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Does Domestic Offshoring Precede International Offshoring? Industry-level Evidence*

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Abstract:

This paper presents descriptive evidence suggesting that there may be something to be learned about the future patterns of international offshoring from the recent patterns of "domestic offshoring", the relocation of activities across regions within countries. Industries appear to offshore activities first within the same country and only later across the national border. Investigating the domestic and international offshoring patterns for West German manufacturing industries between 1992 and 2007, we find that, on the one hand, industries that offshored more extensively domestically offshored less extensively internationally, and vice versa. On the other hand, we find that those industries that offshored more extensively domestically were still in earlier stages of their life cycles while those that offshored more extensively internationally were already in later stages. International unbundling may consequently not be as unpredictable as it is currently believed to be.

Keywords: International offshoring, domestic offshoring, functional fragmentation, industry life cycle, Germany, K density

JEL classification: C46, F21, R12

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1. Introduction

Is the scope of activities that may become internationally offshorable (or outsourcable) in the future as unpredictable as many scholars currently suggest it to be (Baldwin 2006)? Or is there something to be learned about future offshorability of activities from recent offshoring patterns within countries,[1] where the risks, frictions and costs of splitting up the value chain are arguably lower in various dimensions?

The German automobile industry, for example, has expanded the geographic scope of its offshoring gradually in the course of its life cycle after World War II. Offshoring took initially place mainly at the domestic scale and eventually expanded to the continental and ultimately the global scale. German car manufacturers offshored production activities preferably towards rural areas within West Germany during the 1950s and 1960s,[2] towards Spain and Portugal during the late 1970s and the 1980s, and towards Eastern Europe during the 1990s and 2000s. Until 2025, Roland Berger Strategy Consultants predict the European automotive industry to offshore production of components preferably beyond the European shores, especially to Asia.[3] While this geographical expansion and diversification of car production within Germany and Europe has been facilitated by growth and integration of sales markets, it has also involved significant reorganizations of production within the companies. The additional plants in the German or the European periphery have not just been copies of the existing plants. They have specialized in production of specific models and, more recently, components that have gone into final assembly all over Germany or Europe.[4]

These dynamics in the geographic scope of offshoring in the course of an industry's life cycle have received comparatively little attention in the international and the regional economics lit-

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1 While the term offshoring has been used to characterize relocation of activities across *national* borders, we expand its definition to include "domestic offshoring", i.e., relocation of activities across *regional* borders within a country. Like countries, regions within a country differ from each other in terms of their locational characteristics and comparative advantages. They differ, for example, in terms of factor costs (wages, land rents) or the localization or urbanization economies they offer. Like those between countries, these differences between regions may make offshoring profitable. For expositional convenience, we will henceforth use the term "offshoring" to characterize both offshoring and outsourcing, unless otherwise stated.

2 BMW, for example, headquartered in Munich, established additional plants in Berlin (established 1958), Dingolfing (1973) and Regensburg (1986). Volkswagen (VW), headquartered in Wolfsburg, established additional plants in Kassel (1958) and Emden (1964). And Mercedes-Benz, headquartered in Stuttgart, established additional plants in Berlin (car production since 1962) and Rastatt (1992).

3 See Bernhart et. al. (2011). This study also predicts that the industry will establish regional headquarters (HQs) and research and development (R&D) centers all over the world, which will take over tasks from the European-based HQs and R&D centers to better meet the specific demands of fast-growing emerging economies. It reckons that this future wave of global offshoring will put 9% (300,000) of all jobs in the industry in Europe at risk, half of them in Germany, and create another one million new services jobs in Europe.

4 The Emden VW plant, for example, initially produced the "VW Käfer" (Beatle) for export to overseas markets. Today, it assemblies the "VW Passat", using components produced in various plants all over Europe. It also presses car body parts for various VW, Audi, Seat or Skoda models assembled elsewhere. On top of this domestic and intra-European spatial reorganization of production for the local markets, German car manufacturers have expanded globally by establishing a variety of production sites worldwide to serve the non-European markets.

erature so far even though they may contribute to predicting future offshoring patterns. The international economics literature has largely focused on offshoring across national borders and has taken a static view of this in the first place. There are a few notable exceptions, though. Jones and Kierzkowski (2001: 17) recognize both the dynamics and the subnational dimension of offshoring when speculating that “fragmentation is likely to occur first on a local or national basis.” Antras (2005) models outsourcing in the course of the product life cycle but focuses on the international scale. This model suggests that international outsourcing becomes feasible only in later stages of the product life cycle, after product characteristics and production techniques became sufficiently standardized to overcome contractual frictions associated with the fragmentation of production from product development, management or marketing. Domestic outsourcing is not an option in this model, however, even though contractual frictions are arguably significantly lower within than across countries. This may give domestic outsourcing an advantage over international outsourcing in earlier stages of the life cycle. Antras and Helpman (2004) and Grossman and Helpman (2005) allow for domestic outsourcing but do not investigate the dynamics of outsourcing over the product or industry life cycle. In Antras and Helpman (2004), for example, domestic outsourcing is just a low-cost alternative to international offshoring or outsourcing that is pursued only by the least productive firms. In a dynamic setting, domestic outsourcing (or offshoring) may, in contrast, be the first option becoming feasible for the most productive firms as offshoring costs decrease in the course of an industry’s life cycle or of decreasing information and communication technologies.[5]

Complementary to, but largely separate from, this international economics literature, the regional economics literature has focused mainly on the fragmentation of activities within countries or even cities but has not taken the international scale into account. In this literature, Duranton and Puga (2005) is the only theoretical model that investigates fragmentation of production from headquarter (HQ) services in a dynamic perspective.[6] In the course of decreasing costs of unbundling production from HQs, this model suggests that urban centers specialize in HQs while their

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[5] The model by Leahy and Montagna (2008) also treats domestic outsourcing as sort of a stepchild of international outsourcing. It indicates that domestic outsourcing, used by oligopolists only for strategic motives, may even reduce profits. Other models of international offshoring, including Markusen and Venables (2007), Grossman and Rossi-Hansberg (2008), and Baldwin and Robert-Nicoud (2010), address neither domestic offshoring nor the dynamic perspective. Somewhat related to the theoretical work, Kuemmerle (1999) observes that large multinational corporations establish multiple R&D labs in their home country before establishing R&D labs abroad. Munch and Skaksen (2009) present empirical evidence from Denmark suggesting that domestic outsourcing facilitates exploiting gains from deeper division of labor across firms while international outsourcing additionally facilitates exploiting gains from comparative advantages. And Görg and Hanley (2011) find that both international and domestic outsourcing of services affect plants’ innovative activity positively, while only international outsourcing of services affects their productivity positively.

[6] Other models of regional fragmentation, such as Ota and Fujita (1993) and Rossi-Hansberg et al. (2009) investigate fragmentation in a static perspective. Interestingly, all these regional models explain firm fragmentation across regions within countries by using essentially the same trade-off as recent models of international offshoring, namely the trade-off between some benefits and some costs of offshoring. They put, however, more emphasis on the benefits in terms of the external returns to the spatial clustering of HQs in city centers than on those in terms of lower factor costs for production.

suburbs (or hinterlands) specialize on production. Duranton and Puga (2005) and Bade et al. (2004) present evidence for such an increasing spatial fragmentation of blue- and white-collar jobs on aggregate during the past decades in the U.S. and Germany, respectively. Another strand of the regional economics literature investigates in more detail the functional and spatial fragmentation of activities in the course of an industry's life cycle. These studies suggest that firms in younger industries are more integrated both functionally and spatially because economies of scale or scope internal and external to the firm play a pivotal role at early stages of the life cycle. Functional integration facilitates exploiting complementarities between the functions within firms, and spatial clustering additionally facilitates exploiting complementarities across firms within the same industry, which result from spin-offs and knowledge spillovers.[7] As industries grow more mature, firms tend, according to this concept, to fragment both functionally and spatially because the externalities within and across firms loose importance relative to the diseconomies of functional and spatial clustering.

In this paper, we go a first step towards exploring systematic relations between intra- and international offshoring that may help identify future trends in international offshoring from the recent trends in domestic offshoring. We hypothesize that industries expand the geographic scope of offshoring gradually in the course of their life cycles. In early stages of their life cycles, industries are spatially and functionally highly integrated (clustered)[8] within developed countries to exploit significant economies of scale or scope internal and external to the firms. As increasing standardization of products and production processes reduces the economies relative to the diseconomies of spatial and functional integration (high factor costs, congestion) in subsequent stages of their life cycles, the industries start offshoring selected activities from these clusters. This offshoring initially takes place mainly at the domestic scale because offshoring to other regions within the same country is associated with lower costs and frictions than offshoring to other countries. In the course of this domestic offshoring, the industries become spatially and functionally more fragmented within the country. In still later stages of their life cycles, when products and production processes are sufficiently standardized, international offshoring becomes feasible, and the industries offshore activities preferably abroad. The activities off-

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[7] See Arthur (1994), Audretsch and Feldman (1996), or Feldman and Francis (2002), among others. The concept of industry life cycles (Audretsch 1996, Klepper 1997) is closely related to that of product life cycles Antras (2005) refers to. Prominent recent examples of young and highly clustered industries are the computer and semiconductor industries in Silicon Valley or Boston's Route 128 (Saxenian 1996), or the Biotech industry in Massachusetts, Cambridge, UK, or Copenhagen (e.g., Coenen et al. 2004). Similar clustering has been observed for a variety of other industries in early stages of their life cycles, including the automobile industry (Klepper 1997, Cantner et al. 2006, Boschma and Wenting 2007). A typical example of a mature industry is textiles, which has already offshored most of its production from developed to low-cost countries.

[8] We use the terms "integration" and "fragmentation" as antonyms to each other in this paper. High spatial integration by functions means that the different functions are "colocalized", i.e., spatially clustered with each other. High spatial fragmentation by functions means that the different functions are "codispersed", i.e., located in distinctively different places. Likewise, we use the terms "localization" and "dispersion" (and "colocalization" and "codispersion") as antonyms to each other. Localization refers to spatial clustering of an individual function while colocalization refers to spatial clustering of different functions with each other.

shored abroad possibly include many of those activities that were offshored domestically before. As a consequence of this international offshoring, the industries become more fragmented globally but spatially and functionally more integrated again within the developed countries until only a few firms and activities are left in these countries.

We present descriptive evidence for West German[9] manufacturing industries suggesting that industries may in fact expand the geographic scope of offshoring gradually in the course of their life cycles, offshoring first domestically and then internationally. While the time span of our data, which covers only the last about two decades since the fall of the Iron Curtain, is too short to observe significant geographic expansions in offshoring by individual industries, we identify these expansions from the cross section of industries. We do not only observe that the intensities of domestic and international offshoring are negatively related to each other across industries; industries that have offshored more intensively domestically during the past two decades have offshored less intensively internationally, and vice versa. We also observe that those industries that have offshored more intensively domestically were spatially and functionally more integrated within West Germany when the Iron Curtain fell, and that they have grown faster in terms of employment during the two decades. We take this as an indication that these industries have been in earlier stages of their life cycles. By contrast, those industries that have offshored more intensively internationally during the past two decades were spatially and functionally already more fragmented within West Germany when the Iron Curtain fell, and have contracted in terms of employment. We take this as an indication that these industries have been already in later stages of their life cycles.

The paper is organized as follows. Section 2, which makes up the larger part of this paper, investigates the intensities of domestic offshoring by 27 West German industries between 1992 and 2007, and positions the industries in their life cycles. Section 3 adds evidence on the intensities of international offshoring by these industries. Finally, Section 4 concludes.

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[9] West Germany offers a particularly interesting case for evaluating the relationship between international and domestic offshoring because it is one of the countries affected most strongly by the fall of the iron curtain, and arguably engaged particularly intensively in international offshoring. The fall of the iron curtain exposed West German firms suddenly and unexpectedly to fierce competition from large low-cost countries next door. On the one hand, this put West German firms under particularly high pressure to reduce costs and enhance efficiency. On the other hand, it offered them particularly rich opportunities for offshoring activities to countries with a fairly well-educated workforce next door. We exclude East Germany from this analysis because establishment-level data for East Germany is not available for the initial year of this study, 1992. This exclusion comes at the expense of loosing information on offshoring by West German firms to East German locations. This does, however, no affect our results notably, as will be shown in Section 3.

2. Domestic offshoring

2.1. Overview

One of the crucial issues in this paper is measurement of domestic offshoring. While measures of international offshoring such as the growth of outward FDI or imported intermediates are readily available from the literature,[10] measures on the intensities of domestic offshoring are not. Lacking data on interregional trade or on capital or contractual links between establishments within Germany, we measure domestic offshoring separately for 27 manufacturing industries by increasing spatial fragmentation of an industry by three functions, production, headquarters (HQ) and research and development (R&D). We evaluate the changes between 1992 and 2007 in the extent to which these functions were pairwise colocalized, and infer from the changes of all the pairwise colocalizations of functions on the changes of the spatial fragmentation of the industry as a whole by functions. We additionally use the industries' degrees of spatial fragmentation within West Germany in 1992 to infer on their positions in their life cycles. We assume that an industry was in an earlier stage of its life cycle if its degree of spatial integration by function was high in 1992 and has decreased during the subsequent two decades. And we assume that an industry was in a later stage if its degree of spatial fragmentation was high in 1992 and has decreased subsequently. As an additional check, we explore the growth rates of the industries' employment and numbers of establishments, assuming that industries grow in earlier and contract in later stages of their life cycles.

After introducing the data and the empirical methodology, this section presents the estimation results on the levels and the changes of spatial fragmentation of industries by functions, which we use to determine the industries' positions in their life cycles and their intensities of domestic offshoring, respectively. This subsection also discusses possible motives of domestic offshoring in the light of recent theories. From these estimation results, we identify two main groups of industries, for which we coin the terms "domestically fragmenting" and "domestically integrating" industries. The domestically fragmenting industries are characterized by an initially high but subsequently decreasing degree of spatial integration by functions. The decreasing integration (increasing fragmentation) indicates that these industries engaged comparatively intensively in domestic offshoring. Together with the industries' high initial integration, it additionally indicates that the industries were still in earlier stages of their life cycles. The detailed patterns of the decreases in domestic integration suggest that domestic offshoring was mainly driven by factor cost differences between regions in West Germany. The domestically integrating industries are

[10] See Feenstra and Hanson (1996), Borga and Zeile (2004), or Geishecker (2006), among others. Empirical studies show that foreign direct investment and trade in intermediates, which supposedly results from offshoring, have been growing rapidly during the past decades. See, among others, Helpman (2006), Blonigen et al. (2007), Baltagi et al. (2007), Geishecker (2006), or Geishecker and Görg (2008).

characterized by an initially high but subsequently decreasing spatial fragmentation by functions. The decreasing domestic fragmentation (increasing integration) might be interpreted as domestic "onshoring". However, since the detailed patterns of this decreasing fragmentation are inconsistent with theories of domestic offshoring, we interpret it instead as being a consequence of international offshoring. Anticipating the results of the subsequent section 3, we argue that functions became spatially more clustered with each other in these industries because activities that had been offshored domestically before were now offshored abroad. Together with the initially high domestic fragmentation, the decreasing fragmentation additionally indicates that these industries were already in later stages of their life cycles. An analysis of employment growth by industry largely confirms our positioning of industries in their life cycles by showing that employment in most domestically fragmenting industries grew faster than that in domestically integrating industries.

2.2. Data

We use establishment-level data from the German employment statistic to measure domestic offshoring. This statistic covers all persons gainfully employed and subject to the public Social Security System in Germany, which is between 65 and 95% of total employment, depending on the industry. Self-employed, civil servants (*Beamte*), and workers with very low income are not subject to the public Social Security System. Establishment-level data is usually available from this data source for only a few recent years. We succeeded, however, in constructing an establishment-level data set for the year 1992 that is comparable to that in recent years. We thus choose the observation period to be 1992–2007. Unfortunately, we do not observe the evolutions of individual establishments from 1992 to 2007 because the two annual datasets cannot be merged by establishment.

Being used for calculating individual pension claims, the Social Security System employment database is very accurate. It is compiled from reports by all employers with at least one employee subject to the public Social Security System. These reports include personal characteristics of the employees, including occupation and qualification. The database moreover reports characteristics of the reporting establishments, most notably industry and location (municipality).

This paper focuses on manufacturing industries. For 1992 (2007), the dataset comprises 218,281 (169,387) establishments of manufacturing firms in 7,633 (7,092) West German municipalities[11] with a total employment of 7,266,280 (5,683,289). These aggregate figures indicate that the decrease of employment in the manufacturing sector in West Germany during the 15 years under study was accompanied by a decrease of the number of establishments of similar magnitude. The

[11] There have been a few changes in the administrative structure of West-German municipalities during the period under study. Most of these changes involve annections of small municipalities by larger cities. We have not eliminated these changes over time from our data because we do not expect them to affect our results.

average establishment size stayed roughly constant (1992: 33.3 employees, 2007: 33.6 employees), and the number of municipalities with manufacturing establishments decreased only slightly. We disaggregate the manufacturing sector into 27 industries (Table 1). Being based on the European NACE Rev. 2 industry classification, the classification we use takes into account the specific specialization patterns of the manufacturing sector in Germany by, for example, subdividing "Machinery" (NACE 28) into "Metal Forming Machinery and Machine Tools" (NACE 28.4), which is strongly represented in Germany, and "Other Machinery". The "Computer, Electronic and Optical Products" (NACE 26) and "Chemicals and Chemical Products" industries (NACE 20) are subdivided for similar reasons.

Table 1 about here.

As to the functions, this paper investigates a subset of all functions performed in establishments, which we label production, HQ, and R&D. Workers are assigned to these functions by means of their occupation reported by their employers (Table 2).

Table 2 about here.

Table 3 shows that more than 80% of all establishments and about half of all employees in our dataset perform production, while about one fourth of all establishments (4% of all employees) perform HQ, and slightly more than 10% (4-6%) R&D. The functions not included in our analysis, among which are logistics and sales, account for about one third of all workers.

Table 3 about here.

All establishments are georeferenced by the municipality where they are located. Unfortunately, postal codes are not available for a finer georeferencing. We therefore approximate the distance between any two establishments by the Euclidean distance between the centroids of their municipalities, if the two establishments are located in different municipalities, or by two thirds of the municipality's radius, if the two establishments are located in the same municipality. The radius of a municipality is calculated from its area, assuming it to be circular. Two thirds of the radius is approximately the average distance between all points on a disk. These approximations of the distances between establishments introduce several measurement errors into our estimated K densities. We discuss the characteristics and possible sizes of these measurement errors in Appendix 1. Following Duranton and Overman (2005), we account for all measurement errors by kernel-smoothing across distances.

2.3. Methodology

As noted earlier, we evaluate domestic offshoring in an industry by means of the changes of the colocalizations of its functions with each other. In addition to this, we use the colocalizations and the localizations of the functions in the initial year, 1992, to infer on the positions of the industries in their life cycles, and to evaluate our results in the light of theory.

We measure the extent to which two functions were colocalized with each other by employment-weighted bivariate K densities (Duranton and Overman 2005),[12] using georeferenced data on the population of manufacturing establishments in West Germany by 27 industries.[13] The weighted univariate K density measures the localization of a function *j* within industry *i* at a given point in time, *t*. It is defined as

$$\hat{K}_{ijt}(d) = \frac{1}{h\sum_{r=1}^{N_{it}-1}\sum_{s=r+1}^{N_{it}} L_{ijrt}L_{ijst}} \sum_{r=1}^{N_{it}-1}\sum_{s=r+1}^{N_{it}} L_{ijrt}L_{ijst}\, f\left(\frac{d-d_{rs}}{h}\right). \qquad (1)$$

Correspondingly, the weighted bivariate K density measures the colocalization of two functions *j* and *k*. It is defined as

$$\hat{K}_{ijkt}(d) = \frac{1}{h\sum_{r=1}^{N_{it}}\sum_{s=1}^{N_{it}} L_{ijrt}L_{ikst}} \sum_{r=1}^{N_{it}}\sum_{s=1}^{N_{it}} L_{ijrt}L_{ikst}\, f\left(\frac{d-d_{rs}}{h}\right). \qquad (2)$$

$\hat{K}_{ijt}(d)$ and $\hat{K}_{ijkt}(d)$ denote the estimated kernel densities of establishments located at distance *d* from each other, N_{it} is the total number of establishments in industry *i*,[14] d_{rs} the geographical distance between establishments *r* and *s*, approximated by the distance between their municipalities, L_{ijrt} and L_{ikst} the number of function *j*-workers in establishment *r* and function *k*-workers in establishment *s*, respectively, $f(\cdot)$ the kernel function, which we take to be Gaussian, and *h* the bandwidth. By weighting all establishments by the sizes of their workforces in the respective functions (*j* or *k*), we use individual workers rather than whole establishments as the basic units of our analysis. (1) actually evaluates the distances of each function-*j* worker to all other function-*j* workers in the same industry, except those in the same establishment. The value of the K

[12] Distance-based measures like the K density have been used frequently for assessing the localization or colocalization of industries (e.g. Duranton and Overman 2005, 2008, Marcon and Puech 2003, Klier and McMillen 2008, Ellison et al. 2010). The present paper is, to the best of our knowledge, the first to use the K density for assessing the colocalizations of functions within industries, and for assessing the changes of these colocalizations over time. Since this measure does not take ownership or contractual relations between plants into account, part of what we label domestic offshoring may be due to shifts in market shares between competitors located at different places. This problem of identifying offshoring or outsourcing proper is, however, a general problem that applies to the measurement of international offshoring (or outsourcing) as well.

[13] Other available measures that take space explicitly into account are Ripley's K (Marcon and Puech 2003), which is a cumulative density function across distances, and spatial disproportionality measures of concentration (Bickenbach and Bode 2008), which are modified scalar measures of industrial concentration. We prefer the K density over the other measures because it has a couple of features that are helpful in the context of the present study. First, the K density does, in contrast to spatial disproportionality measures, not require predetermining the spatial scales at which activities concentrate. This spatial scale, which differs across activities and is unknown, is an outcome of, rather than an input to, the K density. Second, the K density facilitates, in contrast to Ripley's K and spatial disproportionality measures, evaluating localization at each distance between points in space separately. The values of Ripley's K at given distances depend on the values at all lower distances, and the spatial disproportionality measures map all information on the spatial distribution off activities into a single scalar.

[14] For the analysis of the localization of a single function (equation 1), it is sufficient to limit the set of observations to the $N_{it}(N_{it}-1)/2$ unique establishment pairs (see Duranton and Overman 2005) while the analysis of the colocalization of two functions (equation 2) requires evaluating all N_{it}^2 establishment pairs.

density in (1) at a given distance *d* will, ceteris paribus, be the higher, the more establishments that employ function *j*-workers are located at approximately this distance from each other, and the larger these establishments are in terms of their function *j*-workers. (2) evaluates the distances of each function *j*-worker to all function *k*-workers in the same industry, including those in the same establishment. The value of the K density in (2) at a given distance *d* will, ceteris paribus, be the higher, the more establishments that employ function *j*-workers are located at approximately this distance from establishments that employ function *k*-workers (and vice versa), and the larger these establishments are in terms of their function *j*- or *k*-workers, respectively.

Estimation of the localization of a single function, *j*, or the colocalization of two functions, *j* and *k*, in industry *i* yields a density distribution for (employment-weighted) establishment pairs across distances like that depicted for illustrative purposes by the solid line in Figure 1. Figure 1 shows the estimated bivariate K density of colocalization of production and HQ in one of the domestically offshoring industries, Chemical Products, 1992. The comparatively high densities at shorter distances indicate that the two functions were colocalized fairly strongly in 1992. A comparatively large fraction of workers from the two functions were located close to each other.

Figure 1 about here.

Since the area below each density is standardized to one, comparatively high densities at short distances are necessarily mirrored by comparatively low densities at longer distances. We therefore focus on shorter distances up to 140km. 140km is lower than the distance between many larger West German cities but high enough to encompass the relevant distances across which establishments can reap agglomeration economies through frequent face-to-face contacts, frequent market interactions, or shared local inputs. It is also high enough to encompass the distances across which firms' departments with complementary functions can usually closely monitor and interact with each other through frequent personal contacts and meetings.

To distinguish systematic from accidental localizations or colocalizations, we follow Duranton and Overman (2005) in using Monte Carlo methods for constructing a counterfactual reference for each K density under the null hypothesis that the location patterns of the functions under study were the results of random location decisions. For the measure of localization of a single function in (1), this counterfactual reference indicates how the density distribution for the localization of this function may have looked like in 1992, if, for a given size distribution of this function across establishments, firms from the respective industry had had no incentives or disincentives for colocating establishments performing this function with each other. And for the measure of colocalization of two functions in (2), we construct a similar counterfactual reference that indicates how the density distribution for the colocalization of the two functions may have looked like in 1992, if firms had had no incentives or disincentives for colocating them, given the size distributions of the two functions across establishments. The methods are described in detail in Appendix 2.

For illustration, the dashed lines in Figure 1 above represent the upper and lower bounds of the counterfactual 90% confidence interval for the colocalization of production and HQ in the Chemical Products industry in 1992. Since the actual K density for 1992 (solid line) lies above the upper bound of this confidence interval at short distances, we conclude that production and HQ were significantly colocalized in 1992.[15] This colocalization is estimated to be statistically significant up to the distance of about $d_{jk}^* = 76$ km. Together with similar results for the other pairs of functions we use this result for positioning the industry in its life cycle.

Although the point estimates of the minimum threshold distances, d_{jk}^*, where significant localization or dispersion of a single function, or significant colocalization or codispersion of pairs of functions, turns insignificant may be informative about the spatial reach of the forces driving the systematic location patterns, we will focus on their signs only. "+" will indicate statistically significant localization or colocalization, "–", significant dispersion or codispersion.

To determine changes over time of the localization of an individual function or the colocalization of two functions within an industry, we calculate the difference between the estimated K densities for 2007 and 1992 for all distances.[16] The K densities for 2007 are estimated in exactly the same way as those for 1992. Positive differences over time at short distances indicate increasing, negative decreasing localization or colocalization. We again use Monte Carlo methods to assess the significance of these changes. We construct counterfactual references for the changes of the K densities over time at all distances that indicate how the density for the localization (or colocalization) may have changed between 1992 and 2007, if there had been no incentives or disincentives for colocating establishments performing this function (these functions) at both points in time. The method is described in detail in Appendix 2. Figure 2 depicts for illustrative purposes the estimated changes in the colocalization of production and HQ in the Chemical Products industry from 1992 to 2007. The solid line represents the differences between the estimated K densities of colocalization, while the dashed lines represent the lower and upper bounds of the corresponding 90% confidence interval. Figure 2 indicates that the colocalization of production and HQ in Chemical Products decreased significantly from 1992 to 2007 up to a distance of about $d_{jk}^* = 76$ km. It actually decreased up to a distance of almost 100km but the decreases at distances above 76 km may, according to the confidence interval, be due to the changes of the localization of the Chemical industry as a whole.

Figure 2 about here.

In light of the directions and significances of the changes of the colocalizations of the three functions under study here with each other, we classify an industry as being domestically frag-

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[15] We will say that two functions were "codispersed" if the actual K density lies below the lower bound of its confidence interval at short distances.

[16] We prefer this method over the dynamic bivariate (space-time) K functions discussed in Arbia et al. (2010) mainly because we have only two observations in time. Dynamic K functions require observations in continuous time or at least longer time series in order to mitigate edge effects.

menting or domestically integrating. We will call an industry domestically fragmenting if the majority of the three function pairs under study became significantly less colocalized or significantly more codispersed at short distances. And we will call an industry domestically integrating if the majority of function pairs became significantly more colocalized or significantly less codispersed.[17] In a similar way, we will infer from the colocalizations of the three functions with each other in 1992 on the position of an industry in its life cycle. Significant colocalizations of the majority of function pairs will be indicative of an industry being in an earlier stage while significant codispersions will be indicative of an industry being in a later stage.[18]

2.4. Domestically fragmenting and integrating industries

Table 4 summarizes our main results on domestic offshoring within West Germany. Each cell of this table reports the result of one uni- or bivariate K density estimation for the localization of a function or the colocalization of a pair of functions in each of the 27 industries. The left panel (columns 1 – 6) reports the results of the univariate K density estimations for the localization of the individual functions (production, HQ, and R&D), and the right panel (columns 7 – 12) those of the bivariate K density estimations for the colocalizations of the three pairs of functions (production – HQ, production – R&D, HQ – R&D). There are two columns for each function or pair of functions. The respective first of these two columns, labeled "92" (columns 1, 3, 5, …), report if the function (pair of functions) in question was significantly localized (colocalized) ("+") or dispersed (codispersed) ("–") in the initial year under study, 1992.[19] We use this information for positioning the industries in their life cycles. And the second column, labeled "Δ" (columns 2, 4, 6, …), reports the results on estimated changes of localization or colocalization between 1992 and 2007. Here, "+" indicates that this (pair of) functions became significantly more (co-) localized or significantly less (co-) dispersed, while "–" indicates that it became significantly less (co-

17 Some practical aspects are worth being noted. First, following Duranton and Overman (2005), we use the reflection method (Silverman 1986) to prevent the K density estimates at distances close to zero from being biased downward. Second, we aggregate the observed distances between establishments to intervals of 500 meters to speed up the K density estimations. Each distance interval is represented by its upper bound (i.e., 500m, 1km, 1.5km, …, 891.5km). The highest distance we observe in our data is 891.5km. This implies that all K densities reported in this paper are estimated from 1,783 unique distance points, respectively 3,566 points after applying the reflection method. And third, we use a fixed bandwidth of 20km for all K densities. Appendix 1 discusses possible sources of measurement errors and the choice of the bandwidth.

18 We acknowledge that degree of colocalization within Germany is an insufficient criterion for positioning an industry unambiguously in its life cycle because this degree will possibly evolve nonlinearly over the life cycle. Functions will possibly be highly colocalized in both very young and very mature stages. We additionally need to take the dynamics of the colocalization into account. Colocalization of functions will arguably be high and decreasing in early stages, low and increasing in middle stages and high and further increasing in late stages. This is why we employ an industry's position in its life cycle only as a secondary criterion in this paper. We determine this position only after having classified the industry as domestically fragmenting or integrating. In addition to this, we explore the changes of employment by industry within West Germany, assuming that younger industries grow faster than mature industries.

19 Table A1 in Appendix 3 reports the corresponding point estimates for the threshold distances where the estimated K densities dip into their confidence intervals.

)localized or significantly more (co-) dispersed.[20] We use the changes of colocalization to determine the extent of domestic offshoring, and the changes of localization as additional information that helps in interpreting the results in terms of theory.

Table 4 about here.

In general, we note from Table 4 that there is none among the 27 industries where not at least one function was significantly colocalized or codispersed in 1992. The same holds for localization. In addition to this, there was a considerable amount of mobility in the spatial distributions of functions within West German industries during the 15 years under study. More that 40% (71) of all 162 estimated K densities indicate significant changes in localization or colocalization over time.

The classification of industries into fragmenting and integrating industries[21] is rather straightforward here because there is no industry in our sample where colocalizations changed into opposite directions for different function pairs. In 13 industries, which we will call “domestically fragmenting” industries and which are depicted in the upper part of Table 4, at least one function pair became significantly less colocalized. We interpret the increasing fragmentation of these 13 industries, which account for slightly more than half of total West German manufacturing employment, as domestic offshoring. Almost all of these domestically fragmenting industries had been highly integrated in the early 1990s with respect to the three functions under study. The two knowledge-intensive functions were colocalized not only with each other (column 11) but also with production (columns 7 and 9) in most of these industries. This suggests that the fragmenting industries had not yet offshored production or other functions to a greater extent within Germany prior to 1992. These industries are arguably still in earlier stages of their life cycles.[22]

In another eight industries, which we will call “domestically integrating” industries and which are depicted in the middle part of Table 4, at least one function pair became significantly more colocalized. These industries account for about one third of total West German manufacturing employment. In parallel to our interpretation of increasing fragmentation as domestic offshoring, we might attribute this increasing integration as “domestic onshoring”. However, many of these industries engaged particularly intensively in international offshoring while reducing employ-

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[20] No entry indicates that there was no significant (co-) localization or (co-) dispersion, or no significant change over time.

[21] We recall from Section 2.3 that we define domestically fragmenting and domestically integrating industries by a simple count criterion. Domestically fragmenting industries are those where significantly decreasing colocalization of function pairs dominated while domestically integrating industries are those where significantly increasing colocalization of function pairs dominated. The changes in the colocalizations of function pairs over time are depicted in columns 8, 10 and 12 in Table 4 (headed by “Δ”).

[22] We acknowledge that many of these industries are not “young” in terms of their absolute age. Industries like “Basic Metals”, “Food, Beverages and Tobacco” or “Other Nonmetallic Minerals” have existed for centuries, and have from this perspective been frequently classified as mature, declining industries. Still, they are fairly young by means of the extent of their domestic fragmentation, which is the relevant criterion in this paper.

ment within Germany significantly, as will be shown below.[23] We therefore argue that these industries have become more integrated within Germany because they internationally offshored activities preferably from remote locations in Germany. As to their positions in their life cycles, four of the eight domestically integrating industries had been significantly fragmented back in 1992 ("Metal Forming Machinery and Machine Tools",[24] "Consumer Electronics", "Leather and Apparel") or had neither been fragmented nor integrated ("Printing"). Production had been significantly codispersed from the knowledge-intensive functions (columns 7 and 9), or had at least not been colocalized any more in these industries. In addition to this, production had been significantly dispersed individually (column 1). This suggests classifying these industries as being in middle stages of their life cycles. They had apparently offshored especially production within Germany before 1992. The remaining four domestically integrating industries had been significantly integrated in 1992 ("Furniture", "Electrical Equipment", "Basic Chemicals and Petroleum", "Motor vehicles"). This combination of high and further increasing colocalization suggests classifying these industries as being in late stages of their life cycles. However, the indicators discussed below suggest that this subgroup of industries is rather heterogeneous, and that some of these industries, most notably "Electrical Equipment" and "Basic Chemicals and Petroleum", may actually not fit too well into the category of mature industries.

In the remaining six industries, finally, there were no significant changes in the colocalizations at all. We call these industries "other industries". They are depicted in the lower part of Table 4. Like the fragmenting industries, these industries are characterized by significant colocalizations of the three functions with each other in the early 1990s. In terms of our criteria, these industries may be in a very early or a very mature stage (e.g., "Textiles") of their life cycles. Or they may be subject to political constraints in their location decisions, like "Air- and Spacecraft". We will not discuss the results for these industries in more detail below.

To what extent are the observed changes in the colocalizations of production with knowledge-intensive activities in the domestically fragmenting and integrating industries consistent with theoretical models of domestic offshoring? As to the domestically fragmenting industries, Duranton and Puga (2005) suggests that firms will offshore specific functions to other regions, if the distance-related costs of monitoring and coordinating these functions across larger geographic distances drop relative to the benefits available for these functions at the new locations. The benefits at the new locations may be lower factor costs, which should be particularly rele-

[23] See also Feenstra and Hanson (1996), Geishecker (2006), Baldone et al. (2001) for offshoring in Textiles and Apparel, Kaminski and Ng (2001) for that in Furniture, Motor Vehicles, and Consumer Electronics, and Kimura et al. (2007) and Kimura and Ando (2005) for that in Machinery (broadly defined).

[24] We classify "Metal Forming Machinery and Machine Tools", which accounted for more the 10% of manufacturing employment in 1992, as an integrating industry even though this industry behaved somewhat differently than the other integrating industries. All three functions under study became more dispersed or more codispersed over time. However, the corresponding counterfactual K densities indicate that these functions had become even more dispersed and codispersed, if they had been distributed randomly across all locations of their industry.

vant for the land- or labor-intensive functions, or higher localization economies, which should be particularly relevant for the knowledge-intensive functions. Localization economies may also be relevant for production, though. Production may, for example, benefit from thick markets for specialized workers, suppliers or customers.[25]

To benefit from lower factor costs (wages, land rents), theory suggests that firms will offshore production activities from urbanized to less densely populated areas. In our data, we should observe this domestic offshoring as a decrease of the colocalization of production with knowledge-intensive activities. In addition to this, the localization of production may decrease if firms prefer offshoring their production activities away from those areas where other firms from their industry had located their production activities. In fact, the colocalization of production with knowledge-intensive activities decreased significantly in nine of the 13 domestically fragmenting industries ("–" in columns 8 or 10 in Table 4).[26] In most of these nine industries, the decreasing colocalization went along with significantly decreasing localization of production ("–" in column 2), which was initially both significantly localized individually, and significantly colocalized with at least one knowledge-intensive activity.[27] This suggests that lower factor costs were among the motives for domestic offshoring of production in of these industries. In fact, Bade et al. (2004) find that manufacturing production has been dispersing preferably to peripheral regions while HQ and R&D have been concentrating in metropolitan cores in Germany since the early 1990s. The decreases in the localizations of production additionally suggest that production has not been subject to significant localization economies in these industries.

To benefit from localization economies for knowledge-intensive functions, theory suggests that firms will cluster their knowledge-intensive activities in only a few places, typically urbanized areas. We should observe this increasing clustering as a combination of increasing localization of knowledge-intensive functions, and a decreasing colocalization of these knowledge-intensive

[25] The available evidence suggests that localization economies shape the locations of firms or establishments significantly. Ono (2007), Davis and Henderson (2008) and Strauss-Khan and Vives (2009) show, for example, that stand-alone headquarters of U.S. firms locate preferably in large metropolitan centers to benefit from thick markets for producer services, which offer them greater opportunities to outsource specialized services locally, as well as from proximity to other headquarters, which offers them additional sources of valuable information. See also Defever (2006) for a study of investments by foreign multinationals in Europe. Somewhat related to this, Lovely et al. (2005) find that headquarters of exporters tend to be more agglomerated than headquarters of non-exporters, arguably because information on destination countries is easier to obtain. Henderson and Ono (2008) report also evidence for significant costs associated with their spatial separation from their production plants.

[26] The remaining four fragmenting industries unbundled only the two knowledge-intensive functions from each other but not production from the knowledge-intensive functions that, according to our results. Two industries, "Measuring, Testing etc." and "Other Manufacturing," stand out from this group because their production had already been significantly dispersed in the early 1990s. In "Other Manufacturing," production even became significantly more localized during the study period. In these respects, the two industries show similar features as many of those industries we classify as domestically integrating industries. In fact, we will add more evidence below indicating that these two industries actually have more in common with the domestically integrating than with the domestically fragmenting industries.

[27] Among these industries are "Structural Metal Products", "Basic Metals" and "Fabricated Metal Products", as well as "Chemical Products" and "Plastic Products".

functions with production in our data. We do, however, not observe this pattern in a single of the 13 domestically fragmenting industries.[28] As noted before, we do observe significant decreases in colocalizations of HQ or R&D with production in several of these industries. But we do not observe significant increases in the localizations of HQ or R&D in any of these industries. This implies that firms in the fragmenting industries did rather not offshore knowledge-intensive functions in order to cluster them together with the same functions of other firms from the same industry. Increasing function-specific localization economies within industries were apparently not among the important motives for domestic offshoring in West Germany during the past about two decades.

Why then have the knowledge-intensive functions been unbundled from each other in most of the domestically fragmenting industries, if not for reaping function-specific localization economies? While this question must be left unanswered here, we may speculate that function-specific externalities *across* industries may have become more relevant over time. The industries may have clustered their knowledge-intensive functions with knowledge-intensive functions from other industries in order to take advantage of larger local pools of specialized, high-skilled labor, or of *inter*-industry knowledge spillovers. Or firms unbundled their activities in more complex ways. In addition to offshoring production to peripheral regions, they may have offshored or moved some HQs or R&D labs from larger to smaller metropolitan centers.[29]

As to the domestically integrating industries, theories of domestic offshoring obviously do not fit well. Decreasing costs of monitoring and coordinating different functions across larger geographic distances within Germany may explain why the knowledge-intensive functions became more localized in several of these industries (Table 4, columns 4 and 6). But they do not explain why the knowledge-intensive functions became also more colocalized with each other (column 12), or why the colocalizations of knowledge-intensive functions with production increased in several of the domestically localizing industries (columns 8 and 10). We rather hypothesize that the apparent domestic "onshoring" of functions within West Germany we observe for many domestically localizing industries is the consequence of international offshoring. The industries offshored abroad preferably those activities that they had offshored domestically before. This international offshoring of production from remote locations in Germany will show up in two ways in our data. The production that remained in West Germany will, first, become more localized individually, and it will, second, also become more colocalized with knowledge-intensive functions.[30] We observe this in four of the domestically integrating industries: "Metal Form-

[28] We actually do not observe this pattern in any of our 27 industries.

[29] Bade et al. (2004) show that, while the specialization of the core cities of the largest West German metropolitan areas in management and R&D (relative to production) increased between 1990 and 2002, specialization of the core cities of smaller metropolitan areas increased even faster. Holloway and Wheeler (1991) report similar shifts away from the largest metropolitan centers among the Fortune-500 HQs in the U.S.

[30] If, for example, Siemens, a German consumer electronics company headquartered in the southern Germany city of Munich, offshores a production line from one of its northern German plants to China, the aggregate distance

ing Machinery and Machine Tools", "Consumer Electronics", "Leather and Apparel" and "Furniture".

In another three domestically integrating industries, "Printing", "Basic Chemicals and Petroleum" and "Motor Vehicles", we observe neither increasing localization of production nor increasing colocalization of production with HQ or R&D. These industries are classified as domestically integrating industries only because their knowledge-intensive activities became more colocalized with each other. The apparent need of greater proximity between HQ and R&D may have been motivated by a variety of reasons, which we cannot explore here in detail.[31] Of greater relevance for the purpose of this paper is that the arguably extensive offshoring of production towards Eastern Europe in the "Motor Vehicles" industry during the past two decades affected neither the spatial distribution of production in Germany nor the colocalizations of this production with knowledge-intensive activities to a significant extent. Instead of closing down plants and "exporting German jobs abroad" through offshoring, this industry has apparently merely reorganized its production in the first place, i.e., reassigned activities across the existing and the new locations throughout Europe.

2.5. Industry growth

This subsection aims at substantiating the positioning of industries in their life cycles done in the previous subsection. It adds information on the growth of employment and the numbers of establishments. Younger industries are typically expanding in terms of employment and the numbers of establishments while mature industries are contracting. Table 5 reports the growth rates between 1992 and 2007 of the industries' shares in manufacturing establishments and employment. It reports these growth rates for the industry as a whole as well as for production. Notice that the total number of manufacturing establishments decreased by 22.4% in West Germany between 1992 and 2007, and employment decreased by 21.8%.

Table 5 about here.

We observe from Table 5 that the shares of most domestically fragmenting industries in manufacturing establishments and employment increased between 1992 and 2007. This is true for all functions taken together and for production activities. The employment shares of most of these industries in manufacturing production increased even faster than their shares in all function taken together. Likewise, the shares of establishments where production took place increased

between Siemens' remaining production facilities in Germany will decrease, and more mass will move to shorter distances in our estimated univariate K density for the localization of production in the consumer electronics industry. In addition to this, the aggregate distances between Siemens' remaining production facilities and its headquarter and R&D centers will decrease, and more mass will move to shorter distances in our estimated bivariate K densities for the colocalization of production with HQ or R&D in the consumer electronics industry.

31 Domestic HQs and R&D labs of German multinationals may, for example, have had to cooperate more closely with each other to more efficiently steer expansions of their subsidiaries in overseas markets.

faster than the shares of establishments on aggregate. This generally corroborates our classification of these industries as being in earlier stages of their life cycles. Important exceptions from these general patterns are “Measuring, Testing etc.” and “Other Manufacturing”, whose shares in manufacturing employment decreased considerably. Recall from the previous subsection that these two industries were classified as domestically fragmenting industries only because the colocalization of HQ and R&D decreased significantly while the colocalizations of these knowledge intensive functions with production did not change. It addition, their production had already been dispersed within West Germany, which suggests that they may already have offshored production within Germany to some extent. They may therefore be already past the early stages of their life cycles.

In contrast to those of most domestically fragmenting industries, the shares of many of the domestically integrating industries in manufacturing establishments and employment decreased, or at least increased only marginally between 1992 and 2007. This is especially true for production activities: The shares in production employment and in establishments where production takes place tended to decrease faster than the corresponding shares for all functions in these industries. This generally corroborates our classification of these industries as being in middle or later stages of their life cycles. There is considerable heterogeneity among the domestically integrating industries, though. It is especially the four industries where production had been dispersed and also codispersed from knowledge-intensive industries in 1992 that performed rather poorly in terms of employment growth.[32] These industries fit fairly nicely into our picture of industries in their middle ages that had largely exploited their domestic offshoring opportunities already by the early 1990s and subsequently had to “offshore jobs abroad” to keep production costs at bay.

The remaining industries fit less nicely into this picture. Especially “Electrical Equipment” and “Basic Chemicals and Petroleum” increased their shares in total manufacturing employment and even in production employment significantly. These industries may not be as mature as their localization and colocalization patterns suggest them to be. The “Motor vehicles” industry, by contrast, expanded only marginally in terms of jobs (+8%) and contracted somewhat in terms of establishments (–11%). This is not in stark contrast to our picture of a domestically integrating industry. It corroborates our earlier supposition that the German automotive industry has, in contrast to several other domestically integrating industries, merely reorganized its production across Europe in the first place without exporting jobs abroad to a greater extent.

[32] These industries are “Metal Forming Machinery and Machine Tools”, “Consumer Electronics”, “Leather and Apparel” and “Printing”. Non-production employment expanded considerably in “Consumer Electronics”, though.

3. International offshoring

This section is aims at identifying the links between domestic and international offshoring. It combines the results on domestic offshoring presented in the preceding section with data on the evolution of international offshoring by industry. We use three indicators of international offshoring that are fairly standard in the literature. The first indicator is the growth rate of an industry's intensity of outward FDI between 1992 and 2007. We measure the FDI intensity by the value of FDI stocks held by German firms abroad per domestic worker.[33] To eliminate scale effects, we standardize the industry-specific growth rates of the FDI intensities by the corresponding growth rate in manufacturing on aggregate. The FDI intensity is meant to capture the relocation of production capacities abroad. The second and third indicators are the growth rates of the intensities of imported intermediate materials between 1995 and 2007, calculated as the standardized growth rates of imported intermediate materials per worker. We distinguish between imported intermediate materials in a wide and a narrow definition.[34] The wide definition comprises the value of imports of intermediate goods from all manufacturing industries, the narrow definition the value of imports of intermediate goods from the own industry only. These two indicators are meant to capture the effects of offshoring of components production to the extent that this offshoring creates additional imports of intermediate goods. All three indicators should grow faster for those industries that engaged more extensively in international offshoring.[35]

In addition to these indicators of international offshoring, we also check for the sake of completeness if our inferences are biased by offshoring to East Germany, which is covered neither by our analysis of domestic offshoring nor by the indicators of international offshoring. We use an industry's location coefficient (sometimes also labeled "Balassa index") for East Germany as an indicator. It is defined as the ratio of an industry's share in manufacturing employment between East Germany and Germany as a whole. Since the East German economy went through a fundamental reconstruction after the fall of the Iron Curtain, which was shaped decisively by investments by West German companies, we simply use the level of the location coefficient in 2007 rather than its change over time as our indicator. We take a location coefficient greater than one, which means that the industry is overrepresented in East Germany, as an indication of disproportionately high offshoring to East Germany.

Table 6 reports the values of all four indicators for all 27 industries as well as for the aggregates

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[33] The data on outward FDI stocks is available from the Deutsche Bundesbank (Bestandserhebung über Direktinvestitionen, Statistische Sonderveröffentlichung 10, Table I.3).

[34] These indicators are developed in Geishecker (2006), where they are labeled "material offshoring". See also Baumgarten et al. (2010) and Schwörer (2011). These indicators assign material imports to domestic industries by means of the industries' input coefficients for these goods. We thank Tillman Schwörer for sharing his most recent estimates with us.

[35] We focus only on the growth rates but not on the levels of FDI or import intensities in order to eliminate time-invariant differences in these indicators across industries.

of the 13 domestically fragmenting, eight domestically integrating and six other industries. The aggregate values for the groups of industries indicate that the intensities of domestic and international offshoring are inversely related to each other. On aggregate, the domestically fragmenting industries, which offshored their activities more extensively within West Germany (see Section 2.4), thereby growing in terms of their shares in manufacturing establishments and employment (see Section 2.5), expanded their international activities in terms of FDI and imported intermediates less extensively than the domestically integrating industries, which did not offshore their activities within West Germany and lost in terms of shares in manufacturing employment and establishments.[36] We infer from this that domestically fragmenting industries generally focused more on domestic offshoring while domestically integrating industries generally focused more on international offshoring during the past about two decades.

Table 6 about here.

This general negative relationship between domestic and international offshoring is not mirrored by each and every industry to the same extent, of course. Some of the fragmenting industries feature less than average growth of only one of the two indicators, FDI stocks or intermediates imports. For example, the intensity of intermediates imports increased faster rather than slower than the manufacturing average in “Basic Metals” and “Chemical Products”. This might be due to significant price increases at international commodity markets since the mid-2000s. “Measuring, Testing etc.” and “Other Manufacturing” even feature above-average growth of both FDI and intermediate imports.[37] Quite interestingly, these two industries are among the very few fragmenting industries where production had already been dispersed in Germany in the early 1990 (see Table 4, column 1). In addition to this, these two industries reduced their employment significantly faster than manufacturing on aggregate during the study period (see Table 5). From this perspective, they have much in common with the domestically integrating industries—except for the fact that, according to our data, their production did not become significantly more colocalized with HQ or R&D. Maybe these two industries offshored abroad not only those activities that were located away from the knowledge intensive activities within Germany but also those that were colocated with the knowledge intensive activities.

Likewise, some of the domestically integrating industries, most notably “Consumer Electronics” and “Electrical Equipment”, did not engage particularly extensively in international offshoring. Their intensities of FDI and imported intermediates grew slower rather than faster than the

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[36] The absolute amounts of FDI and imported intermediates show a similar picture. The FDI stocks (in Euro) increased by 129% (from 42 to 96 bill.€) for the domestically fragmenting industries and by 279% (from 27 to 101 bill.€) for the domestically integrating industries. And the shares of imported intermediates (wide) increased by 117% for the domestically fragmenting and by 145% for the domestically integrating industries.

[37] Indeed, “Other Manufacturing” is one of the three industries Feenstra and Hanson (1996: 242) mention explicitly as being particularly prone to international offshoring. As for the “Measuring, Testing and Electromedical equipment” industry, it is worth noting that production of traditional surgical instruments has been offshored to a considerable extent, mainly to Pakistan but also to Poland, Hungary and Malaysia (Nadvi and Halder 2005).

manufacturing average. Recall from Section 2.5 that these industries do not fit too well into our definition of mature, domestically integrating industries either because their domestic employment shares within manufacturing increased rather than decreased.

In spite of these exceptions, we interpret our findings as supporting our hypothesis that the geographic scope of offshoring increases in the course of industries' life cycles. Industries tend to focus on domestic offshoring in earlier stages of their life cycles when they are still spatially and functionally integrated within a country. This domestic offshoring reduces their spatial and functional integration. They eventually become fragmented within the country. As international offshoring becomes feasible in later stages of their life cycles, they offshore more intensively internationally by, among others, relocating abroad those activities they had offshored domestically before. This contributes to them becoming more integrated again within their home county.

Finally, our fourth indicator, the location coefficient for East Germany 2007, suggests that we do not misinterpret domestic offshoring towards East Germany as international offshoring. If any, it is the domestically offshoring rather than the internationally offshoring (while domestically integrating) industries that invested more extensively in East Germany.

4. Conclusions

In this paper, we address a question that has rarely been addressed in the literature so far: Is there something to be learned about the future patterns of international offshoring from the recent patterns of offshoring within countries? Inspired by the product or, for that matter, industry life cycle hypothesis, we present descriptive evidence from the offshoring patterns of West German manufacturing industries between 1992 and 2007 that suggests that there may, in fact, be something to be learned. On the one hand, we observe that industries' relative intensities of domestic and international offshoring are negatively related to each other. Industries that offshored more extensively domestically offshored less extensively internationally, and vice versa. On the other hand, we observe that those industries that offshored more extensively domestically were arguably still in earlier stages of their life cycles, as evidenced by their high spatial and functional integration within West Germany and their above-average growth in terms of employment and numbers of establishments. By contrast, many of those industries that offshored more extensively internationally were arguably already in later stages of their life cycles, as evidenced by their high spatial and functional fragmentation within West Germany and their below-average growth.

These finding make sense in the light of recent economic theories of interregional or international offshoring (or outsourcing) such as Duranton and Puga (2005), Antras (2005) or Antras and Helpman (2004). At gradually decreasing costs of coordinating and monitoring functions across a distance in the course of an industry's life cycle, and with domestic offshoring being less risky or less costly than international offshoring, domestic offshoring may, ceteris paribus, become feasible at an earlier stage of the life cycle than international offshoring. As offshoring costs possibly differ across industries, some industries may exploit offshoring opportunities earlier than others. The industries we identify as those that offshore more intensively internationally are apparently among those that possibly have already been in later stages of their life cycles. Domestic offshoring had possibly been feasible already prior to the 1990s in these industries. While we observe only the probable consequences of this previous domestic offshoring, the comparatively high spatial and functional fragmentation within Germany, for the industries themselves, we observe domestic offshoring more directly for other industries that have arguably been still in earlier stages of their life cycles. And we observe it indirectly from the industries themselves. During the 1990s and 2000s, larger-scale international offshoring has possibly become feasible for these industries. We observe this international offshoring during the past two decades directly by means of standard statistical indicators.

This story of sequential domestic and international offshoring is, however, founded solely on descriptive evidence so far and involves a good deal of suggestive interpretation and speculation. Much more theoretical and empirical research is warranted to substantiate or reject it. This research should cover different aspects. In theoretical models, domestic offshoring or outsourcing should be a fully-fledged alternative to international offshoring. This may be rather cumbersome technically, however, because it requires splitting the home country into two regions, a center and a periphery. On the empirical side, the results found in this paper may, on the one hand, be substantiated by functionally and industrially more disaggregated analyses or by panel regressions of establishment-level data that facilitate controlling for a variety of establishment-, firm- or industry-specific characteristics. On the other hand, we definitely need to know more about the characteristics and determinants of the costs of domestic and international offshoring. These characteristics and determinants possibly vary significantly across functions or tasks and across industries. Regional economics, economic geography or management sciences may help in identifying and quantifying the relevant costs and their determinants. Stylized facts about these costs may also help in micro-founding firms' offshoring decisions, which, in turn, will help identify relevant offshoring costs empirically.

Appendix 1: Bandwidth choice and measurement errors for distances

The choice of the bandwidth is important for several reasons. One reason is that it affects the bias of the kernel density estimator (Silverman 1986). Several methods for selecting an optimal bandwidth are discussed in the literature and are available in standard statistical software packages. These bandwidths usually take the statistical properties of the sample dataset into account. A frequently used selection method, Silverman's rule of thumb, suggests, for example, that the bandwidth should increase with the interquartile range and decrease with the size of the sample. Such a bandwidth, which would range between 50km and 90km, depending on the functions under study, would oversmooth our Kernel densities greatly because our aggregation of establishment pairs across distance intervals of 500m (see Section 2.3) reduces our sample size significantly.

Another reason is that the bandwidth should account for the measurement errors in our distance data. Our approximation of *inter*regional distances is subject to measurement errors from three sources. First, Euclidean distances do not take into account the curvature of the earth. This bias can be expected to be negligible for a small country like Germany where the maximum distance is below 1,000 km. Second, Euclidean distances do not take into account the density and quality of the available infrastructure. The actual travelling time for a km may differ between high- and low density areas. On the one hand, the denser road networks in high-density areas will provide more direct connections. On the other hand, congestion may reduce the speed. While Combes and Lafourcade (2005) show that Euclidean distances and economic distances are correlated very highly with each other (0.97), we have no reliable information on the magnitudes of the errors that result from approximating economic by Euclidean distances.

And finally, not all establishments are located at their municipalities' centroids. The corresponding error may be positive or negative, depending on where exactly the establishments are situated relative to the centroids. If the municipalities' areas were perfectly circular, the magnitude of this error ranged from zero to the sum of the radii of the respective two municipalities. The variance of this error thus tends to be higher for larger municipalities, ceteris paribus. To give an idea of the possible magnitudes of the errors in interregional distances, Figure A1 depicts the distribution across municipalities of their lower and upper bounds, calculated under the assumption that all municipalities are circular. For any two municipalities r and s, these errors are bounded between $-(\tau_r + \tau_s)$ and $(\tau_r + \tau_s)$, where τ denotes the radius of a municipality.[38] For comparison, Figure A1 also depicts a normal distribution whose tails roughly encompass the highest possible approximation errors. The standard deviation of this distribution is 5km. A bandwidth of 5km will thus be sufficient to account for the highest possible measurement errors

[38] This radius is calculated as $\tau_r = \sqrt{A_r / \pi}$, where A_r is the municipality r's area (in sqkm). The radii range from 0.35km to 15.5km for West German municipalities, with a mean of 2.7km and a 90th percentile of 4.7km.

that result from approximating firms' locations within municipalities by the municipalities' centroids. This bandwidth would, however, undersmooth our Kernel densities. As a compromise between Silverman's rule of thumb and the bandwidth needed to account for distance measurement errors, we choose a fixed bandwidth of 20km for all pairs of functions

Figure A1 here.

Appendix 2: Counterfactual references

This appendix discusses the methods of constructing counterfactual references for the uni- and bivariate K densities as well as for their changes over time.

Significance of localization or colocalization

A question that arises naturally from inspecting the extent of localization or colocalization at a given point in time like that illustrated in Figure 1 is whether this is the result of systematic, purposeful location decisions by firms, motivated by the wish to locate functions close to each other, or just the consequence of a series of independent location decisions that happened to generate some spatial clustering of functions. We follow Duranton and Overman (2005) to answer this question, using Monte Carlo methods for constructing a counterfactual reference for each K density under the null hypothesis that the location patterns of the functions under study were the results of random, industry-specific location decisions.

For the measure of localization of a single function in (1), this counterfactual reference indicates how the density distribution for the localization of this function may have looked like in 1992 (or 2007), if firms from the respective industry had had no incentives or disincentives for colocating establishments performing this function with each other. We construct this reference for function *j* in industry *i* by repeatedly resampling (without replacement) all establishments that perform function *j* (including their function-*j* workers) randomly among the population of all industrial sites occupied by establishments from industry *i* in West Germany in the same year, irrespective of whether or not function *j* was actually performed at this site. By resampling only among the sites occupied by the industry rather than among those occupied by any manufacturing industry, we focus, first, on the motives for clustering establishments within this industry. We do not want to call a function localized just because its industry is more localized than manufacturing as a whole. By resampling *without* replacement, we make sure that each feasible industrial site is occupied by at most one establishment in the counterfactual distribution. And by resampling the existing establishments together with their actual number of function-*j* workers, we retain not only the number but also the size distribution of this function across establishments. Second, we exclude the effects of managerial decisions on optimal lot sizes from our analysis. We do not want to call a function localized just because its large minimal optimal lot size requires concentrating employment in only a few sites.

Repeating this random resampling 1,000 times, we obtain 1,000 counterfactual spatial distributions of the actual establishments for function *j* in industry *i,* from which we estimate 1,000 counterfactual weighted univariate K densities in the same way as we estimate the actual K density (see equation 1). We use these 1,000 counterfactual K densities, in turn, to construct a two-sided 90% confidence interval, which we take to cover, for each distance, *d*, the range of densities consistent with no localization of the function in question.

For the measure of colocalization of two functions in (2), we construct a similar counterfactual reference that indicates how the density distribution for the colocalization of the two functions may have looked like in 1992 (or 2007), if firms had had no incentives or disincentives for colocating them, given the size distributions of the two functions across establishments. We randomly resample each of the two functions independently of each other 1,000 times in the same way as described above[39] and estimate from these 2 x 1,000 random distributions 1,000 counterfactual weighted bivariate K densities in the same way as we estimate the actual bivariate K density (see equation 2). From this, we construct a two-sided 90% confidence interval, which we take to cover, for each distance, *d*, the range of densities consistent with no colocalization of the two functions in question.

Significance of changes in localization or colocalization over time

To assess the significance of the changes in localization or colocalization over time, we construct a counterfactual reference that indicates how the density distribution for the localization (or colocalization) may have changed between 1992 and 2007, if there had been no incentives or disincentives for colocating establishments performing this function (these functions) at both points in time. This counterfactual reference should account not only for the changes in the location patterns of the industry as a whole. It should also account for the changes in the locational patterns of each function that are due to changes in their size distributions or optimal lot sizes. We do, for example, not want to conclude that a function became more localized just because its industry as a whole became more localized. We construct the confidence interval for the change of an estimated K density over time from the differences between corresponding counterfactual K densities for 2007 and 1992. These counterfactual K densities are constructed independently of each other for each point in time in the same way as those for the levels of localization or colocalization (see above).[40] If the difference between our estimated K densities lies above the upper bound of the 90% confidence interval of the distribution of these 1,000 counterfactual differences at short distances, we will say that the respective function became more localized (or the two functions became more colocalized) over time. And if it lies below the lower bound of

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[39] We actually use the same counterfactual distributions as those constructed for the references for the univariate measures of localization (see above).

[40] This approach is conceptually very similar to that used to evaluate changes in inequality measures over time (see, e.g., Mills and Zandvakili 1997).

this confidence interval, we will say that the function became more dispersed (or the two functions became more codispersed) over time.

Appendix 3

Table A1 here.

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Table 1. Industry classification

Industry	NACE	shares in total manufacturing			
		establishments		employment	
		1992	2007	1992	2007
Food processing, Beverages, Tobacco	10-12	0.206	0.088	0.164	0.094
Textiles	13	0.016	0.023	0.016	0.012
Leather, Apparel	14-15	0.038	0.027	0.017	0.010
Wood	16	0.052	0.018	0.065	0.020
Paper, Paper Products	17	0.008	0.019	0.010	0.020
Printing	18	0.052	0.029	0.056	0.027
Basic Chemicals, Petroleum	19. 20.1	0.004	0.018	0.008	0.030
Chemical Products	20.2-20.6, 21	0.013	0.056	0.016	0.045
Rubber Products	22.1	0.004	0.011	0.005	0.011
Plastic Products	22.2	0.024	0.031	0.035	0.048
Glass, Ceramics	23.1-23.4	0.008	0.016	0.008	0.013
Other Nonmetallic Minerals	23.5-23.9	0.034	0.019	0.035	0.016
Basic Metals	24	0.010	0.039	0.018	0.048
Structural Metal Products	25.1	0.087	0.040	0.147	0.066
Fabricated Metal Products	25.2-25.9	0.035	0.043	0.042	0.047
Machinery and Equipment n.e.c.	28.1-28.3, 28.9	0.042	0.049	0.061	0.088
Metal Forming Machinery and Machine Tools	28.4	0.066	0.107	0.053	0.075
Computers and Peripheral Equipment	26.1-26.2	0.004	0.006	0.005	0.006
Consumer Electronics	26.4	0.019	0.031	0.019	0.041
Electrical Equipment	27	0.009	0.016	0.009	0.020
Magnetic/Optical Media, Optical Instruments	26.3, 26.7, 26.8	0.014	0.024	0.014	0.029
Measuring, Testing, Navigation, Electromedical Equipment	26.5, 26.6	0.086	0.084	0.093	0.061
Motor vehicles	29	0.018	0.112	0.016	0.121
Ships, Railway Locomotives & Rolling Stock, Other Transport Equipment	30.1, 30.2, 30.4, 30.9	0.006	0.013	0.004	0.006
Air and Spacecraft, Related Machinery	30.3	0.001	0.009	0.002	0.013
Furniture	31	0.083	0.037	0.051	0.021
Other Manufacturing	32, 33	0.063	0.036	0.031	0.014
Total Manufacturing		1	1	1	1

Table 2. Correspondence between functions and occupations

Function	Occupations
Headquarters	Corporate managers, entrepreneurs; CEOs; heads of business organizations; economic and social scientists; Members of Parliament, ministries, or other public administrations
R&D	Engineers; chemists; other natural scientists
Production	Farmers; Miners; skilled manufacturers of stone, ceramic, chemical, wooden, textile, leather, metal, electrical or mechanic products; skilled manufacturers of food or beverages; assemblers; skilled construction workers, (unskilled) laborers; maintenance workers

Table 3. Shares of establishments and workers by functions

Function	Establishments		Employment	
	1992	2007	1992	2007
Headquarters	0.235	0.224	0.035	0.045
R&D	0.109	0.126	0.038	0.057
Production	0.873	0.829	0.575	0.530
Rest (not included)	.	.	0.352	0.369

Table 4. Localization and colocalization of functions by industries in West Germany 1992–2007

	Localization						Colocalization					
	Production		HQ		R&D		Prod.–HQ		Prod.–R&D		HQ–R&D	
	92 (1)	Δ (2)	92 (3)	Δ (4)	92 (5)	Δ (6)	92 (7)	Δ (8)	92 (9)	Δ (10)	92 (11)	Δ (12)
Domestically fragmenting industries												
Structural Metal Products	+	–	+	–	+	–	+	–	+	–	+	–
Basic Metals	+	–	+	–	+	–	+	–	+	–	+	–
Fabricated Metal Products		–						–		–		
Machinery and Equipm. nec	+	–	+	–	+		+	–	+		+	–
Chemical Products	+	–	+	–	+	–	+	–	+	–	+	–
Plastic Products	–	–	+					–			+	
Magnetics, Optics			+		+		+	–	+	–	+	–
Other Nonmetallic Minerals			+		+	–	+		+	–	+	–
Food, Beverages, Tobacco			+	–	+	–	+	–	+		+	–
Rubber Products	+		+		+		+		+		+	–
Wood			+	–	+		+		+		+	–
Measuring, Testing, etc.	–		+	–	+	–					+	–
Other Manufacturing	–	+	+	–	+	–	+		+		+	–
Domestically integrating industries												
Metal Forming Machinery, Machine Tools	–	+					–	+	–	+		+
Consumer Electronics	–	+		+		+	–	+	–	+		+
Leather, Apparel	–	+		+	+		–			+		+
Printing	–					+						+
Furniture	+	+	+		+	–	+	+				
Electrical Equipment			+		+			+			+	+
Basic Chemicals, Petroleum	+			+			+		+			+
Motor vehicles			+		+		+		+		+	+
Other industries												
Textiles					+				+		+	
Paper, Paper Products					+				+		+	
Glass, Ceramics	+	–	+		+		+		+		+	
Computers			+		+		+		+		+	
Air- and Spacecraft			+		+		+		+		+	
Other Transport Equipment	–											

Notes: Results of weighted uni- or bivariate K density estimations. See Section 2.3 for a detailed description of the methodology. Prod: production, HQ: headquarters, R&D: research and development. "+" indicates statistically significant localization or colocalization (columns "92"), or statistically significant change towards higher localization or colocalization 1992–2007 (columns "Δ"). "–" indicates statistically significant dispersion or codispersion (columns "92"), or statistically significant change towards higher dispersion or codispersion 1992–2007 (columns "Δ"). No entry indicates that there was no significant (co-) localization or (co-) dispersion, or no significant change over time. See Table A1 (Appendix 2) for the corresponding point estimates of the threshold distances.

Table 5. Growth rates of shares of industries in total manufacturing establishments and employment 1992 – 2007 – all functions and production activities

Industry / Industry group	All functions		Production	
	# Establ.	Empl.	# Establ.	Empl.
Total manufacturing	0.00	0.00	0.00	0.00
Domestically fragmenting industries	0.09	0.09	0.11	0.15
Structural Metal Products	0.70	0.63	0.68	0.72
Basic Metals	0.81	0.25	0.84	0.41
Fabricated Metal Products	0.20	0.09	0.16	0.11
Machinery and Equipment nec	0.46	0.79	0.47	0.70
Chemical Products	0.22	–0.19	0.23	–0.23
Plastic Products	0.47	0.53	0.47	0.60
Magnetics, Optics	0.01	0.17	0.10	–0.09
Other Nonmetallic Minerals	0.03	–0.15	0.02	–0.15
Food, Beverages, Tobacco	–0.20	0.07	–0.22	0.16
Rubber Products	0.17	0.00	0.22	0.09
Wood	0.25	0.14	0.21	0.19
Measuring, Testing etc.	0.08	–0.27	0.12	–0.26
Other Manufacturing	–0.51	–0.62	–0.50	–0.66
Domestically integrating industries	–0.20	–0.09	–0.23	–0.15
Metal Forming Machinery, Machine Tools	–0.19	–0.30	–0.19	–0.29
Consumer Electronics	0.03	0.29	0.04	0.03
Leather, Apparel	–0.56	–0.63	–0.60	–0.75
Printing	0.08	–0.07	0.02	–0.07
Furniture	–0.38	–0.43	–0.39	–0.42
Electrical Equipment	0.05	0.24	0.01	0.04
Basic Chemicals, Petroleum	0.75	0.67	0.86	0.50
Motor Vehicles	–0.11	0.08	–0.10	0.04
Other industries	0.05	–0.18	–0.01	–0.18
Textiles	0.05	–0.47	–0.02	–0.48
Paper, Paper Products	0.30	0.04	0.26	0.11
Glass, Ceramics	0.00	–0.16	–0.06	–0.15
Computers	0.18	0.01	0.11	–0.21
Air and Spacecraft	0.45	0.51	0.52	0.89
Other Transport Equipment	–0.40	–0.53	–0.39	–0.49

Table 6. Indicators of international offshoring and offshoring to East Germany

Industry / industry group	FDI	Imported intermediate materials		Import / Export ratio	Location coefficient East GER
		wide	narrow		
	1992–2007	1995–2007	1995–2007	1992–2007	2007
Total manufacturing	0.00	0.00	0.00	0.00	1.00
Domestically fragmenting industries	–0.25	–0.09	–0.06	0.01	1.12
Structural Metal Products	–0.67	–0.38	–0.45	–0.48	1.50
Basic Metals	–0.57	0.00	0.02	0.18	0.90
Fabricated Metal Products	0.14	–0.06	–0.04	0.11	0.87
Machinery and Equipm. nec	–0.47	–0.40	–0.37	0.24	0.76
Chemical Products	–0.18	0.30	0.42	0.09	0.89
Plastic Products	–0.36	–0.48	–0.47	–0.30	0.94
Magnetics, Optics	–0.28	–0.29	–0.32	0.10	1.41
Other Nonmetallic Minerals	1.40	–0.36	–0.46	–0.50	1.54
Food, Beverages, Tobacco	0.55	–0.30	–0.35	–0.15	1.41
Rubber Products	–0.01	–0.21	–0.24	–0.17	0.81
Wood	–0.25	–0.51	–0.60	–0.56	1.16
Measuring, Testing etc.	0.99	0.61	0.78	0.13	1.00
Other Manufacturing	3.59	1.38	1.16	0.08	1.66
Domestically integrating industries	0.47	0.23	0.23	0.00	0.75
Metal Forming Machinery, Machine Tools	0.36	0.52	0.70	0.16	0.77
Consumer Electronics	–0.35	–0.42	–0.43	–0.37	1.02
Leather, Apparel	6.82	0.17	0.10	–0.14	0.77
Printing	5.56	–0.44	–0.46	0.01	0.94
Furniture	2.02	0.38	0.38	–0.12	0.99
Electrical Equipment	–0.32	–0.10	0.00	–0.03	0.71
Basic Chemicals, Petroleum	–0.96	–0.38	–0.34	0.24	0.75
Motor Vehicles	0.81	0.31	0.25	0.11	0.55
Other industries	–0.16	–0.14	–0.21	–0.01	1.17
Textiles	–0.46	0.01	–0.28	0.03	1.40
Paper, Paper Products	–0.78	–0.45	–0.47	–0.07	0.97
Glass, Ceramics	1.42	–0.33	–0.43	–0.01	1.49
Computers	–0.82	–0.22	–0.23	–0.07	0.74
Air and Spacecraft	–0.42	–0.36	–0.47	2.84	0.46
Other Transport Equipment	0.87	1.05	0.50	–0.08	2.17

Notes: FDI: Relative growth rate 1992–2007 of FDI stocks per worker, industry / total manufacturing. Imported intermediate materials: Relative growth rate 1995–2007 of imported materials per worker, industry / total manufacturing; wide definition: value of imported goods from all manufacturing industries abroad; narrow definition:: value of imported intermediate inputs from the same industry abroad (see Geishecker 2006). Location coefficient East GER 2007: Share of industry in total manufacturing employment, East Germany / Germany.

Table A1. Point estimates of the threshold distances, d_{jk}^*, for localization and colocalization

	Localization						Colocalization					
	Production		HQ		R&D		Prod.–HQ		Prod.–R&D		HQ–R&D	
	92 (1)	Δ (2)	92 (3)	Δ (4)	92 (5)	Δ (6)	92 (7)	Δ (8)	92 (9)	Δ (10)	92 (11)	Δ (12)
Domestically fragmenting industries												
Structural Metal Products	135	–72	78	–66	58	–54	118	–71	70	–62	69	–63
Basic Metals	77	–76	86	–84	70	–70	87	–84	77	–76	81	–83
Fabricated Metal Products	0	–46	0	0	0	0	0	–29	0	–17	0	0
Machinery and Equipm. nec	36	–67	193	–61	55	0	348	–96	341	0	208	–61
Chemical Products	26	–14	54	–36	39	–22	76	–76	71	–37	72	–44
Plastic Products	–106	–18	17	0	0	0	0	–32	0	0	18	0
Magnetics, Optics	0	0	24	0	26	0	24	–26	22	–24	31	–13
Other Nonmetallic Minerals	0	0	65	0	95	–92	35	0	87	–5	89	–89
Food, Beverages, Tobacco	0	0	40	–24	47	–8	30	–6	28	0	48	–29
Rubber Products	9	0	24	0	31	0	28	0	28	0	32	–12
Wood	0	0	66	–8	42	0	38	0	36	0	67	–16
Measuring, Testing, etc.	–63	0	26	–21	23	–15	0	0	0	0	31	–27
Other Manufacturing	–18	16	37	–34	45	–39	17	0	27	0	44	–42
Domestically integrating industries												
Metal Forming Machinery, Machine Tools	–65	92	0	0	0	0	–50	106	–55	81	0	97
Consumer Electronics	–32	24	0	30	0	26	–29	20	–16	18	0	34
Leather, Apparel	–72	42	0	22	14	0	–56	0	0	46	0	35
Printing	–63	0	0	0	0	32	0	0	0	0	0	19
Furniture	137	18	42	0	32	–24	140	22	0	0	0	0
Electrical Equipment	0	0	10	0	13	0	0	8	0	0	35	32
Basic Chemicals, Petroleum	79	0	0	20	0	0	61	0	75	0	0	13
Motor vehicles	0	0	15	0	24	0	17	0	23	0	29	23
Other industries												
Textiles	0	0	0	0	11	0	0	0	4	0	13	0
Paper, Paper Products	0	0	0	0	69	0	0	0	65	0	65	0
Glass, Ceramics	75	–53	32	0	37	0	63	0	38	0	43	0
Computers	0	0	9	0	15	0	18	0	24	0	26	0
Air- and Spacecraft	0	0	43	0	39	0	100	0	92	0	48	0
Other Transport Equipment	–34	0	0	0	0	0	0	0	0	0	0	0

Notes: Threshold distances, d_{jk}^*, as defined in Section 2.3, resulting from of weighted uni- or bivariate K density estimations. See Section 2.3 for a detailed description of the methodology. Prod: production, HQ: headquarters, R&D: research and development, "Δ": change 1992–2007.

Figure 1. Colocalization of production and headquarters in Chemical Products in 2007

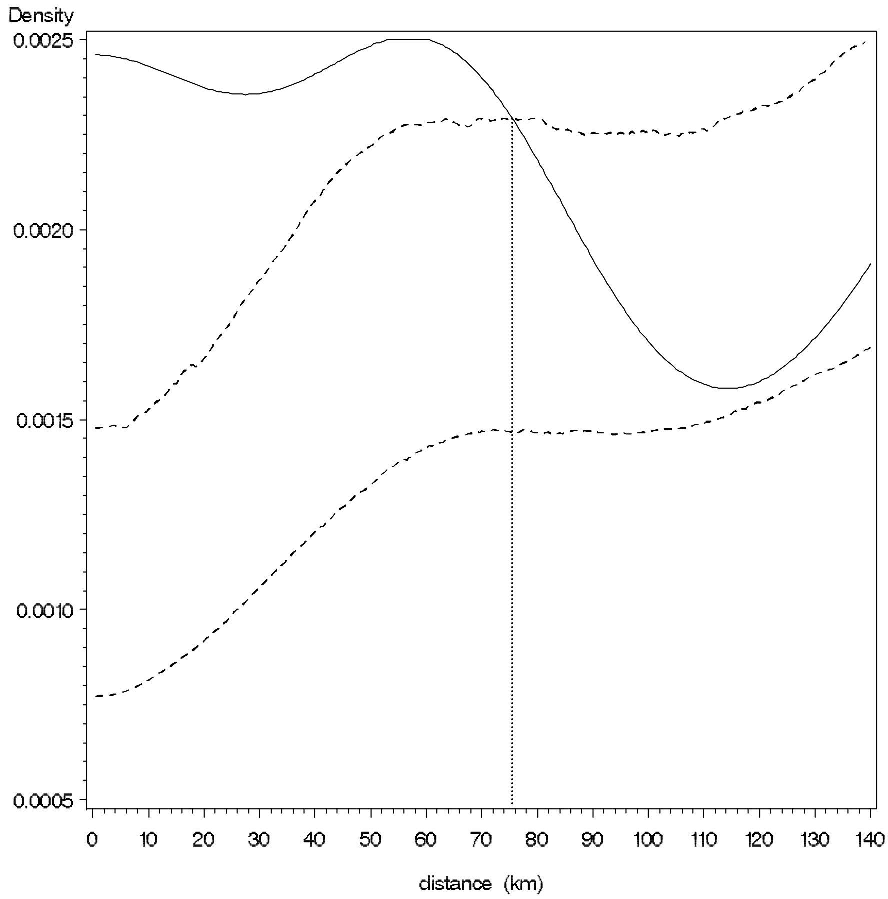


Figure 2. Changes in the colocalization of production and headquarters in Chemical Products 1992 – 2007

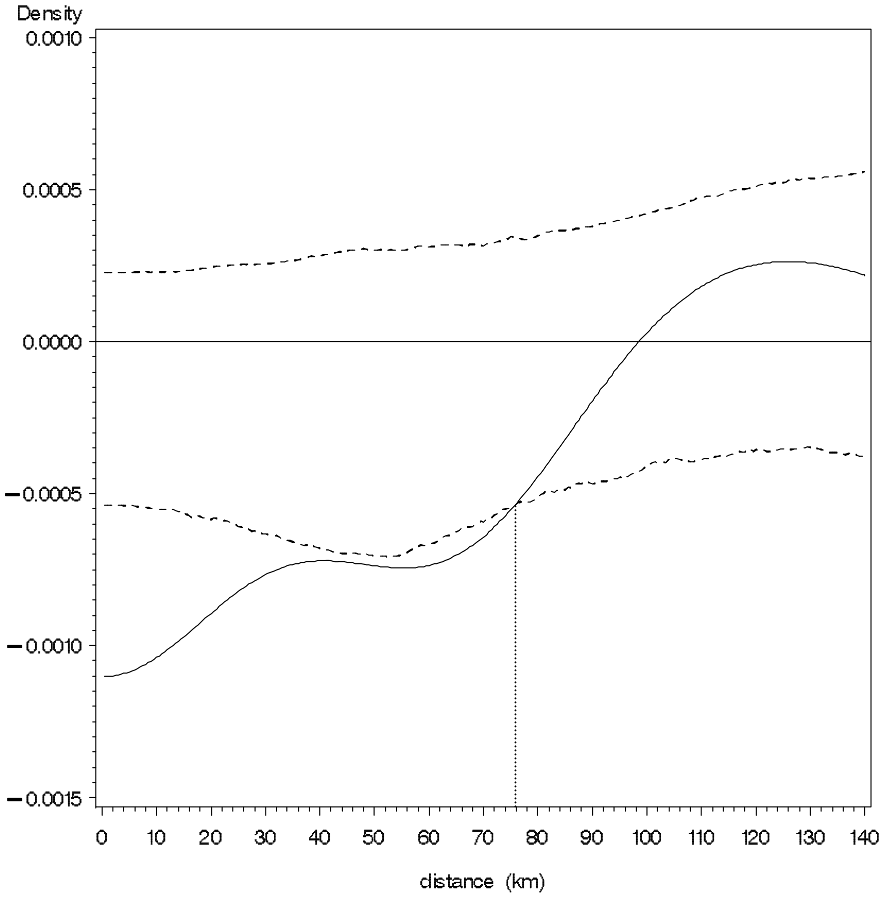
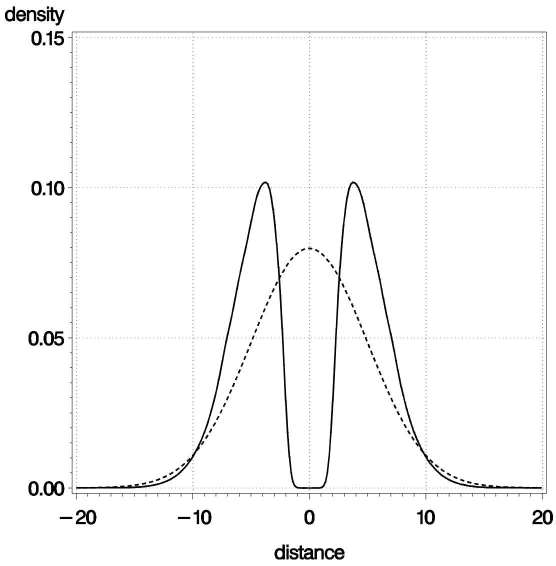


Figure A1. Distribution of approximate maximum approximation errors for distances between West German municipalities and normal distribution with standard deviation of 5km



Notes: Solid line: density of the maxima of the approximation errors for distances between establishments from different municipalities under the assumption that all municipalities' areas are circular. Dashed line: density of N(0, 25).