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Long-run processes of geographical concentration and dispersion

Evidence from Germany

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Abstract

This paper analyzes the evolution of geographical concentration in the West German manufacturing, service, and knowledge-intensive sectors over a time period of 30 years. Drawing on detailed plant data of 187 industries from 1980 to 2010, we observe substantial concentration that is highest in manufacturing. Over time, there is a trend of deconcentration encompassing all economic activity. These patterns remain stable when accounting for both various sectoral and regional levels of aggregation and spatial dependencies between neighbouring regions. Investigating the role of plant births, expansions, contractions, and closures for the decline of concentration, we show that the underlying mechanisms differ across sectors. The dispersion of manufacturing industries is driven by contracting and closing plants within industrial agglomerations, whereas the dispersion of the service sector is fostered by the creation of new plants outside industrial agglomerations.

Zusammenfassung

Dieser Beitrag analysiert die Entwicklung der räumlichen Konzentration im Verarbeitenden Gewerbe, im Dienstleistungssektor und in den wissensintensiven Branchen in Westdeutschland über einen Zeitraum von 30 Jahren. Wir verwenden detaillierte Betriebsdaten von 187 Wirtschaftszweigen für die Jahre von 1980 bis 2010. Alle drei Sektoren weisen räumlich konzentrierte Standortmuster auf, die im Verarbeitenden Gewerbe jedoch am stärksten ausgeprägt sind. Das Ausmaß der Konzentration hat im Beobachtungszeitraum generell abgenommen. Diese räumlichen Muster bleiben auch bestehen, wenn wir verschiedene sektorale und regionale Abgrenzungen sowie räumliche Abhängigkeiten zwischen den Nachbarregionen berücksichtigen. Als Ursachen für die zunehmende Dispersion stellen wir die Bedeutung von Betriebsgründungen, Expansionen, Schrumpfungen und Schließungen in den Vordergrund. Wir zeigen, dass die Dekonzentration im Verarbeitenden Gewerbe insbesondere durch Schrumpfungen und Schließungen von Betrieben innerhalb von Branchenagglomerationen verursacht wurde. Im Dienstleistungsgewerbe wurden hingegen neue Betriebe vermehrt außerhalb von bestehenden Agglomerationen gegründet, was ebenfalls zur räumlichen Dispersion wirtschaftlicher Aktivitäten geführt hat.

JEL classification: R11, R12, O14

Keywords: geographical concentration, long-run development, plant life cycle, Germany

1 Introduction

The geographical concentration of economic activity is one of the central issues in regional science. The agglomeration of firms from the same industry causes external effects, the so called Marshallian forces, that explain why firms from the same industry tend to locate close to each other (Marshall, 1890). A large literature documents the importance of these externalities and their varying impact across different industries (e.g. Rosenthal/Strange, 2004). The importance of the Marshallian forces also varies over time (Neffke et al., 2011). While there are good reasons for firms to agglomerate, there are also costs to being concentrated close to others. Technological progress, structural and geopolitical changes are, for the main part, responsible for alterations of the relative strength of agglomerative and dispersive forces. As a consequence, patterns of geographical concentration change over time as well, with important implications for the organisation of inter-regional production and transport processes, the framework of regional supporting schemes for firms and industries, as well as future prospects of regional economies. This fact, however, has so far only been sparsely documented, with the few existing long-term studies encompassing merely a subset of economic sectors (e.g., Drucker, 2011; Alonso-Villar/Del Río, 2013).

In this paper, we analyze the long-run processes of geographical concentration and dispersion in West Germany over a continuous period of 30 years and for all economic activity that might be subject to the Marshallian forces. For the measurement of concentration, we relate to the the index proposed by Ellison/Glaeser (1997). A large range of studies covering several regional and sectoral delineations has applied this index to provide detailed rankings of industries according to their degree of concentration (see the overview in table A.1 in Appendix A.3). In many cases, only one year is considered, and the sectoral scope is limited to manufacturing. These studies find, for instance, that traditional and low-tech industries as well as those depending on site-specific assets are strongly concentrated, whereas industries producing perishable goods tend to be more dispersed in space. The few studies approaching a dynamic perspective predominantly document the dispersion of manufacturing activity across several European and North American countries (e.g. Cutrini, 2010; Behrens/Bougna, 2015). However, evidence on the factors explaining these long-run changes is still largely missing. An important contribution in this respect is provided by Dumais/Ellison/Glaeser (2002), who decompose aggregate concentration changes into portions attributable to plant births, expansions, contractions, and closures. They show that the geographic concentration of industries is the result of a dynamic process in which the combination of plant births, closures, and expansions/contractions act together to maintain a slow-changing level of industrial concentration.

This paper contributes to the empirical literature on agglomeration in four ways. First, we analyze the long-run evolution of the spatial concentration patterns in West Germany between 1980 and 2010. To the best of our knowledge, our results provide novel information on the changes in the EG index over such a long time period that is consistent both in regional and in sectoral respect. With specific focus on Germany, we further complement the existing findings on spatial concentration (Südekum, 2006; Alecke/Untiedt, 2008; Koh/Riedel, 2014; or Duschl et al., 2014). Second, we conduct our analysis for manufacturing and service industries as well as for the knowledge-intensive sectors. Most related studies solely focus on manufacturing, where externalities are assumed to be most important. However, in knowledge-intensive and in service industries, the Marshallian forces might be of major importance as well. So far, these sectors have not been considered simultaneously throughout thirty years. Third, we take account of the fact that the EG index reacts sensitive towards the chosen level of aggregation. To this end, we compare how the results vary across different sectoral and regional levels. In addition, we acknowledge that agglomerative forces may transcend given administrative boundaries and explicitly integrate neighbourhood effects. Fourth, in the spirit of Dumais/Ellison/Glaeser (2002) we shed light on which stages of the plant life-cycle (formation, growth, decline, closure) contribute to the observed long-term evolution of geographic concentration. Importantly, we empirically scrutinize the results generated by Dumais/Ellison/Glaeser (2002) and thereby add to the single other empirical validation by Barrios et al. (2005) for Ireland and Portugal.

Our main finding is a secular trend towards lower spatial concentration. This trend is visible in the manufacturing and service sector and even in knowledge-intensive industries, albeit to a different degree. Apparently, the external effects leading to agglomeration became less important in times of diminishing transport costs of both goods and information. The main drivers of this deconcentration have been closures of manufacturing plants in industrial agglomerations as well as formation of service plants which are located outside of the existing agglomerations. Although knowledge-spillovers are expected to be pivotal for a high degree of localization of knowledge-intensive industries, we find this sector to be even less concentrated than manufacturing. Other agglomeration factors such as the access to specialized suppliers and skilled workers are decisive for the location choice of such firms, too. Despite of this trend of deconcentration, a considerable set of industries in West Germany continued to be highly localized over time indicating that agglomerative forces still play a substantial role for certain industries to concentrate.

The remainder of the paper is organized as follows. Section 2 presents central theoretical arguments for and against the spatial concentration of economic activity. The indices used for analyzing the long-run evolution of the concentration patterns are introduced in section 3. Section 4 provides detailed evidence on the long-run concentration processes in West Germany at different spatial and industrial scales and discusses the mechanisms driving this development. The key results and prospects for further research are discussed in the last section.

2 Theoretical considerations

The question why economic activity is not evenly distributed across space has been subject to intense theoretical thought. A substantial part of the observed geographical concentration can be traced back to so-called first-nature forces. Firms that rely on natural advantages such as fertile soil, raw materials or the existence of navigable waterways locate close to where these are abundant (Krugman, 1993).[1] The other explanation for

[1] Ellison/Glaeser (1999) find that at least half of the observed geographical concentration in the USA is due to natural advantages. For Germany, Roos (2005) attributes about one third of the agglomeration of economic activity to natural features.

geographic concentration are economies of scale, external to individual firms but internal to co-located firms. These centripetal forces lead to a concentration of economic activities in space. In contrast, centrifugal forces or urban congestion costs act as agglomeration disadvantages that negatively influence benefits and profits. Economic agents have incentives to avoid proximity, which ultimately results in the geographical dispersion of economic activities.

There are several theoretical explanations as to the causes of agglomeration economies (for an overview, see Duranton/Puga, 2004). Rooted in the seminal work of Alfred Marshall (1890), three agglomeration forces have become prominent. First, the proximity of firms reduces transport costs and enables them to benefit from sharing suppliers producing with increasing returns. Second, the local concentration of firms of one sector creates a pool of skilled personnel, reducing search costs for qualified labor and enhancing the probability and quality of successful matches. Third, geographical proximity promotes the flow of knowledge and technology spillovers between firms and people. Knowledge and ideas can be transmitted through formal and informal channels fostering innovation and technological change.

The existence and the sources of agglomeration economies are generally scrutinized for the manufacturing sector (see, e.g., Rosenthal/Strange, 2001). For the service sector, much less evidence is available in both theoretical and empirical terms. Kolko (2010) argues that services are more urbanized, but also less agglomerated than manufacturing. He stresses that services rely much less on physical inputs than manufacturing, thereby reducing the necessity to locate near natural resources. In addition, transports costs for services output and the necessity of face-to-face contact with customers make it important for some service industries to be close to their customers. Moreover, for those firms that serve customers across different industries, the optimal location choice is within a dense and diverse net of businesses that also provides a thick labor market. In his empirical analysis for the USA, Kolko (2010) confirms that services are less concentrated than manufacturing at the county level and much less so at the state level. Natural resources do not statistically explain the location of service firms, whereas the share of workers with graduate degrees as proxy for knowledge spillovers is the only measure that is positive and significant. For Germany, Alecke/Untiedt (2008) and Koh/Riedel (2014) find that the vast majority of service industries is strongly localized and that agglomeration forces play an equally important role as in manufacturing.

Special focus is often put on knowledge-intensive industries, since knowledge spillovers arguably are of major importance for creating and spreading innovations. Because the transfer of knowledge and ideas attenuates very quickly with distance (Feldman/Kogler, 2010), those industries that rely on these inflows should also cluster in space. Jaffe/Trajtenberg/Henderson (1993) and Audretsch/Feldman (1996b) report corresponding results for the USA, and Maurel/Sédillot (1999) also find a high degree of spatial concentration for high-technology industries in France. According to Bottazzi (2001) and Combes/Duranton (2006), however, knowledge-intensive industries can well feature geographically dispersed location patterns. In fact, Devereux/Griffith/Simpson (2004) and Barrios et al. (2009) find little evidence that high-tech industries are more geographically concentrated than other industries. Devereux/Griffith/Simpson (2004: 545) discuss their younger age, developments in communications and transportation and the internalization of knowledge spillovers by merging firms as possible reasons for the lack in concentration.

From a static point of view, agglomeration advantages provide an answer as to why firms locate close to each other, which explains the geographical concentration of economic activities. However, there is no reason to assume that positive external effects prevail in the same magnitude or even increase over time. In the long run, agglomeration advantages may alter due to technological progress or structural or geopolitical changes. For example, because of the rapid technological progress especially in the telecommunications sector, the way individuals or firms can interact has changed fundamentally in the last decades. Likewise, improvements in traffic infrastructure have resulted in much lower transport costs of goods. Moreover, vertical disintegration of production has led to outsourcing parts of the production process to intermediate suppliers that may even be located in different countries. These latter developments might well foster the dispersion of once concentrated structures.

Based on the concept of agglomeration economies, several theoretical models have been developed to explain changes in the geographical concentration of economic activities. In the New Economic Geography literature, for example, the location of production is modelled as the outcome of the interplay between market-crowding and market-access forces with a crucial role assigned to transport costs (Krugman, 1991; see also Ottaviano/Thisse, 2004 for an overview). Under certain conditions, the reduction of transport costs leads to self-augmenting processes that further increase concentration, whereas increasing transport costs eventually foster deconcentration. A further explanation of the explicit development of an industry's geographical concentration over time is provided by the industry life cycle framework (Klepper, 1997). As Neffke et al. (2011: p. 53) note, industries have different agglomeration needs in different stages of their life cycles because their mode of competition, innovation intensity, and learning opportunities change over time. During its growth phase, an industry can be expected to benefit from agglomeration advantages, and hence firms seek mutual proximity. As a consequence, the industry becomes geographically concentrated. When the maturity phase is reached and positive externalities eventually cease to exist, concentration remains simply because it would be too costly to relocate. In traditional manufacturing industries, for example, past agglomeration patterns might still be in place, whereas specific externalities have become obsolete due to declining demand and modern production technologies. When finally demand decreases too strongly, establishments die and concentration dissolves. In the same vein, Audretsch/Feldman (1996a) link the propensity for innovative activity to spatially cluster to the different stages of the industry life cycle. They argue that location matters most during the early stages, whereas the positive agglomeration effects become replaced by congestion effects during later stages. Similarly, in outlining an evolutionary agglomeration theory, Potter/Watts (2011: 419) argue that the Marshallian forces create larger economic performance and increasing returns at the start of the industry life cycle, but declining economic performance and diminishing returns during the later stages. This focus on the development of the economic landscape is also at the heart of the evolutionary economic geography that deals with the processes by which the spatial organization of economic production, distribution and consumption is transformed over time (Boschma/Martin, 2007: 539).

A slightly different way to catch the dynamics of geographical concentration is taken by Dumais/Ellison/Glaeser (2002). They define concentration as the outcome of a life cycle process in which new plants are created, existing plants expand and contract, and ultimately plants are closed down. Decomposing the EG index into these four components, they account for the fact that the aggregate trends in geographical concentration change only slowly, whereas there is a high degree of employment turnover at the level of the individual plants. Knowledge on the precise channels through which localization patterns remain constant is important for various reasons. For example, the EG index might not change simply because the employment decrease due to plants closing down is substituted by employment needs of newly created plants. This provides evidence for a process of creative destruction within the industry with links to the theoretical approaches mentioned above.

Summing up, theoretical reasoning provides various answers as to why the spatial concentration of economic activity should differ across industries and across time. In the empirical part in chapter 4, we will investigate the long-run concentration process in Germany separately for manufacturing, services, and the knowledge-intensive industries. In particular, we resort to the decomposition method of Dumais/Ellison/Glaeser (2002) to determine which components of the plant life cycle have contributed to the changes in concentration over time.

3 Empirical implementation

Several measures can be used to analyze the geographical concentration of industries (see Combes/Overman, 2004 for a discussion). We resort to the agglomeration measure proposed by Ellison/Glaeser (1997: henceforth EG) that is widely used in empirical research on assessing geographical concentration.

EG begin by constructing a measure of an industry's "raw" geographical concentration defined as $G = \sum_{r=1}^{N}(s_r - x_r)^2$, where s_r is the share of the industry's employment in region r, and x_r is the share of total employment in that region. G is very similar to the Gini coefficient and measures concentration relative to total employment. It takes the value of one if an industry is located in a single regions and zero if it is distributed across regions according to each region's size.

The raw concentration index G does not yet control for the structure of the respective industry, because it cannot distinguish between internal and external economies of scale. If an industry in a region consisted of one large establishment instead of a number of smaller establishments, G would still indicate geographical concentration. EG take this into account by deriving their index from a model of location choice.[2] They assume that, in the absence of agglomeration forces, firms choose their location as if dartboards were thrown at a map and that there exists an allocation process that yields the observed employment distribution

[2] Maurel/Sédillot (1999) develop an alternative index of geographical concentration that also takes account of the firm size structure.

in expectation. Under these assumptions, $E(G) = (1 - \sum_{r=1}^{R} x_r^2)(\gamma + (1-\gamma)H)$, where γ is a combined measure of the strength of natural advantages and spillovers between firms in a broad sense. H is the industry's Herfindahl index $H = \sum_{j=1}^{B} z_j^2$, with z_j denoting firm j's share of the industry's employment. Solving for γ, yields the EG index of geographical concentration:

$$\gamma \equiv \frac{G - (1 - \sum\limits_{r=1}^{N} x_r^2)H}{(1 - \sum\limits_{r=1}^{N} x_r^2)(1-H)}. \tag{1}$$

γ is a sophisticated measure of the geographical concentration of an industry that explicitly takes into account its establishment size structure and the aggregate distribution of economic activity. Unlike other measures of geographical concentration, it also allows to test if the observed spatial concentration is significantly stronger than what would be expected by a purely random location choice where positive externalities due to locational advantages do not play a role. In the absence of agglomeration effects, γ would be equal to zero, and consequently $E(G) = (1 - \sum_{r=1}^{R} x_i^2)H$. Assuming normality, EG propose that, in the case of significant concentration, G is at least two standard deviations larger than its expected value $E(G)$.[3] This offers the unique possibility to test the significance of geographical concentration, which distinguishes the EG index from comparable measures.

There are several restrictions of the EG index that should be kept in mind. From a theoretical point of view, the EG index does not distinguish between concentration due to natural advantages and due to true spillovers. This must be taken into account when concentration patterns of different industries are compared. Moreover, it is difficult to interpret absolute index values. Even though Ellison/Glaeser (1997: p. 890) argue that their index is designed to facilitate comparisons between countries and different levels of aggregation, one should be careful when comparing countries with huge disparities in their economic structure. From a methodological point of view, it should be noted that the EG index neither controls for the relative position of geographical units in space nor for the size of an industry. We will elaborate more on the latter two points in section 4.2, where we conduct various sensitivity checks.

4 Results

In the following, we assess the EG index for each West German manufacturing and service industry in each year between 1980 and 2010. Since it reacts sensitive towards the level of sectoral and regional aggregation, we calculate the index for 45 2-digit and 187 3-digit industries at the level of 112 functional labor markets and 326 administrative districts. To this end, we use extensive administrative data that is described further in section A.1 in the Appendix. We start our analysis by discussing the overall development of the EG index along

[3] The variance of G can be obtained as:
$\sigma_G^2 = 2H^2\left[\sum_{r=1}^{N} x_r^2 - 2\sum_{r=1}^{N} x_r^3 + (\sum_{r=1}^{N} x_r^2)^2\right] - 2\sum_{j=1}^{B} z_j^4\left[\sum_{r=1}^{N} x_r^2 - 4\sum_{r=1}^{N} x_r^3 + 3(\sum_{r=1}^{N} x_r^2)^2\right]$.

with several sensitivity checks. In a second step, we present the results for manufacturing, services, and the knowledge-intensive industries separately. Last, we shed some light on the factors underlying the long-run changes in concentration via their decomposition into portions attributable to the different stages of the plant life cycle.

4.1 Overall development

The size of the EG index yields information on the degree of an industry's geographical concentration and allows us to compare the degree of concentration between different industries at the same level of aggregation. In order to gauge to what extend all German industries tend to concentrate, we calculate the yearly unweighed average of this index. We start with a picture of the concentration of all economic activities in West Germany in 2010. For the 3-digit industries, the average EG index amounts to 0.014 (counties) and 0.021 (LMR) (see table 1). The corresponding values at the 2-digit level are 0.008 (counties) and 0.010 (LMR). An assessment if this degree of concentration is high or low is quite difficult due to the very sparse comparable evidence for other countries. For example, Arbia/Dominicis/Groot (2011) report an average EG index of 0.020 of Italy in 2001, referring to all 2-digit sectors and functional areas. The comparable mean EG index for West Germany, based on 2-digit industries and LMR, is considerably lower with 0.009 in 2000. To the best of our knowledge, further overall evidence is available only for Germany. Alecke/Untiedt (2008) use German administrative data from 1998 and obtain an average EG index at the 2-digit level of 0.009 (counties) and 0.015 (planning regions), and for the 3-digit-level mean values of 0.015 (county) and 0.025 (planning regions).

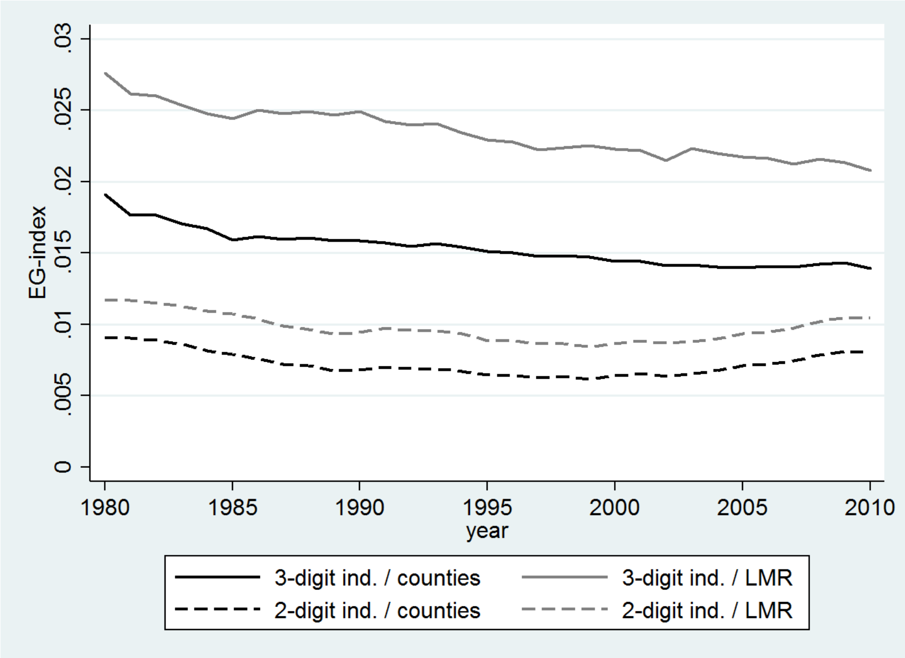
Table 1: EG index and its components for all industries

	1980	1985	1990	1995	2000	2005	2010	Δ 1980-2010	
								abs.	rel.
2-digit industry, county									
Mean EG index	0.009	0.008	0.007	0.006	0.006	0.007	0.008	-0.001	-11.6%
Raw concentration (G)	0.018	0.016	0.014	0.014	0.013	0.014	0.016	-0.002	-12.8%
Plant Herfindahl (H)	0.009	0.008	0.008	0.008	0.007	0.007	0.008	-0.001	-13.5%
2-digit industry, LMR									
Mean EG index	0.012	0.011	0.009	0.009	0.009	0.009	0.010	-0.001	-10.7%
Raw concentration (G)	0.020	0.019	0.017	0.016	0.015	0.016	0.018	-0.002	-12.1%
Plant Herfindahl (H)	0.009	0.008	0.008	0.008	0.007	0.007	0.008	-0.001	-13.5%
3-digit industry, county									
Mean EG index	0.019	0.016	0.016	0.015	0.014	0.014	0.014	-0.005	-27.2%
Raw concentration (G)	0.055	0.051	0.047	0.041	0.036	0.036	0.036	-0.019	-33.8%
Plant Herfindahl (H)	0.038	0.036	0.032	0.027	0.023	0.023	0.023	-0.015	-39.1%
3-digit industry, LMR									
Mean EG index	0.028	0.024	0.025	0.023	0.022	0.022	0.021	-0.007	-24.7%
Raw concentration (G)	0.062	0.058	0.055	0.048	0.043	0.042	0.042	-0.020	-32.3%
Plant Herfindahl (H)	0.038	0.036	0.032	0.027	0.023	0.023	0.023	-0.015	-39.1%

Source: Establishment History Panel; own calculations.

Table 1 reports the EG index and its main components for the different levels of industrial and spatial aggregation. As regards the industrial scope, spatial concentration is stronger at the 3-digit level than at the 2-digit level. This outcome suggests that spillovers accruing from the co-agglomeration of 3-digit-industries within the same 2-digit industry seem not

Figure 1: Development of the overall EG index



Source: Establishment History Panel; own calculations.

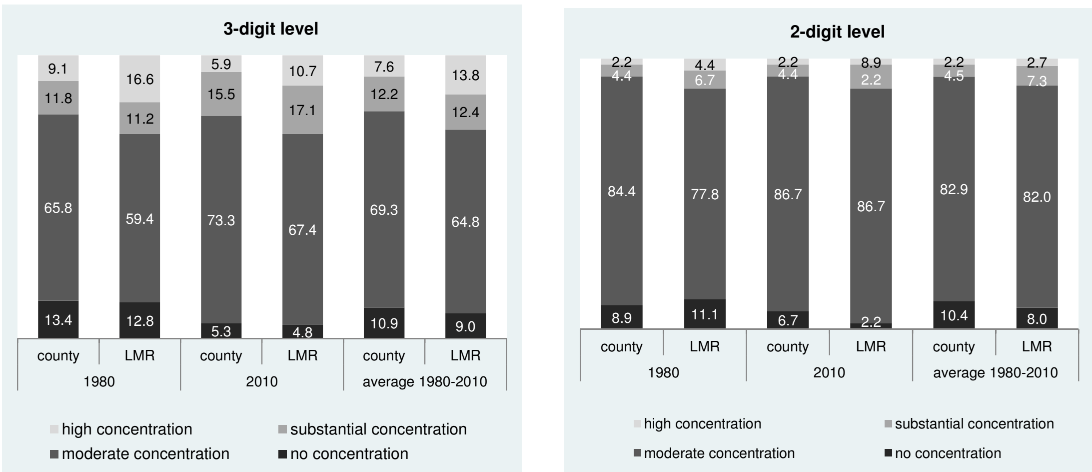
to affect the strength of spatial concentration. Evidently, the sectoral scope of agglomeration effects is confined within 3-digit industries. Industries that are more closely delimited have a larger Herfindahl index H, by construction. Since $\delta G/\delta H$ is smaller than 0, this countervails larger values of the EG index. With respect to the spatial dimension, the EG and the raw concentration index G both increase with the size of the regional units. This outcome is corroborated by Ellison/Glaeser (1997) and further related studies (e.g., Briant/Combes/Lafourcade, 2010). Apparently, the external economies of scale that foster concentration work over longer distances than within small-scale regions such as counties.

Between 1980 and 2010, there is a secular trend of decreasing agglomeration (see figure 1). The decline of the EG index is stronger at the 3-digit-level than at the 2-digit-level. The most notable decreases of agglomeration occur in the first half of the 1980s and from 2000 onwards. The changes in the EG index measured at the LMR level mostly parallel those at the county level, but the degree of concentration is higher. A look at the raw concentration index G and the plant Herfindahl index H that constitute the main components of the EG allows to provide a broad indication for the overall decline in concentration (Dumais/Ellison/Glaeser, 2002). For West Germany, the decline of the EG index at the level of the 2-digit industries can be explained by a slight decrease in G and H (see table 1). At the 3-digit industry level, both components exhibit a strong decline over time, which means that these industries have fractionalized into plants with even sizes that are more evenly distributed across space.

Alterations in the spatial patterns of economic activities become even more visible when comparing the respective fractions of concentrated and non-concentrated industries. Following Ellison/Glaeser (1997), we categorize industries as highly concentrated if the EG index is higher than 0.05, and as substantially concentrated if it is between a range of 0.05 and 0.02. If the EG-Index is equal or lower than 0.02, there is only moderate concentration, and for values smaller than 0, the industry is not concentrated. Figure 2 depicts the resulting distributions for the four industry-region combinations. According to this classification, at least three quarters of all industries are not or moderately concentrated, depending on the level of aggregation. While this pattern is mostly constant over time, we find that the share of highly concentrated 3-digit industries declined.

In order to check whether the underlying spatial patterns of industries might be purely random, we additionally test whether the spatial patterns are 'true' concentrations for the four industry-region combinations and years under observation. For this purpose, we conduct the significance test proposed by Ellison/Glaeser (1997). The majority of the 3- and 2-digit industries have significant index values in each year of the observation period at both regional levels (see table A.4 in Appendix A.3). These findings imply that most industries feature stronger concentrated spatial patterns than would be the case if the plants' location choice were taken by random.

Figure 2: Structure of the size classes of the overall EG index (shares in per cent)



Source: Establishment History Panel; own calculations.

4.2 Sensitivity checks

The baseline results in the previous chapter have shown that the degree of concentration increases with the size of the chosen spatial units. The fact that concentration measures are sensitive to the size and shape of regions is widely addressed as the Modifiable Area Problem (MAUP) (see Duranton/Overman, 2005 or Briant/Combes/Lafourcade, 2010). In order to test whether the obtained EG indices are affected by the chosen level of aggregation, we follow Briant/Combes/Lafourcade (2010) and calculate Spearman rank correlations for the overall EG index and the Gini index at the county and the LMR level, respectively. Since section 4.1 provided evidence that the sectoral scope of agglomeration effects is rather confined to the single 3-digit industries, in the following we concentrate on this sectoral level. The within correlation coefficients for each index depicted in table 2 are generally high. Since the coefficient for the Gini index is even higher, geographical concentration measured by the EG index appears to be slightly more sensitive to the regional aggregation level. Compared to the within correlations the rank correlations between the two indices are considerably smaller. Apparently, size distortions matter less than the choice of the index. This conclusion is also drawn by Briant/Combes/Lafourcade (2010), whose correlation analysis for both concentration measures yields similar results.

Table 2: Spearman rank correlations for the EG and the raw concentration indices

	EG index		Gini index	
	county	LMR	county	LMR
	3-digit industry			
EG index, county	1.000			
EG index, LMR	0.879	1.000		
Gini index, county	0.657	0.733	1.000	
Gini index, LMR	0.671	0.777	0.990	1.000

Source: Establishment History Panel; own calculations.

Since agglomerative forces may transcend given administrative boundaries, one caveat of the EG index is that it does not account for the relative position of regions. We thus explicitly integrate neighbourhood effects by calculating a spatial variant that additionally accounts for plants in nearby regions weighted by an inverse distance matrix and a binary contiguity matrix (see Appendix A.2). This spatially weighted EG index was developed by Guimarães/Figueiredo/Woodward (2011) and is also applied by Behrens/Bougna (2015).[4]

On average, the spatially weighted EG index in table 3 takes on values that are larger than the non-spatial (non-weighted) values. This suggests that spatial concentration is not bound to a given spatial unit, but transcends numerous adjacent areas. The results also comply with those of Behrens/Bougna (2015), who present similar results for manufacturing in Canada. The EG index weighted with the inverse distances between the regions exhibits slightly larger values than in the non-spatial case. The index weighted with the contiguity matrix is even larger than the non-spatial EG index at the LMR level. This result might be induced by the fact that adjacent counties do not necessarily belong to one LMR. Hence, the neighbourhood of regions appears to be accounted for too weakly by the inverse distance matrix and too strongly by the contiguity matrix. Therefore, in the following we focus on the EG index calculated at the 3-digit industrial level and at the level of the LMR. Figure 3 graphically depicts the long-run evolution of geographical concentration according to the different EG indices.

Apart from its non-spatial character, a further issue that merits attention is the sensitivity of the EG index with regard to the industry size structure. It allows for industry concentration via the plant Herfindahl index, but does not control for the size of an industry. The EG index takes on high values if an industry's employees are evenly distributed between establishments, but are concentrated geographically. Since theory assumes that concentration results from establishments exploiting external economies of scale, this feature is desirable and is one of the reasons why this index has been widely used since its introduction. However, it can be argued that spillovers could emerge particularly from large establishments. It is not clear how the EG index reacts if few small establishments are located in the vicinity of one very large establishment, as is often the case in automobile

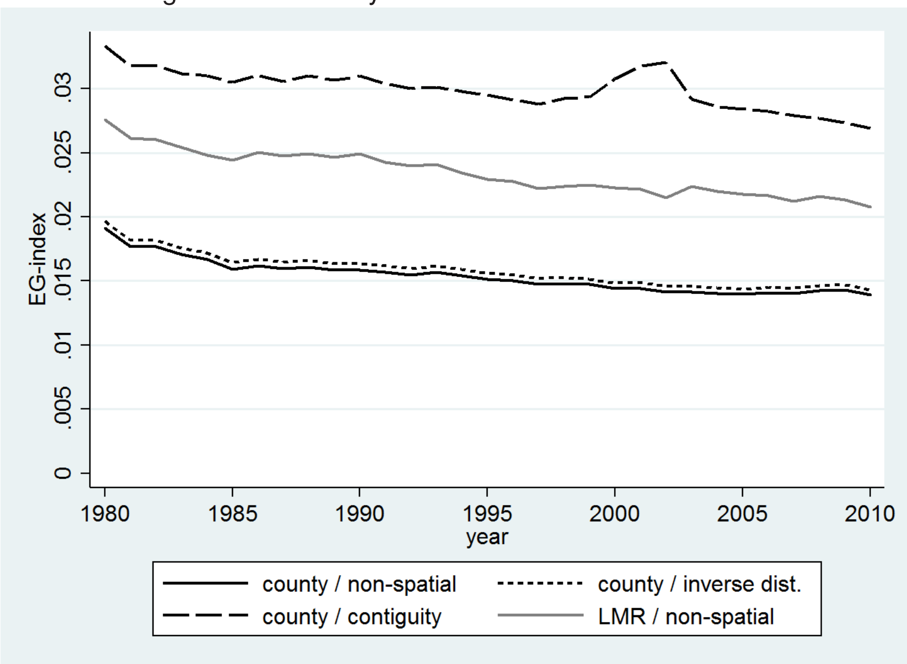
[4] A further possibility is to implement distance-based measures like the index developed by Marcon/Puech (2003) or Duranton/Overman (2005). However, its computational intensity prevents us from calculating this index for a large number of industries and years.

Table 3: Spatially weighted EG indices (3-digit industries)

	1980	1985	1990	1995	2000	2005	2010	Δ 1980-2010 abs.	rel.
county, non-spatial									
Mean EG index	0.019	0.016	0.016	0.015	0.014	0.014	0.014	-0.005	-27.2%
Raw concentration (G)	0.055	0.051	0.047	0.041	0.036	0.036	0.036	-0.019	-33.8%
Plant Herfindahl (H)	0.038	0.036	0.032	0.027	0.023	0.023	0.023	-0.015	-39.1%
county, inverse distance									
Mean EG index	0.020	0.016	0.016	0.016	0.015	0.014	0.014	-0.005	-27.2%
Raw concentration (G)	0.055	0.051	0.047	0.041	0.037	0.036	0.037	-0.019	-33.8%
Plant Herfindahl (H)	0.038	0.036	0.032	0.027	0.023	0.023	0.023	-0.015	-39.1%
county, contiguity									
Mean EG index	0.033	0.030	0.031	0.029	0.031	0.028	0.027	-0.006	-19.3%
Raw concentration (G)	0.067	0.063	0.060	0.053	0.050	0.048	0.047	-0.019	-29.1%
Plant Herfindahl (H)	0.038	0.036	0.032	0.027	0.023	0.023	0.023	-0.015	-39.1%
LMR, non-spatial									
Mean EG index	0.028	0.024	0.025	0.023	0.022	0.022	0.021	-0.007	-24.7%
Raw concentration (G)	0.062	0.058	0.055	0.048	0.043	0.042	0.042	-0.020	-32.3%
Plant Herfindahl (H)	0.038	0.036	0.032	0.027	0.023	0.023	0.023	-0.015	-39.1%

Source: Establishment History Panel; own calculations.

Figure 3: Sensitivity checks for the overall EG index



Source: Establishment History Panel; own calculations.

manufacturing, for example. Hence, we cannot state clearly whether deconcentration is mainly driven by a set of either smaller or larger industries. This drawback raises the question whether we can still find a significant process of deconcentration by controlling for the size of an industry. To this end we consider the average EG index weighted by the industry-specific number of employees. The comparison at the 3-digit level for the LMR in table 4 shows that the unweighted mean EG index is between two and three time larger than the employment-weighted mean EG index over the whole observation period. This implies that spatial deconcentration in West Germany is driven to a large extent by smaller industries.

Table 4: Employment weighted EG index

	1980	1985	1990	1995	2000	2005	2010	Δ 1980-2010 abs.	rel.
3-digit industry, LMR, non-weighted									
Mean EG index	0.028	0.024	0.025	0.023	0.022	0.022	0.021	-0.007	-24.7
Raw concentration (G)	0.062	0.058	0.055	0.048	0.043	0.042	0.042	-0.020	-32.3
Plant Herfindahl (H)	0.038	0.036	0.032	0.027	0.023	0.023	0.023	-0.015	-39.1
3-digit industry, LMR, employment weighted									
Mean EG index	0.010	0.010	0.009	0.008	0.008	0.008	0.008	-0.003	-25.6
Raw concentration (G)	0.023	0.022	0.020	0.017	0.016	0.016	0.015	-0.008	-34.1
Plant Herfindahl (H)	0.013	0.013	0.012	0.009	0.008	0.008	0.008	-0.005	-41.0

Source: Establishment History Panel; own calculations.

4.3 Sectoral developments

We now dissect the overall picture and scrutinize the EG index in manufacturing, services, and knowledge-intensive sectors separately. We focus on the EG index computed for the 3-digit industries and the LMR and begin by a comparison of the degree of concentration between the three sectors for the year 2010 (see table 5).[5]

Table 5: Sectoral EG indices and their components (3-digit sectors and LMR)

	1980	1985	1990	1995	2000	2005	2010	Δ 1980-2010 abs.	rel.
All sectors									
Mean EG index	0.028	0.024	0.025	0.023	0.022	0.022	0.021	-0.007	-24.7
Raw concentration (G)	0.062	0.058	0.055	0.048	0.043	0.042	0.042	-0.020	-32.3
Plant Herfindahl (H)	0.038	0.036	0.032	0.027	0.023	0.023	0.023	-0.015	-39.1
Manufacturing									
Mean EG index	0.032	0.031	0.032	0.028	0.028	0.027	0.026	-0.006	-20.2
Raw concentration (G)	0.069	0.070	0.068	0.060	0.057	0.057	0.057	-0.012	-17.8
Plant Herfindahl (H)	0.040	0.042	0.039	0.034	0.032	0.032	0.034	-0.006	-14.9
Services									
Mean EG index	0.024	0.017	0.017	0.018	0.017	0.017	0.016	-0.007	-30.6
Raw concentration (G)	0.054	0.044	0.038	0.033	0.026	0.025	0.025	-0.029	-54.3
Plant Herfindahl (H)	0.036	0.029	0.022	0.016	0.010	0.010	0.009	-0.026	-73.4
Knowledge-intensive sectors									
Mean EG index	0.032	0.024	0.024	0.023	0.024	0.023	0.024	-0.009	-26.8
Raw concentration (G)	0.094	0.082	0.075	0.064	0.053	0.051	0.051	-0.043	-45.7
Plant Herfindahl (H)	0.069	0.062	0.053	0.043	0.031	0.030	0.029	-0.040	-57.7

Source: Establishment History Panel; own calculations.

[5] Results for the other sector-region combinations yield qualitatively similar results and are available from the authors upon request.

For manufacturing and the year 2010, the EG index takes on a value of 0.026 and is higher than in services and the knowledge-intensive sector. A comparison with other countries is basically restricted to the manufacturing sector only. EG values on the 4-digit level are reported by Devereux/Griffith/Simpson (2004) for the UK (0.033), by Ellison/Glaeser (1997) for the USA (0.051) or by Maurel/Sédillot (1999) for France (0.06). For 6-digit manufacturing sectors in Canada, Behrens/Bougna (2015) report a mean of 0.032. Hence, in a cross-country perspective, manufacturing is apparently less localized in Germany. This view is corroborated by Vitali/Napoletano/Fagiolo (2013) who compare concentration patterns in six European countries. Applying the indices developed by Ellison/Glaeser (1997) and Duranton/Overman (2005), their findings suggest that the agglomeration intensity of manufacturing is lowest in Germany. One reason might be provided by a more decentralized firm location pattern. Other countries such as Great Britain or France have much more centralized patterns of economic activity due to the outstanding role of the respective capital regions, which is reflected in higher values of the EG index.

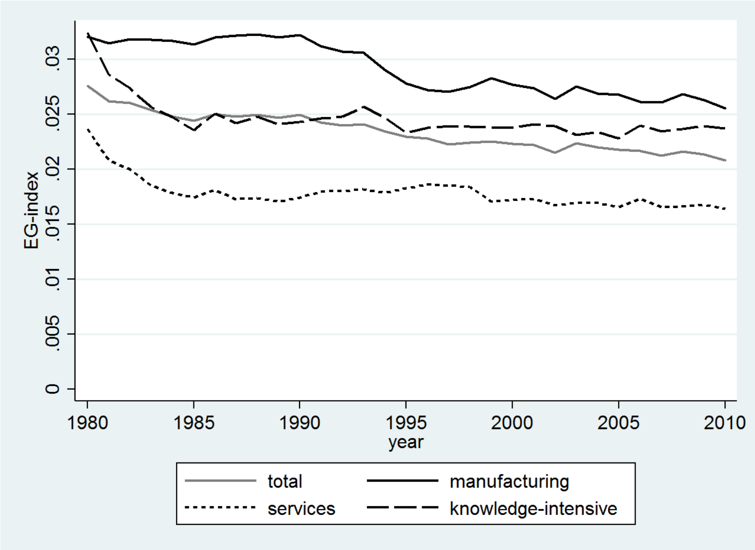
In comparison to manufacturing, services are more dispersed in space. This finding stands in line with Kolko (2010) for the United States and is not surprising given the differing reasons that lead to concentration in the two sectors. Apparently, the location decisions of many services firms follow the (decentralized) location of their customers, emphasizing the importance of face-to-face contacts. In addition, the service industries that serve customers across different industries are often found in urban areas that are distributed evenly across West Germany.

The theories discussed in chapter 2 suggest that the knowledge-intensive sector should be highly localized due to the large importance of knowledge spillovers as the main driving force of spatial agglomeration in the associated industries. On top of that, knowledge spillovers are seen to be extremely relevant as agglomerative force in the early stages of the industry life cycle. Indeed, knowledge-intensive industries are very often in the emergence and growth phase. It is difficult, however, to reconcile these theoretical presumptions with our results. As becomes clearly visible in figure 4, the degree of concentration in the knowledge-intensive sector has decreased considerably during the first half of the 1980s and has remained smaller than in manufacturing throughout the entire observation period.

The fact that knowledge-intensive industries are concentrated, but not excessively strongly, is in line with previous evidence for Germany by Alecke et al. (2006). Extending this comparison to other countries, evidence on the concentration of knowledge and high-tech sectors is mixed. In this respect, Devereux/Griffith/Simpson (2004) and Barrios et al. (2005) discuss whether the theoretical explanations put too much effort on emphasizing knowledge spillovers as agglomeration force, whereas other agglomeration effects such as labor market pooling and specialized supplier networks fall aside. The latter are important driving forces of agglomeration patterns in older and more mature industries that also belong to the knowledge-intensive sector. Nevertheless, in line with previous evidence, our results do not support a special role of knowledge spillovers for knowledge-intensive sectors.

Figure 4 illustrates the long-run sectoral development of the EG index from 1980 to 2010. In manufacturing, a clear decline of concentration becomes visible after 1990. However, in the knowledge-intensive and the service sector, the EG index declined strongly in the first half

Figure 4: Sectoral development of the EG index



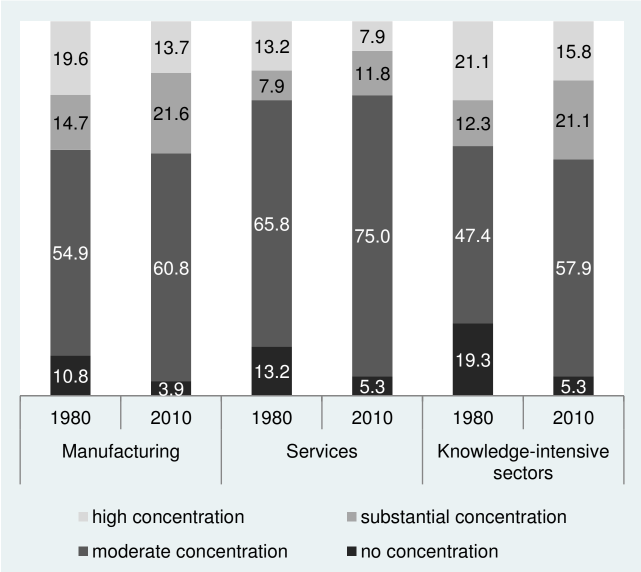
Source: Establishment History Panel; own calculations.

of the 1980s. This decline is backed by a strong decrease of G and an even slightly stronger decline of H. Apparently, the process of deconcentration can be traced back to employment being more evenly spread out across space as well as, even more pronouncedly, to a more balanced plant size structure within the single industries. In manufacturing, in contrast, the comparatively lower decline of both G and H indicates that deconcentration is driven by a more even distribution of employment and by changes in the plant size structure.

The decline of the geographical concentration in manufacturing has also been documented for other countries. Cutrini (2010) states that from the mid-1980s onwards, employment became less localized across the European regions. Drucker (2011) and Behrens/Bougna (2015) find the same development for the USA and for Canada. Explanations for these trends that also hold for Germany might be provided by structural changes along the production lines, with the vertical disintegration of production and the outsourcing of parts of the production process leading to a reduction in plant size (see Drucker, 2011). As to our knowledge, empirical evidence on the long-run (de-)concentration trends in services or in the knowledge-intensive sectors has so far not been available. One reason for the process of deconcentration since 1997 could be the intensified use of advanced information and communication technology that has made the necessity of spatial closeness between providers and customers increasingly obsolete. This holds especially true for the knowledge-intensive business services.

The comparison of the shares of concentrated industries within the three sectors again illustrates the differences and the changes in the respective spatial patterns. Figure 5 depicts the distributions for the 3-digit industry level and the LMR. All three sectors exhibit highly skewed distributions of the EG index. Interestingly, in the knowledge-intensive sector the proportion of both the highly and the non concentrated industries is highest. Yet, the general shift towards a more dispersed pattern of economic activity can be observed in all three sectors.

Figure 5: Structure of the size classes of the sectoral EG index (shares in per cent)



Source: Establishment History Panel; own calculations.

4.4 Agglomeration patterns in individual sectors

As evidenced for other countries, agglomeration patterns in West Germany vary widely between the single sectors. Table 6 provides an overview of the 30 most concentrated 3-digit industries in the year 2010 on the level of the LMR. The largest part consists of mature and low-tech manufacturing industries such as textiles, ceramics, jewellery, watches, and cutlery. These industries are marked by a strong decline in employment and a trend of deagglomeration. The concentration of some of these industries can be dated back to historical specializations of regions.[6] Industries requiring the access to natural sites or other site-specific features are highly localized as well. For instance, refining industries such as oil or industries that hinge on natural advantages such as fishing are top ranked. Transport activities (e.g., shipping) and related services (e.g., shipbuilding agents) depending on access to harbors or navigable waterways exhibit also a high degree of concentration. These overall findings coincide with the concurrent evidence for other countries (e.g., Behrens/Bougna, 2015).

As mentioned above, although concentration of the knowledge-intensive sector is moderate, a small group of the corresponding industries is highly localized. One example are software services going through the emergence and growth phase with both increasing employment and concentration. Likewise, the manufacture of office machinery is nowadays in its maturity stage. It was successfully modernized, while workforce and spatial concentration continued to increase.

The comparison of the industry rankings in 1980 and 2010 points towards a quite stable pattern over time. As for the LMR, 22 out of the top 30 concentrated 3-digit industries

[6] For instance, jewellery has been located for centuries in the cities of Idar-Oberstein and Pforzheim. This phenomenon might be due to dense and close networks that are crucial for the functioning of this industry within and between the jewellery agglomerations worldwide. Further examples are cutlery in Solingen and ceramics in the regions of Saarland and Oberfranken.

Table 6: The 30 most concentrated industries 2010

		2010			1980		
3-digit industry	sector	rank	EG	employment	rank	EG	employment
231 Manuf. of coke oven products	m	1	0.300	1,249	5	0.246	3,998
152 Proc. & pres. of fish & fish products	m	2	0.208	7,450	4	0.271	8,677
611 Sea & coastal water transport	s,k	3	0.206	22,089	3	0.289	35,563
632 Other supporting transport activities	s	4	0.166	81,427	11	0.115	44,134
335 Manuf. of watches & clocks	m	5	0.149	3,321	1	0.354	14,518
921 Motion picture & video activities	s,k	6	0.091	37,951	18	0.068	11,313
296 Manuf. of weapons & ammunition	m,k	7	0.082	6,634	8	0.166	13,843
263 Manuf. of ceramic tiles & flags	m	8	0.080	2,768	7	0.195	8,909
232 Manuf. of refined petroleum products	m,k	9	0.078	22,887	20	0.067	37,635
671 Activ. auxiliary to fin. intermed.	s,k	10	0.076	35,057	19	0.068	1,707
362 Manuf. of jewellery & related articles	m	11	0.072	12,519	6	0.219	27,354
176 Manuf. of knitted & crocheted fabrics	m	12	0.069	6,801	16	0.075	77,249
351 Building & repairing of ships & boats	m,k	13	0.063	17,530	24	0.061	50,644
652 Other financial intermediation	s,k	14	0.063	27,962	38	0.037	8,029
193 Manuf. of footwear	m	15	0.063	14,417	10	0.116	54,574
172 Textile weaving	m	16	0.061	10,990	36	0.042	66,405
924 News agency activities	s,k	17	0.056	9,445	21	0.066	2,977
315 Manuf. of lighting equipment & electric lamps	m,k	18	0.052	33,698	27	0.055	41,756
284 Forging, pressing, etc. of metal	m	19	0.051	37,017	9	0.121	29,595
202 Manuf. of panels and boards	m	20	0.050	10,826	35	0.043	20,906
157 Manuf. of prepared animal feeds	m	21	0.048	12,022	29	0.054	6,821
365 Manuf. of games & toys	m	22	0.047	11,004	15	0.077	18,102
603 Transport via pipelines	s,k	23	0.045	1,223	142	0.002	939
262 Manuf. of (non-)refractory ceramic goods	m	24	0.044	25,050	25	0.058	71,112
621 Scheduled air transport	s	25	0.044	26,093	44	0.027	17,927
724 Database activities	s,k	26	0.044	4,498	185	-0.031	35
271 Manuf. of basic iron & steel & of ferro-alloys	m	27	0.043	78,124	28	0.054	258,080
612 Inland water transport	s	28	0.042	7,834	13	0.095	14,044
171 Preparation & spinning of textile fibres	m	29	0.041	7,833	40	0.032	62,464
403 Steam & hot water supply		30	0.037	3,812	12	0.096	2,071

m: manufacturing, s: services, k: knowledge-intensive.

Source: Establishment History Panel; own calculations.

in 2010 were also ranked highest in 1980. In addition, the correlation of the EG index distributions between the two years provides an indication to what extent the EG industry ranking changed over time. The Spearman rank correlation between the distributions of 1980 and 2010 yields a coefficient of 0.768, thus corroborating the stable patterns.

4.5 What drives the changes in concentration?

Which forces have driven the decline of concentration evidenced in sections 4.1 and 4.3? To shed light on the underlying mechanisms, we decompose the aggregate concentration changes into the four factors constituting the life cycle of plants as applied by Dumais/Ellison/Glaeser (2002). They encompass the entire "life" of a firm from its creation on to the subsequent stages of (employment) growth until (employment) decline and firm closure.[7]

Intuitively, the formation of a new plant could contribute to concentration or dispersion depending on where it is established. If a new firm is opened in a region where others are already located, the industry's concentration increases and vice versa. Analogously, a plant closure has the opposing effect on the industry's overall concentration.

To implement the plant life cycle concept into our analysis, we construct four counterfactual plant distributions for manufacturing and for services, respectively. Each counterfactual mirrors the geographical distribution of an industry if the respective factor would not have been drawn upon by the firms. Figure 6 displays how the EG index would have developed if there were no i) plant creation, ii) plant growth, iii) plant decline, iv) plant closure, respectively, between 1980 and 2010. For reasons of clarity, we only display the counterfactual EG values in five-year intervals.

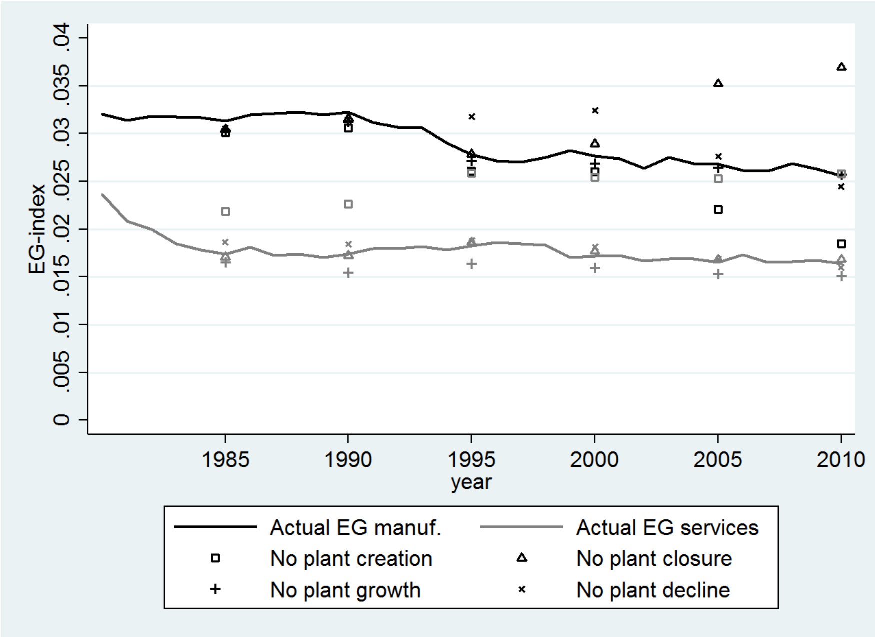
Figure 6 visualizes clear differences between manufacturing and services. In the manufacturing sector, concentration remained largely stable throughout the 1980s, with only a slight impact of firm dynamics. In the 1990s, we see a decline of geographical concentration that would not have taken place if the existing manufacturing plants had retained their original size. Apparently, plants in agglomerations systematically reduced their workforces more strongly than plants located outside these agglomerations. Conversely, in the 2000s, two opposing effects arising from plant closures and openings came forward. On the one side, plant closures enforced a downward trend of the EG index. On the other side, the creation of new plants worked against this process by more or less sustaining the degree of concentration. As a conclusion, both plant closures and openings predominately happened in agglomerations. While agglomerative forces appear to have lost importance during the 1990s, agglomerations in the manufacturing sector appear to have undergone a process of creative destruction in the last decade of our observation period.

In the service sector, the slow decline of the EG index appears to result from plant creation outside of agglomerations throughout the whole observation period. One reason for the large impact might be the increasing importance for new and young service firms to locate close to their customers. The other three factors play only a minor role for the changes in

[7] From a regional perspective, the relocation of plants are considered analogously as births and deaths.

concentration. Obviously, agglomeration forces seem to be more important for the location decisions in manufacturing than in services.

Figure 6: Counterfactual EG indices in absence of plant creation, closure, growth, decline



Source: Establishment History Panel; own calculations.

Comparing our results on the role of the plant life cycle for changes in concentration with those for other countries yields slightly contrasting results at first sight. Dumais/Ellison/Glaeser (2002) conclude for the United States that the location choices of new firms play a deagglomerating role, whereas plant closures have tended to reinforce agglomeration. Similar effects were found by Barrios et al. (2005) for Portugal and Ireland. It has to be noted, however, that both studies cover a shorter period of time that does not exceed the year of 1994. Hence, the possible impact of the grave structural and geopolitical changes starting around 1990 is not covered. The particular role that plant closures play for the decline of concentration in manufacturing might well be linked to such changes. In how far the plants took location decisions to newly available regions abroad currently remains unanswered, however.

5 Conclusions

This paper has investigated the geographical concentration of economic activities in West Germany, using the index developed by Ellison/Glaeser (1997). We have assessed the changes between 1980 and 2010 in all economic sectors and in manufacturing, services, and the knowledge-intensive sector separately. We have also shed light on which mechanisms drive the long-run changes in geographical concentration. The results yield, as we believe, first-time information on the development of agglomeration for several sectors simultaneously over such a long time span of 30 years, thereby expanding the existing empirical literature on location patterns and their dynamics over time.

The results show that most industries in West Germany are stronger geographically concentrated than a purely random distribution of firms would imply. Since 1980, the location of economic activity has been subject to a process of deconcentration. This downward trend can also be observed when resorting to various sectoral and regional delineations and when applying sensitivity checks to the EG index that explicitly incorporate neighbourhood effects and the industry size structure. Hence, it can be concluded that deagglomerative forces have slightly prevailed as the driving motor for spatial dynamics in West Germany. Although these changes took place slowly over time and some shifts towards more dispersed industries can be observed, the pattern of spatial concentration across single industries has remained considerably stable over time.

From a methodological point of view, the detailed analysis encompassing two different levels of industrial and regional aggregation emphasizes the dependance of the results of the EG index from the chosen delineations. The degree of concentration decreases with the classification of the industrial units and increases with the size of the spatial units. Clearly, as evidenced by the spatially weighted EG indices, agglomerative forces are not bound within administrative borders and but can reach over somewhat larger distances.

We further disclose some differences in the agglomeration patterns and dynamics between the three considered sectors. Manufacturing is more concentrated in space than services and the knowledge-intensive sector. Furthermore, the long-run dynamics clearly differ. Whereas in manufacturing a trend of deconcentration can be ascertained from 1990 onwards, agglomeration in services and the knowledge-intensive sector decreased in the first half of the 1980s, only to remain roughly constant afterwards.

The results also display great heterogeneity across individual industries. In spite of structural crisis and decline, the persistence of established spatial patterns can be observed particularly in old-fashioned industries. More concentrated patterns exist especially in knowledge-intensive manufacturing industries and business services. However, these industries are not as strongly concentrated as one would expect according to theoretical reasoning. Furthermore, many industries from both manufacturing and services experience a weakening or strengthening of spatial concentration, thus confirming the diverging impacts of agglomerative and deagglomerative forces operating at the industrial level. The illustration of industry-specific developments further emphasizes the influence of the geographical raw concentration and the firm concentration indices that both enter into the EG index. Given the vast diversity of possible spatial dynamics at the industry level between the two poles of concentration and deconcentration, one may pose the question whether it is empirically justified to consider overall trends of spatial dynamics at all. It is clearly worth investigating the evolution of the location patterns in single industries, in line with the propositions from industry life cycle theories and evolutionary economic geography.

Our last main finding concerns the role of the different components of the plant life cycle for the changes in the degree of concentration. In the manufacturing sector, the decline of concentration in the 1990s can largely be ascribed to existing plants in agglomerations that systematically declined more strongly than plants located outside these agglomerations. In the subsequent first decade of the 2000s, then, opposing effects by plant creations and closures prevailed. Obviously, agglomerative forces have lost in importance, giving over to a process of creative destruction within manufacturing. In the services sector, in contrast, the creation of plants outside of agglomerations has contributed to the stability of the EG index over time.

Based on the findings of this paper, further research needs to be undertaken in order to gain more insights into the forces underlying the spatial dynamics of economic activity. In this respect, the long-term analysis on the dynamics of geographical concentration for distinct industries in the form of case studies may provide valuable information on the specific role of agglomeration effects and their role over time.

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A Appendix

A.1 Data issues

The Establishment History Panel (EHP) of the Institute for Employment Research (IAB) is a comprehensive database that comprises information on the full universe of German establishments with at least one employee required to make social security contributions as of June 30 of a given year (see Gruhl/Schmucker/Seth, 2012 for further details). From 1999 onwards, the EHP also contains plants with at least one marginal part-time employee not obliged to pay social security contributions. To obtain consistent time series data, they are excluded from the analysis. The EHP consists of worker-level information from the social security insurance system, aggregated to the establishment level via unique firm-specific identifiers. Due to its original use to calculate retirement pensions, this data is highly reliable. We refer to a time span of 30 years that covers the years from 1980 to 2010. We exclude East Germany for two reasons. First, the shorter data availability since 1993 precludes a longer-term analysis. Second, and more importantly, many location choices of firms before and after the German reunification were made according to different criteria compared to the West. Specifically, many West German firms opened subsidiaries in the East after reunification in order to benefit from subsidies (the so-called "extended workbenches").

The industrial classification system in the EHP has undergone several revisions. The greatest change took place when the WZ 1973 (up to the 3-digit level) was replaced by the more disaggregated German versions of the NACE classifications (up to the 5-digit level) from 1999 onwards: NACE 1.0 (1999-2003), NACE 1.1 rev (2003-2008) and NACE 2.0 rev (since 2008). To obtain a consistent industry coding system over time, we use the NACE 1.0 classification as reference. Following the method of Eberle et al. (2011), we construct correspondence tables between the different classifications and subsequently assign to each plant one unique industry code of the NACE 1.0 covering the entire time period. We disregard the primary sector, since agriculture and fishing are made up largely by self-employed persons who are not covered by the EHP, and since mining plants are clearly primarily subject to first-nature forces. We also disregard the public sector, as location decisions are only remotely subject to market-based forces and agglomeration economies. In addition, we exclude the 3-digit industries "Processing of nuclear fuel" (class 233), "Space transport" (class 623), and "Other computer-related activities" (class 726), because they consist for most of the years of only one firm. The final sectoral setting consists of a total of 45 2-digit industries that can be disaggregated into 187 3-digit industries.

Our data set contains information on 1.0 to 1.3 million firms and 14.1 to 14.7 million full-time equivalent employees per year in West Germany. In 2010, the service (manufacturing) sector accounted for 57.8 (33.9) % of total employment (see table A.2). Its prevalence is the result of a dynamic employment growth of 46.5% since 1980 and to a simultaneous decline in manufacturing (-28.6%). The average number of employees per firm in manufacturing clearly exceeds the mean firm size in services. For the demarcation of the knowledge-intensive sectors we follow the classification of Legler/Frietsch (2007). Table A.3 lists the corresponding 3-digit industries. A major advantage is that it encloses also knowledge-intensive service industries that often fall aside in empirical research. In 2010, the knowledge-intensive sector accommodated 33.6% of the whole employment stock in West Germany.

Figure 7 in Appendix A.3 visualizes the uneven geographical distribution of economic activity across counties as measured by the average number of employees per plant. In general, average plant size is much larger in cities than in rural areas. This holds especially in the service sector, whereas the concentration of large plants in the manufacturing and in the knowledge-intensive sector can also be found in rural areas in the Northwest and in the Southwest. The latter region (e.g., Baden-Württemberg), for instance, hosts many traditional manufacturing and knowledge-intensive activities.

Since empirical analyses on geographical concentration react sensitive towards the level of data aggregation (Ellison/Glaeser, 1997, Mameli/Faggian/McCann, 2008), we conduct our investigation at two different levels both in industrial and regional respect. First, we calculate degree of geographical concentration on the 2-digit and 3-digit industrial level. Thereby, we can address the issue whether the degree of concentration in a 2-digit industry group stretches out evenly across its 3-digit subindustries, implying a common effect of the industry, or if it results from the concentration of single 3-digit sectors only (see also Alecke et al., 2006: 23). Second, we refer to 326 counties that correspond to NUTS-3 regions and to 112 labor market regions (LMR) based on the definitions of Kosfeld/Werner (2012). County borders are often delineated by administrative requirements, whereas LMR are defined according to commuting patterns. Those counties that are characterized by intense inter-regional commuter flows are pooled into one LMR, ensuring that economic centers and their surroundings are integrated accordingly.

Combining the two industrial dimensions of 2- and 3-digit industries with the regional dimensions of counties and LMR, we end up with four industry-region categories for which we scrutinize the degree of geographical concentration for all industries as a whole and for the manufacturing, service and knowledge-intensive sector over a time period of 30 years.

A.2 The spatial EG index

We follow Behrens/Bougna (2015) and employ a version of the EG index that accounts for agglomerations that reach across borders of regions, which was introduced by Guimarães/Figueiredo/Woodward (2011).

We start by writing the EG index in matrix notation:

$$\gamma = \frac{G - (1 - \sum_{r=1}^{N} x_r^2)H}{(1 - \sum_{r=1}^{N} x_r^2)(1 - H)} = \frac{G - H(1 - X'X)}{(1 - H)(1 - X'X)}, \tag{2}$$

where H and $G = (S - X)'(S - X)$ are scalars of industry i's Herfindahl and raw concentration indices. S and X are $(N \times 1)$ vectors containing each region r's $(r = 1, \ldots, N)$ share of the industry and of total employment, respectively.

We then obtain the spatial version of this index by inserting a modified spatial weights matrix ψ into the formula:

$$\gamma_s = \frac{G_s - H(1 - X'\psi X)}{(1 - H)(1 - X'\psi X)}, \tag{3}$$

with $G_s = (S - X)'\psi(S - X)$. $\psi = I + W$ has ones on the main diagonal. We use two different versions of W: First, each element $w_{rs;r \neq s}$ denotes the inverse distance between the centroids of regions r and s. Second, element $w_{rs;r \neq s}$ takes the value of 1 if regions r and s share a common border and 0 otherwise.

γ_s thus accounts not only for the presence of an industry in region r, but also in regions close or contiguous regions. This means that G_s takes larger values if close or contiguous regions have higher-than-average shares of and industry, while γ would treat each region separately.

A.3 Appendix tables and figures

Table A.1: Selected empirical studies on geographical concentration using the EG index

Study	Country	Data
		Static analyses
Ellison/Glaeser (1997)	USA	t: 1987, s: 459 manuf., r: US states
Rosenthal/Strange (2001)	USA	t: 2000, s: 4-digit manuf.,
Devereux/Griffith/Simpson (2004)	UK	t: 1992, s: 211 4-digit manuf., r: 113 postcode areas
Alecke et al. (2006)	Germany	t: 1998, s: 116, r: NUTS3-regions
Alecke/Untiedt (2008)	Germany	t: 1998, s: 213, r:NUTS2-regions
Barrios et al. (2009)	Ireland, Belgium, Portugal	t: 1998, s: 63 4-digit manuf., r: NUTS3 to NUTS5-regions
Vitali/Napoletano/Fagiolo (2013)	Belgium, France, Germany, Italy, Spain, UK	t: 2004, 2005, or 2006, s: manufacturing, r: NUTS3-regions
		Dynamic analyses
Dumais/Ellison/Glaeser (2002)	USA	t: 1972, 1977, 1982, 1987, 1992, s: 134 3-digit manuf., r: U.S. states
Bertinelli/Decrop (2005)	Belgium	t: 1997-2000, s: 4-digit manuf., r: NUTS4-regions
Barrios et al. (2005)	Ireland, Portugal	t: 1985-1998, s: manuf., r: NUTS3-regions
De Dominicis/Arbia/De Groot (2013)	Italy	t: 1991, 2001, s: 2-digit manuf. and services, r: NUTS 2 and 3, functional areas
Behrens/Bougna (2015)	Canada	t: 2001, 2005, 2009, s: 6-digit manufacturing, r: provinces, economic regions, and census divisions

t: time period, s: sectors, r: regions.

Table A.2: Descriptive statistics by sectors, 1980 and 2010

	All sectors	Manufacturing	Services	Knowledge-intensive
		1980		
Number of 2-digit industries	45	22	20	17
Number of 3-digit industries	187	102	76	57
Number of employees	14,659,875	6,979,691	5,795,493	4,370,107
Number of plants	1,092,920	205,607	724,508	152,158
Number of employees per plant	13.4	33.9	8.0	28.7
		2010		
Number of 2-digit industries	45	22	20	17
Number of 3-digit industries	187	102	76	57
Number of employees	14,684,560	4,985,025	8,489,239	4,931,956
Number of plants	1,746,891	186,564	1,371,456	345,415
Number of employees per plant	8.4	26.7	6.2	14.3

Source: Establishment History Panel; own calculations.

Table A.3: Industries contained in the knowledge-intensive sector

Manufacturing		Services	
221	Publishing	523	Retail sale of medical, and cosmetic goods
232	Refined petroleum products	603	Transport via pipelines
241	Basic chemicals	611	Sea and coastal water transport
242	Pesticides and other agro-chemical prod.	622	Non-scheduled air transport
244	Pharmaceuticals, medicinal chemicals	651	Monetary intermediation
245	Soap and detergents, cleaning products	652	Other financial intermediation
246	Other chemical products	660	Insurance and pension funding
247	Man-made fibres	671	Activities auxiliary to financial intermediation
283	Steam generators, except central heating	701	Real estate activities with own property
291	Turbines, pumps, valves, bearings	721	Hardware consultancy
292	Other general purpose machinery	722	Software consultancy and supply
294	Machine-tools	723	Data processing
295	Other special purpose machinery	724	Database activities
296	Weapons and ammunition	725	Maintenance and repair of office machinery
300	Office machinery and computers	726	Other computer related activities
311	Electric motors, generators, transformers	731	R&D in natural sciences
312	Electricity distribution and control apparatus	732	R&D in social sciences
314	Accumulators, and batteries	741	Legal, accounting, book-keeping, auditing
315	Lighting equipment and electric lamps	742	Architectural and engineering activities
316	Electrical equipment n.e.c.	743	Technical testing and analysis
321	Electronic valves and tubes	744	Advertising
322	Television and radio transmitters	921	Motion picture and video activities
323	Television and radio receivers	922	Radio and television activities
331	Medical and surgical equipmen	923	Other entertainment activities
332	Instruments for measuring, checking	924	News agency activities
333	Industrial process control equipment	925	Libraries, archives, museums
334	Optical and photographic instruments		
341	Motor vehicles		
343	Parts and accessories for motor vehicles		
351	Building and repairing of ships and boats		
352	Railway, tramway locomotives, rolling stock		
353	Aircraft and spacecraft		

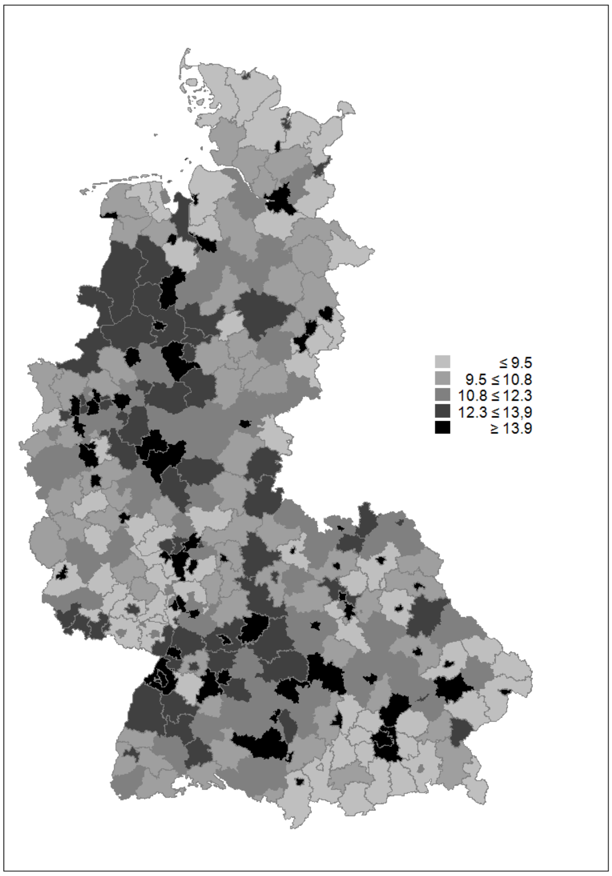
Source: Legler/Frietsch (2007: 20f)

Table A.4: Number of industries per year with a significant EG value

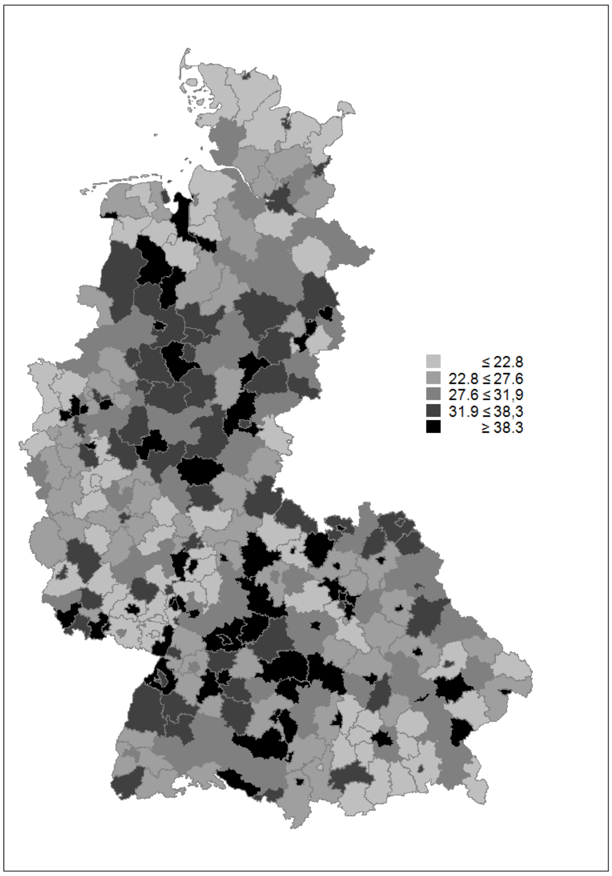
Years of significant concentration	2-digit industries county	2-digit industries LMR	3-digit industries county	3-digit industries LMR
0	3	3	11	14
1 to 10	3	2	26	15
11 to 20	3	4	16	20
21 to 30	5	2	20	25
31	31	34	114	113
total	45	45	187	187

Figure 7: Average plant size per county in Germany (number of employees per plant), 2010

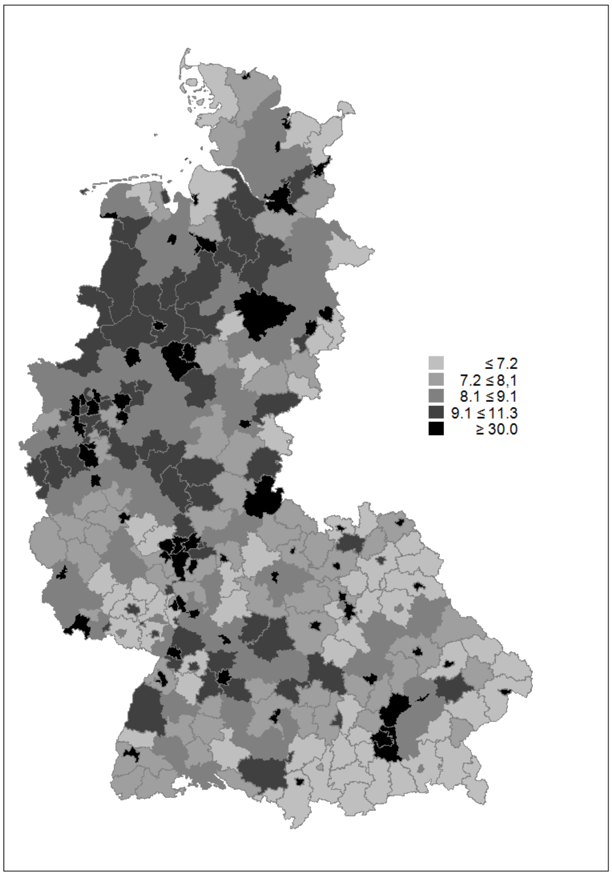
All sectors



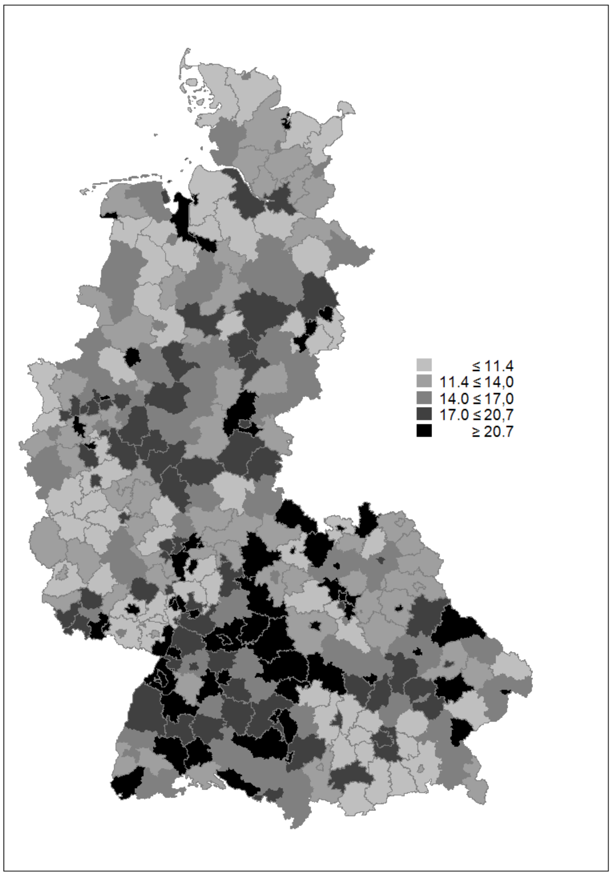
Manufacturing



Services



Knowledge-intensive sectors



Source: Establishment History Panel; own calculations.

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