Spatial Concentration of Manufacturing Industries in the United States: Re-Examination of Long-Run Trends [1]

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Abstract

We re-examine the long-run geographical development of U.S. manufacturing industries using recent advances in spatial concentration measures. We construct spatially-weighted indices of the geographical concentration of U.S. manufacturing industries during the period 1880 to 2007 using data from the Census of Manufactures, Bureau of Labor Statistics, and Economic Census. Doing so we improve upon the existing indices by taking into account industrial structure and checkerboard problem. Several important new results emerge. First, we find that average spatial concentration was much lower in the late 20th- than in the late 19th-century and that this was the outcome of a continuing reduction over time. Second, spatial concentration of industries did not increase in early twentieth century as shown by traditional indices but rather declined, implying that we do not find an inverted-U shape pattern of long-run spatial concentration. Third, the persistent tendency to greater spatial dispersion was characteristic of most manufacturing industries. Fourth, even so, economically and statistically significant spatial concentration was pervasive throughout this period.

Keywords: manufacturing belt; spatial concentration; transport costs.

JEL Classification: N62; N92; R12.

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1. Introduction

It is well-known that patterns of regional specialization and the spatial concentration of American manufacturing industries have changed markedly over time. A standard narrative concerns the rise and fall of the manufacturing belt in the mid-19th century and second half of the 20th century, respectively. This is seen as a key aspect of a pattern of divergence followed by convergence of U.S. regions.

Kim (1995) provided a much-cited quantitative account of these trends. He calculated Hoover's coefficient of localization for 2-digit industries through time and found that the weighted average rose from 0.243 in 1880 to 0.316 in 1927 before falling to 0.197 in 1987. Krugman (2009) saw this experience in terms of new economic geography with the success of the manufacturing belt based on a phase of increasing returns in manufacturing but with the applicability of this model evaporating in the late 20th century.

In this paper we seek to re-examine and improve on these accounts. First, we take advantage of improved measurement techniques to estimate the extent of spatial concentration allowing for industrial structure and the *checkerboard problem*. To do this, we use an approximation to a spatially-weighted Ellison-Glaeser index. Second, we highlight the importance of changing locations patterns *within* the manufacturing belt, and the propensity of manufacturing to move *outside* the manufacturing belt already before World War II. We describe a clear tendency to spatial dispersion even during the heyday of a rising size of plants.

In order to re-examine long-run trends in the spatial concentration of U.S. manufacturing industries we construct a new dataset which permits the calculation of a spatially-adjusted version of the EG index at both SIC2 and SIC3 levels for selected census years from 1880 through 2007. To circumvent data limitations we use the spatially-weighted version of the Maurel and Sedillot (1999) adaptation of the EG index which does not require plant-level employment data. Construction of the index required assignment of industries into SIC categories and a procedure to deal with problems posed by withholding of data to prevent identification of individual firms.

Our main findings are as follows. First, the weighted average of the spatially-weighted EG index for SIC3 industries is at its maximum in 1880 at 0.223 after which it declines slowly to 0.183 in 1940 and then more rapidly to 0.098 in 2007. Unlike Kim (1995), we do not find an episode of increasing spatial concentration in the early 20th century. Spatial-weighting is important in arriving at this conclusion. Second, increasing spatial dispersion over time is a general experience across American manufacturing industries over the long run and especially after 1940. At SIC2 level, all but one sectors have lower spatial concentration in 2007 than either in 1880 or in 1940 while 17 out of 20 industries were already more dispersed in 1940 than in 1880. At SIC3 level, in 12/20 SIC2 categories at least 2/3rds of the constituent SIC3 industries were more dispersed in 2007 than in 1880 and in 12/20 SIC2 categories the same was true for 1940 compared with 1880.

Third, even so, it is important to recognize that almost all SIC3 industries always exhibit spatial concentration in the sense that their spatially-weighted EG index score is positive and significantly different from zero. This is the case even at the end of the period when spatial concentration has generally declined. In fact, all 20 exceptions out of 1300 observations occur before 1947. The average of 0.098 in 2007 is at a level where it can be thought of as economically significant according to the criterion proposed by Ellison and Glaeser (1997). It would be incorrect to suppose that spatial concentration of manufacturing industry was no longer an important phenomenon in the early 21st century.

2. Literature Review

The relative decline of the manufacturing belt in the second half of the 20th century is well-known and features prominently in economists' reviews of the evolution of American industrial geography. Krugman (2009) in his Nobel Prize Lecture highlights that the manufacturing belt began to dissolve after World War II while Holmes and Stevens (2004) in their handbook chapter stress that as late as the 1950s manufacturing activity was still heavily concentrated in the North East and Upper Midwest around the Great Lakes in the manufacturing belt after which time it moved out and into other parts of the country. The data reported in Table 1 are consistent with these accounts in that they show 72.5 per cent of manufacturing employment was in the manufacturing belt in 1947 but this share fell to only 42.9 per cent in 2007.

That said, the economic geography literature has always recognised that the spatial distribution of manufacturing had evolved considerably before World War II. Already in the 1930s and 1940s geographers were discussing the 'decentralization of industrial activity'. Smith (1947) in a quantitative analysis of manufacturing employment commented on a steady movement in the direction of decentralization. Hoover (1948) noted a trend toward more equal inter-regional distribution of manufacturing for many decades prior to 1940 and pointed out that the locational histories of many industries involved an early stage of increasing concentration followed by a later stage of re-dispersion. Easterlin (1960) found that there had been a substantial shift in the location of manufacturing between 1869 and 1947 and calculated that a minimum of 30 per cent of wage earners in 1947 would need to be relocated to restore the 1869 percentage distribution by state.[2] Eriksson et al. (2019) documented the spread of manufacturing between

[2] Of the 30 per cent, 8.3 percentage points accrued between 1889 and 1909, 10.8 percentage points between 1909 and 1929 and 5.3 percentage points between 1929 and 1947.

1910 and 1940 noting the decline of New England and the Northern Great Lakes region and the expansion of the Southern Great Lakes region and most of the Appalachians.

This also is reflected in Table 1 where it is seen that New England declined from 24.0 per cent of manufacturing employment in 1880 to 12.5 per cent in 1940 while the East North Central region rose from 19.1 per cent to 27.9 per cent. Table 1 also shows that there had been a notable decrease in the share of the manufacturing belt between these two dates from 87.2 per cent to 73.6 per cent. The point to note is that while the manufacturing belt still accounted for much of American manufacturing employment in the 1940s it was already a good deal less dominant than in the 1880s.[3]

These developments in shares of manufacturing employment were related to the pattern of trade within the United States. By 1949, the earliest date for which railroad freight data are available, as is reported in Table 2, the East North Central region was responsible for more inter-state trade than New England and Middle Atlantic combined while West North Central and West South Central together exceeded Middle Atlantic while accounting for 21.7 per cent of trade despite having only 9.4 per cent of employment, and California was the source of nearly as much inter-state trade (3.3%) as New England (3.5%).

A staple finding of the literature on the location of manufacturing is that industries with larger plant sizes tend to have higher levels of geographic concentration (Holmes and Stevens, 2004). The basic new economic geography model reviewed by Krugman (2009) predicts that industry will concentrate in the core region with the best market access if economies of scale are large relative to transport costs. Kim (1995) pointed to a rise in the scale of production as reflected by the size of plants measured in terms of employment as a key factor in first rising and then declining spatial concentration over the course of the 20th century. Table 3 reports average

[3] We should also note that the overall share of manufacturing employment shows a declining trend since the WWII as noted in Fort et al (2018).

plant size at the SIC 2-digit level and this confirms that plant sizes were generally rising until at least the 1940s but were generally falling in the decades towards the end of the century. However, a quite important point to note is that even prior to World War II an increasing number of locations had market sizes which could support large scale production. For example, Rhode (2001) stresses that this was true of California by the 1920s and 1930s where the automobile and tire industries constructed plants at that time. In 1949, shipments of cars from California to Oregon and Washington were 20 times those from Michigan while within California shipments by rail were 10 times those from Michigan to California (ICC, 1951).

Nevertheless, Kim (1995) found that spatial concentration was increasing in the early decades of the 20th century. He calculated Hoover's coefficient of localization for 2-digit industries and found that the unweighted and weighted average figures rose from 0.243 in 1880 to 0.327 in 1947 and from 0.242 in 1900 to 0.316 in 1927, respectively, before subsequently declining. However, since Kim wrote his paper, which has become the standard reference on the topic, there have been important developments in the measurement of spatial concentration which suggest that a new look is required.

Ellison and Glaeser (1997) explained that it is important to control for differences in the size distribution of plants to obtain a meaningful measure of spatial concentration and developed an index in which raw geographic concentration is modified by taking account of the plant Herfindahl index.[4] An important refinement to the basic EG index is to take account of the geographical position of regions through allowing for 'neighbourhood effects'. This leads to the spatially-weighted version of the EG index proposed by Guimarães et al. (2011) which represents a significant advance on Hoover's localization coefficient.

[4] An industry in which production comes from very few plants will appear as spatially concentrated even if it is randomly located.

3. Methodology

We use an index developed by Ellison and Glaeser (1997) (henceforth EG index) which makes an important change to Hoover's localization index by taking industrial concentration into account. An example provided in Ellison and Glaeser (1997) highlights their rationale: in US vacuum cleaner industry, around seventy five percent of employees work in one of the four largest plants. It would be misleading to regard this industry as highly geographically concentrated just because most of its employment concentrates in one plant. In other words, we would mistake industrial concentration for geographical concentration. Accordingly, the EG index controls for differences in the size distribution of plants by taking account of the plant Herfindahl index. The index is defined as follows

$$\gamma_i^{EG} = \frac{G_i - H_i(1 - X'X)}{(1 - H_i)(1 - X'X)} \qquad (1)$$

where H_i is a Herfindahl index measuring the industry concentration at plant level, $G_i=(S-X)'(S-X)$ is the geographical index where the vector S is the fraction of employment in industry i across geographical areas j, $X'=[x_1, x_2, \ldots, x_j]$ is the vector of the aggregate employment across geographical areas j.

One of the pitfalls of spatial indices, including the EG index, is that they do not take into account the relative geographical position of regions, known as the 'checkerboard problem'. To illustrate the problem, we follow an example from Guimaraes et al. (2011) who used a diagram reproduced here as Figure 1. It is intuitively obvious that spatial concentration is greater in Figure 1a than in Figure 1b – spillovers across regional boundaries would seem much more likely in the former case. The EG index, however, would not be able to distinguish 1a from 1b and would give them the same levels of spatial concentration, which is an example of the ‘checkerboard problem’ mentioned above.

In fact, the checkerboard problem appears to be important in the early decades of the 20th century notably in the context of movement within the manufacturing belt from the north-east to the mid-west. For example, in the case of SIC 364 (electric lighting and wiring equipment), Map 1 shows that, in 1900, there were two disjointed clusters of a few states with employment in electric lighting concentrated around Illinois and the state of New York, respectively. By 1920, as Map 2 shows, this feature becomes even more pronounced and employment concentrates mostly in New York, Ohio, and Illinois – states without adjacent borders. As Map 3 shows, by 1940 the checkerboard problem is maintained by the rise of California. Since the EG index does not take the geographical position of individual states into account, it misinterprets the concentration of employment into fewer states as a sign of higher geographical concentration even though those states are geographically disjointed, an error which is corrected by spatial weighting.

A solution is to find a measure which takes the relative geographical position of regions into account. Before that, as a useful first step, we formally test for spatial correlation, hence whether the geographical position of individual states matters or not. We use Moran’s I index of spatial autocorrelation which allows us to diagnose the presence of spatial correlation among US states. It would, for example, correctly diagnose the unsuitability of the EG index for SIC364 as it shows that this industry was highly spatially autocorrelated with the statistically significant values of the statistics of 0.043, 0.039, and 0.058 in 1900, 1920, and 1940 respectively.

Moran's I is, however, a statistic designed to test for spatial correlation and is not a measure of spatial concentration per se. Guimarães et al. (2011) addressed this challenge and developed the spatially-adjusted version of the EG index that takes neighbourhood effects into account.

The index is defined as follows

$$\gamma_i^{SEG} = \frac{G_i^S - H_i(1 - X'\Psi X)}{(1 - H_i)(1 - X'\Psi X)} \tag{2}$$

Where, as with the EG index, H_i is a Herfindahl index measuring industry concentration at plant level, $G_i^S=(S-X)'\Psi(S-X)$ is the spatially weighted version of the geographical index where the vector S is the fraction of employment in industry i across geographical areas j, $X'=[x_1, x_2, \ldots, x_j]$ is the vector of the aggregate employment across geographical areas j and Ψ is a spatial weight matrix. Ψ is defined as $\Psi=W+I$ where $\boldsymbol{I}$ is the identity matrix and $\boldsymbol{W}$ is a weight matrix for adjacent regions.

We implement variants of this approach. Our main results are derived using a first-order contiguity matrix $\boldsymbol{W}$ defined such that each element takes one for contiguous US states and zero otherwise. As a robustness check, we also use an alternative spatial weighting also suggested by Guimarães et al (2011). In particular, we consider spatial matrices in which neighbours are identified using a pre-defined bandwidth: a spatial unit j is considered a neighbour of a spatial unit i if the distance between their centroids is less than the pre-defined bandwidth b. We discuss this in detail later.

A problem in using the EG index to study the long-run development of spatial concentration is that it requires plant-level employment data. These are not available for the entire period under study. Fortunately, Maurel and Sedillot (1999) (henceforth MS) developed a version of the EG index where the Herfindahl index H_i is replaced by $1/N_i$ (N_i is the number of plants in industry i), and where the vector S is defined as the fraction of *plants* in industry i across geographical areas *j*. They show that their index is an unbiased estimator of the EG index. This allows us to circumvent the problem of the lack of plant-level employment data and we can calculate the MS index for the entire period 1880-1997. Guimarães et al (2011) also provide a spatially-weighted version of the MS index (henceforth SMS) which is defined as follows:

$$\gamma_i^{SMS} = \frac{N_i G_i^S - (1 - X'\Psi X)}{(N_i - 1)(1 - X'\Psi X)} \tag{3}$$

The formula for the SMS index in equation (2) is the main focus of our analysis. When $\Psi=I$, the index collapses into a standard spatially unweighted EG index. To facilitate a comparison with the spatially weighted index, we also present results for the MS index which is defined as

$$\gamma_i^{MS} = \frac{N_i G_i - (1 - X'X)}{(N_i - 1)(1 - X'X)} \tag{4}$$

where $G_i=(S-X)'(S-X)$ with S and X defined as above.

We will perform a statistical analysis using a one-sided statistical test assuming that γ_i is asymptotically normally distributed. Ellison and Glaeser (1997) derive a formula for the variance of EG index under the null hypothesis that $\gamma_i=0$ and the spatially-weighted version is provided by Guimarães et al (2011):

$$V(\hat{\gamma}_i^{SMS}) = \frac{2H_i^2 tr\left[\Psi[\mathrm{diag}(\mathrm{X}) - XX']\Psi[\mathrm{diag}(\mathrm{X}) - XX']\right]}{[(1-H_i)(1-X'\Psi X)]^2} \tag{5}$$

4. Data Sources

We analyse the evolution of the spatial concentration of SIC 2- and SIC 3-digit level industries across 48 U.S. states in every decade between 1880 and 1997, specifically for the following years: 1880, 1890, 1900, 1910, 1920, 1930, 1940, 1947, 1958, 1967, 1977, 1987, 1997, 2007. The construction of the indices requires data on employment and on the number of plants by

U.S. states at SIC 2- and SIC 3-digit level industries, and also a spatial weight matrix. The spatial weight matrix for 48 U.S. contiguous states was obtained from the REPEC data repository.[5] The data on U.S. state-industry employment and number of plants were collected from the U.S. Census of Manufactures for the period 1880-1967 and 2007, from the Bureau of Labor Statistics for the years 1977-1997, and from the US Economic Census for 2007.

The construction of the EG index over the period of 120 years presents three challenges. First, we need to harmonize SIC 2- and SIC 3-digit level industries across time. Harmonization of the data for the post World War II period is straightforward as the Census of Manufactures reports the SIC industrial categories and a great deal of information was published about changes in SIC classifications between 1947 and 1997. There are no SIC codes reported in the Censuses before 1947. Here we use the assignment of industries into SIC 2- and 3-digit categories created by Klein and Crafts (2012) and by Klein and Crafts (2020) for the years 1880, 1890, 1900, 1910, 1920, 1930, and 1940. Details of the harmonization of SIC 3-digit industries are in the Appendix 3. Second, construction of the Herfindahl index requires data on employment in plants. Ellison and Glaeser (1997) used data from the 1987 Census of Manufactures which reports employment in plants belonging to 10 employment size categories. Unfortunately, the Census of Manufactures does not report plant employment data before 1947. Therefore, we use the MS index and the spatially-adjusted version of it (SMS) which require only the number of plants, making it feasible to construct the indices all the way back to 1880. Third, when there are issues about disclosure of information on individual companies, the Census either withholds the data or reports the data in employment classes. Similarly, the Bureau of Labor withholds information in order to protect the identity or identifiable information of individual firms. Hence, we have incomplete state-industry employment and

[5] Following Guimarães et al (2011) we used the usswm package developed by Scott Merryman; the original spatial weight matrix was created by Luc Anselin.

plant data. Fortunately, the data are in the form of matrices with rows being totals for U.S. states and columns totals for U.S. industries. This allowed us to take advantage of a methodology developed in Golan et al. (1994). They use a maximum entropy procedure to recover missing data in multi-sectoral matrices with information about row and column sums as well as information contained in the multi-sectoral matrices. In our case, we used across-state and across-industry adding-up constraints to recover missing information on state-industry employment and plant data.

5. Results

The methodology we use to re-examine the long-run patterns in spatial concentration in manufacturing was set out in section 3. The first step is to use Moran's I spatial autocorrelation index as a diagnostic tool to detect whether the geographical position of individual states matters or not. We calculate the Moran's I statistic for each SIC 3-digit industry in all years under study. Table 4 presents a summary of the results by year and SIC 2-digit category. We see in Panel A that in a large percentage of SIC 3 industries Moran's I is statistically significant, starting at over eighty percent in 1880 and 1890. The percentage declines over time but even in 2007 about forty percent of industries still exhibit significant spatial autocorrelation. In Panel B, we report that all SIC 2 sectors exhibit a large share of SIC 3 subcategories with significant spatial autocorrelation except for printing and publishing. This confirms that spatial correlation across individual states mattered for the entire period 1880-2007 and is not confined to a few industries. Therefore, we use the SMS index which addresses this substantial spatial autocorrelation. As for the sign of statistically significant Moran's I, almost all had a positive sign with only eleven year-industry pairs showing negative signs.[6] Figures A1-A4 in the

[6] The following SIC 3 industries show negative and statistically significant Moran's I: Women's & Misses' Outerwear, Miscellaneous Apparel & Accessories, Greeting Cards, Handbags & Personal Leather Goods, Farm & Garden Machinery, Fur Goods, Photographic Equipment & Supplies, Carpets & Rugs.

Appendix depict histograms and kernel distributions of statistically significant Moran's I for the periods 1880-2007, 1880-1920, 1920-1958, and 1958-2007 respectively. They confirm that almost all were positive with fewer very high values in the later periods.

We first report the results of the weighted average SMS index for all SIC3 industries over the long run where the weights are the shares of employment in SIC3 industry, robustness checks with respect to the spatial matrix, and a comparison with the original, spatially EG unweighted index. The weighted average SMS Index is reported in Table 5, column I and we plot it in Figure 2 as well. The highlight of this longer-term account is that the levels of spatial concentration were considerably higher (almost twice as large as in 2007) in the early decades of the 20th century through to 1940 and then fell quite rapidly after World War II. Furthermore, mean spatial concentration for SIC3 industries was distinctly lower in 1930 and 1940 than in 1880. Although the rate of decrease of mean SMS accelerated after 1940, about a third of the total fall between 1880 and 2007 had already occurred by 1940. Overall, our estimates show that spatial concentration of industries was much more prevalent in the late 19th- than in the late 20th-century.[7]

It is interesting to compare these results with the (spatially unweighted) MS index, other EG-type indices in the literature, and Kim (1995). The MS index is presented in Table 5, column II, and in Figure 2: this shows a similar proportionate decline in geographical dispersion between 1910 and 2007. Unlike the SMS index, however, the MS index shows an increase in spatial concentration in the early 20th century. A comparison with the EG averages reported by Dumais et al. (2002) for the years 1972 to 1992 reveals that our estimates are somewhat larger but show a similar decrease in this period. Contrary to Kim (1995), who reported the weighted average of Hoover's coefficient of localization for SIC2 industries which is presented

[7] We also explored alternative methods of spatial weighting as a robustness test, see Appendix 1.

in Figure 3, we do not find an episode of increasing spatial concentration in the 1910s and 1920s when looking at the SMS index.

To examine this in more detail, we look at which industries drove the increase in MS index. We calculate the ratio of the MS and SMS indices to their 1900 values respectively for each decade between 1910 and 1940. The results are summarized in Table 6 and discussed further in Appendix 4. Table 6 shows the percentage of SIC 3 industries for which the MS ratio is greater than the SMS ratio for each decade between 1910 and 1940. A clear pattern emerges: a majority of SIC 3 industries have an MS ratio larger than the SMS ratio. Even the SIC 2 industries with the lowest percentage, such as SIC 29 petroleum and coal products, or SIC 32 stone, clay and glass products, have more than fifty percent of their SIC 3 subcategories in which this is the case. This, similarly to Moran's I index, confirms that the checkerboard problem affects the entire spectrum of the manufacturing sector, leading to bias in the MS index as well as Kim's (1995) index. Accordingly, the spatial concentration of manufacturing sector in the first four decades of the twentieth century was not an inverted U-shape as suggested by Kim (1995); actually, it was declining slowly.

SMS estimates for all SIC2 industries are reported in Table 7. A general tendency to greatly increased spatial dispersion over time is clear; in every case except one, namely, SIC 21 tobacco and tobacco products, the SMS index was lower in 2007 than in either 1880 or 1940 and in all but one sector the reduction was at least 40 per cent. The highest SMS score in 1997 (0.17) would have been the second lowest in 1880. In the vast majority of sectors (17/20), there was already dispersion between 1880 and 1940. The largest reductions in the SMS index between 1880 and 2007 are in SIC 30, rubber and plastic products, SIC 35, machinery, SIC 36, electrical equipment, and SIC 37, transportation equipment.

The experience of changing spatial concentration at SIC3 level is summarized in Table 8. In 12/20 SIC2 categories at least 67 per cent of the constituent SIC3 industries were more dispersed in 2007 than in 1880 and in 12/20 SIC2 categories the same was true for 1940 compared with 1880. So, there was quite a high incidence of spatial dispersion but it was by no means universal.[8]

The evolution of spatial concentration in three groups of industries, those whose origins were in the first industrial revolution, those from the second industrial revolution and those from the ICT revolution, is displayed in Figure 4.[9] In each case, spatial concentration starts out quite high and then decreases much as Hoover (1948) suggested. Interestingly, the second industrial revolution industries are dispersing continuously from 1910 onwards and the ICT industries are the least spatially concentrated of the three groups in the late 20th century. This is because ICT industries were developing in three geographically disjoined states of Texas, California, and later Washington, which is controlled for in our spatially weighted version of Ellison and Glaeser index.

Although we have stressed that there was a strong tendency for spatial concentration of industries to decline over time, especially after 1940, it is important to recognize that even at the end of our period there was a very high incidence of localization at the SIC3 level. Spatial concentration was almost always present to an extent which was both statistically and economically significant. We have tested the statistical significance using equation 4 under the null hypothesis that SMS index is equal to zero. We can reject the null hypothesis at the 1 percent significance level in all but 20 instances (none after 1940). Table 9 lists all the cases where the SMS index is not statistically significantly above zero.

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[8] Our results do not lend support to the hypothesis of stability in geographic concentration advanced by Dumais et al. (2002). See Appendix 2.

[9] The list of industries belonging to the first, second and ICT revolutions, respectively, is in the appendix, Tables A3-A5.

Furthermore, Figure 5 displays kernel distributions for SMS for selected years with the charts on the right truncated at zero for 1880 and 1940. It is apparent that, with spatial weighting, there are very few observations below 0.05, the conventional level described as 'highly concentrated' and, as we saw in Table 5, the mean SMS at SIC3 level is way above 0.05 throughout the period. The criterion of 0.05 was originally chosen by Ellison and Glaeser (1997) because it is consistent with the existence of substantial local cost advantages. Therefore, our results imply that economically significant spatial concentration was the norm across industry continuously from 1880 through 2007.

6. Discussion

A notable implication of our results is that forces promoting the spatial dispersion of American manufacturing were present throughout the 20th century. The most important of these was surely the continuing long-run decline of transport costs first in the railroad era and then sustained by trucking. Lower shipping costs for goods meant that manufacturing could move out of the large industrial cities in which it concentrated at the start of the 20th century (Glaeser and Kolhase, 2004). Market potential would matter less and high wage costs in production would matter more and this eroded the advantages of the manufacturing belt. The ratio of the average wage in states in the manufacturing belt compared with other nearby states followed an inverted-U shape with its peak in 1940. Over the long run, industrial location continually evolved as fundamentals changed.

Glaeser and Kohlhase (2004) noted that the costs of moving manufactured goods declined by over 90 per cent in real terms between 1890 and 2000 from 18.5 cents per ton-mile to 2.3 cents (at 2001 prices). In fact, much of this decrease occurred by 1967 when the cost was only 5.6 cents (at 2001 prices) and by 1891 the railroad revolution had cut transport costs to about 10 per cent of the 1820s' level.[10] We calculate that the ratio of the average wage in manufacturing in East North Central and Mid-Atlantic states relative to East and West South Central states rose from 1.22 in 1890 to 1.52 in 1940 before falling to 1.15 in 1987.[11]

Average plant size according to our estimates from the Census of Manufactures rose from 11.0 in 1880 to 60.6 in 1947, after which it stayed on a plateau until 1977 when it was 62.7 before falling to 41.8 in 2007. As many writers including Kim (1995) have noted, the decrease in plant size in the later 20th century was conducive to lower spatial concentration. In the period of rising plant size combined with spatial dispersion prior to World War II, the point to note is that the rise of the mid-west relative to the north-east which tended to lower SMS scores was associated with establishment of larger plants. By 1940, 14 SIC 2-digit industries out of 20 had a larger average plant size in the mid-west than in New York whereas in 1880 that was true of only 3 of the 20.

So, in the long run the locational advantages of agglomeration in the manufacturing belt were undermined by rising wage costs, falling transport costs and a reduction in average plant size. In some respects, this combination of changes over time is reminiscent of the later phase of the stylized core-periphery model presented by Krugman and Venables (1995). This model would see a move from very high to intermediate to very low transport costs driving a move from dispersed to spatially concentrated then back to dispersed locations for manufacturing. In the spatially concentrated (manufacturing belt) phase the core benefits from economies of scale and proximity to markets and suppliers raise productivity but also tend to raise wages;

[10] These estimates of transport costs are based on Carter et al. (2006), volume 4, pages 781 and 932-934.

[11] The former group of states comprises Illinois, Indiana, Michigan, New Jersey, New York, Ohio, Pennsylvania, and Wisconsin while the latter comprises Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee and Texas. The average wage rates are obtained by dividing the wage bill by the number of workers in the Census of Manufactures.

subsequently, however, in the context of much lower transport costs, the wage gap becomes too high and moves to the periphery promote a convergence of wage rates.

Recent research has produced empirical results which are broadly consistent with a core-periphery model. Klein and Crafts (2012) found that the location of manufacturing in the early 20th century was strongly influenced by the attraction of market potential to industries with large plants and strong linkages with industrial customers and suppliers. This pattern underpinned the existence of the manufacturing belt. Crafts and Klein (2015) found that home bias in U.S. domestic trade was much lower in 1949 than in 2007. In 1949, some commodities actually exhibited negative home bias at a time when the ratio of inter- to intra-state trade was much higher and much production in the manufacturing belt was still exported to the rest of the United States. They showed that in 1949 home bias was inversely correlated with geographic concentration of industries. This configuration had, however, evaporated by 2007.

Reality was often more complex but reflected similar issues. An excellent example of this is Motor Vehicles and Equipment (SIC 371) where overall geographic concentration fell in the second half of the 20th century but where significant localization persisted in a new configuration. The SMS index for SIC 371 was 0.191 in 1940, 0.120 in 1958, 0.106 in 1977 and 0.094 in 1997. Maps 4 to 7 show an evolving pattern of its spatial concentration over time such that by 1997 the move away from the 1940 situation of a dominant position for Michigan and an east-west corridor in the southern Great Lakes region has been superseded by one in which Michigan is still a major centre but clusters within ‘Auto Alley’ extend as far south as Alabama (Klier and Rubenstein, 2008). Two key developments that underlay these changes were the switch of assembly plants in the 1960s away from the coasts to central areas to reduce the costs of transporting cars to customers once these plants became specialized in models for sale throughout the United States and the advent of Japanese producers in the 1980s and 1990s who chose to locate further south – initially Kentucky and Tennessee and then in the deep south. Throughout, parts suppliers wanted to locate close to auto producers. Transport costs were instrumental in some of these decisions but the move to the south by the Japanese was encouraged by a quest for lower labour costs.

It is interesting to view changes in the location of manufacturing together with the evolution of spatial concentration in knowledge-intensive business services.[12] These activities which are typically supplying intermediates, often to other business services providers, appear to benefit strongly from economies of agglomeration which stem from thick markets in human capital, advantages of proximity to users and suppliers and knowledge spillovers. Since 1980, their geographical concentration has been increasing and these activities are now strongly localized in densely populated metropolitan areas such that they have become more agglomerated than manufacturing whereas the opposite was very much the case in 1930. It appears that the attraction of market potential in the context of linkage effects has started to matter a lot for knowledge-intensive business services while at the same time it has lost its attraction for manufacturing (Cermeno, 2019).

There is a marked contrast between employment patterns in large metropolitan areas at the beginning and end of the twentieth century. In 1910, 35.1 per cent of employment in the largest MSAs was in manufacturing and 6.2 per cent was in business services compared with 25.1 per cent and 4.4 per cent, respectively, in non-MSA locations. In 1995, 14.3 per cent of employment in the largest MSAs was in manufacturing compared with 21.3 per cent in business services compared with 26.9 per cent and 9.1 per cent, respectively, in non-MSA locations (Kolko, 1999).[13] By 1995 in an era of much lower transport costs for goods, relatively land-intensive manufacturing had relocated to areas where real estate was cheaper and, at least in

[12] Knowledge-intensive business services comprise finance, insurance and real estate, business services, and professional services.
[13] Kolko notes that in 1995 business service *occupations* accounted for 41.8 per cent of employment in the largest MSAs.

the cities which had successfully regenerated, been replaced by human-capital intensive business services (Desmet and Fafchamps, 2005). This is the story for Boston though not for Detroit (Glaeser, 2005). A subset, but only a subset, of traditional manufacturing cities was able to make the transition to becoming a successful services-based agglomeration.

Accounting for the checkerboard problem corrects the long-run pattern of spatial concentration: the inverted U-shape pattern, driven by an increase of spatial concentration in the first half of the twentieth century, does not hold anymore and instead we find stability followed by a slow decline before WWII. This is consistent with the core-periphery pattern analysed in Klein and Crafts (2012). They show that the manufacturing belt was the main location of industrial sector as early as the beginning of the twentieth century. Industries continued to locate there, but that does not necessarily imply an increase in spatial concentration if the checkerboard problem was present, as indeed it was. Maps 1-3 illustrate this clearly. We see that between 1900 and 1920, even though the employment in this industry increased in the manufacturing belt, it increased in the states are geographically *disjointed*: employment concentrates mostly in New York, Ohio, and Illinois – states which are not adjacent. As for 1920-1940, while the increase in employment created a contiguous area of Middle Atlantic and Midwest regions, we see a substantial increase of employment in California. This reinstates the checkerboard problem because these two dominant regions of employment are geographically disjointed: one in the East and Midwest, the other in the West.

Besides contributing to the checkerboard problem, the ascent of California as a manufacturing location adds to the richness of the historical picture. Initially, Californian manufacturing was based mainly on resource-processing industries but already by the late-1930s it was developing a significant presence in knowledge-based industries and a comparative advantage based on human capital and localized technological spillovers, first in aircraft followed by electronics and information technology (Rhode, 2001). A good post-war example can be found in the semi-conductor industry where spatial dispersion took place over the long run in the context of a reconfiguration of the sector driven by technological change. The key development was the advent of the integrated circuit in 1959 which was discovered in California and Texas. This triggered a long-term move to those states and away from Massachusetts and New York where, in the 1950s, semiconductors were produced by vacuum tube manufacturers. Nevertheless, the industry continued to experience a significant level of localization in which knowledge spillovers and proximity to buyers played a big part (Ketelhöhn, 2006).

In the context of a general move towards greater spatial dispersion, it is noteworthy how weak correlations of localization at the industry level were over time. Even so, it is striking how pervasive significant excess spatial concentration has been throughout our period. As the manufacturing belt lost its manufacturing dominance the new locational patterns saw new pockets of spatial concentration emerge rather than a scattering of plants across the rest of the country. Nevertheless, it seems quite possible that the underlying reasons for concentration have changed over time and that individual-industry experiences provide many variations on this theme. These are important topics for future research.[14]

7. Conclusions

We have constructed spatially-weighted indices of geographic concentration of SIC2 and SIC3 manufacturing industries in the United States over the period 1880 to 2007 and have shown that this is possible notwithstanding data constraints. These estimates embody recent methodological innovations. We offer a new and improved perspective on long-run trends in spatial concentration of American manufacturing. We show that it is very important to use spatial weighting in order to achieve this. This leads us to a very different picture of long-run

[14] For example, as one of the founding fathers of the 'new economic geography' reflected, its models may have more salience to the era of the manufacturing belt than the present day (Krugman, 2011).

trends in spatial concentration from that which was found by Kim (1995); we do not find an inverted-U shape.

The first striking feature of our estimates is that by the end of the 20th century average levels of spatial concentration in manufacturing were much lower than in the late 19th century. The weighted average for SIC3 industries for the SMS index was 0.098 in 2007 compared with 0.223 in 1880. Although spatial concentration fell more rapidly after World War II, a significant decrease had already taken place by 1940 in the context of an early decline in the importance of the manufacturing belt and a switch towards the mid-west within the manufacturing belt. A second important point is that this experience is characteristic of the vast majority of SIC2 industries. It is also notable that correlations over time of our index of geographic concentration are quite low. The third major finding that comes from our estimates is that ‘excess’ spatial concentration is pervasive at the SIC3 level throughout the whole period. Across almost all industries and all years, spatial concentration is significant both statistically and economically.

References

Carter, S.B., Gartner, S.S, Haines, M.R., Olmstead, A.L., Sutch, R., Wright, G. (eds.) (2006) *Historical Statistics of the United States: Earliest Times to the Present*. Cambridge: Cambridge University Press.

Cermeno, A.L. (2019). The driving forces of service localization during the twentieth century: evidence from the United States. *European Review of Economic History*, 23: 145-174.

Crafts, N., Klein, A. (2015) Geography and intra-national home bias: U.S. domestic trade in 1949 and 2007. *Journal of Economic Geography*, 15: 477-497.

Desmet, K., Fafchamps, M. (2005) Changes in the spatial concentration of employment across US counties: a sectoral analysis, 1972-2000. *Journal of Economic Geography,* 5: 261-284.

Dumais, G. Ellison, G., Glaeser, E.L. (2002) Geographic concentration as a dynamic process. *Review of Economics and Statistics*, 84: 193-204.

Easterlin, R.A. (1960) Redistribution of manufacturing. In S. Kuznets, A.R. Miller and R.A. Easterlin (eds.), *Population Redistribution and Economic Growth*, vol. 2, pp. 103-139. Philadelphia: American Philosophical Society.

Ellison, G., Glaeser, E.L. (1997) Geographic concentration in U.S. manufacturing industries: a dartboard approach. *Journal of Political Economy*, 105: 889-927.

Eriksson, K., Russ, K.N., Shambaugh, J.C., Xu, M. (2019) Trade shocks and the shifting landscape of U.S. manufacturing. NBER Working Paper No. 25646.

Fort, T. C., Pierce, J. R., & Schott, P. K. (2018). New perspectives on the decline of US manufacturing employment. *Journal of Economic Perspectives*, 32: 47-72.

Glaeser, E. (2005) Reinventing Boston, 1640-2003. *Journal of Economic Geography,* 5: 119-153.

Glaeser, E. L., Kohlhase, J. E. (2004) Cities, regions and the decline of transport costs. *Papers in Regional Science*, 83: 197-228.

Golan, A., Judge, J., Robinson, S. (1994) Recovering information from incomplete or partial multi-sectoral data. *Review of Economics and Statistics,* 74: 541-549.

Guimarães, P., Figueiredo, O., Woodward, D. (2011) Accounting for neighboring effects in measures of spatial concentration. *Journal of Regional Science,* 51: 678-693.

Holmes, T. J., Stevens, J.J. (2004) Spatial distribution of economic activities in North America. In J.V. Henderson, J. F. Thisse (eds.), *Handbook of Regional and Urban Economics*, vol. 4, pp. 2797-2843. Amsterdam: Elsevier.

Hoover, E.M. (1948) *The Location of Economic Activity*. New York: McGraw-Hill.

Interstate Commerce Commission (1951), *Carload Waybill Statistics, 1949*. Washington, DC.: Bureau of Transport Economics and Statistics.

Ketelhöhn, N.W. (2006) The role of clusters as sources of dynamic externalities in the US semiconductor industry. *Journal of Economic Geography*, 6: 679-699.

Kim, S. (1995) Expansion of markets and the geographic distribution of economic activities: the trends in U.S. regional manufacturing structure, 1860-1987. *Quarterly Journal of Economics*, 110: 881-908.

Klein, A., Crafts, N. (2012) Making sense of the manufacturing belt: determinants of U.S. industrial location, 1880-1920. *Journal of Economic Geography*, 12: 775-807.

Klein, A., Crafts, N. (2020) Agglomeration externalities and productivity growth: U.S. cities, 1880-1930. *Economic History Review*, 73, 209-232.

Klier, T. and Rubenstein, J. (2008) *Who Really Made Your Car?* Kalamazoo: W.E. Upjohn Institute for Employment Research.

Kolko, J. (1999) Can I get some service here? Information technology, service industries, and the future of cities. http://dx.doi.org/10.2139/ssrn.985712

Krugman, P. (2009) The increasing returns revolution in trade and geography. *American Economic Review*, 99: 561-571.

Krugman, P. (2011) The new economic geography, now middle-aged. *Regional Studies*, 45: 1-7.

Krugman, P., Venables, A. J. (1995) Globalization and the inequality of nations. *Quarterly Journal of Economics*, 110: 857-880.

Maurel, F., Sedillot, B. (1999) A measure of the geographic concentration in French manufacturing industries. *Regional Science and Urban Economics*, 29: 575-604.

Mowery, D., Rosenberg, N. (1999) *Paths of innovation: Technological change in 20th-century America*. Cambridge: Cambridge University Press.

Rhode, P. (2001) *The Evolution of California Manufacturing*. San Francisco: Public Policy Institute of California.

Smith, G.C. Jr. (1947) Lorenz curve analysis of industrial decentralization. *Journal of the American Statistical Association*, 42: 591-596.

Table 1. Regional Shares of Manufacturing Employment (%).

	1880	1890	1900	1910	1920	1930	1940	1947	1958	1967	1977	1987	1997	2007
Manufacturing Belt	**87.2**	**81.2**	**80.3**	**78.3**	**78.1**	**75.1**	**73.6**	**72.5**	**63.8**	**61.7**	**54.5**	**48.8**	**45.3**	**42.9**
New England	24	19.5	18.3	17.3	15.7	12.9	12.5	10.3	8.6	8.2	7.2	7.2	5.6	5.3
Middle Atlantic	37.5	34.2	34.2	33.8	32.1	29.2	27.9	27.7	24.4	22.3	18.2	15.5	12.6	11.2
East North Central	19.1	23.3	23.4	22.8	26.6	29	27.9	30.3	26.6	26.9	24.9	21.8	23.2	22.7
South Atlantic (part)	6.6	4.2	4.4	4.4	3.7	4	5.3	4.2	4.2	4.3	4.2	4.3	3.9	3.7
Non-Manufacturing Belt	**12.6**	**18.8**	**18.7**	**21.8**	**21.9**	**24.8**	**26.4**	**27.5**	**36.1**	**38.2**	**45.3**	**51.2**	**54.7**	**57.1**
South Atlantic (part)	2.3	3.4	4.7	5.5	4.9	6.2	7.4	6.3	8.3	8.5	10.4	12.2	12.2	11.4
West North Central	4.5	6.8	5.8	5.4	5	5.1	4.9	5.5	7.2	6.3	6.7	7	8	9
East South Central	2.7	3.6	3.6	3.8	3.3	4.1	4.7	4.4	4.8	5.6	7	7.1	7.8	7.9
West South Central	1	1.8	2.2	3	3	3.2	3.3	3.9	4.8	5.7	7.5	7.8	9.2	10.3
Mountain	0.4	0.6	0.8	1	1	1	0.9	1	1.4	1.6	2.4	3.2	4	4.6
Pacific	1.7	2.6	2.6	3.1	4.7	5.2	5.2	6.4	9.6	10.5	11.3	13.9	13.5	13.9
% from US total employment	**16.3**	**14.0**	**17.8**	**18.2**	**21.6**	**19.1**	**16.6**	**25.0**	**25.2**	**25.7**	**21.5**	**17.0**	**14.4**	**9.1**

Notes: South Atlantic states inside the manufacturing belt are Delaware, Maryland, Virginia and West Virginia.
Source: US Census of Manufactures; US Historical Statistics, Millennial Edition, tables Ba349, Ba471, Ba481; US Bureau of Labor.

Table 2. Inter-State Trade in Manufactures in 1949.

US Region	% carloads originating in each region
Manufacturing Belt	*62.3*
New England	3.5
Middle Atlantic	20
East North Central	32.4
South Atlantic (part)	6.4
Non-Manufacturing Belt	*37.7*
South Atlantic (part)	3.8
West North Central	9
East South Central	5.8
West South Central	12.7
Mountain	1.8
Pacific	4.6

Source: Interstate Commerce Commission (1951)

Table 3. Average Plant Size in SIC 2-Digit Industries: Number of Production Workers.

	1880	1920	1947	1967	1997	2007
Food & Kindred Products	5.09	10.92	35.52	50.63	72.44	69.74
Tobacco & Tobacco Products	13.03	14.9	105.23	246.23	243.98	189.73
Textile Mill Products	76.4	156.02	151.03	131.59	90.89	59.59
Apparel & Related Products	32.67	29.21	35.21	51.7	32.9	19.26
Lumber & Wood Products	6.79	18.6	24.24	15.12	20.21	26.98
Furniture & Fixtures	10.31	30.8	42.55	42.88	45.47	34.40
Paper & Allied Products	30.23	78.31	110.56	108.97	92.56	82.53
Printing & Publishing	17.43	8.84	24.54	27.05	23.1	23.55
Chemicals & Allied Products	15.75	35.37	62.84	71.63	73.28	58.88
Petroleum & Coal Products	12.78	46.65	155.03	76.83	57.49	45.95
Rubber & Plastic Products	113.88	329.79	352.49	80.53	56.99	58.91
Leather & Leather Products	6.32	55.12	76.91	90.5	46.13	25.61
Stone, Clay & Glass Products	12.9	29.68	43.99	37.07	32.7	27.25
Primary Metal Products	44.47	57.79	237.69	187.53	96.07	82.64
Fabricated Metal Products	3	56.23	65.04	49.04	39.51	35.93
Machinery	20.41	94.98	91.69	49.44	35.13	31.16
Electrical Engineering	24.03	119	202.77	175.55	87.42	71.86
Transportation Equipment	13.28	172.94	319.24	247.18	121.54	123.07
Instruments & Related Products	5.52	19.68	90.78	89.21	64.18	63.44
Miscellaneous Manufacturing	16.91	40.07	33.12	30.27	21.98	16.49
US Average Plant Size	10.95	31.53	60.61	59.48	46.1	41.86
Standard Deviation	26.41	74.85	94.26	68.18	49.09	40.27

Source: US Census of Manufactures.

Table 4: Percentage of SIC 3-Digit Industries with significant Moran's I Spatial Autocorrelation by Year and SIC 2 Category.

Panel A

Year	*%*	*Year*	*%*
1880	82.5	1947	65.2
1890	82.9	1958	50.0
1900	79.4	1967	58.7
1910	68.9	1977	47.1
1920	69.0	1987	42.1
1930	59.5	1997	43.6
1940	72.2	2007	40.6

Panel B

SIC 2 Industry	*%*	*SIC 2 Industry*	*%*
Food and kindred product	42.1	Rubber and plastic products	57.1
Tobacco and tobacco product	82.2	Leather and leather products	63.3
Textile mill product	97.3	Stone, clay, and glass products	57.9
Apparel and related products	62.3	Primary metal products	67.7
Lumber and wood products	74.2	Fabricated metal products	67.2
Furniture and fixtures	46.6	Machinery	74.3
Paper and allied products	67.7	Electrical equipment	53.8
Printing and publishing	18.4	Transportation equipment	40.3
Chemicals and allied products	61.6	Instruments and related products	45.7
Petroleum and coal products	47.5	Miscellaneous manufacturing	67.9

Source: see text.

Note: Panel A shows the percentage of SIC 3-digit industries with significant Moran's I spatial autocorrelation in each year under study. Panel B shows the percentage of SIC 3-digit industries with significant Moran's I by SIC 2-digit categories over the entire period 1880-2007.

Table 5. MS and SMS Indices, SIC 3-Digit Industries, 1880-2007

Year	SMS mean (standard deviation)	MS mean (standard deviation)
	I	II
1880	0.223 (0.150)	0.104 (0.093)
1890	0.204 (0.129)	0.098 (0.159)
1900	0.207 (0.117)	0.096 (0.136)
1910	0.206 (0.156)	0.123 (0.218)
1920	0.203 (0.094)	0.121 (0.139)
1930	0.190 (0.089)	0.119 (0.142)
1940	0.183 (0.116)	0.118 (0.150)
1947	0.163 (0.056)	0.103 (0.109)
1958	0.143 (0.046)	0.088 (0.084)
1967	0.122 (0.059)	0.079 (0.073)
1977	0.115 (0.030)	0.067 (0.072)
1987	0.102 (0.029)	0.069 (0.059)
1997	0.096 (0.024)	0.063 (0.043)
2007	0.098 (0.053)	0.056 (0.087)

Note: mean values are weighted averages using employment shares as weights.
Source: own calculations, see the text.

Table 6: Percentage of SIC3 Industries with MS Ratios greater than SMS Ratios by Decade and SIC2 Industry Group.

SIC	1910-1900	1920-1900	1930-1900	1940-1900	Average
			%		
Food and kindred product	89	33	67	56	61
Tobacco and tobacco product	0	100	100	100	75
Textile mill product	67	71	71	57	67
Apparel and related products	71	86	86	71	79
Lumber and wood products	67	33	67	67	58
Furniture and fixtures	67	100	67	67	75
Paper and allied products	100	75	33	33	60
Printing and publishing	50	71	71	83	69
Chemicals and allied products	100	67	100	100	92
Petroleum and coal products	100	33	67	33	58
Rubber and plastic products	100	50	50	100	75
Leather and leather products	100	80	80	80	85
Stone, clay, and glass products	57	71	33	50	53
Primary metal products	67	71	57	50	61
Fabricated metal products	50	88	75	88	75
Machinery	83	71	71	43	67
Electrical equipment	100	75	75	100	88
Transportation equipment	50	50	75	75	63
Instruments and related products	75	50	75	50	63
Miscellaneous manufacturing	67	100	83	83	83

Sources: see the text.

Note: The reported percentages are calculated as follows.

We calculate the ratios of MS and SMS indices relative to 1900 for each decade respectively. Then we take the difference (MS-SMS) and weight it by the share of value added of the corresponding SIC3 industry. The percentage of the weighted (MS-SMS) which is greater than 0 is reported above.

Table 7. SMS Index Estimates, SIC2-Level Industries, 1880-2007

Sic 2 industry code	SIC 2 Industry	1880	1890	1900	1910	1920	1930	1940	1947	1958	1967	1977	1987	1997	2007
20	Food and kindred product	0.16	0.17	0.16	0.15	0.14	0.12	0.12	0.11	0.11	0.1	0.1	0.09	0.05	0.06
21	Tobacco and tobacco product	0.23	0.24	0.22	0.21	0.21	0.25	0.24	0.19	0.17	0.17	0.13	0.1	0.13	0.26
22	Textile mill product	0.22	0.15	0.16	0.21	0.24	0.2	0.21	0.26	0.23	0.21	0.2	0.18	0.17	0.16
23	Apparel and related products	0.25	0.2	0.19	0.26	0.29	0.26	0.25	0.24	0.24	0.22	0.17	0.11	0.07	0.07
24	Lumber and wood products	0.17	0.15	0.15	0.14	0.14	0.13	0.11	0.13	0.11	0.12	0.11	0.1	0.1	0.09
25	Furniture and fixtures	0.19	0.21	0.19	0.17	0.17	0.14	0.14	0.12	0.11	0.1	0.09	0.09	0.08	0.08
26	Paper and allied products	0.32	0.33	0.3	0.28	0.27	0.22	0.21	0.19	0.16	0.14	0.12	0.11	0.1	0.10
27	Printing and publishing	0.19	0.15	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.11	0.1	0.09	0.06	0.03
28	Chemicals and allied products	0.21	0.23	0.22	0.22	0.17	0.16	0.13	0.13	0.12	0.11	0.11	0.09	0.08	0.08
29	Petroleum and coal products	0.18	0.18	0.16	0.37	0.18	0.19	0.12	0.13	0.11	0.11	0.11	0.1	0.09	0.11
30	Rubber and plastic products	0.39	0.34	0.34	0.3	0.19	0.17	0.19	0.2	0.14	0.12	0.1	0.1	0.08	0.09
31	Leather and leather products	0.18	0.2	0.17	0.19	0.2	0.27	0.25	0.28	0.23	0.21	0.14	0.11	0.09	0.07
32	Stone, clay, and glass products	0.19	0.18	0.17	0.16	0.17	0.16	0.15	0.14	0.11	0.11	0.1	0.1	0.09	0.10
33	Primary metal products	0.23	0.22	0.2	0.18	0.16	0.16	0.19	0.19	0.15	0.14	0.13	0.12	0.11	0.13
34	Fabricated metal products	0.18	0.17	0.16	0.2	0.22	0.19	0.17	0.19	0.13	0.12	0.11	0.1	0.06	0.07
35	Machinery	0.2	0.2	0.18	0.18	0.17	0.18	0.15	0.19	0.13	0.12	0.11	0.1	0.03	0.07
36	Electrical equipment	0.26	0.24	0.23	0.23	0.21	0.18	0.18	0.17	0.15	0.12	0.1	0.08	0.05	0.07
37	Transportation equipment	0.18	0.17	0.17	0.16	0.14	0.15	0.15	0.11	0.08	0.08	0.08	0.08	0.03	0.07
38	Instruments and related products	0.18	0.19	0.16	0.18	0.17	0.16	0.17	0.17	0.15	0.13	0.11	0.09	0.07	0.08
39	Miscellaneous manufacturing	0.25	0.18	0.16	0.16	0.15	0.14	0.13	0.17	0.14	0.13	0.11	0.09	0.08	0.08

Sources: see text

Table 8: Percentage of SIC 3 industries which became more localized and dispersed, by their SIC 2 group, 1880-2007.

SIC 2	Industry	1880-1940		1940-2007		1880-2007	
		more dispersed in 1940 than 1880	more localized in 1940 than in 1880	more dispersed in 2007 than 1940	more localized in 2007 than in 1940	more dispersed in 2007 than 1880	more localized in 2007 than in 1880
20	Food and kindred product	89	11	89	11	56	44
21	Tobacco and tobacco product	50	50	100	0	0	100
22	Textile mill product	50	50	44	56	33	67
23	Apparel and related products	43	57	11	89	100	0
24	Lumber and wood products	100	0	80	20	33	67
25	Furniture and fixtures	67	33	40	60	100	0
26	Paper and allied products	50	50	50	50	75	25
27	Printing and publishing	80	20	57	43	80	20
28	Chemicals and allied products	100	0	14	86	100	0
29	Petroleum and coal products	100	0	100	0	100	0
30	Rubber and plastic products	50	50	75	25	25	75
31	Leather and leather products	17	83	0	100	100	0
32	Stone, clay, and glass products	71	29	50	50	43	57
33	Primary metal products	43	57	20	80	0	100
34	Fabricated metal products	75	25	67	33	75	25
35	Machinery	60	40	67	33	40	60
36	Electrical equipment	67	33	20	80	100	0
37	Transportation equipment	100	0	83	17	67	33
38	Instruments & related prod	75	25	20	80	75	25
39	Miscellaneous manufacturing	67	33	17	83	100	0

Sources: see text
Note: Percentages are calculated relative to the total number of industries in each SIC2 group.

Table 9. Not Significantly Spatially Concentrated SIC3 Industries.

SIC 3	Industry
1880	
305	Hose and Belting and Gaskets and Packing
323	Products of Purchased Glass
334	Secondary Nonferrous Metals
1890	
302	Rubber and Plastics Footwear
308	Miscellaneous Plastics Products nec
358	Refrigeration and Service Industry
1900	
261	Pulp Mills
305	Hose and Belting and Gaskets and Packing
365	Household Audio and Video Equipment
1910	
261	Pulp Mills
302	Rubber and Plastics Footwear
354	Metalworking Machinery
364	Electric Lighting and Wiring Equipment
365	Household Audio and Video Equipment
1920	
305	Hose and Belting and Gaskets and Packing
372	Aircraft and Parts
1930	
302	Rubber and Plastics Footwear
358	Refrigeration and Service Industry
1940	
302	Rubber and Plastics Footwear
374	Railroad Equipment

Note: these industries in every case have a negative SMS index.
Source: own calculations, see the text.

Figure 1. The Checkerboard Problem.

3	3		
3	3		

Figure 1a: Hypothetical Distribution of Firms

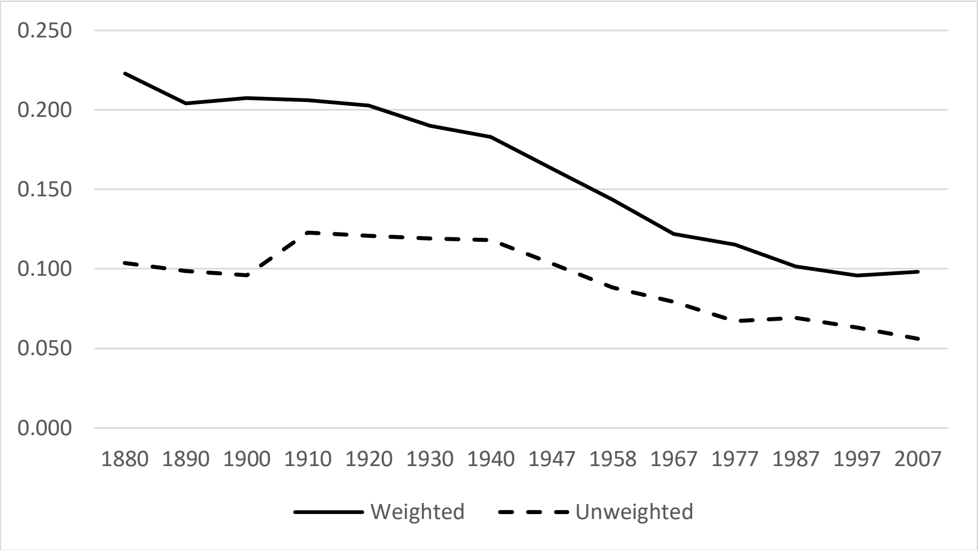
	3		3
	3		3

Figure 1b: Hypothetical Distribution of Firms

Note: these are hypothetical distributions of 12 equally sized firms in 16 equally sized regions and each firm in is the centre of its region. The Ellison-Glaeser measure gives the same score for spatial concentration in each case (0.1273). A spatially- weighted version of the Ellison-Glaeser index will result in distribution a getting a much higher score: (0.2857 vs. 0.0649) if the weighting scheme suggested by Guimaraes et al. (2011) is used.

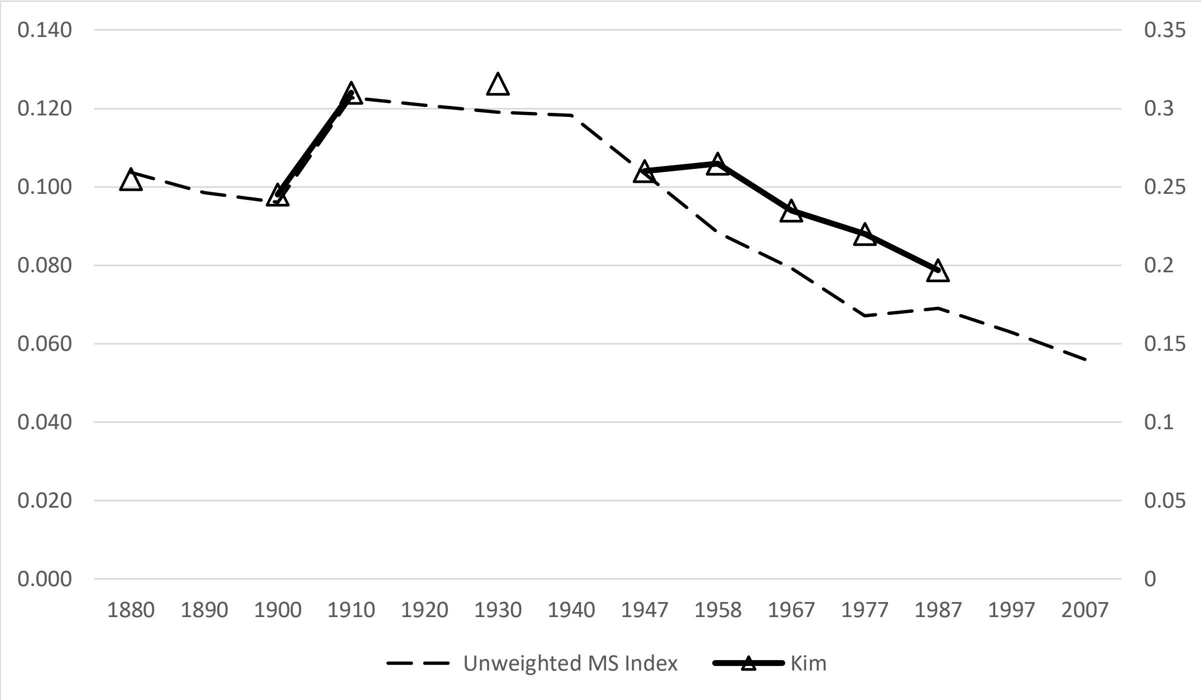
Source: Guimaraes et al. (2011).

Figure 2: SMS and MS Index, 1880-2007.



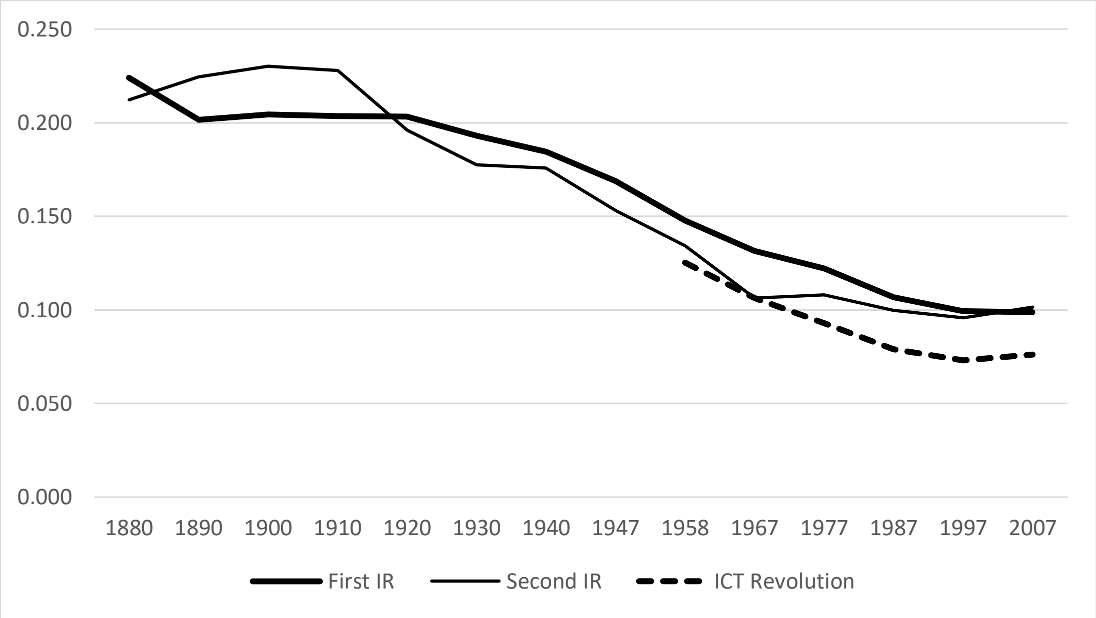
Sources: see the text.

Figure 3: Unweighted MS Index 1880-2007, Kim (1995) Index 1880-1987



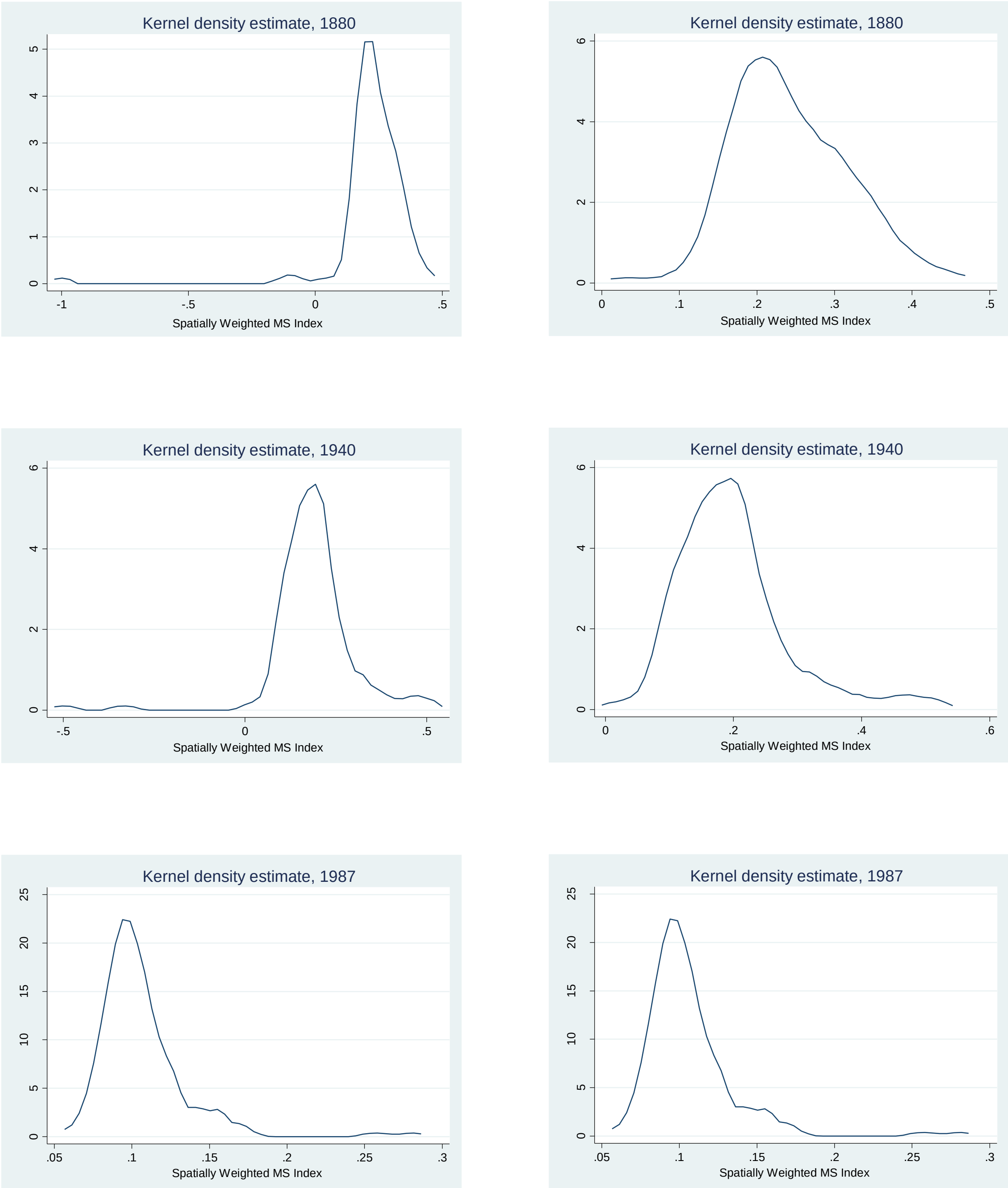
Sources: Kim's index: Kim (1995), unweighted MS index: Figure 2.
Notes: the right x-axis refer to Kim's index, the left x-axis to the unweighted MS index.

Figure 4: Spatially Weighted MS Index by Industries, 1880-2007.



Sources: see the text

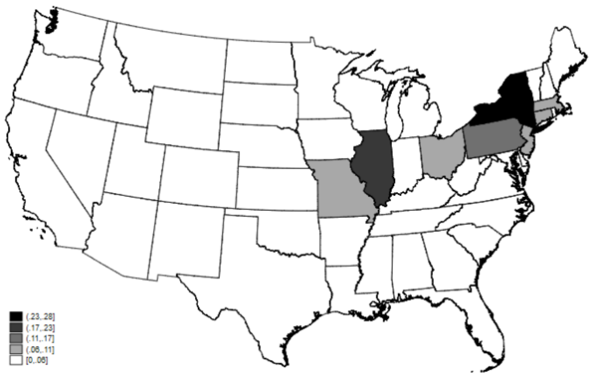
Figure 5: Kernel Density of SMS Index.



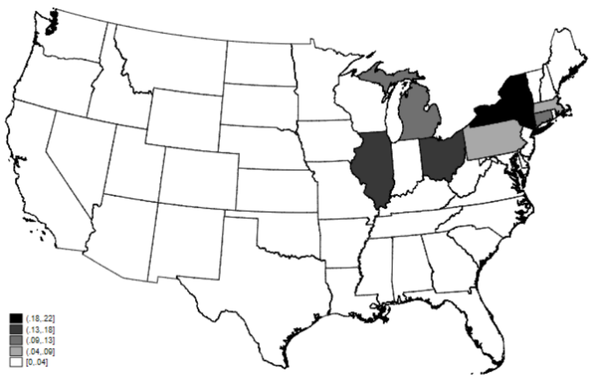
Maps 1-3

SIC364: Electric Lighting & Wiring Equipment

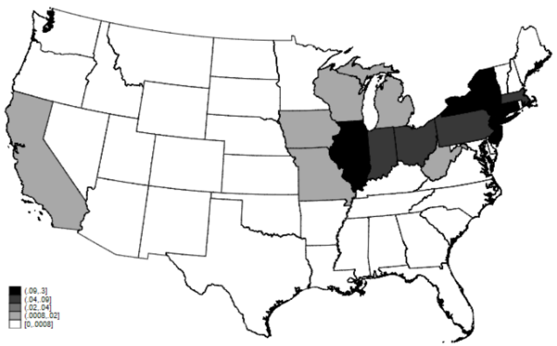
Map 1: 1900



Map 2: 1920



Map 3:1940

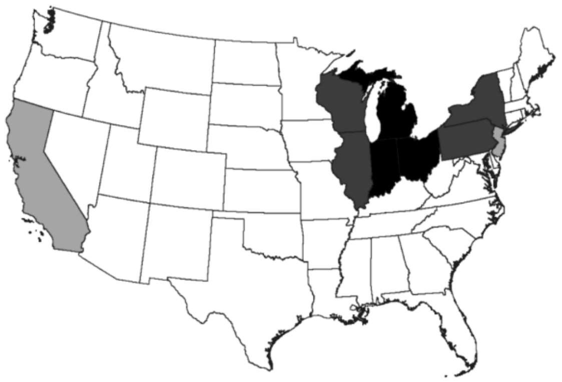


Note: all maps plot geographical index G_i^S as defined in section 3

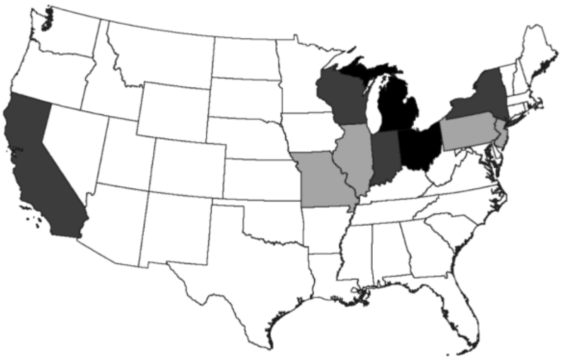
Maps 4-7

SIC 371 – Motor Vehicles & Motor Vehicle Equipment

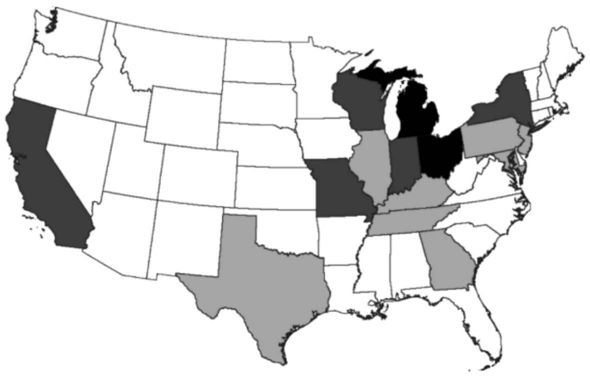
Map 4: 1940



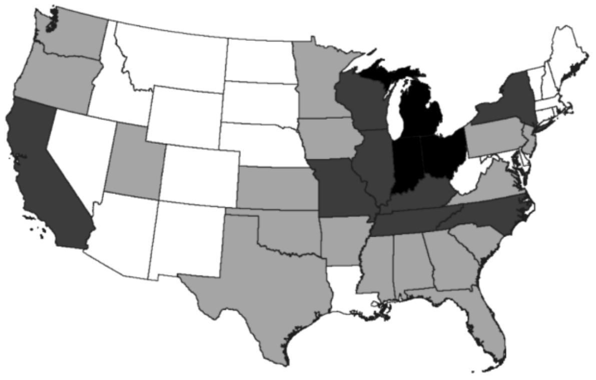
Map 5: 1958



Map 6: 1977



Map 7: 1997



Note: all maps plot geographical index G_i^S as defined in section 3

Appendix 1

The results in Table 1 and Figure 2 were derived using the first-order contiguity spatial matrix. As was discussed in the methodology section, Guimarães et al (2011) point out that it might be desirable to explore other spatial matrices, especially where there is considerable heterogeneity in the size and shape of spatial units. Therefore, we also use spatial matrices in which neighbours are identified using a pre-defined bandwidth. For example, it could be that the effect of the nascent rubber industry in Ohio in 1900 spilled over not only to neighbouring states such as Pennsylvania or Indiana but also to the state of New York or Illinois which are not adjacent to Ohio.

Ideally, the bandwidth should be large enough to capture spillovers that extend beyond areal boundaries, but not too large to dilute spillover effects. There is little theoretical research on how large the bandwidth should be. Therefore we follow a pragmatic approach. Specifically, we calculated SMS indices with bandwidths starting at 100 miles and going up to 1000 miles by a 50-mile increment, creating thus spatial matrices with neighbours defined over the mile distance of 100-150, 100-200, 100-250, 100-300, etc. This ensures that the spatial matrix captures potential spillovers which extend beyond the borders of individual states.

Figure A5 presents the average of these SMS indices. Specifically, it presents four different versions: first, the average of SMS indices starting at 100 miles and going up to 1000 miles, second, the average of the bandwidth starting at 100 miles and going up to 600 miles, third, the average of the bandwidth starting at 300 miles and going up to 600 miles, and fourth, the average of the bandwidth starting at 400 miles and going up to 500 miles. The reason we included the averages of the bandwidths ranging from 100 to 600 miles and from 300 to 600 miles respectively is to see how sensitive they are to the bandwidths which are either too small or too large. The inclusion of the average of the bandwidths ranging from 400 to 500 miles is due to a suggestion of Guimarães et al (2011) that a bandwidth of approximately 450 miles was preferable when analysing modern state-level data.

We see the overall pattern in all four cases remains basically the same as in Figure 2: large geographical concentration in 1880 relative to 1997, distinctly lower spatial concentration in 1930 and 1940 and a considerable decline of the values of SMS index after 1940. We also see the importance of exploring the role of very large bandwidths. In particular, Figure A1 shows that the plot for the averages of SMS with bandwidths between 100 and 1000 miles crosses the plot for the averages of SMS with the bandwidths between 400 and 500 miles in 1967 and then declines more. The reason is the inclusion of the bandwidths over 600 miles in 100-1000 plot and once excluded, the plot of averages over the bandwidths between 100 and 600 miles no longer crosses the plot for the bandwidths of 400-500 miles. This is not surprising: the spatially weighted indices with the bandwidths over 600 miles boil down to the unweighted MS indices since the bandwidths are too large to capture the neighbourhood effects of US states.

Appendix 2

In Table A1 we report the correlation matrix for the SMS index at SIC3 industry level between different years. On the whole, the correlation coefficients are quite low and a different picture emerges. We find a correlation coefficient of 0.17 between 1967 and 1997 and of 0.17 for 1880 and 1987 compared with 0.92 for the EG index between 1972 and 1992 and 0.64 (at SIC2 level) for Hoover's coefficient of localization between 1860 and 1987 in Dumais et al. (2002).

To test whether the distributions of the SMS indices across decades are similar or not, we use two non-parametric tests, namely, the median test and the Mann-Whitney test. The former is based on the position of each observation relative to the overall median of the distribution, while the latter also takes into account the rank of the observation. As a result, the median test makes fewer assumptions than the Mann-Whitney test. Both tests confirm the pattern emerging from Figure 2: a relatively stable distribution of the spatial concentration of manufacturing activities before World War II and quite rapid changes after that. In Table A2, we see that the distributions of the SMS indices decade-by-decade are mostly *not* statistically significantly different from each other before 1940 while that picture changes after 1940. Even so, the cumulative effect of the pre-1940 changes has the implication that on both tests the distribution in 1940 was significantly different from 1880.

Appendix 3

Manufacturing employment at the two-digit and three-digit SIC level in the U.S. state 1880-1940: The data are taken from the U.S. Census of Manufactures 1880, 1890, 1900, 1910, 1920, 1930, and 1940. We aggregated them into the two-digit SIC level using Niemi (1974) classification and into three-digit SIC level using 1987 SIC classification. To assign an industry listed in the U.S. Census of Manufactures into to the relevant SIC three-digit category, we used detailed descriptions of activities to make the correct matching. The 1910 Census of Manufactures excluded so-called hand trades which are the industries providing repair work or work based on individual orders, e.g. bicycle repairing, furniture repairing, blacksmithing, jewelry engraving. To make the data comparable, we have excluded the hand trades in other years as well. Furthermore, we have excluded repair shops in car manufacturers from 1890 onwards since they did not conduct manufacturing activities. The Census of Manufactures reports a special industry category called 'All Other'. This industry category contains less than one percent of the state's total manufacturing employment and includes the industries with a small number of firms to prevent the identification of those firms. As a result, this category contains a heterogeneous set of industries which makes it difficult to assign it to any of the SIC categories. We have decided to perform the analysis with this industry category assigned to SIC 39, miscellaneous, as well as without that industry. The results are virtually unchanged.

Manufacturing employment at the two-digit and three-digit SIC level in the U.S. state 1947-2007: The data are taken from the U.S. Census of Manufactures 1947, 1958, and 1967, from Bureau of Labor Statistics for the years 1977, 1987, and 1997, and from Economic Census for 2007.[15] Harmonization of SIC three-digit industries was needed, especially for the year

[15] Data for 2007 were access from American FactFinder. This web site was discontinued during the revision of the paper and the data can be found at https://data.census.gov/cedsci/.

1947 which presented us with the biggest challenge. Several industries which were coded as SIC four-digit industries became three-digit industries in later census, hence they needed to be recoded. For 1947, Industry SIC261 had to be adjusted by subtracting SIC2611, SIC286 by subtracting SIC2823 and 2825, and SIC346 by subtracting SIC347. For 1958, SIC264 was added to SIC267 to make it consistent with the subsequent censuses. For that year, as well as for the years 1967 and 1977, SIC303 and SIC307 were reclassified to SIC305 and SIC308 respectively. For 1977 and 1987, SIC264 was recoded as SIC267, and SIC383 was added to SIC382. Furthermore, SIC303 and 304 were added up to create SIC305.

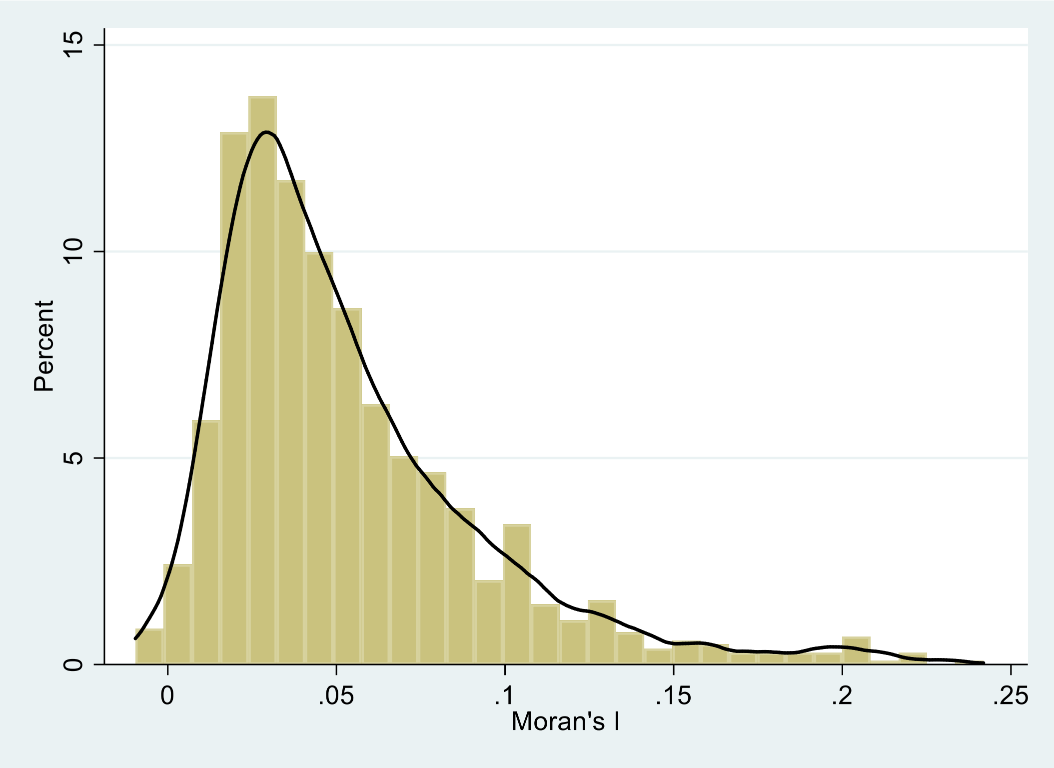
Appendix 4.

Figure 2 shows that unlike the SMS index, the MS index increases appreciably between 1900 and 1910 and then plateaus at about the 1910 level throughout the interwar period. The SMS index is, on the other hand, stable between 1900 and 1920 before it slowly begins to decline. During 1900 to 1940, the example of SIC 364 in Maps 1 to 3 was not atypical as concentration of employment in an industry was no longer in neighbouring states but spread over pockets in much wider geographic areas. This implied in many cases a divergence between movements in the MS and SMS index scores.

To identify which industries drove in the increase in the average MS increase relative to 1900, we calculate a ratio of the MS index in 1910, 1920, 1930, and 1940 relative to 1900, respectively, for each SIC3 industry. The industries with the ratio greater than one are these which drive the increase of MS index after 1900. To see whether SMS indices for these industries increased, decreased, or remained largely unchanged, we calculate the same ratio relative to 1900. When we do this for SIC 364, the industry featured in Maps 1 to 3, we find that the ratio of the MS index in 1920 and 1940 relative to 1900 is 1.12 and 1.13, respectively, while that of the SMS index is 0.88 and 0.83, respectively.

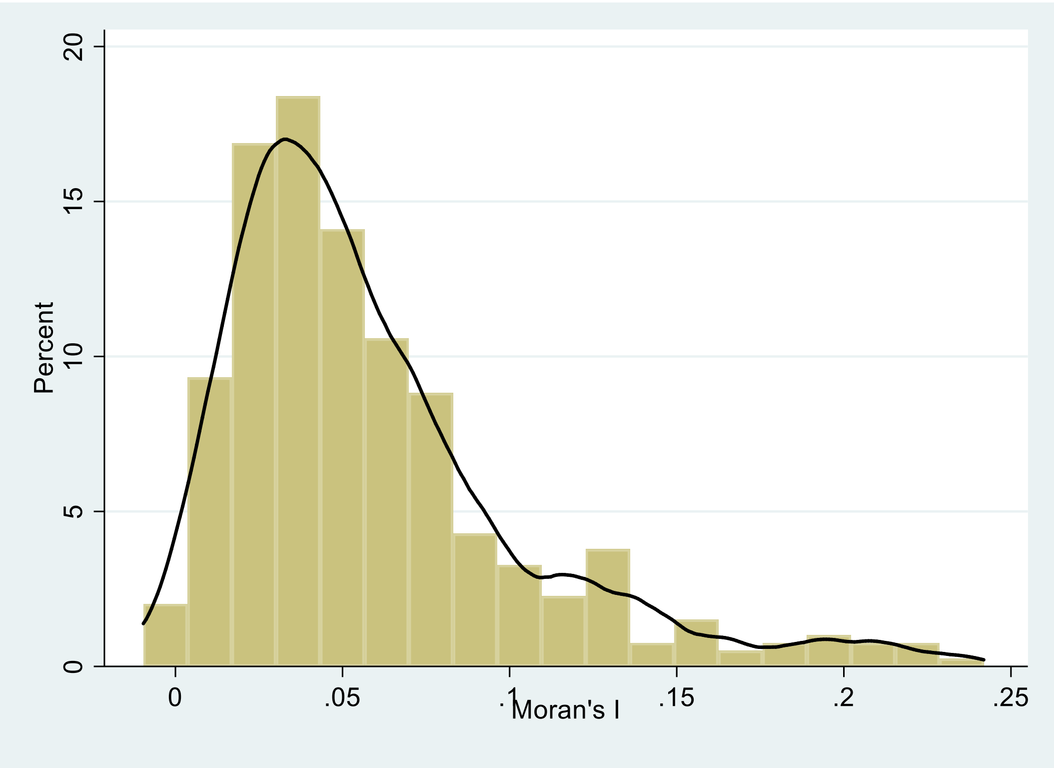
The industries in which the MS ratio is greater than one, their SMS counterparts, and their share of manufacturing value added are presented in Tables A6-A9. We see clear patterns: (i) these industries come from the entire spectrum of the manufacturing sector, (ii) the weighted average of ratios of MS indices relative to 1900 over 1910-1940 is about 1.7, meaning that MS indices in 1910-1940 increased, on average, by seventy percent, (iii) the corresponding weighted average of ratios of SMS indices is about 0.98, which means that SMS indices decreased, on average, by two percent, and (iv) they represented, on average, a quarter of the entire manufacturing sector.

Figure A1: The Distribution and Kernel Density of Moran's I, 1880-2007.



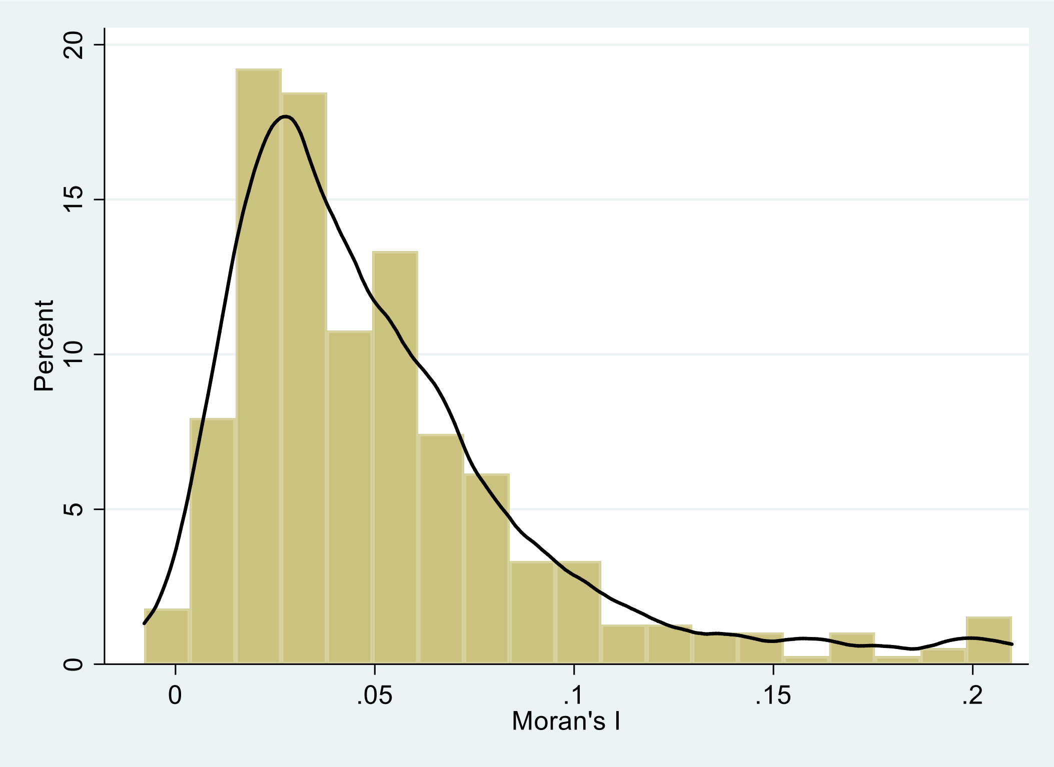
Source: see the text; Note: the figure depicts the values of statistically significant Moran's I.

Figure A2: The Distribution and Kernel Density of Moran's I, 1880-1920.



Source: see the text; Note: the figure depicts the values of statistically significant Moran's I.

Figure A3: The Distribution and Kernel Density of Moran's I, 1920-1958.



Source: see the text; Note: the figure depicts the values of statistically significant Moran's I.

Figure A4: The Distribution and Kernel Density of Moran's I, 1958-2007.

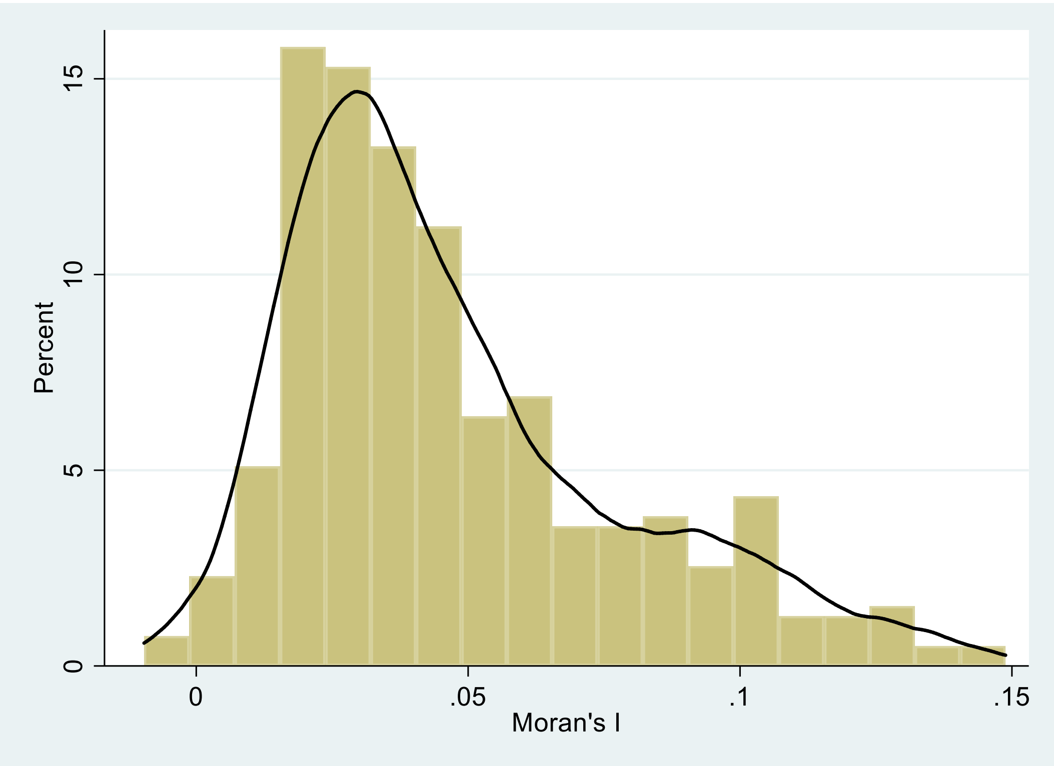
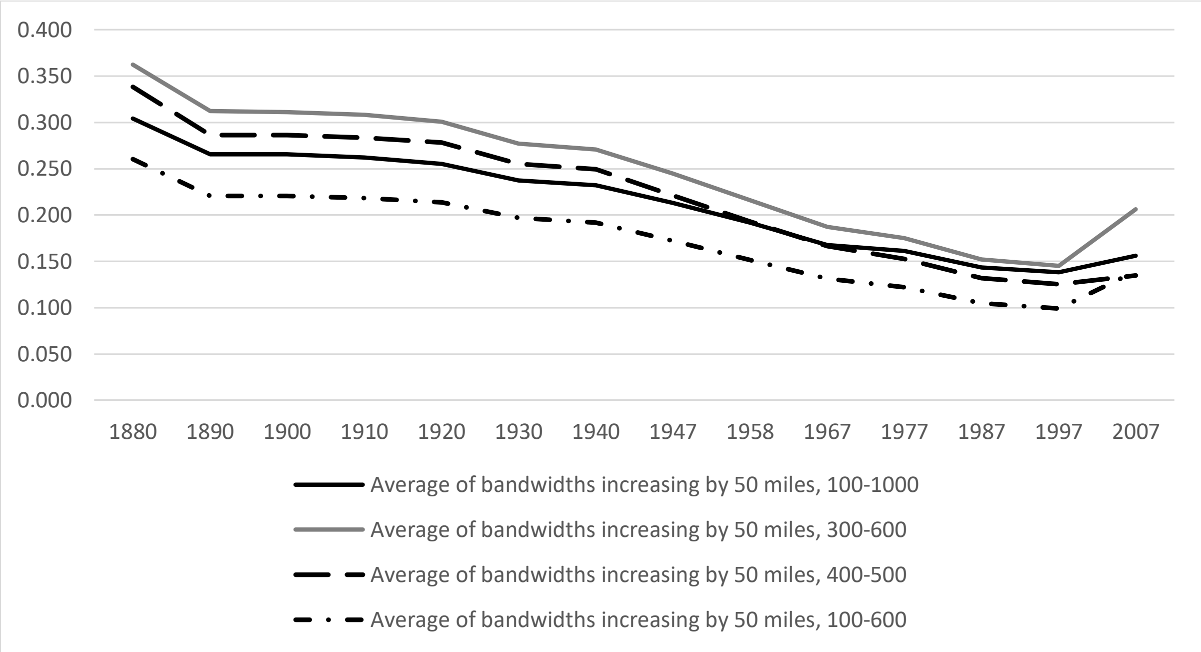


Figure A5: Spatially Weighted Index: Robustness of Spatial Weighting Matrix



Sources: see the text

Table A1. SMS Correlation Matrix, 1880-1997.

	1880	1890	1900	1910	1920	1930	1940	1947	1958	1967	1977	1987	1997
1890	0.56												
1900	0.33	0.18											
1910	0.19	0.54	0.23										
1920	0.29	0.20	0.52	0.37									
1930	0.29	0.65	0.07	0.58	0.55								
1940	0.29	0.63	-0.09	0.46	0.24	0.77							
1947	0.25	0.32	0.16	0.25	0.43	0.50	0.54						
1958	0.14	0.27	0.16	0.32	0.44	0.48	0.53	0.80					
1967	0.20	0.15	0.13	0.01	0.33	0.23	0.24	0.49	0.64				
1977	0.19	0.18	0.23	0.26	0.49	0.44	0.47	0.67	0.82	0.64			
1987	0.17	0.13	0.14	0.31	0.36	0.39	0.43	0.49	0.59	0.42	0.83		
1997	0.17	0.29	-0.05	0.22	0.05	0.28	0.32	0.13	0.16	0.17	0.35	0.67	
2007	0.09	-0.12	0.16	-0.13	0.24	0.01	-0.19	-0.16	-0.26	0.11	0.06	0.12	0.16

Sources: see text.

Table A2: Non-parametric tests on the similarity of the distribution of Ellison and Glaeser Spatially Weighted Indices.

Decades	Median test	Mann-Whitney test
1880-1890	0.393	0.314
1890-1900	0.472	1.491
1900-1910	0.123	0.472
1910-1920	0.119	0.577
1920-1930	4.03*	1.883*
1930-1940	0.003	0.063
1940-1947	17.932***	4.596***
1947-1958	7.124*	2.902**
1958-1967	6.3*	3.735***
1967-1977	0.357	-0.997
1977-1987	12.857***	4.082***
1987-1997	6.914**	2.774**
1997-2007	-0.804	2.4148
1880-1958	109.714***	11.945***
1958-1997	58.562***	10.419***
1958-2007	6.363***	37.157***
1880-1920	4.476**	2.81**
1890-1920	0.459	2.525*
1900-1920	0.018	1.226
1900-1930	7.329**	3.046***
1900-1940	3.047	1.971**

Source: see text

Notes: Median Test tests a hypothesis that two samples come from the distributions with the same median. The reported statistics is Person's chi-square statistics. Mann-Whitney test tests a hypothesis that two samples come from the same distribution. *, **, *** denote statistical significance at 10%, 5%, and 1% respectively.

Table A3: List of Industries Categorised as First Industrial Revolution Industries.

SIC Code	Industry	SIC Code	Industry
201	Meat Products	272	Periodicals
202	Dairy Products	273	Books
203	Preserved Fruits & Vegetables	274	Miscellaneous Publishing
204	Grain Mill Products	275	Commercial Printing
205	Bakery Products	276	Manifold Business Forms
206	Sugar & Confectionery Products	277	Greeting Cards
207	Fats & Oils	278	Blankbooks & Bookbinding
208	Beverages	279	Printing Trade Services
209	Miscellaneous Food & Kindred Products	284	Soap, Cleaners & Toilet Goods
211	Cigarettes	285	Paints & Allied Products
212	Cigars	305	Hose & Belting & Gaskets & Packing
213	Chewing & Smoking Tobacco	311	Leather Tanning & Finishing
214	Tobacco Stemming & Redrying	313	Footwear Cut Stock
221	Broadwoven Fabric Mills, Cotton	314	Footwear, Except Rubber
222	Broadwoven Fabric Mills, Manmade	315	Leather Gloves & Mittens
223	Broadwoven Fabric Mills, Wool	316	Luggage
224	Narrow Fabric Mills	317	Handbags & Personal Leather Goods
225	Knitting Mills	319	Leather Goods, nec
226	Textile Finishing, Except Wool	321	Flat Glass
227	Carpets & Rugs	322	Glass & Glassware, Pressed or Blown
228	Yarn & Thread Mills	323	Products of Purchased Glass
229	Miscellaneous Textile Goods	324	Cement, Hydraulic
231	Men's & Boys' Suits & Coats	325	Structural Clay Products
232	Men's & Boys' Furnishings	326	Pottery & Related Products
233	Women's & Misses' Outerwear	327	Concrete, Gypsum & Plaster Products
234	Women's & Children's Undergarments	328	Cut Stone & Stone Products
235	Hats, Caps & Millinery	329	Miscellaneous Nonmetallic Mineral Products
236	Girl's & Children's Outerwear	331	Blast Furnace & Basic Steel Products
237	Fur Goods	332	Iron & Steel Foundries
238	Miscellaneous Apparel & Accessories	333	Primary Nonferrous Metals
239	Miscellaneous Fabricated Textile Products	334	Secondary Nonferrous Metals
241	Logging	335	Nonferrous Rolling & Drawing
242	Sawmills & Planing Mills	336	Nonferrous Foundries (Castings)
243	Millwork, Plywood, & Structural Members	339	Miscellaneous Primary Metal Industries
244	Wood Containers	342	Cutlery, Handtools & Hardware
245	Wood Buildings & Mobile Homes	343	Plumbing & Heating, Except Electric
249	Miscellaneous Wood Products	344	Fabricated Structural Metal Products
251	Household Furniture	345	Screw Machine Products, Bolts, Etc.
252	Office Furniture	348	Ordnance & Accessories, nec
253	Public Building & Related Furniture	349	Miscellaneous Fabricated Metal Products
254	Partitions & Fixtures	373	Ship & Boat Building & Repairing
259	Miscellaneous Furniture & Fixtures	387	Watches, Clocks, Watchcases & Parts
261	Pulp Mills	391	Jewellery, Silverware & Plated Ware
262	Paper Mills	393	Musical Instruments
263	Paperboard Mills	394	Toys & Sporting Goods
265	Paperboard Containers & Boxes	395	Pens, Pencils, Office & Art Supplies
267	Miscellaneous Converted Paper Products	396	Costume Jewelry & Notions
271	Newspapers	399	Miscellaneous Manufacturers

Source: based on Mowery and Rosenberg (1998).

Table A4: List of Industries Categorised as Second Industrial Revolution Industries.

SIC Code	Industry
281	Industrial Inorganic Chemicals
282	Plastics Materials & Synthetics
283	Drugs
286	Industrial Organic Chemicals
287	Agricultural Chemicals
289	Miscellaneous Chemical Products
291	Petroleum Refining
295	Asphalt Paving & Roofing Materials
299	Miscellaneous Petroleum & Coal Products
301	Tires & Inner Tubes
302	Rubber & Plastics Footwear
306	Fabricated Rubber Products, nec
308	Miscellaneous Plastics Products, nec
341	Metal Cans & Shipping Containers
346	Metal Forgings & Stampings
347	Metal Services, nec
351	Engines & Turbines
352	Farm & Garden Machinery
353	Construction & Related Machinery
354	Metalworking Machinery
355	Special Industry Machinery
356	General Industry Machinery
358	Refrigeration & Service Industry
359	Industrial Machinery, nec
361	Electric Distribution Equipment
362	Electrical Industrial Apparatus
363	Household Appliances
364	Electric Lighting & Wiring Equipment
371	Motor Vehicles & Equipment
372	Aircraft & Parts
374	Railroad Equipment
375	Motorcycles, Bicycles & Parts
379	Miscellaneous Transportation Equipment
382	Measuring & Controlling Devices
384	Medical Instruments & Supplies
385	Ophthalmic Goods
386	Photographic Equipment & Supplies

Source: based on Mowery and Rosenberg (1998).

Table A5: List of Industries Categorised as ICT Revolution Industries.

SIC Code	Industry
357	Computer & Office Equipment
365	Household Audio & Video Equipment
366	Communications Equipment
367	Electronic Components & Accessories
369	Miscellaneous Electrical Equipment & Supplies
376	Guided Missiles, Space Vehicles, Parts
381	Search & Navigation Equipment

Source: based on Mowery and Rosenberg (1998).

Table A6: List of SIC 3 industries driving the increase of MS index in 1910 relative to 1900.

Year	SIC Code	SIC 3 Digit Industry	SMS Index		MS Index		Ratio to 1900		Value Added
			1900	1910	1900	1910	MS	SMS	%
1910	202	Dairy Products	0.216	0.221	0.119	0.153	1.286	1.023	0.5
1910	208	Beverages	0.173	0.165	0.068	0.077	1.132	0.954	5.4
1910	209	Miscellaneous Food & Kindred Products	0.150	0.108	0.060	0.072	1.200	0.720	0.9
1910	223	Broadwoven Fabric Mills, Wool	0.175	0.207	0.085	0.113	1.329	1.183	1.9
1910	225	Knitting Mills	0.319	0.298	0.197	0.198	1.005	0.934	1.1
1910	232	Men's & Boys' Furnishings	0.194	0.220	0.114	0.247	2.167	1.134	3.7
1910	233	Women's & Misses' Outerwear	0.195	0.228	0.113	0.478	4.230	1.169	2.1
1910	237	Fur Goods	0.167	0.113	0.331	0.519	1.568	0.677	0.3
1910	239	Misc Fabricated Textile Products	0.431	0.468	0.184	0.220	1.196	1.086	1.1
1910	242	Sawmills & Planing Mills	0.163	0.164	0.059	0.079	1.339	1.006	0.3
1910	251	Household Furniture	0.186	0.175	0.085	0.116	1.365	0.941	0.2
1910	259	Miscellaneous Furniture & Fixtures	0.197	0.174	0.087	0.092	1.057	0.883	1.6
1910	267	Miscellaneous Converted Paper Products	0.273	0.281	0.173	0.201	1.162	1.029	0.4
1910	284	Soap, Cleaners & Toilet Goods	0.220	0.262	0.103	0.126	1.223	1.191	0.5
1910	286	Industrial Organic Chemicals	0.395	0.315	0.181	0.247	1.365	0.797	0.1
1910	299	Misc Petroleum & Coal Products	0.356	0.414	0.154	0.226	1.468	1.163	0.5
1910	302	Rubber & Plastics Footwear	0.643	-0.143	0.294	1.000	3.401	-0.222	0.1
1910	311	Leather Tanning & Finishing	0.201	0.224	0.078	0.094	1.205	1.114	1.0
1910	319	Leather Goods, nec	0.164	0.147	0.051	0.070	1.373	0.896	0.6
1910	326	Pottery & Related Products	0.205	0.244	0.095	0.116	1.221	1.190	0.6
1910	327	Concrete, Gypsum & Plaster Products	0.223	0.211	0.107	0.159	1.486	0.946	0.3
1910	331	Blast Furnace & Basic Steel Products	0.277	0.327	0.110	0.225	2.045	1.181	4.6
1910	335	Nonferrous Rolling & Drawing	0.210	0.189	0.081	0.302	3.728	0.900	0.2
1910	345	Screw Machine Products, Bolts, Etc.	0.378	0.241	0.197	0.225	1.142	0.638	0.0
1910	354	Metalworking Machinery	0.183	-0.100	0.425	1.000	2.353	-0.546	0.1
1910	356	General Industry Machinery	0.321	0.144	0.144	0.153	1.063	0.449	0.0
1910	359	Industrial Machinery, nec	0.261	0.257	0.119	0.155	1.303	0.985	0.0
1910	362	Electrical Industrial Apparatus	0.227	0.229	0.113	0.122	1.080	1.009	1.6
1910	373	Ship & Boat Building & Repairing	0.148	0.105	0.084	0.090	1.071	0.709	0.4
1910	375	Motorcycles, Bicycles & Parts	0.172	0.176	0.069	0.165	2.391	1.023	0.1
1910	393	Musical Instruments	0.273	0.248	0.168	0.173	1.030	0.908	0.6
1910	394	Toys & Sporting Goods	0.321	0.203	0.173	0.607	3.509	0.632	0.0
1910	395	Pens, Pencils, Office & Art Supplies	0.194	0.183	0.104	0.107	1.029	0.943	0.1
1910	396	Costume Jewellery & Notions	0.273	0.283	0.130	0.199	1.531	1.037	0.2

Source: US Census of Manufactures 1900, 1910

Note: Percentage of value added is calculated from the total value added in manufacturing in 1910

Table A7: List of SIC 3 industries driving the increase of MS index in 1920 relative to 1900.

Year	SIC Code	SIC 3 Digit Industry	SMS Index		MS Index		Ratio to 1900		Value Added
			1900	1920	1900	1920	MS	SMS	%
1920	206	Sugar & Confectionery Products	0.163	0.029	0.072	0.373	5.181	0.178	0.6
1920	207	Fats & Oils	0.132	0.134	0.061	0.065	1.066	1.015	0.6
1920	211	Cigarettes	0.228	0.230	0.105	0.145	1.381	1.009	1.6
1920	213	Chewing & Smoking Tobacco	0.296	0.235	0.108	0.151	1.398	0.794	0.3
1920	225	Knitting Mills	0.319	0.318	0.197	0.211	1.071	0.997	0.0
1920	229	Miscellaneous Textile Goods	0.316	0.328	0.169	0.213	1.260	1.038	0.2
1920	233	Women's & Misses' Outerwear	0.195	0.229	0.113	0.486	4.301	1.174	2.0
1920	237	Fur Goods	0.167	0.136	0.331	0.469	1.417	0.814	0.3
1920	249	Miscellaneous Wood Products	0.147	0.157	0.038	0.043	1.132	1.068	3.9
1920	251	Household Furniture	0.186	0.179	0.085	0.113	1.329	0.962	0.3
1920	259	Miscellaneous Furniture & Fixtures	0.197	0.169	0.087	0.089	1.023	0.858	1.3
1920	267	Miscellaneous Converted Paper Products	0.273	0.310	0.173	0.187	1.081	1.136	0.4
1920	274	Miscellaneous Publishing	0.213	0.230	0.214	0.238	1.112	1.080	0.0
1920	278	Blank books & Bookbinding	0.237	0.217	0.144	0.167	1.160	0.916	0.2
1920	283	Drugs	0.169	0.185	0.077	0.083	1.078	1.095	0.2
1920	299	Misc Petroleum & Coal Products	0.356	0.390	0.154	0.210	1.364	1.096	1.0
1920	302	Rubber & Plastics Footwear	0.643	0.429	0.294	0.487	1.656	0.667	0.2
1920	311	Leather Tanning & Finishing	0.201	0.240	0.078	0.100	1.282	1.194	1.2
1920	316	Luggage	0.172	0.186	0.084	0.124	1.476	1.081	0.1
1920	319	Leather Goods, nec	0.164	0.150	0.051	0.054	1.059	0.915	0.2
1920	325	Structural Clay Products	0.174	0.164	0.057	0.058	1.018	0.943	0.7
1920	326	Pottery & Related Products	0.205	0.166	0.095	0.124	1.305	0.810	0.2
1920	327	Concrete, Gypsum & Plaster Products	0.223	0.210	0.107	0.123	1.150	0.942	0.1
1920	331	Blast Furnace & Basic Steel Products	0.277	0.318	0.110	0.195	1.773	1.148	6.5
1920	333	Primary Nonferrous Metals	0.154	0.158	0.090	0.095	1.056	1.026	0.4
1920	335	Nonferrous Rolling & Drawing	0.210	0.216	0.081	0.089	1.099	1.029	0.3
1920	339	Miscellaneous Primary Metal Industries	0.215	0.165	0.218	0.312	1.431	0.767	0.0
1920	356	General Industry Machinery	0.321	0.169	0.144	0.159	1.104	0.526	0.2
1920	357	Computer & Office Equipment	0.159	0.146	0.104	0.374	3.596	0.918	0.2
1920	359	Industrial Machinery, nec	0.261	0.183	0.119	0.239	2.008	0.701	0.0
1920	363	Household Appliances	0.238	0.222	0.103	0.108	1.049	0.933	0.1
1920	364	Electric Lighting & Wiring Equipment	0.264	0.232	0.163	0.183	1.123	0.879	0.1
1920	386	Photographic Equipment & Supplies	0.154	0.162	0.053	0.180	3.396	1.052	0.3
1920	393	Musical Instruments	0.273	0.261	0.168	0.188	1.119	0.956	0.3
1920	394	Toys & Sporting Goods	0.321	0.250	0.173	0.175	1.012	0.779	0.1
1920	395	Pens, Pencils, Office & Art Supplies	0.194	0.213	0.104	0.119	1.144	1.098	0.1
1920	396	Costume Jewellery & Notions	0.273	0.308	0.130	0.221	1.700	1.128	0.2

Source: US Census of Manufactures 1900, 1920

Note: Percentage of value added is calculated from the total value added in manufacturing in 1920

Table A8: List of SIC 3 industries driving the increase of MS index in 1930 relative to 1900.

Year	SIC Code	SIC 3 Digit Industry	SMS Index		MS Index		Ratio to 1900		Value Added
			1900	1930	1900	1930	MS	SMS	%
1930	396	Costume Jewellery & Notions	0.273	0.278	0.130	0.214	1.646	1.018	0.1
1930	395	Pens, Pencils, Office & Art Supplies	0.194	0.192	0.104	0.124	1.192	0.990	0.1
1930	393	Musical Instruments	0.273	0.220	0.168	0.189	1.125	0.806	0.1
1930	391	Jewellery, Silverware & Plated Ware	0.285	0.224	0.182	0.202	1.110	0.786	0.5
1930	386	Photographic Equipment & Supplies	0.154	0.116	0.053	0.071	1.340	0.753	0.3
1930	364	Electric Lighting & Wiring Equipment	0.264	0.155	0.163	0.167	1.025	0.587	0.3
1930	359	Industrial Machinery, nec	0.261	0.248	0.119	0.249	2.092	0.950	0.0
1930	358	Refrigeration & Service Industry	0.243	-0.036	0.196	0.453	2.311	-0.148	0.0
1930	357	Computer & Office Equipment	0.159	0.186	0.104	0.271	2.606	1.170	0.1
1930	352	Farm & Garden Machinery	0.194	0.154	0.073	0.085	1.164	0.794	0.5
1930	344	Fabricated Structural Metal Products	0.172	0.168	0.066	0.097	1.470	0.977	0.8
1930	343	Plumbing & Heating, Except Electric	0.197	0.186	0.075	0.085	1.133	0.944	1.3
1930	339	Miscellaneous Primary Metal Industries	0.215	0.047	0.218	0.309	1.417	0.219	0.0
1930	335	Nonferrous Rolling & Drawing	0.210	0.220	0.081	0.091	1.123	1.048	0.5
1930	331	Blast Furnace & Basic Steel Products	0.277	0.230	0.110	0.181	1.645	0.830	0.5
1930	326	Pottery & Related Products	0.205	0.189	0.095	0.169	1.779	0.922	0.4
1930	325	Structural Clay Products	0.174	0.149	0.057	0.058	1.018	0.856	0.7
1930	319	Leather Goods, nec	0.164	0.170	0.051	0.175	3.431	1.037	0.1
1930	316	Luggage	0.172	0.187	0.084	0.150	1.786	1.087	0.1
1930	311	Leather Tanning & Finishing	0.201	0.208	0.078	0.105	1.346	1.035	0.5
1930	302	Rubber & Plastics Footwear	0.643	-0.111	0.294	1.000	3.401	-0.173	0.1
1930	299	Misc Petroleum & Coal Products	0.356	0.305	0.154	0.264	1.714	0.857	0.5
1930	295	Asphalt Paving & Roofing Materials	0.221	0.229	0.082	0.150	1.829	1.036	0.2
1930	287	Agricultural Chemicals	0.191	0.227	0.067	0.088	1.313	1.188	0.2
1930	284	Soap, Cleaners & Toilet Goods	0.220	0.170	0.103	0.138	1.340	0.773	0.9
1930	283	Drugs	0.169	0.168	0.077	0.100	1.299	0.994	0.2
1930	278	Blank books & Bookbinding	0.237	0.191	0.144	0.188	1.306	0.806	0.2
1930	274	Miscellaneous Publishing	0.213	0.138	0.214	0.370	1.729	0.648	0.5
1930	271	Newspapers	0.141	0.115	0.042	0.043	1.024	0.816	3.9
1930	259	Miscellaneous Furniture & Fixtures	0.197	0.142	0.087	0.112	1.287	0.721	0.1
1930	251	Household Furniture	0.186	0.143	0.085	0.125	1.471	0.769	0.4
1930	249	Misc Wood Products	0.147	0.163	0.038	0.046	1.211	1.109	3.1
1930	239	Misc Fabricated Textile Products	0.431	0.381	0.184	0.195	1.060	0.884	1.6
1930	237	Fur Goods	0.167	0.104	0.331	0.541	1.634	0.623	0.4
1930	235	Hats, Caps & Millinery	0.168	0.182	0.056	0.365	6.518	1.083	0.5
1930	234	Women's & Children's Undergarments	0.245	0.261	0.162	0.404	2.494	1.065	0.1
1930	233	Women's & Misses' Outerwear	0.195	0.188	0.113	0.511	4.522	0.964	2.6
1930	227	Carpets & Rugs	0.247	0.288	0.138	0.271	1.964	1.166	0.2
1930	225	Knitting Mills	0.319	0.276	0.197	0.259	1.315	0.865	0.1
1930	213	Chewing & Smoking Tobacco	0.296	0.172	0.108	0.202	1.870	0.581	0.1
1930	211	Cigarettes	0.228	0.247	0.105	0.128	1.219	1.083	2.3
1930	207	Fats & Oils	0.132	0.118	0.061	0.066	1.082	0.894	0.5

Source: US Census of Manufactures 1900, 1930

Note: Percentage of value added is calculated from the total value added in manufacturing in 1930

Table A9: List of SIC 3 industries driving the increase of MS index in 1940 relative to 1900.

Year	SIC Code	SIC 3 Digit Industry	SMS Index		MS Index		Ratio to 1900		Value Added
			1900	1940	1900	1940	MS	SMS	%
1940	207	Fats & Oils	0.132	0.112	0.061	0.062	1.016	0.848	0.4
1940	211	Cigarettes	0.228	0.186	0.105	0.266	2.533	0.816	0.8
1940	213	Chewing & Smoking Tobacco	0.296	0.283	0.108	0.128	1.185	0.956	0.0
1940	227	Carpets & Rugs	0.247	0.291	0.138	0.189	1.370	1.178	0.3
1940	232	Men's & Boys' Furnishings	0.194	0.226	0.114	0.116	1.018	1.165	0.8
1940	235	Hats, Caps & Millinery	0.168	0.183	0.056	0.399	7.125	1.089	0.3
1940	237	Fur Goods	0.167	0.086	0.331	0.697	2.106	0.515	0.3
1940	239	Misc Fabricated Textile Products	0.431	0.279	0.184	0.243	1.321	0.647	0.4
1940	244	Wood Containers	0.208	0.124	0.082	0.091	1.110	0.596	0.3
1940	249	Miscellaneous Wood Products	0.147	0.124	0.038	0.049	1.289	0.844	0.3
1940	259	Miscellaneous Furniture & Fixtures	0.197	0.146	0.087	0.128	1.471	0.741	0.2
1940	273	Books	0.178	0.174	0.083	0.167	2.012	0.978	0.6
1940	278	Blank books & Bookbinding	0.237	0.177	0.144	0.162	1.125	0.747	0.3
1940	283	Drugs	0.169	0.160	0.077	0.079	1.026	0.947	1.0
1940	284	Soap, Cleaners & Toilet Goods	0.220	0.166	0.103	0.108	1.049	0.755	0.6
1940	286	Industrial Organic Chemicals	0.395	0.310	0.181	0.228	1.260	0.785	0.2
1940	295	Asphalt Paving & Roofing Materials	0.221	0.195	0.082	0.087	1.061	0.882	0.2
1940	302	Rubber & Plastics Footwear	0.643	-0.333	0.294	1.000	3.401	-0.518	0.1
1940	311	Leather Tanning & Finishing	0.201	0.230	0.078	0.142	1.821	1.144	0.4
1940	319	Leather Goods, nec	0.164	0.187	0.051	0.123	2.412	1.140	0.1
1940	326	Pottery & Related Products	0.205	0.183	0.095	0.157	1.653	0.893	0.3
1940	331	Blast Furnace & Basic Steel Products	0.277	0.290	0.110	0.165	1.500	1.047	4.5
1940	335	Nonferrous Rolling & Drawing	0.210	0.221	0.081	0.085	1.049	1.052	1.0
1940	343	Plumbing & Heating, Except Electric	0.197	0.176	0.075	0.084	1.120	0.893	1.3
1940	344	Fabricated Structural Metal Products	0.172	0.137	0.066	0.074	1.121	0.797	0.8
1940	357	Computer & Office Equipment	0.159	0.190	0.104	0.189	1.817	1.195	0.2
1940	364	Electric Lighting & Wiring Equipment	0.264	0.219	0.163	0.184	1.129	0.830	0.5
1940	375	Motorcycles, Bicycles & Parts	0.172	0.043	0.069	0.243	3.522	0.250	0.1
1940	379	Miscellaneous Transportation Equipment	0.167	0.097	0.054	0.138	2.556	0.581	0.0
1940	384	Medical Instruments & Supplies	0.181	0.174	0.082	0.107	1.305	0.961	0.2
1940	386	Photographic Equipment & Supplies	0.154	0.129	0.053	0.073	1.377	0.838	0.0
1940	391	Jewellery, Silverware & Plated Ware	0.285	0.236	0.182	0.229	1.258	0.828	0.3
1940	395	Pens, Pencils, Office & Art Supplies	0.194	0.200	0.104	0.134	1.288	1.031	0.1
1940	396	Costume Jewellery & Notions	0.273	0.252	0.130	0.290	2.231	0.923	0.2

Source: US Census of Manufactures 1900, 1940

Note: Percentage of value added is calculated from the total value added in manufacturing in 1940