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Kronenberg, Kristin and Volgmann, Kati

Research Institute for Regional and Urban Development (ILS),
Maastricht University, Statistics Netherlands (CBS)

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Knowledge-intensive employment growth in the Dutch Randstad and the German Rhine-Ruhr area: the impact of centrality and peripherality

Kristin Kronenberg

Research Institute for Regional and Urban Development (ILS), Dortmund, Germany
Maastricht University, Maastricht, The Netherlands
Statistics Netherlands (CBS), Heerlen, The Netherlands

Kati Volgmann

Research Institute for Regional and Urban Development (ILS), Dortmund, Germany

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Abstract

This paper investigates to what extent the different subsectors of the knowledge economy are subject to sector-specific spatial patterns of employment dynamics, and whether these patterns are conditional upon the general economic climate in a particular region. To this end, we analyze and compare patterns of employment growth in the knowledge economy and its subsectors in the different settlement zones of the (growing) Dutch Randstad and the (declining) German Rhine-Ruhr area, thus investigating the impact of centrality respectively peripherality within a polycentric metropolitan region on municipal knowledge-intensive employment growth. Our results show that with respect to knowledge-intensive employment, both the Randstad and the Rhine-Ruhr area exhibit sector-specific spatial patterns of employment dynamics. Furthermore, centrality and peripherality are found to play important roles in determining municipal knowledge-intensive employment growth, suggesting that the location of a municipality within a metropolitan region affects its employment dynamics, and this impact differs both between sectors, and between regions being subject to either growth or decline.

JEL classification: O18, R11, R12

Keywords: employment growth, knowledge economy, settlement structure, the Netherlands, Germany, metropolitan region, centrality, peripherality

1 Introduction

In recent years, the notion of the 'knowledge economy' has received considerable attention in the literature on localized knowledge spillovers, innovation and economic development. Knowledge-intensive activities have been argued to foster innovative activity, productivity and growth (e.g. Chadwick et al., 2008; Raspe & van Oort, 2006; van Oort et al., 2009), therefore having an impact on regional prosperity (Stein, 2003) and competitiveness (Chadwick et al., 2008).

The knowledge economy has been claimed to be inherently urban (e.g. Glaeser et al., 1992; van Oort et al., 2009) due to the fact that knowledge can be transmitted more easily between actors who are concentrated in space (e.g. van Oort et al., 2009). In this context, it has been argued that the 'development chances of urban regions today are determined in particular by their potential and capacities in the field of knowledge-intensive economic activities' (Krätke, 2007, p. 4).

Yet, it should be considered that neither metropolitan regions, nor the knowledge economy are homogeneous in nature. Instead, specific locations within a city region are likely to possess certain characteristics which will be especially conducive to particular subsectors of the knowledge economy. This leads us to the questions of

1. whether the different subsectors of the knowledge economy are subject to sector-specific spatial patterns of employment dynamics,

2. whether the location - hence its centrality or peripherality - of a municipality within the metropolitan region has an impact on employment growth, and
3. whether these patterns are conditional upon the general economic conditions present in a particular region.

In this study, we therefore firstly analyze and compare spatial patterns of employment growth in different sectors of the knowledge economy in polycentric urban regions, using the examples of the (growing) Dutch Randstad and the (declining) German Rhine-Ruhr area. Secondly, we investigate the impact of centrality and peripherality on employment growth in these two metropolitan regions for the different subsectors of the knowledge economy. Our analysis benefits from the fact that the data at hand are available on the detailed level of the municipality, and that the two regions under investigation are comparable regarding e.g. their size, population and polycentric structure, yet exhibit differences regarding overall growth respectively decline.

This paper contributes to the existing body of literature in several ways. Firstly, it investigates the relationship between settlement structure and employment dynamics, focusing on the location of a municipality relative to the entire urban region it is situated in. While various studies have used settlement structure as an explanatory variable when investigating employment dynamics (e.g. Kowalewski, 2011), to our knowledge, only van der Laan et al. (2005) have yet addressed the relationship between settlement

structure and employment growth on the detailed level of the municipality. Furthermore, we specifically focus on the knowledge economy and its subsectors, thereby identifying areas which are conducive to growth in this increasingly important sector of the economy respectively its different subsectors. Thirdly, this study compares employment dynamics taking place in a growing (Randstad) and a declining (Rhine-Ruhr) urban region, hence investigating whether employment growth or decline in knowledge-intensive sectors follows a generalizable pattern, or is dependent upon the general economic conditions in the respective region.

The paper is structured as follows: In Section 2, we discuss the relevance of the knowledge economy in a spatial context, and derive the hypotheses which guide the empirical research. Section 3 introduces the regions of study and presents the data used in the empirical analyses. In Section 4, we investigate patterns of municipal employment growth between the years 2000 and 2005 in the four subsectors of the knowledge economy, both in the Dutch Randstad and in the German Rhine-Ruhr area. In Section 5, the effect of settlement structure on municipal employment growth in the knowledge-intensive sectors of the economy is analyzed, and in Section 6, we discuss our findings. In section 7, we indicate the limitations of this study, and Section 8 concludes.

2 The knowledge economy in a spatial context

The knowledge economy has been argued to be intrinsically linked to urban agglomerations which facilitate the exchange of information due to the physical closeness of relevant actors (e.g. van Oort et al., 2009) and the resultant minimization of transaction costs. At the same time, however, firms in central locations have to put up with agglomeration diseconomies such as crowding, congestion and high rents (e.g. Glaeser et al., 1992; Parr, 2002a).

In addition, the general economic conditions in a specific region can be expected to have an effect on the relationship between settlement structure and the location of employment: In growing regions, rents and land prices in central, favored locations can be expected to be elevated due to high demand, whereas in declining regions, low demand may result in affordable office space and facilities, even in the core cities.

Polycentric metropolitan regions can be argued to inherently possess a certain degree of centrality, as each locality will be located reasonably close to at least one (and in most cases more than one) major conurbation. Here, it may be the case that 'if a firm shuns the metropolis in order to avoid agglomeration diseconomies, it is probably not required to forgo the benefits of a metropolitan location, or at least not all of these' (Parr, 2002a, p.728). On the other hand, the metropolitan core cities are likely to possess certain qualities (e.g. regarding density, accessibility, or costs) which will be different from

those characterizing their nearby surrounding areas, larger urban zones, and distant commuting regions.

Hence, it may be asked in which respect the development of specific subsectors of the knowledge economy is linked to their location within a particular metropolitan region. In other words: In which respect do centrality and peripherality within a polycentric metropolitan region have an impact on municipal employment growth in the different subsectors of the knowledge economy in different metropolitan regions?

In a comprehensive treatise on its definition and measurement, Raspe & van Oort (2006) define the knowledge economy as 'the use of knowledge in interactive relations between market actors and others, while producing and using goods and services, from the first idea to final products' (p. 1213). Yet, as there is no general consensus about what constitutes the knowledge economy and how it can be measured, various empirical studies classify different economic branches, groups of professionals or other measures on a specific spatial scale as knowledge economy indicators.

On the basis of Stein (2003), Zillmer (2010) suggests a differentiation of the knowledge economy into four subcategories: High-technology manufacturing (HT), Transformation-oriented services (TF), Transaction-oriented services (TA), and Information- and media-related manufacturing and services (IM). These four sectors are argued to possess distinct characteristics with respect to the utilization and exchange of

knowledge which are assumed to result in specific patterns, preferences and choices regarding the location of employment (Kujath, 2010; Kujath and Schmidt (2010b), Zillmer, 2010). See Table 1 for detailed information on the operationalization of the knowledge economy and its four subsectors¹.

TABLE 1 ABOUT HERE

High-technology manufacturing: In this subsector of the knowledge economy, the focus lies on the production of knowledge-intensive tangible goods, facilitated by the integration of product- or process related innovations. This includes extraction of crude petroleum and natural gas, mining of chemical and fertilizer materials, reproduction of recorded media, processing of nuclear fuel, building and repairing of ships and boats, manufacture of refined petroleum products, chemicals, other non-metallic mineral products, machinery and equipment, office machinery and computers, electrical machinery and apparatus, radio, television and communication equipment and apparatus, medical, precision and optical instruments, motor vehicles, railway and tramway vehicles, and air- and spacecrafts (Kujath & Schmidt, 2010a; Zillmer 2010).

Transformation-oriented services: Firms in this subsector transform existing into new knowledge which can be applied in various contexts. This includes service activities

¹ The classification employed in this paper follows Zillmer (2010), who refers to the German Classification of Economic Activities (WZ 2003) which corresponds to the Nomenclature statistique des activités économiques dans la Communauté européenne (NACE).

incidental to oil and gas extraction, maintenance and repair of office, accounting and computing machinery, research and development activities, architectural and engineering activities and related technical consultancy, and technical testing and analysis (Kujath & Schmidt, 2010a; Zillmer 2010).

Transaction-oriented services: This subsector comprises service firms which focus on the organization and management of transactions taking place within or between organizations. This includes transport via pipelines, space transport, telecommunications, monetary and other financial intermediation, insurance and pension funding, real estate activities, renting of (other) machinery and equipment, hardware consultancy, legal, accounting, book-keeping and auditing activities, and advertising (Kujath & Schmidt, 2010a; Zillmer 2010).

Information- and media-related manufacturing and services: Firms in this subsector transform and codify knowledge into the prototypes of goods which facilitate the storage and transport of information. This includes publishing, software consultancy and supply, data processing, database activities, other computer-related activities, motion-picture and video activities, radio and television activities, other entertainment activities, and news agency activities. (Kujath & Schmidt, 2010a; Zillmer 2010).

Firms in the former two sectors (high-technology manufacturing and transformation-oriented services) are often found to spatially agglomerate, yet these clusters are not

necessarily situated in the central locations of the metropolitan region (Kujath, 2010; Kujath & Schmidt, 2010b). These firms can be expected to benefit from being situated in more peripheral locations within the metropolitan region, as they tend to have developed relatively stable and recurring business dealings and are thus not reliant upon regular face-to-face interactions (Kujath, 2010). Moreover, with especially manufacturing firms often being comparatively large in size, firms in these sectors may instead decide to take advantage of the lower rents and land prices which can be found in more peripheral locations (e.g. Cheshire, 1995; Kronenberg, 2012). We thus assume that newly founded organizations in these sectors may be established in these areas, existing firms may relocate there at some point, or incumbents may grow comparatively faster than their counterparts in the more central regions, all of which favors employment growth in the more peripherally located municipalities.

Service employment in general has been reasoned to prefer urban locations over those situated in the periphery, as businesses processing information (not goods) require regular face-to-face contacts which can most easily be realized in centrally located places (e.g. Cheshire, 1995; Kloosterman & Musterd, 2001; Parr, 2002a). This holds especially true for innovative activities which are 'based on the exchange of richly layered information' (Kloosterman & Musterd, 2001, p. 626). Hence, for firms in the transaction-oriented service sector (TA), it is essential to be located in central locations in order to be able to effectively communicate and coordinate their activities, and therefore minimize

the costs of their business transactions (Coffey & Shearmur, 2002; Kujath, 2010). Likewise, firms in the information- and media-related manufacturing and service sector (IM) can be expected to benefit from being situated in more central locations within the metropolitan region, since in these places, the ease of access to novel information is facilitated, and creative input is abundant (Kujath, 2010). We thus assume that newly founded organizations in these sectors may be established in these areas, existing firms may decide to relocate there, or incumbents may grow comparatively faster than their counterparts in the more peripheral regions, all of which favors employment growth in the more centrally located municipalities.

We therefore hypothesize:

Hypothesis 1a/b: In a) the high-technology manufacturing (HT) and b) the transformation-oriented service (TF) sectors, the larger urban zones and the distant commuting areas in the Dutch Randstad and the German Rhine-Ruhr region will on average gain more respectively lose fewer employees than the core cities and their nearby surrounding areas.

Hypothesis 2a/b: In a) the transaction-oriented service (TA) and b) the information- and media-related manufacturing and service (IM) sectors, the core cities and their nearby surrounding areas in the Dutch Randstad and the German Rhine-Ruhr region will on average gain more respectively lose fewer employees than the larger urban zones and the distant commuting areas.

From this, we draw that:

Hypothesis 3a/b: Municipal employment growth in the different sectors of the knowledge economy sectors is contingent upon the location of a municipality within the metropolitan region, with peripherally located municipalities being conducive to growth in a) the high-technology manufacturing (HT) and b) the transformation-oriented service (TF) sectors.

Hypothesis 4a/b: Municipal employment growth in the different sectors of the knowledge economy sectors is contingent upon the location of a municipality w within the metropolitan region, with centrally located municipalities being conducive to growth in a) the transaction-oriented service (TA) and b) the information- and media-related manufacturing and service (IM) sectors.

3 Data

3.1 The Dutch Randstad

The dataset for the Netherlands incorporates the municipalities located in the Randstad, a metropolitan region in the North-West of the Netherlands. Not having a dominant core, but consisting of a multitude of (both larger and smaller) cities which are located in close proximity, yet constitute independent entities, the Randstad is a prime example of

a polycentric or polynuclear urban region (e.g. Kloosterman & Lambregts, 2001; Kloosterman & Musterd, 2001, Lambooy, 1998; Meijers, 2005).

It is characterized by high population density (1.224 inhabitants/km² in 2002), low unemployment rates, and the inflow of considerable amounts of FDI (OECD, 2007). The Randstad consists of the so-called 'Green Heart' which is surrounded by built-up areas, including the four largest Dutch cities of Amsterdam (736.562 inhabitants), Rotterdam (599.651 inhabitants), The Hague (463.826 inhabitants) and Utrecht (265.151 inhabitants)². In total, it has about seven million inhabitants, and more than two fifths of the Dutch population live in this area, although it only accounts for about one fifth of the country's surface.

Following the suggestions regarding its delineation as proposed by Regio Randstad (Regio Randstad, 2013), we define this area as consisting of the four provinces North-Holland, South-Holland, Utrecht and Flevoland³. This area consists of 190 municipalities, eight of which constitute core cities with more than 100.000 inhabitants, 35 represent immediately neighboring municipalities with continuous building

² These numbers refer to the year 2003.

³ It should be noted that no definite demarcation of the Randstad region exists. Our approach aims to facilitate comparability with the data employed for the Rhine-Ruhr area, thus including the municipalities in the 'Green Heart' between the four largest cities of the Netherlands as well as the areas north of Amsterdam, Haarlem and Amersfoort, all of which are situated in commuting distance to the high-density areas surrounding the eight large(st) cities in the area. Yet, the Randstad has also been delineated differently, either only consisting of the aforementioned eight cities located in a ring-shaped manner across the provinces of North-Holland, South-Holland and Utrecht and their immediate surroundings, or stretching further towards the East and South of the Netherlands, thus also embracing cities such as Breda, Arnhem and Nijmegen.

development which are part of an urban agglomeration, 42 more constitute areas which are part of a larger urban zone, and 105 municipalities can be characterized as distant commuting regions.

The data on the Randstad employed in this study were provided by Statistics Netherlands (CBS). Information regarding firms (sector, size, municipality of location) is available on the level of the business unit. These data originate from the Social Statistical Database (SSB), the Dutch business register, the Survey on Employment and Wages, the Survey Production Statistics, and information provided by the Dutch Tax Administration. Based on this information, employment per municipality was established for the years 2000 and 2005, both for the entire knowledge economy and its four subsectors, and changes in employment taking place during this period were thus determined.

Data concerning employees' level of education originates from the Dutch central student register, which is based on information derived from the Informatie Beheer Groep, a Dutch governmental institution. As each employee can be linked to the respective employer, the share of highly educated workers (age 22-40) per municipality could be established for the entire knowledge economy as well as its four subsectors.

Basic information regarding the Dutch municipalities (e.g. population density, settlement structure) originates from Statline, a publicly available database provided by Statistics Netherlands providing aggregate regional information on the municipal level.

For the Dutch Randstad, spatial delineations employed in this study correspond to the classification system developed by Vliegen (2005). 'Core cities' are the eight core cities in the Randstad region having more than 100.000 inhabitants and being surrounded by a city region, and 'nearby surrounding areas' (in Dutch: stedelijke agglomeraties) are those 35 municipalities which are directly adjacent to one of the main urban centers, constitute a built-up area, and are part of an urban agglomeration which in total offers more than 50.000 jobs. 'Larger urban zones' (in Dutch: stadsgewesten) are those 42 municipalities which are located within the catchment area surrounding one of the main urban centers. This area is identified by at least 70% within-region commuters, and at least 70% of its residential moves taking place within the region. 'Distant commuting areas' are those 105 municipalities which are located within the Randstad, and therefore in remote commuting range from one (or more) of the centers of economic activity, but have not been classified as being part of a city region. The classifications are mutually exclusive.

The dataset thus consists of municipal-level information regarding settlement structure, population density, the share of highly educated workers (age 22-40), the number of workers in the knowledge economy as well as its four sub-sectors, sectoral specialization

(relative to the Netherlands) in the knowledge economy as well as its four sub-sectors in 2000, total employment change, and employment change in the knowledge economy as well as its four sub-sectors. Generally, the variables refer to the year 2000 (or, in the case of employment change, to the difference between 2000 and 2005)⁴.

3.2 The German Rhine-Ruhr Metropolitan Region

In North Rhine-Westphalia, we focus on the Rhine-Ruhr region, a polycentric metropolitan region which embraces both the Ruhr area with cities such as Dortmund, Bochum, Essen, Duisburg and Gelsenkirchen, and the stretch along the Rhine where cities such as Düsseldorf, Cologne and Bonn are situated.

For the German Rhine-Ruhr Metropolitan Region, spatial delineations correspond to the classification system pertaining to the metropolitan city region ('Großstadtregion') developed by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR; in German: Bundesinstitut für Bau-, Stadt- und Raumforschung). 'Core cities' are the 20 core cities (in German: Kernstädte) with more than 100.000 inhabitants, and 'nearby surrounding areas' (in German: Ergänzungsgebiete) are those 70 municipalities which are directly adjacent to a core city, have a high population

⁴ Unfortunately, information regarding the municipal settlement structure and population density could not be employed for the year 2000 due to the fact that a large number of Dutch municipalities were subject to restructuring (in most cases merging) between 2000 and 2005. We therefore use information for 2005 instead.

density (inhabitants + in-commuters - out-commuters \geq 500), and have more in- than out-commuters and/or at least 50% of the out-commuters commute into the main urban center/core city. 'Larger urban zones' are those 56 municipalities from which at least 50% of the out-commuters commute into the core city or the adjacent area, and 'distant commuting areas' are those 44 municipalities from which between 25% and 50% of the out-commuters commute into the core city or the adjacent areas. Again, the classifications are mutually exclusive. Altogether, 12.8 million people live in the 190 municipalities which comprise the functional urban region (FUR) Rhine-Ruhr (BBSR, 2013)⁵. Together with a large number of densely populated smaller communities, they constitute a spatially connected core area which ranges from Hamm in the east to Bonn in the southwest.

The data on the Rhine-Ruhr area employed in this study were provided by Statistics North Rhine-Westphalia (IT.NRW). Corresponding to the data for the Dutch Randstad, the dataset for the Rhine-Ruhr Metropolitan Region comprises municipal-level information regarding settlement structure, population density, the share of highly educated workers, the number of workers in the knowledge economy as well as its four sub-sectors, sectoral specialization (relative to North Rhine-Westphalia) in the knowledge economy as well as its four sub-sectors in 2000, total employment change,

⁵ Actually, the area consists of 191 municipalities, of which one (Kalkar, which is located close to the Dutch border and the city of Nijmegen) was found to be located outside a metropolitan city region. This municipality was therefore excluded from the analysis.

and employment change in the knowledge economy as well as its four sub-sectors. All variables refer to the year 2000 (or, in the case of employment change, to the difference between 2000 and 2005).

4 Employment dynamics in the different settlement zones of the Randstad and the Rhine-Ruhr area

As shown in Table 2, the Randstad has been subject to employment growth in the knowledge economy and its subsectors between the years 2000 and 2005, the only exception being the transformation-oriented service sector, in which employment declined by 2.4%. The total knowledge economy was subject to a growth rate of 9.6%, and the growth rates for high-technology manufacturing, transaction-oriented services, and information- and media-related manufacturing and services amounted to 7.5%, 7.7%, and 24.2%, respectively. In the Rhine-Ruhr area, on the other hand, knowledge-intensive employment declined by 1.0%, with the high-technology manufacturing and the transformation-oriented service sectors losing 8.5% respectively 6.4% of their employment. Yet, the number of employees in both the transformation-oriented services, and in the information- and media-related manufacturing and services increased by 1.8% and 6.0%, respectively.

TABLE 2 ABOUT HERE

4.1 Spatial patterns of employment change in the knowledge economy in the Randstad and the Rhine-Ruhr area

As Table 3 illustrates, municipal employment growth in the knowledge economy in the Dutch Randstad between the years 2000 and 2005 exhibits a bimodal pattern: Especially the core cities, but also the municipalities located in the larger urban zones have been subject to considerable employment growth, with an average gain of 828 respectively 390 employees. The municipalities located in the nearby surrounding areas as well as in the distant commuting areas, by contrast, have grown noticeably less, exhibiting an average gain of only 159 respectively 251 employees. In the Rhine-Ruhr area, however, employment growth in the knowledge economy is largely confined to the core cities, which gain on average 286 employees. Those municipalities which are located the nearby surrounding areas, the larger urban zones, and the distant commuting areas face a considerable decline, losing on average 112, 23 and 65 employees, respectively. These findings suggest that in the Rhine-Ruhr area, the knowledge economy exhibits a 'traditional' spatial pattern where knowledge-intensive employment is largely located (and thriving) in the core cities. In the Randstad, conversely, knowledge-intensive employment is subject to growth both in the core cities and in more peripheral municipalities, hence possibly bringing about new hubs of knowledge-based economic activity in more suburban locations.

TABLE 3 ABOUT HERE

4.2 Spatial patterns of employment change in the subsectors of the knowledge economy in the Randstad and the Rhine-Ruhr area

By means of differentiating the knowledge economy into its four subsectors, we are able to investigate whether particular subsectors benefit from being situated in specific locations within the metropolitan region, and will therefore exhibit distinct spatial patterns of employment dynamics. In Table 4, the average municipal employment growth in the four subsectors of the knowledge economy in the four settlement zones of the Dutch Randstad and the German Rhine-Ruhr area is presented.

TABLE 4 ABOUT HERE

The average employment growth in the high-technology manufacturing sector in the Randstad amounted to 86 employees for the core cities, whereas those municipalities located in the nearby surrounding areas and in the larger urban zones lost on average 7 respectively gained only 5 employees. Those municipalities located in the distant commuting areas, on the other hand, were - with an average gain of 55 employees – also subject to considerable employment growth. Hence, a bimodal growth pattern can be observed. These findings suggest possible intra-sectoral differences between those

(possibly smaller) firms in high-technology manufacturing which benefit from being situated in central locations, and those (supposedly larger) companies taking advantage of the lower costs which can be associated with more peripheral places. In the Rhine-Ruhr area, a different spatial pattern of employment growth can be discerned: Especially in the core cities, but also in the distant commuting areas, employment in high-technology manufacturing declines considerably, with an average municipal loss of 380 respectively 66 employees. The average loss in the nearby surrounding areas amounts to 39 employees, whereas those municipalities located in the larger urban zones experience – though very moderate – average growth. These findings may be explained by the fact that the Rhine-Ruhr area generally declines, regarding both population and employment, so that locations closer to the core cities have become affordable and may e.g. constitute the preferred locations of firms relocating there from the distant commuting regions in order to be situated more centrally. Regarding both the Randstad and the Rhine-Ruhr area, *Hypothesis 1a* can thus be only partly confirmed.

In the transformation-oriented service sector, employment growth in the Randstad takes place in those municipalities situated in the larger urban zones as well as in the distant commuting areas, exhibiting an average municipal employment growth of 13 respectively 6 employees. Employment in the core cities and the nearby surrounding areas, on the other hand, declines considerably, with average losses of 197 respectively 37 workers. Hence, a pattern of 'spreading out' in favor of the more peripheral locations

within the metropolitan region can be observed. Likewise, albeit employment in this sector in the Rhine-Ruhr area generally declines, the average losses in those municipalities located in the larger urban zones and in the distant commuting areas – losing on average 8 respectively 7 workers - are only marginal compared to those in the core cities and the nearby surrounding areas. Apparently, the more peripheral regions within the metropolitan region are indeed conducive to employment growth in this subsector of the knowledge economy, both in the Randstad and in the Rhine-Ruhr area. *Hypothesis 1b* is thus confirmed.

Employment growth in the transaction-oriented service sector in the Randstad mainly takes place in those municipalities located in the larger urban zones and in the distant commuting areas, with average gains of 259 respectively 145 employees. The core cities, on the other hand, lose on average 481 employees between the years 2000 and 2005. This is surprising, as the transaction-oriented service sectors have been expected to depend upon being centrally located in order to coordinate their actions and have regular face-to-face encounters. In the Rhine-Ruhr area, conversely, employment growth follows a bimodal pattern, with the core cities gaining on average 495 employees, but the distant commuting areas experiencing a moderate average gain of 10 employees. At the same time, facing average losses of 47 respectively 20 employees, the municipalities located in the nearby surrounding areas and in the larger urban zones are subject to employment decline. These findings thus only partly support *Hypothesis 2a*.

Both in the Randstad and in the Rhine-Ruhr area, the highest average employment growth in the information- and media-related manufacturing and service sector can be observed in the core cities, experiencing average municipal employment gains of 1420 (Randstad) respectively 224 (Rhine-Ruhr) employees. The nearby surrounding areas, by contrast, gain on average 167 (Randstad) respectively 9 (Rhine-Ruhr) employees, while the more peripheral regions grow even less. These findings suggest that the core cities possess specific locational attributes (e.g. access to novel information in order to generate new knowledge and ideas) which are conducive to employment growth in the information- and media-related manufacturing and service sector and cannot be realized in more peripheral locations. *Hypothesis 2b* is thus strongly supported.

5 A regression model of municipal employment growth

The previous analysis already gives an overview regarding the (average) employment dynamics in the knowledge economy and its subsectors in the different settlement zones of the Randstad and the Rhine-Ruhr area. In this section, we further aim to establish the relationship between the location of a municipality within a polycentric urban structure and its employment dynamics in the different sectors of the knowledge economy, controlling for other locational characteristics which can be expected to have an effect on employment growth.

5.1 Model specification

We estimate a linear regression model in order to analyze the determinants of municipal employment growth in the knowledge economy and its subsectors, both in the Dutch Randstad and the German Rhine-Ruhr area. The dependent variable in our analysis is employment growth ($EMPL_GROWTH$) between the years 2000 and 2005 in sector s in municipality m , which is defined as

$$EMPL_GROWTH_{s,m} = \frac{EMPL_{s,m,2005}}{EMPL_{s,m,2000}}$$

where $EMPL$ denotes employment (in 1000 employees). We then estimate employment growth as follows:

$$EMPL_GROWTH_{s,m} = \beta_1 POPDENS_m + \beta_2 LQ_{s,m} + \beta_3 HIGH_EDUC_m + \beta_4 EMPL_{s,m} + \beta_5 EMPL_GROWTH_TOTAL_m + \sum_{c=1}^4 \delta_c SETTLEMENT_STRUCTURE_m + \varepsilon_{s,m}$$

with $SETTLEMENT_STRUCTURE$ indicating whether a municipality has been characterized as core city ($CORE$), as municipality located in the nearby surrounding

area (*URB_AGGLO*), as municipality located in the larger urban zone (*LUZ*), or as distant commuting region (*DIST_COMM*).

Locational advantages which originate from urban size and density without being sector-specific are termed urbanization economies (e.g. Frenken et al., 2007; Parr, 2002b). They may occur due to high local demand, which decreases transport costs (Glaeser et al., 1992), or due to the presence of a variety of organizations, facilitating the exchange of ideas, knowledge and information across sectors (Frenken et al., 2007; Glaeser et al., 1992; Kronenberg, 2012). Although, for example, core cities are likely to be densely populated, urbanization differs from settlement structure in the sense that the former refers to the absolute characteristics of an area, whereas the latter refers to the characteristics of an area in relation to those of the metropolitan region as a whole. We control for urbanization economies by including population density (*POPDENS*) as a control variable.

If an industry concentrates at a specific locality, intra-sectoral knowledge spillovers as well as the intentional transfer of workers and information are facilitated, and firms are likely to benefit from the nearby existence of suppliers and clients (e.g. de Vor & de Groot, 2010; Glaeser et al., 1992; Frenken et al., 2007; Kronenberg, 2012; Kowalewski, 2011). The location quotient (*LQ*), which proxies these localization economies, is therefore also included as a control variable.

The regional stock of human capital may have an effect on employment growth, as highly educated individuals can be expected to be especially capable of with respect to the absorption and application of novel information and the consequent realization of product and process innovations, which in turn may stimulate regional development (e.g. Kowalewski, 2011, van Oort et al., 2009). We control for this effect by adding the local share of workers with a university/college degree (*HIGH_EDUC*) to the model.

Furthermore, since high initial employment in a sector at a specific location has been found to lessen subsequent employment growth (e.g. Glaeser et al., 1992; de Vor & de Groot, 2010), we control for initial employment (*EMPL*) by including the number of employees (in 1000) in the knowledge economy respectively one of its subsectors in the year 2000. Lastly, in order to control for any changes regarding the overall local economic climate (Hoogstra & van Dijk, 2004), we also include total municipal employment change (in 1000) between the years 2000 and 2005 (*EMPL_GROWTH_TOTAL*).

TABLE 5 ABOUT HERE

See Table 5 for an overview of the variables. The model is estimated separately for the entire knowledge economy and each of its four subsectors, both for the 190 municipalities constituting the Dutch Randstad, and those 190 municipalities forming the German Rhine-Ruhr metropolitan area.

In order to allow for the inclusion and straightforward interpretation of all four dummy variables referring to the settlement structure of a municipality, the model is estimated as a least squares regression without intercept⁶. Since this estimation may generate unreliable measures of fit (e.g. Park, 2009), we also estimated the model as a least squares regression with a reference category (*CORE*), which resulted in R²-values (adjusted) very close to those presented below.

6 Results

Results are presented in Tables 6 and 7. With respect to the entire knowledge economy, we find that in the Randstad, constituting a core city has a negative effect on employment growth. In the Rhine-Ruhr area, conversely, we find a negative effect of being located in an urban agglomeration on knowledge-intensive employment growth, whereas the effect of constituting a core city is positive (albeit not significant).

⁶ There would have been two other possibilities: One would have been to use one of the categories as reference category, yet this would have required the interpretation of the remaining coefficients in relation to this reference category. Another option would have been the estimation of a constrained linear regression in which the sum of the coefficients of the four different settlement structures is set equal to zero, so that the coefficients of the dummy variables would have shown 'the extent to which behavior in the respective regions deviates from the (...) average' (Suits, 1982). Since both approaches would have made the interpretation of the coefficients rather cumbersome, and since we established that the inclusion of the four dummy variables has a negligible impact on the direction and magnitude of the coefficients of the other variables, we opted for estimating the model without intercept.

For the high-technology manufacturing sector, we find that in the Randstad, constituting a core city has a positive effect on employment growth, whereas the effect of being situated more peripherally is negative, although both magnitude and level of significance decrease with increasing distance from one of the core cities. For the Rhine-Ruhr area, we do not find any significant effects. These findings do not support *Hypothesis 3a*, but suggest that in the Randstad, high-technology manufacturing employment benefits from being situated in central locations despite the high costs that are usually attributed to these localities. There is a possible explanation for this finding: As already suggested in Table 5, the group of high-technology manufacturing firms appears to be rather heterogeneous, with employment either flourishing in the core cities, or – to a certain extent - in the distant periphery. Table 1 supports this notion, indicating that the high-technology manufacturing subsector embraces a much higher number of (supposedly diverse) 3-digit sectors than all other subsectors of the knowledge economy together.

For the transformation-oriented service sector, we find that being located in a municipality which is part of a larger urban zone is beneficial for employment growth in the Randstad. Again, we do not find any significant effects for the Rhine-Ruhr area. *Hypothesis 3b* is thus partly supported. Our findings suggest that in growing regions such as the Dutch Randstad, more peripherally located municipalities may indeed be conducive to employment growth in the transformation-oriented service sector. In the

generally declining Rhine-Ruhr area, however, the assumed benefits of the periphery with respect to the costs of buying or renting land and/or office space appear to have vanished, rendering central and peripheral locations comparatively equivalent regarding their locational advantages fostering employment growth in the transformation-oriented services.

For the transaction-oriented service sector, we find that in the Rhine-Ruhr area, constituting a core city positively affects employment growth, yet we do not find any significant effect of settlement structure on employment growth for the Randstad. *Hypothesis 4a* is therefore only partly supported. In line with our results regarding the transformation-oriented service sector, these findings again suggest that the general economic conditions in a larger urban agglomeration play a prominent role regarding the interplay of settlement structure and employment dynamics: In the declining Rhine-Ruhr area, employment in the transaction-oriented services is subject to growth in the core cities, whereas in the growing Randstad, rents and land prices are supposedly so high and space is so scarce that despite the advantages of being centrally located, employment growth also takes place in the more peripherally located municipalities.

For the information- and media-related manufacturing and service sector, we find that both in the Randstad and in the Rhine-Ruhr area, being located in the periphery has a negative impact on employment growth. These findings strongly support *Hypothesis 4b*,

and fortify the notion that in this subsector of the knowledge economy, firms depend upon the novel information and creative input which can easily be assessed in central locations.

TABLES 6 AND 7 ABOUT HERE

7 Limitations

This study is not without limitations. Firstly, an analysis of employment dynamics would have benefited from a differentiation between employment growth due to firm growth, to relocations, or the establishment of new organizations. Secondly, with microdata at the business level, it would have been worthwhile to investigate the effects of (changes in) firms' locational choices on (changes regarding) their operating costs and profitability. Unfortunately, this could not be realized with the data at hand. Thirdly, the operationalizations of the Dutch and German settlement structures, though we consider these to be highly comparable, are not subject to entirely identical criteria, which may have affected our findings. Fourthly, since our analysis only covers the years 2000 until 2005, our findings can not necessarily be generalized across time.

8 Conclusions and future outlook

In the present paper, we investigate to what extent the different subsectors of the knowledge economy are subject to sector-specific spatial patterns of employment dynamics, and whether these patterns are conditional upon the general economic climate in a particular region. To this end, we analyze and compare patterns of employment growth in the knowledge economy and its subsectors in the different settlement zones of the (growing) Dutch Randstad and the (declining) German Rhine-Ruhr area, thus investigating the impact of centrality respectively peripherality within a polycentric metropolitan region on municipal knowledge-intensive employment growth.

Our results suggest a relationship between settlement structure - hence the location of a municipality within the metropolitan region - and knowledge-intensive employment growth. We find this relationship to differ between the different subsectors of the knowledge economy, as well as between regions being subject to either growth or decline.

The assumption underlying our research had been that particularly in those sectors being subject to high transaction costs, employment growth will predominantly take place in the core cities. This hypothesis could only be confirmed for the information- and media-related manufacturing and service sector. For the transaction-oriented

service sector, however, we only find the expected effect in the declining Rhine-Ruhr area. At the same time, the more peripheral municipalities in the growing Randstad are subject to employment growth in the transformation-oriented service sector, hence turning into sub-centers of knowledge-intensive employment. One possible explanation for this development could be that in this sector of the knowledge economy, the market is already saturated in the core cities and their surrounding areas. Another reason could be that due to the small supply and resulting high costs of land in the central locations of a thriving metropolitan region, companies are forced to expand into more peripheral areas. These findings suggest that not only the particular characteristics of the different subsectors of the knowledge economy, but also the general economic conditions within a region – hence the resultant costs of land and office space - have a noticeable effect on knowledge-intensive employment growth respectively decline in the different settlement zones of a metropolitan region.

From our findings, we are able to draw several noteworthy conclusions. We find evidence that the knowledge economy is indeed heterogeneous in nature, as the relationship between settlement structure and employment growth varies between the different subsectors of the knowledge economy. More specifically, we establish that for the information- and media-related manufacturing and service sector, the benefits of a central location evidently outweigh the costs which can be associated with it, whereas for the transformation- and transaction-oriented service sectors, the relationship

between settlement structure and employment growth is also dependent upon the general economic conditions in a particular region, with central locations apparently becoming more affordable in declining regions. Furthermore, we find employment growth in high-technology manufacturing to take place in either the core cities or, to a lesser degree, in the remote commuting regions, which suggests this sector to be highly heterogeneous.

While the present analysis certainly answers some interesting questions, it also poses new ones: Our findings suggest that within the four subsectors of the knowledge economy, further differentiations would have been possible and worthwhile. While these detailed analyses would, unfortunately, have been beyond the scope of this paper, they constitute an interesting avenue for further research. Furthermore, with suitable data at hand, it will be possible to differentiate between employment growth due to firm growth, relocation, or the establishment of new organizations, and to investigate the relationship between locational choices, operating costs, and profits at the level of the firm.

Table 1: Classification of the subsectors of the knowledge economy

Classification	NACE sectors
High-technology manufacturing (HT)	111, 143, 223, 232, 233, 241, 242, 243, 244, 246, 247, 268, 291, 292, 293, 294, 295, 296, 297, 300, 311, 312, 314, 315, 316, 321, 322, 323, 331, 332, 333, 334, 341, 343, 351, 352, 353
Transformation-oriented services (TF)	112, 725, 731, 732, 742, 743
Transaction-oriented services (TA)	603, 642, 651, 652, 660, 701, 702, 703, 713, 721, 741, 744
Information- and media-related manufacturing and services (IM)	221, 722, 723, 724, 726, 921, 922, 923, 924

Table 2: Employment growth in the knowledge economy and its subsectors in the Dutch Randstad and the German Rhine- Ruhr metropolitan area, 2000-2005

	2000		2005		Relative change (%)	
	Randstad	Rhine-Ruhr	Randstad	Rhine-Ruhr	Randstad	Rhine-Ruhr
Knowledge economy	574.484	637.859	629.414	631.595	+9.6 %	-1.0%
High-technology manufacturing sectors (HT)	85.747	156.148	92.172	142.933	+7.5%	-8.5%
Transformation-oriented service sectors (TF)	73.676	66.633	71.942	62.394	-2.4%	-6.4%
Transaction-oriented service sectors (TA)	304.468	328.060	327.952	333.999	+7.7%	+1.8%
Information- and media-related manufacturing and service sectors (IM)	110.593	87.018	137.349	92.269	+24.2%	+6.0%

Source: own calculations, based on data from Statistics Netherlands and IT.NRW

Table 3: Average municipal employment growth in the knowledge economy in the different settlement zones of the Dutch Randstad and the German Rhine- Ruhr metropolitan area, 2000-2005

	Randstad	Rhine-Ruhr
Core cities	828	286
Nearby surrounding areas	159	-112
Larger urban zones	390	-23
Distant commuting areas	251	-65

Source: own calculations, based on data from Statistics Netherlands and IT.NRW

Table 4: Average municipal employment growth in the four subsectors of the knowledge economy in the different settlement zones of the Dutch Randstad and the German Rhine-Ruhr area, 2000-2005

	High-technology manufacturing sectors (HT)		Transformation-oriented service sectors (TF)		Transaction-oriented service sectors (TA)		Information- and media-related manufacturing and service sectors (IM)	
	Randstad	Rhine-Ruhr	Randstad	Rhine-Ruhr	Randstad	Rhine-Ruhr	Randstad	Rhine-Ruhr
Core cities	86	-380	-197	-54	-481	495	1420	224
Nearby surrounding areas	-7	-39	-37	-34	35	-47	167	9
Larger urban zones	5	1	13	-8	259	-20	112	4
Distant commuting areas	55	-66	6	-7	145	10	46	-3

Source: own calculations, based on data from Statistics Netherlands and IT.NRW

Table 5: Definitions of variables used in the analysis

Variable	Definition
<i>EMPL_GROWTH</i>	Change in employment between 2000 and 2005 (in 1000 employees)
<i>POPDENS</i>	Population density (in 1000 inhabitants per m ²)
<i>LQ</i>	Location quotient (relative to the Netherlands respectively North Rhine-Westphalia)
<i>HIGH_EDUC</i>	Share of workers with a college/university degree
<i>EMPL</i>	Employees in 2000 (in 1000 employees)
<i>EMPL_GROWTH_TOTAL</i>	Total employment change (all sectors) between 2000 and 2005 (in 1000 employees)
<i>CORE</i>	Municipality is classified as core city (dummy)
<i>URB_AGGLO</i>	Municipality is classified as being part of an urban agglomeration (dummy)
<i>LUZ</i>	Municipality is classified as being part of a larger urban zone (dummy)
<i>DIST_COMM</i>	Municipality is classified as distant commuting region (dummy)

All variables are measured on the level of the municipality. For the Dutch Randstad, the variable *HIGH_EDUC* refers to workers aged 22-40.

Table 6: Ordinary least squares regression for municipal employment growth in the knowledge economy and its four subsectors in the Dutch Randstad, 2000-2005

	Knowledge economy			HT			TF			TA			IM		
	Coeff.		SE	Coeff.		SE	Coeff.		SE	Coeff.		SE	Coeff.		SE
POPDENS	0.132	**	(0.050)	0.055	**	(0.016)	0.006		(0.018)	0.037		(0.036)	0.058	**	(0.023)
LQ	-0.209		(0.154)	0.015		(0.019)	-0.058	**	(0.014)	-0.214	**	(0.102)	-0.102	**	(0.029)
HIGH_EDUC	2.055	**	(0.840)	0.699	**	(0.227)	-0.168		(0.256)	1.400	**	(0.617)	0.777	*	(0.399)
EMPL	-0.017	**	(0.008)	-0.221	**	(0.018)	-0.078	**	(0.027)	-0.069	**	(0.010)	0.156	**	(0.014)
EMPL_GROWTH_TOTAL	0.229	**	(0.020)	0.041	**	(0.006)	0.016	**	(0.007)	0.122	**	(0.014)	0.055	**	(0.009)
CORE	-0.729	**	(0.366)	0.246	**	(0.115)	0.162		(0.133)	-0.217		(0.261)	-0.200		(0.164)
URB_AGGLO	-0.197		(0.193)	-0.163	**	(0.062)	0.061		(0.066)	0.041		(0.138)	-0.079		(0.090)
LUZ	-0.218		(0.167)	-0.153	**	(0.052)	0.094	*	(0.056)	0.092		(0.120)	-0.153	*	(0.076)
DIST_COMM	-0.091		(0.131)	-0.073	*	(0.041)	0.067		(0.043)	0.054		(0.091)	-0.106	*	(0.056)
R²	0.5349			0.5421			0.2359			0.4407			0.7326		
Adjusted R²	0.5118			0.5194			0.1979			0.4129			0.7193		
N	190			190			190			190			190		

Standard errors are shown in parentheses. ** indicates significance at the 5%-level. * indicates significance at the 10%-level.

Table 7: Ordinary least squares regression for municipal employment growth in the knowledge economy and its four subsectors in the German Rhine-Ruhr area, 2000-2005

	Knowledge economy			HT			TF			TA			IM		
	Coeff.		SE	Coeff.		SE	Coeff.		SE	Coeff.		SE	Coeff.		SE
POPDENS	0.639	**	(0.219)	0.105		(0.133)	0.041		(0.099)	0.343	**	(0.117)	0.123	*	(0.063)
LQ	-0.803	**	(0.262)	-0.074		(0.056)	-0.082		(0.074)	-0.498	**	(0.166)	-0.017		(0.052)
HIGH_EDUC	7.067	**	(3.407)	3.086		(1.994)	1.974		(1.525)	-0.025		(1.817)	2.653	**	(1.014)
EMPL	0.012		(0.010)	-0.114	**	0.041	-0.259	**	(0.049)	0.052	**	(0.009)	-0.009		(0.014)
EMPL_GROWTH_TOTAL	0.221	**	(0.048)	0.000		(0.030)	-0.027		(0.021)	0.130	**	(0.024)	0.037	**	(0.013)
CORE	0.667		(0.504)	-0.147		(0.307)	0.210		(0.230)	0.608	**	(0.273)	0.095		(0.145)
URB_AGGLO	-0.589	**	(0.286)	-0.233		(0.171)	-0.123		(0.134)	-0.079		(0.156)	-0.238	**	(0.080)
LUZ	-0.247		(0.193)	-0.145		(0.116)	-0.051		(0.095)	0.059		(0.108)	-0.138	**	(0.056)
DIST_COMM	-0.220		(0.200)	-0.157		(0.121)	-0.073		(0.093)	0.084		(0.108)	-0.128	**	(0.058)
<i>R</i> ²	0.2259			0.1693			0.2100			0.2621			0.1791		
<i>Adjusted R</i> ²	0.1874			0.1280			0.1707			0.2254			0.1382		
<i>N</i>	190			190			190			190			190		

Standard errors are shown in parentheses. ** indicates significance at the 5%-level. * indicates significance at the 10%-level.

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