeed the case, the cities that have chosen to specialize in various economic sectors (Amsterdam, Rotterdam, The Hague, Utrecht and all the medium-sized and smaller towns in between) will be regionally complementarily.

In order to investigate the existence of such regional complementarities we examine the spatial dimension of economic networks, an aspect of spatial-economic research that has to date enjoyed relatively little attention due to the lack of data. Relationships between companies are potentially present throughout the entire production chain, from the purchasing of raw materials to the marketing of consumer goods, services or knowledge. In our analysis,

we aggregate the flows of these relationships by *municipality*, since it is at this level that the spatial policy manifests itself most clearly⁵. Aspects that are specific to the commercial activities of a company or sector, such as organizational structure, are of importance to the companies concerned, but are far less relevant to our research. We focus on the spatial policy-related aspects. Nevertheless, we do take the effect of the specific commercial aspects into account by particularizing the analyses by sector and by the size of the companies concerned. In this context, we investigate the spatial networking structure of all possible purchasing and sales relationships (of physical products, services and knowledge) that are related to a company's decision to locate in a particular municipality. By investigating economic network formation between companies in the Randstad, this paper contributes to the discussion regarding scale and scaling in physical planning policy and regional economic policy, and to the discussion concerning the spatial structure of the networks within the Randstad region. Literature regarding the planning aspects of the network economy assumes that the increased flexibility enjoyed by companies within their economic relationships will be reflected by the development of a larger region (a question of scale), with several urban centres within one and the same region, resulting in a spatially fragmented structure (Graham & Marvin 2003). We have therefore chosen to investigate the extent to which the Randstad functions as a single economic system (network) with *complementary* regional sub-economies, and whether this gives rise to regional clusters of economic relationships – either throughout the Randstad as a whole or at the level of its constituent 'North Wing' and 'South Wing' – which are often argued to function as *substitutes* (competitors) to each other⁶. Further to this, we investigate whether spatial-economic relationships in the Randstad region have a structure based on a central location (monocentrism around the largest centre), or by polycentrism (with criss-cross relationships between more centres). Finally, we ask whether the strong regional or local positions within the Randstad's economic networks are accompanied by, or dependent upon, local sectoral specializations (complementarities, see also Van Oort et al. 2006).

The networks of companies have been studied by means of a questionnaire-based survey, in which each company was asked to identify its ten most important business relationships

⁵ Although the term 'municipality' generally refers to an administrative rather than a geographic division, it is adopted in this paper and refers to a city, town or local authority area. There are 483 'municipalities' in the Netherlands (2004).

⁶ The North Wing constitutes of the adjacent regions around Amsterdam and Utrecht, the South Wing of the adjacent regions of Rotterdam and The Hague. The four regions (and hence 2 wings) together form the larger-scale Randstad region.

(purchasing *and* sales). The sample of businesses, taken from the LISA database⁷, has been stratified according to the size of companies concerned and the industry in which it is active (industrial, business services, or distribution: see Table 1). Overall, the relationships that we study are potentially structured by the economic specialisations that have emerged in the region over the past decades. For example, a complex of similar companies in the logistics sector clustered around Schiphol airport and the Rotterdam harbour (see for a detailed overview of economic specialisations in the Netherlands Van Oort 2004). In the following sections an investigation of economic relationships that are based on the main purchasing and sales transactions of firms (being either goods, services or knowledge being traded) reported by the companies surveyed. We examine the extent to which the relationships are the result of specialization and complementarities between the urban regions of the Randstad in section 3. Section 4 concludes.

Table 1 Number of businesses per urban region: population, sample and response

Region	Population	Sample	Response	Response %
Amsterdam	19045	7035	574	8.2%
Rotterdam	10789	5668	514	9.1%
The Hague	5468	3655	291	8.0%
Utrecht	6096	3943	297	7.5%
Total	41398	20301	1676	8.3%

2 Economic relationships between companies in the Randstad

2.1 *The central location model and the network model*

The attractiveness of a region as a location for business activities is important in a network economy (Lambooy 1998). In a network economy, companies tend to organize themselves in global, extremely specialist clusters and knowledge networks. At the same time, however, the immediate spatial business setting is also growing in importance. There is a ‘global-local paradox’ (Ralet & Torre 2000, Jones 2005). In the regional context, companies seek out

⁷ Landelijk Informatiesysteem Arbeidsplaatsen, national register on employment and firms in the Netherlands.

relationships that are essential to their critical business processes in the areas of supply and outsourcing, but more especially in that of cooperation in innovation and knowledge development. Accordingly, within the international networks we frequently see clusters of knowledge-intensive companies that are organised on a marked regional basis (Van Oort et al. 2006).

In order to analyse the economic interrelationships (supply and outsourcing) at individual company level within the Randstad, we have collected primary data. There is little to no available statistical information about business relationship flows at a low spatial level. Using a large-scale questionnaire among companies in the Randstad, information regarding trade flows (the origins and destination of goods and services) has been collected at the level of individual company locations, and then aggregated to city and urban region levels. In order to ensure an adequate number of respondents and hence a representative sample, three aspects are of importance. Firstly, only four regions (and their central cities) are included in the analysis. In each case, the ‘urban region’ was defined as the area within a fifteen-kilometre radius of the city nucleus. This distance is seen as an indication of local communication conducted with some degree of regularity (Cabus & Vanhaverbeke 2006). Secondly, based on hypotheses derived from the literature, we once again differentiated between various types of economic activity. The study took into account possible differences in the spatial configurations of different sectors, such as industrial activities, business services and distribution. We opted not to include economic activities that rely on the local population density such as retail or personal services. Instead, we concentrated on the basic (driving) economic activities, i.e. firms in those activities for which the choice of location does not depend on the size of the local population. Lastly, the questionnaire research distinguishes between ‘large’ and ‘small’ companies. This difference is also frequently cited in the literature as being significant in terms of the companies’ ability or desire to function within networks. Large companies will often occupy a different position within a network than their smaller counterparts (Nooteboom 1999, Ebers 1999). Moreover, large companies are more likely to operate at more than one level of scale at the same time, while small companies are more dependent on the local and regional supply and sales markets (Cooke 2004). The sample of respondents is fully representative in terms of region, sector and size of company. The study included only company locations with more than one member of staff.

This section is concerned with the network characteristics of the ten main business relationships cited by each respondent. As stated in the introductory section, although thinking in terms of networks is commonplace in economic geography, there has never previously been any test of whether there is really a network economy within the Dutch Randstad (other than some research into patterns of commuting, see Van der Laan 1998). The more tradition *central location model* assumes an urban hierarchy, with most flows focusing on the main centre, whereby cities of the same size and having the same functions will have the same spatial ‘outreach’. However, there are several important aspects of the model that are frequently ignored (Borchert 2001). Firstly, the model assumes that relationships are linked to the physical movement of goods, services or people. These physical and functional relationships are indeed included in the current study, the respondents having been asked to identify their ten most important business relationships. Second, a ‘central location’ is not of equal importance to every function. Amsterdam, for example, is a central location in terms of financial services, but less so for distribution and industrial activities. A classification by sector is therefore essential, as is an evaluation of the complementarities between centres that specialize in different sectors. This classification is therefore controlled for in our analyses. Third, hierarchy will not necessarily be determined by the size of the cities. It is relatively simple to compile a ‘league table’ of towns and cities based on various indicators, but whether this actually represents the true hierarchy is a different matter altogether. Our research specifically examines the supply and sales relationships of the respondent companies: in other words, the *functional* relationships. Cities that are centrally located within the overall pattern of relationships in Randstad region have greater importance and influence in terms of the functional networks.

By contrast, the *network model* (according to the literature, at least) assumes a far more diffuse structure of flows, with criss-cross relationships between cities and outlying regions. The relationships do not always rely on the larger cities, but may involve municipalities of equal or lower hierarchical status (Batten 1995, Clark 2000, Van der Knaap 2002). Central to the analysis presented in this section is therefore the question on which level of scale the economic networks take place, and the degree to which the regions display monocentric or multinodal characteristics and criss-cross relationships.

2.2 Visualization of the spatial network patterns of companies

In studying the network relationships within the Randstad region, it is important to remember that the relationships considered are, by definition, distributed asymmetrically across the municipalities within the region. Larger cities and areas in which municipalities proximate to each other will have a greater number of companies located in nodes and hence larger inter-municipality interactions between firms (Freeman 1997. Kogut 2000). It is therefore necessary to distinguish between the *absolute* number of relationships and the *relative* number (corrected for the size of the municipalities involved and the distances between them). Moreover, although the hierarchy does not depend on size (as stated above), the size of a municipality does bear a relationship to its rank within both the hierarchy and the network structure. In this section we visualize and examine the *absolute* number of economic relationships between companies (based on the representative sample). In doing so, we ignore the size of municipalities and the distances between them for the time being. In the following section, we shall examine the extent to which local structure characteristics (including the size of the municipalities and the distances between them) can ‘explain’ the number of relationships and, having made the necessary corrections, what spatial structures within the networks are relevant.

We have analysed the ten most important relationships of firms – five purchasing relationships and five sales relationships – identified by each respondent company. Since we know the exact location of each relationship (its origin and destination), it is possible to reconstruct a detailed map of the spatial economic networks within the Randstad. By aggregating the information regarding the ten most important relationships to the level of cities or municipalities, all links to and from that location can be charted. When plotting the networks between municipalities, we can draw conclusions regarding their position and structure within a regional network (system), and regarding the functioning of that network as a whole (Bogatti & Everit 2005, Wasserman & Faust 1994). Figures 6 – 8 present the networks of economic relationships between companies for the North and South Wing and the Randstad as a whole, respectively. Here, the respondent population is not classified by sector and size, and no correction is made for the turnover weight of the companies concerned. In these figures, the circles represent the extent of relationships within one and the same city (e.g. where companies based in The Hague maintain relationships with other companies based in The Hague), while the lines show the relationships between companies in different municipalities.

The North Wing (figure 1)

Figure 1 shows the economic relationships of companies in the ‘North Wing’ of the Randstad, being that part of the Randstad that includes the Amsterdam and Utrecht regions. It is clear that the connections between these two regions are largely based on the attractive force of the two central cities themselves. The Amsterdam region has an economic network of companies that shows a marked similarity to the centre-periphery model: Amsterdam is involved in most relationships within the region and with other regions. This is primarily due to the fact that Amsterdam itself occupies a very central place within the network and has a hub function for the surrounding areas. There are some criss-cross relationships in the region, but they are in absolute terms of lesser importance. It is interesting to note that only small number of relationships occur within the Utrecht region. Although the network of the Utrecht region is based on the same number of companies as that of The Hague, the major difference between them is that Utrecht has an extremely open network. Most of the business relationships maintained by companies in the region are with companies outside the region. The motive for a company to locate in Utrecht is therefore probably not based on local or regional advantages. Many companies opt to locate in Utrecht due to its central location in the Netherlands as a whole. If we ‘zoom in’ on the network of the Utrecht region itself, we see a moderately large number of internal relationships in Utrecht, Woerden and Nieuwegein, but extremely few criss-cross relationships. Most flows that do exist have a relationship with the central city of Utrecht itself.

The South Wing (figure 2)

Figure 2 shows the network of the ‘South Wing’ of the Randstad with the adjacent regions around Rotterdam and The Hague. There appears to be a strong connection between the regions of The Hague and Rotterdam. However, the South Wing does have two clear centres (Rotterdam and The Hague), and many relationships involve one or both of these major cities (the medium-sized cities of Zoetermeer and Delft having relationships with both). The cities capture not only the internal relationships, but most relationships within the network involve the central cities as well. Nevertheless, compared to the North Wing there appears to be a more substantial number of relationships that do not involve the two central cities. But although the criss-cross relationships are very visible, they actually involve only small numbers of firms. In the next section we will focus on the question whether the number of

criss-cross relations is significantly more than expected from the economic structure of the regions.

The Randstad (figure 3)

Figure 3 presents the network of the entire Randstad, a region with four main centres: Amsterdam, Utrecht, Rotterdam and The Hague. Each of these four major cities has many internal relationships, but there are also flows visible between them as well as a significant number of criss-cross relationships. In general, each of the four major cities of the Randstad (Amsterdam, Rotterdam, The Hague and Utrecht) appears to have a central hub function in the complete Randstad network. The vast majority of internal relationships are within these central cities, which are also involved to a substantial degree in the relationships with (companies) in other municipalities. In terms of economic relationships, the Randstad network system is therefore dominated – in absolute terms – by the central cities. However, the four cities also have a ‘overflow area’ of economic relationships in the rest of the Randstad, involving a large and diverse range of goods and services. Amsterdam appears to be the largest hub of the entire network. Infrastructural networks also appear to be very important in terms of the spatial network formation of companies, as the orientation alongside the A2, A4 and A12 motorways appears to suggest (compare Thissen et al. 2006 and Van Ham et al. 2001).

Figure 1 The regional network of the North Wing of the Randstad

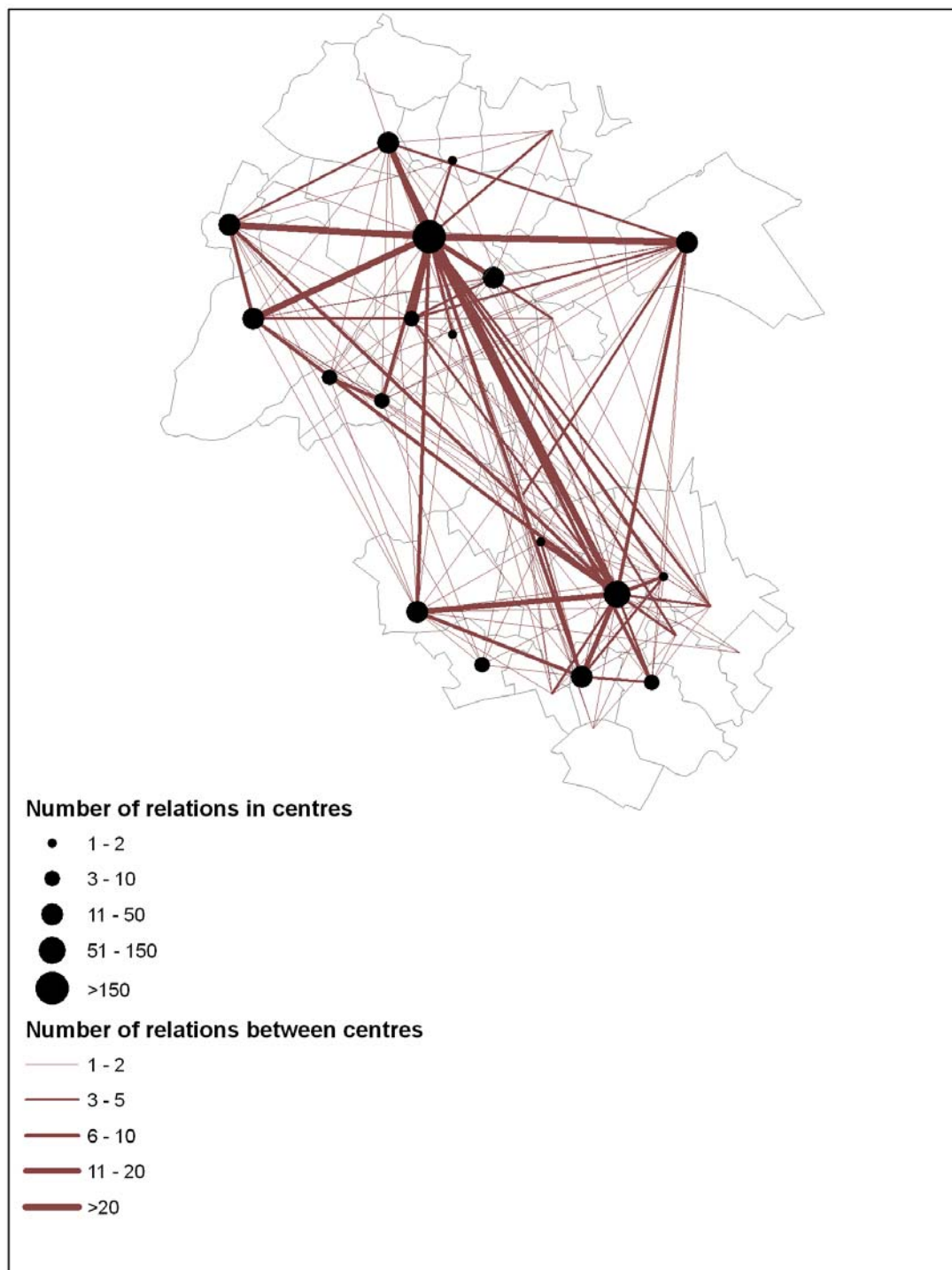


Figure 2 The regional network of the South Wing of the Randstad

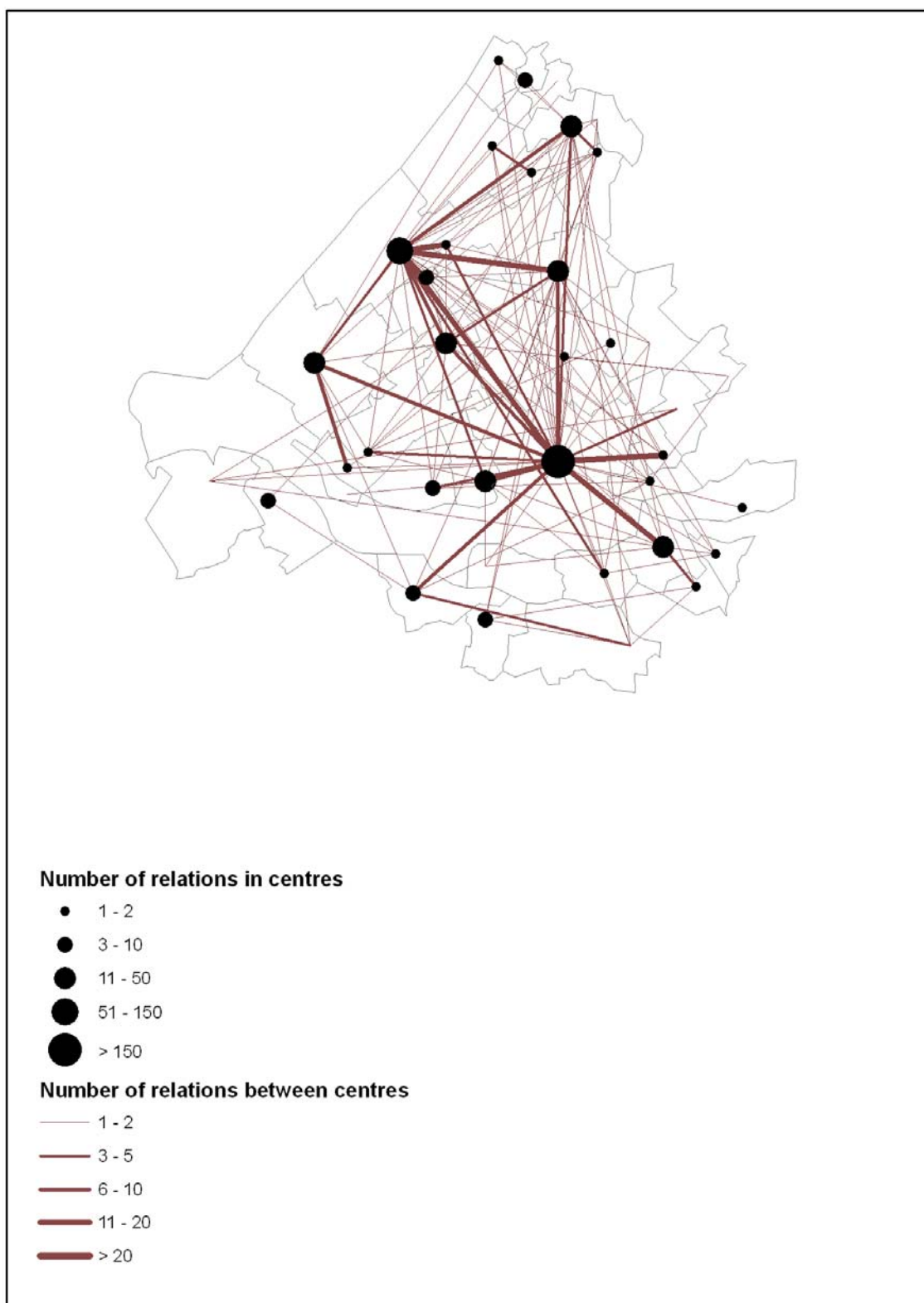
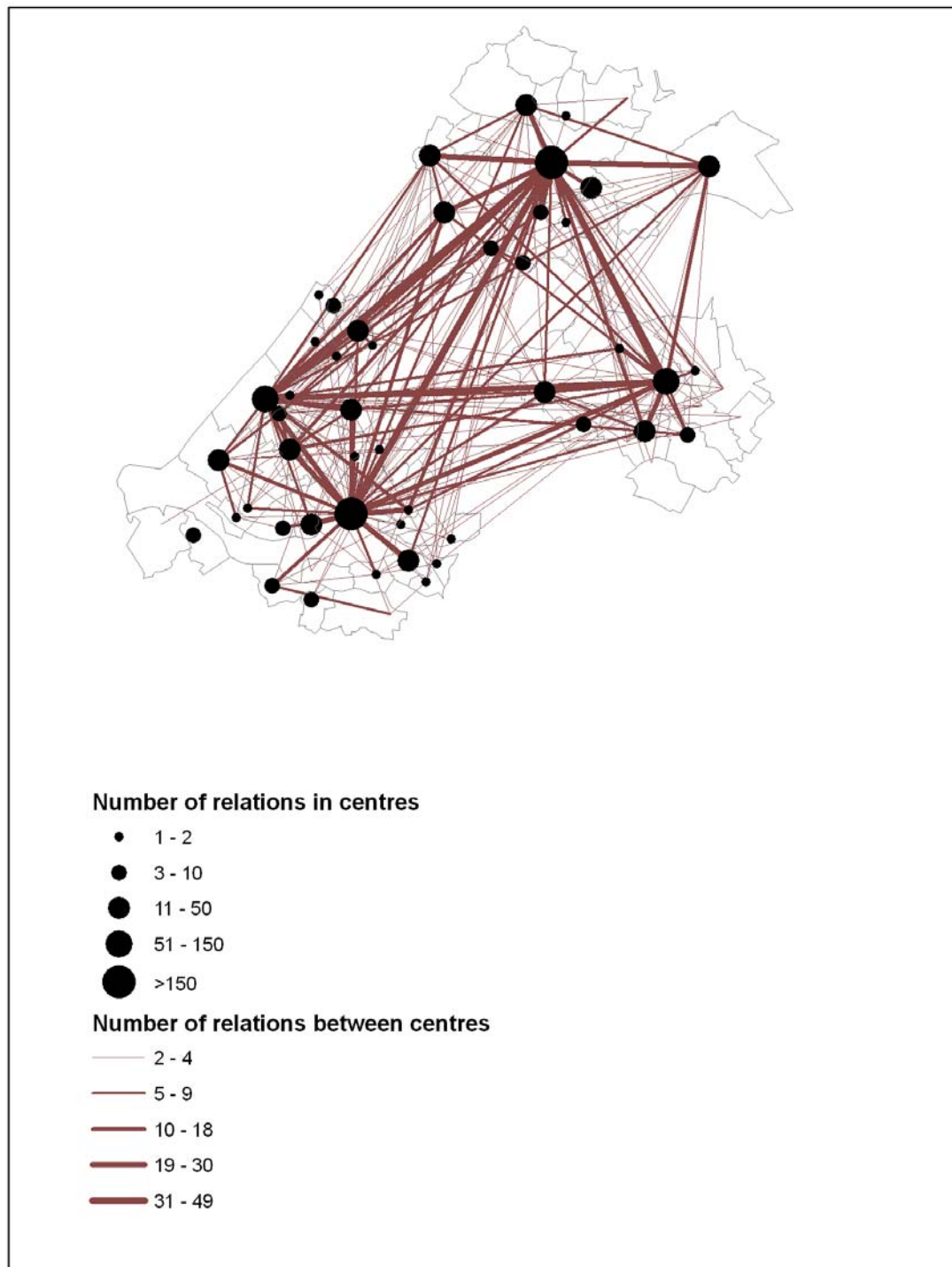


Figure 3 The regional network of the Randstad as a whole



2.3 *Economic relationships between types of centers in the Randstad*

When we aggregate the economic relationships between the various types of urban areas within the Randstad, a more general overview of the role of municipalities within the network emerges (Table 2). We then can speak of intra-core relationships (those flows which take place entirely within the central city), core-periphery relationships (those flows between the central city and the neighbouring municipalities), inter-peripheral relationships (between towns in the same region, but not involving the central city) and inter-city relationships (between the central cities of the Randstad). The intra-core dynamic within a central city appears strongest in the case of Amsterdam, where no fewer than 44% of economic relationships involve parties within Amsterdam itself. This proportion is higher than that of the other central cities, such as Utrecht, where ‘only’ 25% of all relationships involve firms within the same central city. It is interesting to note that the proportion of relationships *between* the central cities of the Randstad is relatively small, representing an average of only 4% of the total number of incoming or outgoing relationships in each urban region. Also notable is the special attractive force that Amsterdam appears to exert. This is certainly the case within the Randstad, but Amsterdam also appears to have a special attraction in terms of economic relationships originating in the Eindhoven, Arnhem-Nijmegen and Groningen regions, all of which appear to have a relatively strong orientation on Amsterdam (Van Oort *et al.* 2006). In the final three rows of the table, all relationships are aggregated at the level of the North and South Wings of the Randstad and for the Randstad as a whole. The South Wing has a greater proportion of relationships that are conducted entirely within its own region (approximately 60%), while this figure for the North Wing is 54%. 43% of the economic relationships transcend the level of scale of the Randstad region: 28% are with companies outside the Randstad, and 15% with companies in other countries. Companies in The Hague have the least interaction with those in other countries, while those in Amsterdam have the most. Aggregated maintains the North Wing a larger number of international relationships than the South Wing. In summary, the central cities appear to maintain many internal relationships. The relationships *between* the major cities in different regions are relatively small in number.

Table 2 Economic relationships by region and by type of town (number of relationships)

<i>To</i> <i>From</i>	Core Amst	Rest Amst	Coret Rdam	Rest Rdam	Core Haag	Rest Haag	Core Utr	Rest Utr	Other NL	Inter- nat.
Core Amst	44.0	8.0	2.9	1.3	4.3	2.2	3.4	0.7	22.0	11.1
Rest Amst	12.7	21.1	2.6	1.7	2.4	2.2	3.0	2.4	29.6	22.3
Core Rdam	5.2	3.8	30.7	10.2	2.8	6.2	3.0	2.4	23.0	12.8
Rest Rdam	4.2	2.3	13.9	16.6	4.0	6.9	3.0	1.1	33.3	14.7
Core Haag	5.8	4.8	5.1	1.9	38.7	13.7	2.9	3.5	19.2	4.5
Rest Haag	5.3	4.7	6.1	1.7	9.9	27.1	1.9	2.5	23.0	17.8
Core Utr.	6.1	3.9	2.9	2.2	4.7	3.6	25.4	7.9	34.1	9.3
Rest Utr.	6.9	4.3	2.6	1.7	3.5	2.6	9.3	16.4	37.2	15.5
North Wing	12.7	18.7	2.7	1.6	3.5	2.5	2.9	9.7	29.6	16.1
South Wing	5.0	3.7	6.7	15.2	5.3	19.7	2.6	2.2	25.6	13.9
Randstad	6.6	13.9	3.2	9.6	2.5	12.6	1.5	7.3	27.7	15.1

	Intra-core relationships (4 centres)
	Intra-periphery relationships (in same region)
	Core-periphery relationships (in same region)
	Inter-core relationships (4 centres)

2.4 The degree of openness of regions in the Randstad

The embedding of a network in the region can also be expressed using an index that indicates the degree of ‘openness’ (or reciprocal its degree of ‘closure’). This index is derived by dividing the number of relationships in the economic network *within* the region by the number of relationships *beyond* the region. Where the result is 1, the number of relationships within the region is equal to that of the relationships beyond the region. A value higher than 1 indicates relative closure: the number of internal relationships is larger than that of the external relationships. A value that is lower than 1 indicates relative openness, with the number of relationships outside the region higher than that of the relationships within the region. The index enables us to compare the regions within the Randstad. In this section, we

analyse the degree of openness for various types of economic network. First we examine the individual urban regions. Then we calculate the index for purchasing and selling relations and for industrial companies, business services providers and companies active in trade and distribution separately. Finally, we focus on the difference between small companies and their large(r) counterparts. In doing so, we distinguish between companies with fewer than 15 employees (which are classified as ‘small’) and those with more than 15 employees (‘large’).⁸

Table 3 presents the openness indices for purchasing relationships, sales relationships, the total number of relationships, and relationships classified by sector and size of company. Overall, we learn that sales relationships are more closed than purchasing relationships. The sales function is more regional in nature, while purchasing is more likely to be conducted beyond the regional boundaries. In all regions, business services providers have the largest number of ‘closed’ relationships. Business services providers in Amsterdam are significantly more closed locally than those in the other regions, having a greater number of relationships within the region than beyond. In spatial terms, the trade and distribution sector has the largest networks, which is indeed appropriate to the function of the distribution arm as the ‘spider in the web’ of trading relationships. We also see that the larger companies generally have larger networks in spatial terms. The exception is this is the Utrecht region, where smaller companies have a relatively larger and more open network than the larger companies.

Table 3 also confirms our earlier finding that, in spatial terms, all urban regions have more external relationships than internal relationships. Amsterdam is the most closed urban region probably because there is a large and diverse group of potential business partners within the region (whereupon there is a high degree of regional ‘self-reliance’). Utrecht is the most open. The table further shows that the South Wing of the Randstad is more closed as a system than the North Wing. The Randstad as a whole has indices larger than 1. The Randstad is larger than each of the individual urban regions, whereby more relationships will be entirely within the region. The hypothesis that business service providers and small firms generally serve the

⁸ The distinction between large and small firms is set at 15 employees in order to ensure a statistically representative sample. This differs from the standard definitions of a ‘small business’ (fewer than ten employees), ‘medium-sized business’ (fewer than 100 employees) and ‘large business’ (more than 100 employees). Our research focuses on the differences in size in relation to the networks with the hypothesis that the larger a company is, the larger are the potential networks in spatial terms. The average size of the group of ‘small’ companies studied is 7 employees, while that of the large companies is 103. The group of companies with more than 15 employees is not evenly divided among the categories of sector and region, but is evenly divided in terms of the overall business population.

regional production and trading companies within the same region is confirmed by table 3. Local specialization in certain sectors and regional differences in the average size of companies therefore give rise to marked regional differences in the degree of economic openness displayed by the business networks. From this we can conclude that the Randstad region does not function as a homogenous system for all sectors and sizes of companies.

Table 3 Openness index by urban region, sector and size of company

	Total	Pur- chase	Sales	Trade/ distrib.	Buss. serv	Indus- trial	Small	Large
Amsterdam	0.71	0.68	0.75	0.35	1.16	0.56	0.81	0.56
Rotterdam	0.53	0.46	0.63	0.36	0.67	0.54	0.60	0.44
The Hague	0.71	0.77	0.65	0.32	0.98	0.71	0.78	0.58
Utrecht	0.39	0.39	0.40	0.20	0.52	0.43	0.40	0.61
North Wing	0.78	0.75	0.82	0.40	1.19	0.69	0.89	0.72
South Wing	0.89	0.78	1.01	0.49	1.22	0.83	0.98	0.73
Randstad	1.34	1.18	1.54	0.68	1.50	1.22	0.68	2.18

3 Hierarchy versus network spatial structure?

In Section 2 it was suggested that, in general, the regions around the cities of Amsterdam, Rotterdam, The Hague and Utrecht are centralized and monocentric in nature, that they have few criss-cross relationships, that many of the relationships are entirely within the central city, while a significant proportion of relationships also involve companies outside the region. In other words, although recent national policy documents assume the presence of a regional economic network model in the Randstad, at the regional level the central place model is still holding ground. However, one criticism of the method of analysis applied in the foregoing section is that it focuses on the *number* of relationships without taking into account the differences in the absolute sizes of the municipalities involved. Accordingly, it remains possible to explain the significant number of relationships conducted entirely within the central city in terms of the size of the city compared to that of the (immediate) surrounding area. In other words, the likelihood of being able to maintain a relationship with (a party in) a

large city is larger than that of maintaining a relationship with a smaller municipality. Moreover, a lack of size and potential might be compensated by a relatively small distance to nearby centres of economic activity. If these aspects are not taken into account, a distorted picture of the interpretation of monocentrism may emerge, suggesting the absence of criss-cross relationships in the respective urban regions and in the Randstad as a whole. In this section, we therefore refine the earlier findings with regard to region-internal relationships⁹ by looking at the differences between the actual and the expected flow frequency (of economic relationships), between and within the smaller municipalities of the Randstad. Conclusions on the question whether the relationships are more or less frequent than would be expected are derived by incorporating three further factors into the analysis: (a) the share of a particular town in the overall flow of relationships within the region (the size of the origin and destination towns), (b) the distances between urban concentrations and (c) characteristics of the origin and destination towns in terms of centrality.

3.1 *Actual versus expected relationships*

As stated above, larger cities will automatically attract a greater number of relationships. To correct for this, we use the ‘T-index’ (Theil, 1967; Theil, 1972), which corrects for the size of the origin and destination municipality. The T-index, which derives from the discipline of information theory, can be regarded as an indicator of the degree of integration within the region. (A more detailed explanation is provided in Frenken 2002 and Van Oort et al. 2006, Appendix A)¹⁰.

Figures 4-6 show the same maps as in Figures 1 - 3. However, allowance is now made for the number of expected relationships based on the size of the originating and destination municipalities. Where the number of actual relationships is larger than the expected figure, this is shown in red. Where the number of actual relationships is smaller than the expected figure, this is shown in blue. All figures demonstrate the same predominant pattern, whereby

⁹ We have chosen not to examine further into the many relationships that involve an origin or destination outside the region, but to concentrate on the 57% of relationships that remain entirely within the Randstad in order to investigate their spatial structure.

¹⁰ In brief, the indicator predicts (per cell of an interaction matrix) the number of expected relationships between towns, based on their respective share of the total number of relationships in the rows (origins) and columns (destination) of the matrix. The interpretation of the T-indicator in our research is that the lower the resulting value, the larger the degree of integration of municipalities within a regional network, allowing for their size. Moreover, the higher the value, the greater the degree of bias towards specific municipalities that, based on their size alone, would not be expected to play a significant part in the (network) system. Further to a standardization procedure, we have expressed the T value as the deviation from the expected frequency of relationships.

the internal relationships of companies located within the same municipality are always larger in number than would be projected based on the size of that town. The relationships between the central cities and their periphery are generally fewer than would be expected. Looking solely at the size of the municipalities involved, we would expect a larger number of relationships between them. This is particularly interesting, since at first sight the central cities would appear to exert a 'magnetic force' attracting many relationships. However, once we apply a correction for the size of the municipalities involved, this attraction is rather less than might be expected. The criss-cross relationships entirely outside the major cities – corrected for the size of the municipalities involved – are generally larger in number than would be expected – but as mentioned before in absolute terms small in number.

Figure 6 shows the relationships for the Randstad as a whole. The relationships between the four major cities are, in general, significant in number. However, when corrected for the size of the cities, we see that there are actually fewer relationships than would be expected. It is therefore inappropriate to speak of a balanced regional system in which each city achieves a share of the relationships that is appropriate to its interaction setting. The interaction system of the North Wing is shown in Figure 4, in which the connections between the Amsterdam and Utrecht regions are less marked than would be expected. The criss-cross relationships within each of the two separate regions remain larger in number than expected. In the South Wing too (Figure 5), the interconnections between the two regions are less strong than would be expected from the size of the cities concerned. However, this situation is not so marked as in the North Wing because there are a larger number of criss-cross relationships between the two regions. It may therefore be concluded that the Randstad, its North Wing and South Wing all comprise sub-systems that are linked to each other - but these links are not strong enough to allow us to speak of a fully integrated system.

Figure 4 The regional network of the North Wing of the Randstad (more and less as expected)

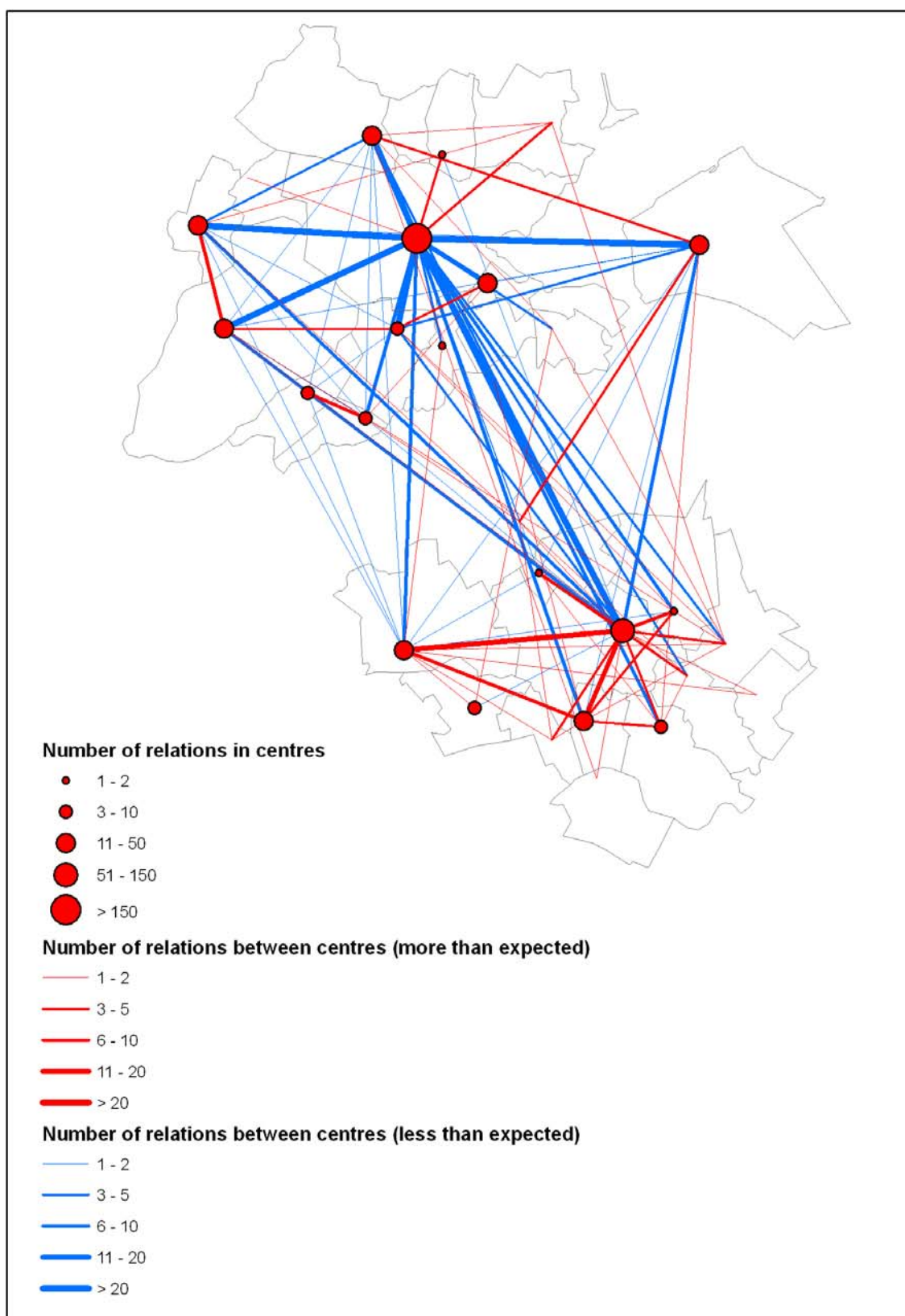


Figure 5 The regional network of the South Wing of the Randstad (more and less as expected)

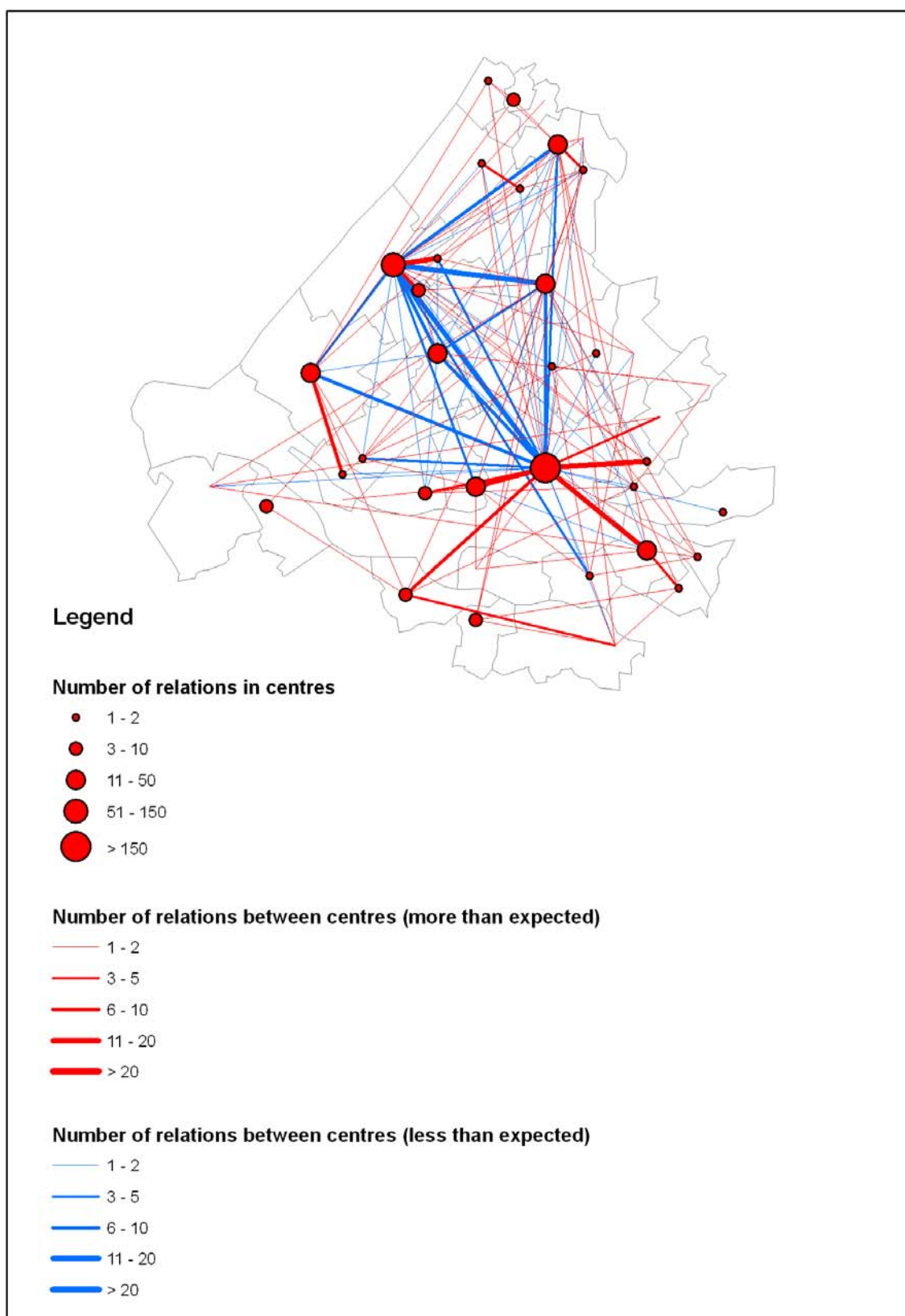


Figure 6 The regional network of the Randstad as a whole (more and less as expected)

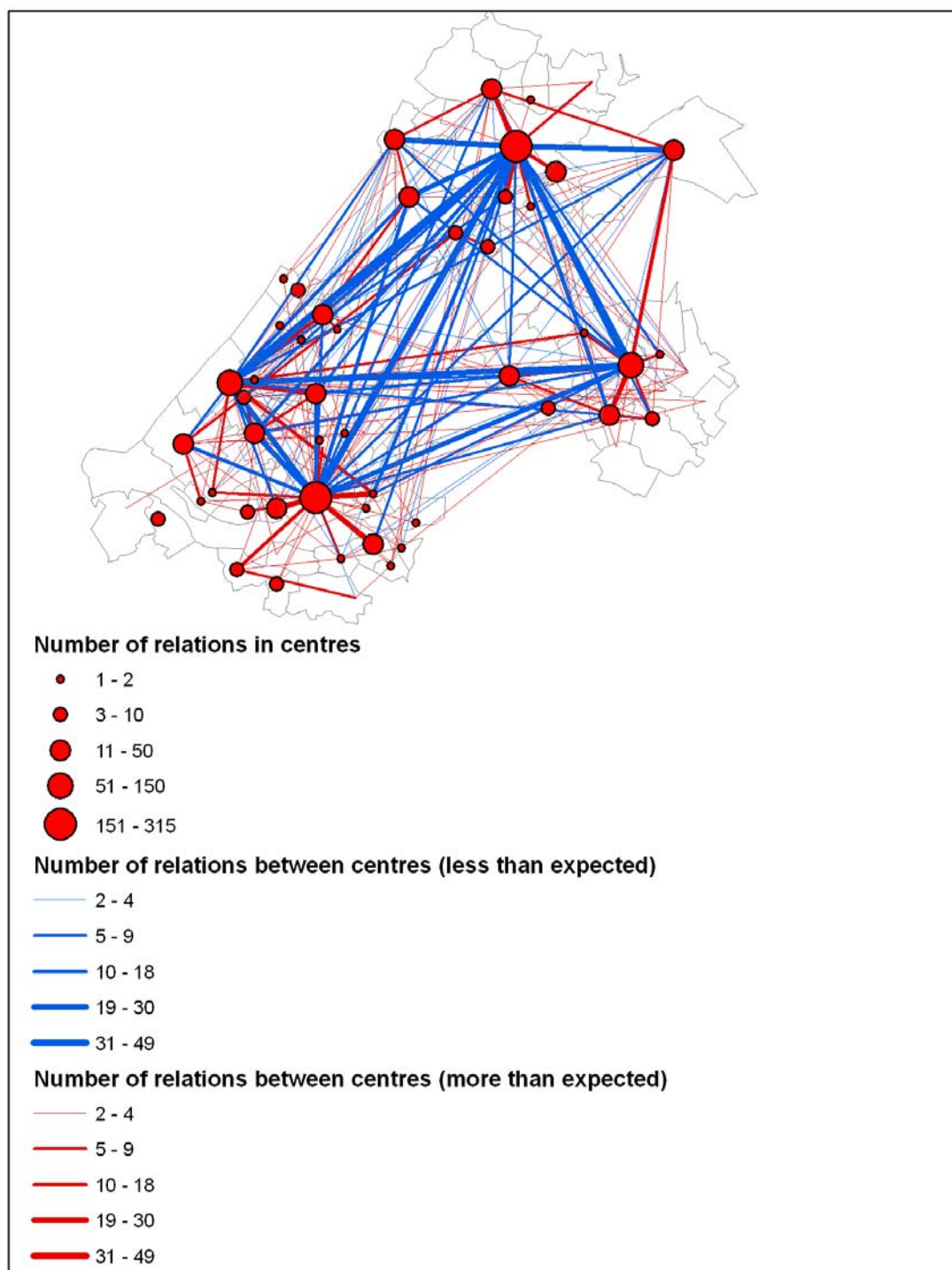


Table 4 shows the degree of integration for each of the individual urban regions. The T-index is highest in the case of The Hague, which means that the smaller municipalities within this region are less integrated with each other than would be expected based on the total number of relationships involving each municipality. The individual towns of the Utrecht region show a much stronger degree of integration within their system. The T-values can be further disaggregated into inter-nodal and intra-nodal indicators. This is particularly useful, since it allows us to investigate whether there are fewer or more relationships between the types of towns than would be expected. The conceptualisation of urban networks suggests that in a more advanced stage of network-formation, there will be a larger number of criss-cross and core-periphery relationships. In other words, there would be an increasing number of relationships between municipalities that do not form the nucleus of the region. We can distinguish four types of relationships between municipalities that are of significance to this conceptualisation (after Van Oort et al. 2006). The first is the intra-core relationship, which remains entirely within the largest centre (or nucleus) of the region. For the purposes of this study, these are therefore the central cities of Amsterdam, Rotterdam, The Hague and Utrecht. The second is the intra-periphery relationship that remains within the neighbouring municipalities of the central city but excludes the central city itself. This is the case in for instance Almere-Almere and Diemen-Diemen, relations. Intra-nodal relationships include all relationships entirely within one particular municipality, and are therefore the sum and (weighted) average of the intra-core and intra-peripheral relationships. The third type of relationship is the core-periphery relationship, in which one ‘side’ of the relationship, be it the origin or the destination, always involves the central city. Finally, relationships between towns outside the central cities that are conducted with a partner outside this town are known as inter-periphery relationships. Together, the core-periphery and inter-periphery relationships form the inter-nodal relationships.

Table 4 classifies the T-index according to the various types of relationships. By looking at the deviation from the total (original) T-value, we can conclude upon the bias of the sub-systems compared to the degree of integration within the system as a whole. It becomes clear that the T-index of the intra-nodal relationships is always positive, the intra-core bias always being larger than the expected interaction. In this regard, the region of The Hague emerges as the most closed, while the Utrecht region is the most open (as we saw previously from the openness index). The core-periphery bias, on the other hand, is generally smaller than would be expected on the basis of the size of the cities and suburbs concerned. Although these are

major flows in absolute terms, they ought to have been even larger based on the size of the central cities. Inter-nodal networks are, in general, much more significant than would be expected, with the exception of those in the Amsterdam region. However, they remain less so than the intra-nodal relationships. The inter-nodal relationships always comprise negative T-values for the centre-periphery relationships (indicating fewer relationships between the central city and its surrounding municipalities than would be expected), and positive values indicating a greater number of relationships between the municipalities of separate peripheries (inter-periphery). These are universal patterns that apply to all regions (including those outside the Randstad: see Van Oort et al. 2006).

Table 4 Theil (T) coefficients and biases of T values, by region and by type of relationship (unweighted)

Region	Integration	Intra-nodal bias (deviation from T)			Inter-nodal bias (deviation from T)		
		Intra-nodal	Intra-core	Intra-periphery	Inter-nodal	Core-periphery	Inter-periphery
Amsterdam	0.48	0.86	0.29	2.25	-0.23	-0.55	0.57
Rotterdam	0.59	0.80	0.22	2.36	0.37	-0.04	-0.26
The Hague	0.73	1.25	0.51	1.90	0.04	-0.36	0.71
Utrecht	0.39	0.75	0.36	1.40	0.05	-0.35	0.08
North Wing	0.71	1.24	0.55*	-	0.15	-	-
South Wing	0.92	1.54	0.88**	-	0.44	-	-
Randstad	0.98	1.85	1.24**	-	0.46	-	-

* Intra-core relationships for the North Wing are defined as those involving Amsterdam

** Intra-core relationships for the South Wing are defined as those between Rotterdam and The Hague; those for the Randstad as a whole are defined as those between Amsterdam, Rotterdam, The Hague and Utrecht

How can we now compare the network patterns based on absolute figures and those in which we apply a correction for the absolute size of the cities and towns involved? Although the identified network pattern of economic relationships between companies in the same municipality and in different municipalities appears to be far from integrated – with the criss-cross relationships being significant in relative terms, thus indicating the importance of the spatial network model – we perceive that this is very much overshadowed by the actual situation in which the major cities are (in absolute terms), involved in the majority of the

relationships. Applying a correction for the size of the towns and cities concerned does not mean that they no longer have any spatial significance at all.

3.2 *Distance and the spatial context of network relationships*

In Section 3.1 we used information theory to determine the extent to which the size of originating and destination towns is a determinant of the network relationships that emerge between them. However, the T-index takes no account of the (physical) distance between the towns, which can form an obstacle to the development and maintenance of an economic relationship. Similarly, the analysis in the foregoing section did not take into account other spatial peculiarities (regimes or contexts) applying to the network structures of economic relationships. In this section, we integrate the aspects of distance and spatial context with the size of the originating and destination municipalities, using gravitation models. These models reveal the effects of distance based and municipal-particular factors on the aggregated economic relationships between municipalities.

The gravity model assumes that the attraction between two objects (in our study, the interaction between companies, aggregated at the level of municipalities) depends on the mass of those objects and the distance between them. The hypothesis is that the larger the mass and the smaller the distance, the larger the attraction (and interaction) between them. This can be expressed as a formula:

$$I_{ij} = K \frac{M_i * M_j}{d_{ij}^b}$$

where I is the gravitational force or interaction between towns i and j, M is mass and d is the distance between towns. K is a constant. This formula can be resolved to give the following testable comparison:

$$(\log)I_{ij} = K + a_1 (\log)M_i + a_2 (\log)M_j - a_3 (\log)d_{ij} + a_4 (\text{characteristics}) + a_5 (\text{characteristics } j) + \epsilon$$

The absolute number of interactions (aggregated by municipality) is thus rendered dependent on the (absolute size of the) originating and destination municipalities, the distance between them and other factors. Intra-town relationships have been included in the analysis using a

distance of 0. Using this formula we can carry out multiple regressions (Maggioni & Uberti 2005, Dalgin *et al.* 2004, Sen & Smith 1995). A total of 729 (aggregated) interactions of varying extent between all towns and cities of the Randstad are included in the analysis. The units of mass relate to the total number of relationships of each town or city, as embedded in the network. The variables of masses and distances are measured in absolute values, what means that they show a non-normal statistical distribution. Logarithmic transformation provides only a partial solution to this problem. Because these variables are automatically unevenly distributed as a product of the size of the municipalities concerned, the regressions have been conducted using *negative binomial regression estimation procedures for count data* (Cameron & Trivedi 1998, Long 1997)¹¹. These models are estimated by maximum likelihood estimation techniques. We introduce (dummy) variables that express the spatial context of the towns, what enables us to examine whether there is more or less interaction between them due to:

- 2 Intra-regional relationships that remain within one of the four urban regions. This is captured by a dummy variable for relationships within the individual regions;
- 3 Intra-core relationships that remain entirely within the central city. This is captured by a dummy variable for relationships within the cities of Amsterdam, Rotterdam, The Hague and Utrecht;
- 4 Intra-periphery relationships that remain within the suburbs of the central city;
- 5 Intra-nodal relationships that remain entirely within a particular municipality (not in combination with 2 and 3 above);
- 6 Core-periphery relationships between the central cities and one of its 'own' suburban municipalities;
- 7 Inter-periphery relationships between peripheral municipalities other than the core-periphery relationships;
- 8 Inter-core relationships between the central cities of Amsterdam, Rotterdam, The Hague and Utrecht;
- 9 Intra North Wing relationships that remain entirely within the North Wing of the Randstad (the Utrecht and Amsterdam regions combined);
- 10 Intra South Wing relationships that remain within the South Wing of the Randstad (the Rotterdam and The Hague regions combined);

¹¹ A likelihood ratio test was applied to establish whether the data follows a Poisson distribution, and hence could be processed using a Poisson regression. This proved not to be the case, whereupon it was decided to use the negative binomial regression method.

- 11 Inter-Wing relationships between municipalities in the North and South Wings of the Randstad,
- 12 Intra-sectoral and sectoral hybrid relationships that occur between municipalities that specialise in business service provision, industrial activities or combinations thereof. This is captured by dummy variables based on the figures in Section 2. Relationships between a municipality specializing in industry and one specializing in business services are classed as ‘hybrid’.

The masses of the originating and destination municipalities are assumed to have a direct correlation with the absolute number of relationships within those municipalities. Distance is assumed to have an inverse correlation with the interaction intensity: the further apart two centres are, the less likelihood there is of any interaction. That an interaction takes place within one of the four urban regions is clear. However, whether this will lead to other interaction volumes is assessed using the region dummy variables in the model. Some region or relationship dummies cannot, by definition, be introduced in the model alongside others. In many cases, regions or individual towns and cities develop different regimes. Table 5 (at the end of this paper) presents the specifications of the eight different models applied.

The findings presented in Table 5 represent the outcome of a series of models in which an increasing number of variables was assessed in each. The first model, (model 1, ‘null model’) includes only the variables of the mass of the originating and destination towns and the distance between them. The size of both the originating and the destination town has a marked direct correlation with the total number of interactions between the municipalities of the Randstad, while distance has a marked inverse correlation. These basic findings remain true in all specifications (models 2-8). Models 2-8 add additional information about the spatial embedding of firm’s relations in the municipalities in the Randstad. Model 2 shows that, following corrections for the size of the originating and destination municipalities, the relationships within the urban regions of Amsterdam and Rotterdam have an additional dynamic feature. The Hague does so to a more limited degree while Utrecht does not. Model 3 demonstrates that the common ‘intra-region’ indicator that is highly significant can replace the regional effects of Model 2. An indicator for intra-core relationships (within the four central cities) then proves to be very significant in addition to the mass and distance variables. An indicator for intra-periphery relationships is reasonably significant, while that for inter-periphery relationships (criss-cross relations beyond the central cities) is not significant.

In Model 4, the regional effects of Model 2 are replaced by core-periphery relationships. Intra-core and intra-periphery relationships are then replaced by intra-nodal relationships (where relationships remain within the same municipality). It comes to the fore that the indicators for intra-nodal, inter-periphery, inter-core and core-periphery relationships are all significant in explaining the economic network relationships within the Randstad. Model 5 tests whether the classification of relationships within the North Wing is important in comparison to relationships between the North and South Wings. This proves to be the case, in a positive sense. Ignoring the earlier significant indicators, it appears that companies located in the North Wing of the Randstad maintain a significantly larger number of relationships with each other than with companies located outside the North Wing. Model 6 in a similar vein reveals a *negatively* significant effect in the South Wing. Ignoring the effects of the size of towns and the distances between them, companies in the South Wing generate and maintain significantly fewer relationships within the same region, while companies in the North Wing generate and maintain significantly more. Finally, Model 7 shows that municipalities that specialise in business services or industrial activities (in both the origin and destination locations of a relationship) do marginally significant account for a larger number of relationships – leaving out all previously assessed variables. Hybrid specialization (i.e. originating and destination municipalities having different specializations) actually account for fewer relationships. In Model 8 though, the most parsimonious complete model with all variables introduced to the model, neither business service not industrial specialised towns show any tendency towards more intensive contact with each other. Accordingly, we must conclude that, despite the frequently formulated hypotheses, sectoral specialisation does not give rise to greater interaction ('buzz') within or between towns – other characteristics are more dominant. Complementarities between municipalities and regions within the Randstad are not unambiguously clear.

As said, Model 8 weighs all the previously introduced variables against one another by means of a multiple regression. This model has the highest degree of explanatory power – of all models it fits the data best. Here we see that the indicators for intra-core, intra-periphery and intra-regional relationships are more significant than the North and South Wing indicators. All relationships are predominantly focused on the local area, be that the city, region or smaller municipality. Accordingly, we conclude that the Randstad as a whole functions to a large degree by means of economic relationships involving the central cities and/or the

immediate region of the originating company. There is little robust evidence to support the hypothesis of spatial network theorists for the existence of separate sub-systems in the North and South Wings, once corrections have been made for the size of the central cities and the distances between them and for the relationships that remain entirely within a particular municipality.

4 Synthesis

The analyses presented in this paper offer information regarding the extent to which the central place model and the network model determine the spatial form of economic networks within the Dutch Randstad region. Some of the outcomes of the analyses indeed seem to prompt a reconsideration of the dominant impression of monocentrism, central locations and a hierarchy. Although only a limited number (in absolute terms) of the relationships between cities and smaller municipalities can be classified as criss-cross relationships we see that there are (in relative terms) more such relationships than would be expected, in all regions. Core-periphery relationships, on the other hand, are fewer in number than expected. One particularly interesting finding is the asymmetry of the interaction between Amsterdam and the other three central cities of the Randstad. Amsterdam seems to exert a particular attractive force, more so than in the opposite direction. In first instance, the division of the Randstad into a North and a South Wing (discounting all other urban typologies) reveals a difference in network intensity, this being greater in the North Wing. However, once the other indicators are weighted accordingly, this effect is not robust. The city of Utrecht and its urban region often adopts a different position in terms of economic network structures than that of the other three cities. There are fewer criss-cross relationships in the region and a relatively larger number of relationships that have the other three central cities as their destination rather than their origin, with small companies having a more open network that extends beyond the region itself. In the three other regions, the small companies and business service providers are notable for a more closed (region-internal) system of network relationships. This all would seem to indicate that the ‘central location model’ and the ‘network model’ have a joint imprint on the structure of economic relationships at the level of the urban regions.

However, the distinction between ‘absolute’ and ‘relative’ numbers of economic relationships is particularly important. The gravity models show that the economic-functional hierarchy within and between the central cities is extremely dominant in explaining the absolute

numbers of relationships. Overall, we consider the patterns of monocentrism to be more dominant than those of multinodality: it is not realistic to ‘define away’ the effects of the size of the central cities. The four major cities of the Randstad hold central positions within the network and account for a disproportionately large share of the economic relationships between all municipalities in the region. The pattern of economic relationships within the Randstad can be explained in terms of the size of the various towns and cities involved, the distances between them, and the degree to which relationships tend to remain within the local town or region, or extend shortly beyond it. Within the Randstad, we can therefore still speak of four separate core-periphery models, each based on a particular urban region, in which the central cities maintain a considerable number of relationships with themselves and their immediate suburbs. There is no evidence to support the existence of a fully integrated network model that respects the current differences in size between the urban centres and incorporates various criss-cross relationships between areas of different types. Moreover, it is difficult to establish any direct link between the sectoral specialisations of the various urban regions and the positions occupied by towns and cities within the economic networks. The specialisation of each urban region is unique, but this has little impact in terms of the *overall* network centrality (the specialisations do cause heterogeneity among relations in terms of sizes and sectors of firms involved – but the general structure of the system is invariant to these aspects). The interaction between the central cities and the urban regions of the Randstad is relatively limited. The analyses do *not* show any marked complementarities of economic functions leading to relationships between companies located in the various regions of the Randstad.

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Table 5 Gravity models (NBR) of economic relationships between the municipalities of the Randstad region (n=729); unweighted.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	-2.32 (.151)**	-2.59 (.189)**	-3.11 (.233)**	-3.20 (.164)**	-2.27 (.152)**	-2.13 (.160)**	-2.49 (.161)**	-3.11 (.242)**
Mass origin (log)	0.51 (.023)**	0.51 (.023)**	0.50 (.026)**	0.49 (.026)**	0.51 (.023)**	0.51 (.023)**	0.52 (.024)**	0.51 (.026)**
Mass destination (log)	0.52 (.024)**	0.51 (.024)**	0.50 (.027)**	0.49 (.027)**	0.51 (.024)**	0.51 (.024)**	0.52 (.026)**	0.51 (.028)**
Distance (kilometres)	-0.03 (.002)**	-0.02 (.003)**	-0.01 (.002)**	-0.02 (.002)**	-0.04 (.003)**	-0.04 (.003)**	-0.03 (.002)**	-0.02 (.003)**
Position (region):								
Amsterdam region		0.29 (.120)**						
Rotterdam region		0.28 (.126)**						
The Hague region		0.24 (.129)*						
Utrecht region		0.20 (.141)						
Intra-regional			0.33 (.080)**					0.33 (.081)**
Position (central cities):								
Intra-centre (within 4 cities)			1.96 (.118)**					1.89 (.121)**
Intra-periphery			1.52 (.090)**					1.43 (.097)**
Intra-nodal (intra-centre & intra-periphery)				2.01 (.131)**				
Inter-periphery			0.07 (.071)	0.57 (.148)**				0.07 (.071)
Inter-centre (between 4 cities)			0.68 (.107)**	0.67 (.113)**				0.65 (.108)**
Centre-periphery (4 urban centres)				0.51 (.161)**				
Position (Wings):								
Intra-North Wing					0.14 (.074)**			0.01 (.060)
Intra-South Wing						-0.14 (.074)**		
Inter-wing					0.67 (0.130)**	0.53 (.120)**		0.14 (.108)
Specializations of cities/towns:								
Intra-Business Services towns							0.17 (.067)**	0.03 (.056)
Intra-industrial towns							0.93 (.163)**	0.26 (.134)*
Hybrid relationships							-0.27 (.086)**	-0.12 (.071)*
Log likelihood	-1369.24	-1365.68	-1199.2957	-1207.57	-1356.43	-1356.43	-1347.79	-1195.58
Pseudo R ²	0.227	0.229	0.323	0.319	0.235	0.235	0.239	0.325

**p<0.05, *p<0.10, N=220. Standard deviation in brackets

