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Diffusion of municipal manufacturing specialization: Evidence from Mexico's municipalities

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Abstract

We estimate contagion rates in the manufacturing sector across Mexico's municipalities, conceptualized as the diffusion of municipal manufacturing specialization and reflected in the regional transmission of industrial expertise, technological capabilities, and skilled labor practices. High contagion rates indicate that specialized manufacturing capabilities are rapidly adopted by other regions. This can lead to the development of industrial clusters where knowledge sharing and advanced techniques drive economic growth. To analyze this issue, we begin by determining the specialization of Mexican municipalities in different manufacturing industry groups and study the diffusion of specialization over time by state and industry group in the periods 2004–2009, 2009–2014, and 2014–2019.

Keywords: Specialization; Diffusion; Manufacturing industry groups.

JEL Classification: O14; O33.

1. Introduction.

As defined by Hidalgo and Hausmann (2009), the term productive knowledge (or productive capabilities) refers to the specialized skills, expertise, technologies, and organizational abilities required to produce goods. It encompasses both tacit knowledge (i.e., that which is experience-based and hard to codify) and explicit knowledge (i.e., that which is formalized in processes, designs, or instructions). In the manufacturing sector specifically, productive knowledge includes: i) technical skills (e.g., operating machinery and precision engineering); ii) process optimization (e.g., lean manufacturing and automation); iii) material science and innovation (e.g., advanced composites and nanotechnology); and iv) organizational and logistical expertise (e.g., supply chain management and production planning), and so on.

The diffusion or transmission of productive capabilities—through training, industrial collaboration, technology transfer, and so on—creates positive spillover effects, allowing neighboring regions to adopt best practices, reduce inefficiencies, enhance competitiveness, and ultimately boost economic growth. By examining the spread of productive knowledge through regional specialization, we can gain a better understanding of how industrial capabilities evolve over time and space.

Our goal is to measure the diffusion of productive knowledge by examining the spread of manufacturing specialization at the municipal level in the subperiods 2004–2009, 2009–2014, and 2014–2019.[1] We begin by identifying those municipalities that can be considered specialized in diverse manufacturing industries and, consequently, have the potential to aid in their spread. To achieve this, we compute a standardized specialization metric to identify municipalities specialized in the various Manufacturing Industry Groups (MIGs).[2] Next, we examine the transmission of productive knowledge through the diffusion of municipal manufacturing specialization, proposing a method that quantifies how initially specialized municipalities influence both neighboring and more distant ones over time.

[1] We limit the sample to this period due to data availability in the most comprehensive and reliable source of economic and industrial information in Mexico—the Economic Censuses published by Mexico's National Institute of Statistics and Geography (INEGI).

[2] Appendix 1 shows the 86 MIGs in the North American Industry Classification System (NAICS), 4-digit classification level.

It is essential to highlight that the specialization diffusion metric is calculated for the following:[3] (i) *neighbor-induced diffusion*, which occurs when a municipality specialized in a given year (e.g., 2004) has an adjacent municipality that was not specialized at that time but which becomes specialized by the end of the subperiod (e.g., by 2009); and (ii) *independent or spontaneous specialization*, which takes place when a municipality becomes specialized on its own without being geographically adjacent to a previously specialized municipality. These calculations allow us to gain an understanding of how specialization evolves over time by state and by industry.

Our findings confirm that patterns observed in other economies also extend to Mexico's municipalities: geographic proximity promotes the diffusion of manufacturing specialization and associated knowledge transfer. This spatial clustering is observed consistently for all the examined MIGs across both states and the nation as a whole. Moreover, these calculations enable a deeper analysis of the spatial distribution of two key MIGs—3341 and 3361—and their main input suppliers. The results indicate that manufacturing specialization is dynamic, with different regions in Mexico showing distinct patterns of specialization growth and decline across both of the aforementioned industries. Several interconnected factors may explain the dynamic nature of manufacturing specialization across Mexican regions, for example: i) economic cycles affect regions differently depending on their industrial composition; ii) regional policy incentives shift over time, favoring different areas or industries; and iii) rising labor costs in established manufacturing hubs drive production relocations. However, our analysis does not explore these causal mechanisms.

The remainder of the article is organized as follows. Section 2 outlines some of the studies most closely related to our research. Section 3 presents the data and methodology used to determine the municipalities that are specialized in the various MIGs. Section 4 describes the methodologies to compute the diffusion of specialization, by state and by MIG. The diffusion of the specialization results is shown and examined in Section 5. Finally, Section 6 presents the concluding remarks and a number of suggestions for future research.

[3] We conduct this analysis specifically to contrast the influence of physical distance on the transmission of specialization. As we will discuss later, previous international studies have shown that geographic proximity facilitates knowledge spillovers, but we want to know whether there is evidence of this in Mexico.

2. Related literature

The Product Space framework (Hidalgo *et al*., 2007) maps products based on their complexity and the productive capabilities required for their production. It illustrates how countries diversify by focusing on products related to their existing specializations. The framework suggests that economies tend to develop new products or industries closely linked to their current productive structure, facilitating smoother transitions and successful specialization diffusion.

This theoretical concept has been examined for specific economies. One example is that of Boschma *et al*. (2013), who use a proximity-based framework to analyze how the relatedness between existing industries influences the emergence of new ones across different regions in Spain. Their main findings are as follows: i) industry relatedness matters; new industries are more likely to emerge in regions where related industries already exist, as they provide complementary knowledge, infrastructure, and skilled labor; ii) geographic proximity plays a role; regions with strong industrial connections and that are close geographically benefit from easier knowledge spillovers, fostering new industry development; and iii) path dependency; the existing industrial structure significantly shapes the evolution of regional economies, meaning that new industries tend to emerge in places where they have a related industrial base. In general, the study in question highlights the importance of regional policies that leverage local industrial strengths to promote diversification and economic growth. It suggests that fostering industries related to existing ones can be a more effective strategy than attempting to attract entirely new, unrelated industries.

Neffke *et al*. (2011) highlight the importance of regional policies that leverage local industrial strengths to promote diversification and economic growth. They suggest that fostering industries related to existing ones can be a more effective strategy than attempting to attract entirely new, unrelated industries. Their main findings are: i) path-dependent diversification; regions are more likely to develop new industries that share similar capabilities, skills, and infrastructure to their existing industries; ii) industry relatedness as a driver; the closer a potential new industry is to a region's current industrial structure, the higher the likelihood of its successful emergence; and iii) gradual economic evolution; instead of radical shifts, regional economies typically evolve through incremental changes, expanding into related sectors over time. The study suggests that policymakers should focus on supporting industries that align with a region's existing strengths rather than trying to introduce completely unrelated industries. Encouraging knowledge transfer and innovation within related industries can help foster sustainable economic growth. The two studies described above, along with others, provide empirical evidence in support of the core prediction of the Product Space framework.

While the present study shares a similar framework, it approaches the topic from a different perspective: rather than analyzing how municipalities develop and specialize in new MIGs connected to their existing ones, we focus on how established industries spread from one municipality to neighboring ones. In the process of doing so, we first determine the specialization of municipalities, then propose a method to measure the diffusion of specialization. This method is used to quantify the diffusion of specialization among neighboring and non-neighboring municipalities in order to evaluate contagion dynamics, thereby enabling us to distinguish the role of geographic proximity in the spillover of productive knowledge. This topic has been widely explored in previous studies—see, for example, Audretsch and Feldman (1996), Boschma (2005), and Boschma and Frenken (2011)—with strong evidence supporting the role of geographic proximity in fostering knowledge transfer.

3. Data and methodology to compute municipal specialization

To estimate the industrial specialization of Mexico's municipalities, we employ the variable *Economic Units* (EU), in this case the number of existing firms per municipality and MIG. Data taken from the 2004, 2009, 2014, and 2019 editions of Mexico's Economic Censuses enables us to analyze specialization diffusion across three subperiods: 2004–2009, 2009–2014, and 2014–2019.

This data is organized in matrices (one per year) denoted as $EU_{m,i}$. Each of these comprises rows, m= 1, 2, 3, …, 2448, containing municipalities[4] and columns, i=1, 2, 3, …, 86 containing MIGs. Cell (m,i)=100 implies that municipality m has 100 EU (or firms) that carry out an economic activity belonging to MIG i.

[4] Although there are more municipalities, we eliminate all those for which there is no information for each of the years.

3.1 Computation of the binary matrix that defines a municipality's specialization

The specialization of each municipality is obtained by using the definition of Location Quotient (LQ) commonly employed in regional science literature. This involves transforming the data from each $EU_{m,i}$ matrix into a matrix of zeros and ones denoted as $EU^B_{m,i}$, as explained below,

$$LQ_{m,i} = \frac{\frac{eu_{m,i}}{\sum_{i=1}^{N_i} eu_{m,i}}}{\frac{\sum_{m=1}^{N_m} eu_{m,i}}{\sum_{m=1,\ i=1}^{N_m,Ni} eu_{m,i}}}$$

where $eu_{m,i}$ is the number of EU in municipality *m* that perform economic activities belonging to MIG *i*; $\sum_{m=1}^{N_m} eu_{m,i}$ (the sum of row *m* of $EU_{m,i}$) is the total number of EU in municipality *m,* regardless of the MIG they belong to; $\sum_{i=1}^{N_i} eu_{m,i}$ (the sum of the *i* column of $EU_{m,i}$) is the total number of EU in the country that carry out economic activities belonging to MIG *i*; $\sum_{m=1,\ i=1}^{N_m,N_i} eu_{m,i}$ (the sum of all cells in $EU_{m,i}$) is the total number of EU in the country.

Each cell of $EU^B_{m,i}$ is defined as follows, $eu^B_{m,i} = \begin{cases} 1 & if\ LQ_{m,i} \geq R^* \\ 0 & in\ any\ other\ case \end{cases}$

A threshold $R^* = 1$ implies that municipality *m* is considered to be specialized in MIG *i* if the proportion of existing EUs belonging to MIG *i* with respect to the total number of EUs (regardless of the MIG) in that municipality is greater than or equal to the equivalent proportion nationwide.

3.2 Results of municipal specialization

Table 1 presents the results of the analysis of municipal specialization in the various manufacturing sector MIGs in each year.

Table 1. Specialization of Mexico's municipalities by year

	2004	2009	2014	2019
Total number	16,725	18,792	20,101	22,009
Percentage of specialization in the country	7.94 %	8.92 %	9.54 %	10.45 %
Percentage change		12.35 %	6.96 %	9.49 %

These figures indicate that in 2004, 16,725 municipalities were specialized in one or other of the 86 MIGs, a figure that steadily increases over time. The second row shows the corresponding percentage of specialized municipalities.[5] These findings also suggest a significant increase in the number of municipalities specialized across all subperiods. The smallest growth rate (nearly 7%) occurred between 2009 and 2014, followed by a 9.5% rise from 2014 to 2019, while the highest increase (12.3%) was recorded between 2004 and 2009. Using the matrices that show municipal specialization, $EU^{B}_{m,i}$, and INEGI's shapefiles, we measure the spatial diffusion of productive knowledge.[6] The following section outlines the methodology used for quantifying the number of municipalities specializing according to these two alternatives, both by state and by MIG.

4. Methodology used to compute the diffusion of specialization by state and by MIG

4.1 Methodology for calculating the diffusion of MIG specialization by state

As an example for the purpose of explaining the method used to measure new specializations, Table 2 presents a hypothetical distribution of geographic specialization for 30 municipalities within a particular state and MIG from 2004 to 2009. The main distinction between this hypothetical scenario and the actual analysis of new specializations or contagion rates lies in its limited scope—this example focuses on a single MIG within one state—. In contrast, the full analysis incorporates all 86 MIGs in order to provide a comprehensive assessment of specialization and diffusion at the state level.

In Table 2, each cell represents a municipality and contains a number on the left side and another on the right (either a zero or a one). The number on the left represents the municipality's specialization status in 2004 and that on the right its status in 2009, where zero indicates no specialization and one indicates specialization. The table's rows and columns represent a Cartesian plane, which shows the geographic proximity between municipalities.

[5] The maximum possible number of specialized municipalities per period is 210,528, i.e., the number of municipalities in the country times the number of different industries (2,448*86).

[6] INEGI's shapefiles are digital geospatial data files, which, among another attributes, identify the geographic location and boundaries of each municipality, state, and locality.

Table 2. MIG diffusion by state, 2004–2009

	Column 1		*Column 2*		*Column 3*		*Column 4*		*Column 5*	
	2004	2009	2004	2009	2004	2009	2004	2009	2004	2009
Row 1	1	1	0	0	0	0	1	0	0	0
Row 2	0	1	0	1	0	0	0	0	0	0
Row 3	0	0	0	0	0	0	0	1	0	0
Row 4	0	1	0	1	0	0	0	1	0	0
Row 5	0	0	0	0	1	0	0	1	1	1
Row 6	1	1	0	0	0	0	0	0	0	0

a) We consider there to be *neighbor-transmitted or neighbor-induced specialization* diffusion in a state when in 2004, a specialized municipality has adjacent neighboring municipalities that were not specialized at that time but which became specialized by the start of the subsequent period (2009).[7] This occurs three times in the table above:

- in the case of the municipality in row 1 column 1—or (1,1)—, which was specialized in 2004 and by 2009 its neighbors (2,1) and (2,2) were also specialized
- in the case of municipality (5,3), which was specialized in 2004 and by 2009 its neighbors (4,2), (4,4), and (5,4) were also specialized
- in the case of municipality (5,5), which was specialized in 2004 and by 2009 its neighbors (4,4) and (5,4) were also specialized.

It is essential to emphasize the fact that, in this instance, we only recognize five cases of transmission or diffusion: municipalities (2,1), (2,2), (4,2), (4,4), and (5,4); this is because municipalities (4,4), (5,4) are counted only once, as they were influenced either by (5,3) or (5,5).

As a result, neighbor-transmitted or neighbor-induced specialization occurs in only five out of a total of 30 cases, reflecting a corresponding contagion rate of 16.6%.

b) We consider there to be *independent or spontaneous specialization* in a state if its municipalities become specialized independently or without having had a previously specialized adjacent neighbor.

- Municipalities (4,1) and (3,4) became specialized in 2009, but none of its adjacent neighbors were specialized in 2004.

[7] When examining the real geographic distribution of municipalities, this type of diffusion can occur only if the municipalities share a common border.

As a result, independent or spontaneous specialization occurs in only two out of a total of 30 cases, reflecting a corresponding contagion rate of 6.66%.

As the contagion rates of the first type of specialization (i.e., neighbor-transmitted) surpasses those of spontaneous specialization, this serves as empirical evidence that geographic proximity significantly influences the transmission and diffusion of productive knowledge.

Diffusion or transmission within a state does not occur in the following cases:

- municipality (1,4), which was specialized in 2004 but did not transmit its specialization to any adjacent neighbors by 2009
- municipality (6,1), which was specialized in 2004 but did not transmit its specialization to any adjacent neighbors by 2009.

4.2 Methodology for calculating the diffusion of specialization in the country by MIG

The method for assessing the country's specialization diffusion by MIG follows a similar approach to that previously outlined, the key distinction being that it focuses on sectoral rather than regional diffusion.

We utilize a comparable binary table to track sectoral specialization evolution between two consecutive years, 2004 and 2009. In this case: (i) the table includes all municipalities nationwide rather than those in a single state, and (ii) each MIG *i* is examined individually, with a similar assessment being conducted for all 85 MIGs.

Table 3. MIG *i* diffusion in the country, 2004–2009

	Column 1		*Column 2*		*Column 3*		*Column 4*		*Column 5*		*Column 6*	
	2004	2009	2004	2009	2004	2009	2004	2009	2004	2009	2004	2009
Row 1	0	1	1	1	0	1	0	0	1	0	0	0
Row 2	0	0	1	1	0	0	0	0	0	0	0	0
Row 3	0	0	0	0	0	0	0	0	0	0	1	1
Row 4	0	1	0	0	0	1	0	0	0	1	0	0
Row 5	0	0	0	0	0	0	1	0	0	0	1	1
Row 6	0	0	0	1	0	0	1	0	0	1	0	0

a) We consider there to be *neighbor-transmitted or neighbor-induced specialization diffusion* of MIG *i* when a municipality is not specialized in that MIG in 2004 but has an adjacent municipality that is, and subsequently goes on to become specialized in it itself by 2009. In the table above, this occurs in the following cases:

- municipalities (1,1) and (1,3), which were not specialized in 2004 but had adjacent neighbors (1,2) and (2,2) that were, and went on to become similarly specialized by 2009
- municipalities (4,3), (4,5) and (6,5), which were not specialized in 2004 but had adjacent neighbors (5,4) and (6,4) that were, and went on to become similarly specialized by 2009.

It is essential to emphasize that we only recognize five instances of transmission or diffusion for municipalities (1,1), (1,3), (4,3), (4,5), and (6,5), that is to say, municipalities (1,1), (1,3), and (6,5) are only counted once, though they were influenced by more than one municipality specialized in 2004.

As a result, neighbor-transmitted specialization occurred in only five out of a total of 36 cases, reflecting a corresponding contagion rate of 13.8%.

b) We consider there to be *independent or spontaneous specialization in MIG i* when municipalities become specialized independently, i.e., without having a previously specialized adjacent neighbor. This occurs twice in the table above:

- Municipalities (4,1) and (6,2) became specialized by 2009 without any of their adjacent neighbors having been specialized in 2004.

As a result, spontaneous specialization occurs in two out of a total of 36 possible cases, reflecting a corresponding contagion rate of 5.5%.

As with state-level cases, if the contagion rate of the neighbor-transmitted specialization exceeds that of spontaneous specialization, this serves as empirical evidence that geographic proximity aids in the spread or diffusion of knowledge.

MIG *i* diffusion or transmission does not occur in the following case:

- municipality (1,5) was MIG *i* specialized in 2004 but did not transmit its specialization to any adjacent neighbors by 2009.

5. Results

5.1 Comparing the diffusion of specialization by state and MIG: neighbor-transmitted vs spontaneous specialization

Table 4 shows the estimated contagion rates or specialization diffusion by state and subperiods, for both neighbor-transmitted and spontaneous specialization.

The 0.040 value in the second cell of row one of this table indicates that between 2004 and 2009, 4 percent of all the municipalities in Aguascalientes became specialized in one or other of the 86 MIGs after having had at least one neighboring municipality already specialized in that same MIG at the outset. The numbers in the next cells for different subperiods can be interpreted in the same way. The 0.013 in the fifth cell of row one indicates that between 2004 and 2009, 1.3 percent of Aguascalientes' municipalities became spontaneously specialized in one or other of the 86 MIGs; these municipalities were not specialized in 2004 nor did they have any neighboring municipality at that time that specialized in the MIG they themselves would go on to become specialized in. The rest of the cells can be interpreted in the same way.[8]

Table 4. Specialization contagion rates or diffusion of specialization by state and subperiod

State	*Neighbor-transmitted*			*Spontaneous specialization*		
	2004–2009	*2009–2014*	*2014–2019*	*2004–2009*	*2009–2014*	*2014–2019*
Aguascalientes	0.040	0.110	0.072	0.013	0.036	0.018
Baja California	0.056	0.230	0.086	0.023	0.105	0.028
Baja California Sur	0.012	0.063	0.033	0.042	0.042	0.035
Campeche	0.021	0.054	0.029	0.030	0.035	0.008
Chiapas	0.030	0.079	0.038	0.018	0.025	0.021
Chihuahua	0.041	0.084	0.043	0.023	0.020	0.027
CDMX	0.021	0.050	0.034	0.013	0.016	0.011
Coahuila	0.020	0.043	0.016	0.017	0.028	0.014
Colima	0.063	0.247	0.075	0.013	0.017	0.011
Durango	0.024	0.057	0.032	0.012	0.014	0.009
Guanajuato	0.040	0.095	0.052	0.017	0.025	0.020
Guerrero	0.024	0.055	0.039	0.017	0.017	0.016
Hidalgo	0.027	0.059	0.038	0.020	0.019	0.018
Jalisco	0.034	0.093	0.043	0.015	0.016	0.013
Estado de México	0.047	0.090	0.057	0.017	0.016	0.016
Michoacán	0.028	0.064	0.042	0.019	0.020	0.017

[8] The figures shown in Appendix 2 use the results in Table 4 to show scatterplots that allow a comparison of neighbor-transmitted contagion rates in different subperiods.

Morelos	0.033	0.065	0.035	0.021	0.018	0.026
Nayarit	0.024	0.065	0.053	0.019	0.024	0.020
Nuevo León	0.034	0.109	0.047	0.013	0.018	0.012
Oaxaca	0.015	0.030	0.025	0.011	0.010	0.009
Puebla	0.021	0.053	0.030	0.014	0.014	0.015
Queretaro	0.041	0.105	0.063	0.021	0.033	0.019
Quintana Roo	0.012	0.023	0.011	0.027	0.020	0.018
San Luis Potosí	0.022	0.057	0.031	0.014	0.019	0.013
Sinaloa	0.032	0.072	0.044	0.027	0.039	0.031
Sonora	0.020	0.042	0.031	0.015	0.020	0.016
Tabasco	0.023	0.070	0.035	0.019	0.032	0.017
Tamaulipas	0.019	0.048	0.024	0.024	0.027	0.017
Tlaxcala	0.028	0.073	0.048	0.022	0.019	0.018
Veracruz	0.022	0.051	0.030	0.016	0.014	0.014
Yucatán	0.022	0.055	0.032	0.017	0.015	0.014
Zacatecas	0.029	0.056	0.038	0.018	0.015	0.012
Mean	**0.029**	**0.076**	**0.041**	**0.019**	**0.025**	**0.017**

Table 5 shows the estimated contagion rates or diffusion of specialization by MIG and subperiod for both neighbor-transmitted and spontaneous specialization.

The 0.018 value in the second cell of row one of this table indicates that between 2004 and 2009, 1.8 percent of the country's municipalities became specialized in MIG 3111, after having had at least one neighboring municipality already specialized in it at the outset. The 0.013 value in the fifth cell of row one indicates that between 2004 and 2009, 1.3 percent of the country's municipalities achieved spontaneous specialization in MIG 3111, having not specialized in it in 2004 and not had a neighboring municipality specialized in it in the initial period. The rest of the cells can be interpreted in the same way.

Table 5. Contagion rates or diffusion of specialization by MIG and subperiod

MIG	*Neighbor-transmitted*			*Spontaneous specialization*			*MIG*	*Neighbor-transmitted*			*Spontaneous specialization*		
	04-09	***09-14***	***14-19***	***04-09***	***09-14***	***14-19***		***04-09***	***09-14***	***14-19***	***04-09***	***09-14***	***14-19***
3111	0.018	0.046	0.028	0.013	0.019	0.023	3311	0.000	0.002	0.001	0.002	0.008	0.002
3112	0.033	0.069	0.053	0.025	0.024	0.013	3312	0.007	0.021	0.016	0.008	0.013	0.013
3113	0.048	0.092	0.080	0.033	0.020	0.030	3313	0.006	0.011	0.006	0.007	0.004	0.006
3114	0.041	0.074	0.087	0.035	0.039	0.027	3314	0.005	0.010	0.007	0.007	0.006	0.008
3115	0.115	0.284	0.161	0.026	0.026	0.019	3315	0.006	0.026	0.012	0.006	0.009	0.015
3116	0.111	0.190	0.150	0.040	0.027	0.023	3321	0.012	0.019	0.012	0.009	0.013	0.012
3117	0.004	0.009	0.002	0.004	0.009	0.006	3322	0.018	0.024	0.024	0.022	0.024	0.024
3118	0.118	0.553	0.136	0.007	0.008	0.004	3323	0.134	0.491	0.183	0.007	0.007	0.005
3119	0.054	0.102	0.107	0.039	0.042	0.037	3324	0.009	0.025	0.012	0.009	0.013	0.009
3121	0.092	0.232	0.146	0.030	0.027	0.022	3325	0.008	0.016	0.009	0.015	0.009	0.009
3122	0.002	0.002	0.002	0.002	0.005	0.003	3326	0.010	0.029	0.017	0.020	0.011	0.018
3131	0.013	0.031	0.028	0.023	0.020	0.012	3327	0.033	0.061	0.029	0.026	0.012	0.016
3132	0.017	0.029	0.025	0.024	0.006	0.034	3328	0.010	0.023	0.015	0.014	0.009	0.008
3133	0.014	0.020	0.026	0.028	0.012	0.022	3329	0.018	0.035	0.016	0.011	0.020	0.013
3141	0.017	0.022	0.034	0.041	0.023	0.033	3331	0.012	0.029	0.018	0.008	0.017	0.015
3149	0.032	0.065	0.052	0.047	0.013	0.021	3332	0.012	0.021	0.014	0.017	0.013	0.014

3151	0.031	0.050	0.051	0.026	0.030	0.036	3333	0.007	0.013	0.010	0.008	0.014	0.007
3152	0.095	0.206	0.108	0.028	0.022	0.023	3334	0.008	0.016	0.011	0.003	0.012	0.009
3159	0.026	0.031	0.051	0.044	0.036	0.029	3335	0.003	0.013	0.013	0.006	0.008	0.004
3161	0.004	0.007	0.002	0.009	0.010	0.012	3336	0.003	0.005	0.004	0.002	0.004	0.004
3162	0.011	0.033	0.015	0.009	0.030	0.011	3339	0.009	0.023	0.011	0.008	0.014	0.010
3169	0.036	0.067	0.046	0.031	0.035	0.021	3341	0.001	0.004	0.003	0.002	0.004	0.003
3211	0.015	0.038	0.019	0.009	0.013	0.019	3342	0.002	0.008	0.005	0.004	0.008	0.006
3212	0.004	0.006	0.008	0.003	0.007	0.012	3343	0.001	0.005	0.003	0.002	0.007	0.008
3219	0.139	0.225	0.200	0.030	0.032	0.019	3344	0.002	0.014	0.005	0.004	0.012	0.004
3221	0.004	0.011	0.006	0.003	0.008	0.007	3345	0.004	0.012	0.006	0.007	0.004	0.005
3222	0.048	0.091	0.100	0.042	0.029	0.023	3346	0.001	0.004	0.000	0.002	0.001	0.001
3231	0.009	0.024	0.017	0.016	0.032	0.023	3351	0.008	0.021	0.008	0.014	0.009	0.008
3241	0.004	0.020	0.009	0.003	0.013	0.008	3352	0.009	0.019	0.010	0.009	0.011	0.008
3251	0.009	0.033	0.012	0.004	0.013	0.013	3353	0.007	0.017	0.007	0.005	0.011	0.011
3252	0.004	0.015	0.009	0.002	0.009	0.005	3359	0.004	0.017	0.009	0.007	0.009	0.009
3253	0.008	0.025	0.014	0.013	0.015	0.019	3361	0.002	0.006	0.002	0.002	0.004	0.004
3254	0.008	0.022	0.014	0.018	0.016	0.014	3362	0.022	0.036	0.025	0.017	0.023	0.018
3255	0.008	0.024	0.013	0.005	0.013	0.011	3363	0.014	0.047	0.022	0.011	0.011	0.010
3256	0.018	0.044	0.038	0.028	0.022	0.026	3364	0.000	0.002	0.002	0.004	0.005	0.002
3259	0.023	0.034	0.031	0.024	0.027	0.017	3365	0.000	0.004	0.004	0.002	0.003	0.002
3261	0.018	0.040	0.023	0.016	0.018	0.022	3366	0.002	0.003	0.004	0.004	0.007	0.007
3262	0.009	0.018	0.013	0.012	0.016	0.013	3369	0.004	0.010	0.005	0.007	0.009	0.009
3271	0.021	0.067	0.027	0.021	0.027	0.013	3371	0.135	0.257	0.129	0.026	0.030	0.016
3272	0.015	0.043	0.019	0.013	0.026	0.011	3372	0.012	0.036	0.018	0.019	0.020	0.019
3273	0.101	0.244	0.122	0.015	0.019	0.014	3379	0.015	0.033	0.026	0.021	0.031	0.011
3274	0.014	0.026	0.019	0.019	0.026	0.018	3391	0.022	0.038	0.024	0.019	0.025	0.015
3279	0.041	0.092	0.057	0.022	0.028	0.015	3399	0.037	0.059	0.057	0.042	0.041	0.029
Mean								**0.024**	**0.057**	**0.035**	**0.015**	**0.016**	**0.014**

To assess whether the average neighbor-induced specialization contagion rate surpasses that of spontaneous specialization, we conduct a series of hypothesis tests, comparing the mean values of both groups. The tests are performed separately for states and MIGs and include one test for each subperiod and a general test encompassing the entire 2004–2019 period. In every case, the null hypothesis asserts that the average transmission rate of spontaneous specialization (*ss*) is equal to that of neighbor-induced specialization (*ns*), while the alternative states that *ns* is statistically greater than *ss*:

$$H_0: \mu_{ss} - \mu_{ns} = 0$$

$$H_1: \mu_{ss} - \mu_{ns} \leq 0$$

As can be seen in the last row of Tables 4 and 5, for every subperiod, the average transmission rates for neighboring specialization are higher than those for spontaneous specialization, whether analyzed by state or by MIG. However, the key issue is to determine whether or not this observed difference is statistically significant.

Table 6. Results of the statistical comparison of the group means

Period	*By State (p-value)*	*By MIG (p-value)*
2004–2009	1.19 E-05	0.081

2009–2014	3.27 E-09	0.007
2014–2019	1.52 E-14	0.005
2004–2019	6.25 E-14	0.000

Table 6 presents the p-values for each test. The values in the second column correspond to the comparison by state and support the rejection of the null hypothesis of equal average values. This suggests that when considering all MIGs, the states' average neighboring specialization rate is significantly higher than the spontaneous specialization rate.

The values in the third column correspond to the comparison by MIG and likewise support the rejection of the null hypothesis. This suggests that at the national level, the average rate of specialization among neighboring municipalities consistently surpasses the rate of spontaneous specialization across all MIGs. With the exception of the 2004–2009 subperiod—for which the null hypothesis is rejected at the 10% significance level—the null is rejected at the 1% level in all other subperiods.

The findings in this subsection highlight the key role of geographic proximity in enabling the transmission of productive knowledge through mechanisms such as labor mobility, skill transfer, firm linkages, and technology diffusion.

5.2 Spatial diffusion of MIGs in relation to 3341 and 3361

This subsection analyzes the spatial diffusion of the two most prominent MIGs in the study period: 3341 (Computer and Peripheral Equipment Manufacturing) and 3361 (Motor Vehicle Manufacturing), together with MIGs closely associated with these. Their significance stems not from high contagion rates but rather from their exceptional performance: these MIGs exhibited the highest growth in total production and account for approximately 60% of Mexico's manufacturing exports. Given their increasing importance to the national economy, it is essential to identify the regions that have become specialized not only in these leading industries but also in those closely linked to them; specifically, those industries that serve as major suppliers of production inputs. Analyzing this spatial diffusion provides valuable insight into the evolving structure of regional industrial specialization and the broader dynamics of economic integration within the country.

Table 7 highlights the MIGs that account for at least 1% of the production inputs utilized by the two dominant industries, based on data from the 2018 Mexican input-output matrix provided by INEGI.[9] MIG 3341 sourced 88.51% of its inputs from eight MIGs, while MIG 3361 obtained 65.53% of its inputs from nine MIGs

Table 7. Key supply MIGs contributing ≥1% of inputs to 3341 and 3361

Supplying MIG to 3341	*% of inputs*	*Supplying MIG to 3361*	*% of inputs*
3344	54.84	3363	43.30
3341	22.92	3336	5.48
3342	4.17	3261	5.35
3363	1.54	3362	2.39
3261	1.42	3311	2.04
3359	1.30	3262	1.82
3353	1.21	3255	1.78
3343	1.12	3313	1.78
		3343	1.55
Total	88.51%		65.53%

Understanding the linkages between these industries—specifically, which MIGs serve as key input suppliers—provides insight into the structure of inter-industry dependencies and the broader industrial ecosystem that supports them. These results have major implications for understanding the spatial diffusion and regional specialization of high-performing manufacturing sectors. By identifying the key input-supplying MIGs, researchers and policymakers can better target support mechanisms, infrastructure investment, and regional development strategies aimed at strengthening these industrial value chains. Moreover, recognizing those regions that specialize in both leading and supply sectors can aid in the mapping of industrial clusters and assess the potential for spillover effects in local economies. Such insights are essential for fostering sustained and inclusive industrial growth at the national and subnational levels.

Table 8 ranks the states based on the change in the number of municipalities that have become specialized in MIGs 3341, 3361, or their key suppliers.[10]

Table 8. State ranking by increase in municipal specialization

State	*MIG 3341*			*State*	*MIG 3361*		
	Diversity 2004	*Diversity 2019*	*% change*		*Diversity 2004*	*Diversity 2019*	*%*
Aguascalientes	8	19	137.5	Guanajuato	27	61	125.9

[9] https://www.inegi.org.mx/programas/mip/2018/#tabulados

[10] To be included in the ranking, states must meet at least one of the following criteria in 2004: either i) account for more than 4% of all specialized municipalities nationwide or ii) have more than 30% of their own municipalities exhibiting specialization. If these thresholds are not imposed, states with initially very few or no specialized municipalities could rank among the highest due to minimal absolute gains, potentially distorting the interpretation of spatial diffusion dynamics. The number of municipalities varies substantially across states.

Guanajuato	19	40	110.5	Sinaloa	6	11	83.3
Tlaxcala	22	42	90.9	Querétaro	18	32	77.8
Coahuila	31	42	35.5	Aguascalientes	12	21	75.0
Querétaro	24	31	29.2	Puebla	40	66	65.0
Tamaulipas	26	33	26.9	Baja California	13	21	61.5
Nuevo León	63	73	15.9	Tlaxcala	27	43	59.3
Estado de México	84	97	15.5	Chihuahua	23	33	43.5
San Luis Potosí	19	21	10.5	Morelos	12	17	41.7
Sonora	39	43	10.3	Michoacán	32	43	34.4
Jalisco	56	55	-1.8	Coahuila	36	47	30.6
Chihuahua	34	33	-2.9	Nuevo León	72	90	25.0
Baja California	26	23	-11.5	Jalisco	64	75	17.2
Hidalgo	28	24	-14.3	Veracruz	49	54	10.2
CDMX	54	43	-20.4	Hidalgo	40	43	7.5
Morelos	16	12	-25.0	San Luis Potosí	23	24	4.3
				Estado de México	127	125	-1.6
				CDMX	50	40	-20.0

On the left side, the states of Aguascalientes, Guanajuato, and Tlaxcala stand out due to their substantial increases in the number of specialized municipalities there, with Aguascalientes exhibiting the most pronounced relative growth in MIG 3341 at 137.5%. Coahuila, Querétaro, and Tamaulipas also show positive but more moderate increases. Conversely, states such as Jalisco, Chihuahua, Baja California, Hidalgo, CDMX, and Morelos experienced a reduction in specialization within this industry, potentially indicating a process of deindustrialization, strategic shifts toward other sectors, or a diminishing competitive advantage.

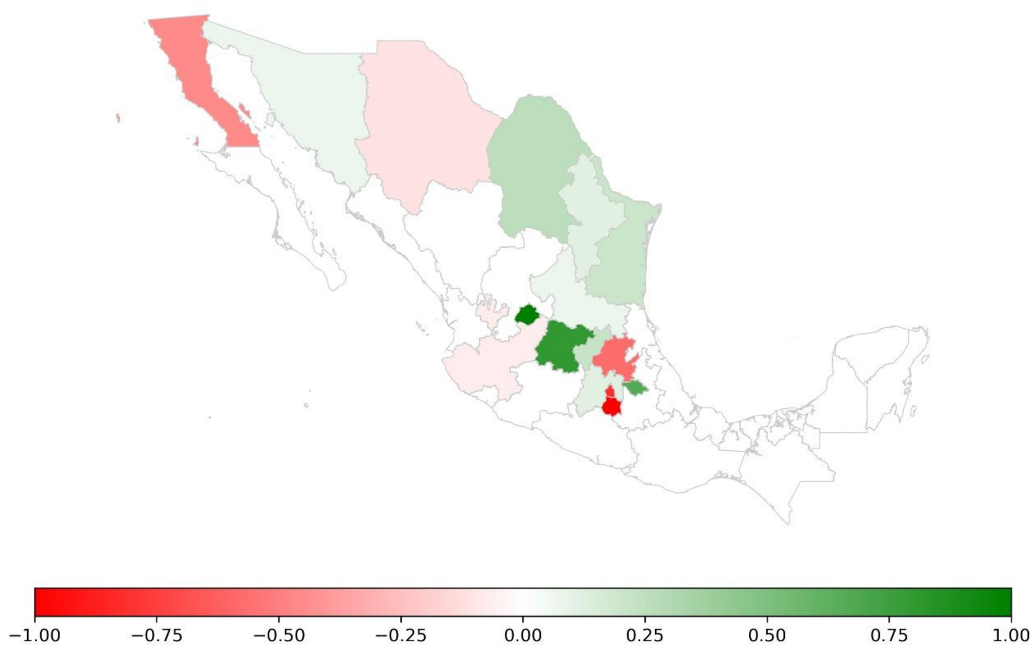
The right side of the table presents changes in municipal specialization in MIG 3361. Guanajuato ranks among the leading states, exhibiting a substantial increase of 125.9%, followed by Sinaloa, Querétaro, and Aguascalientes, all of which registered notable gains. These increases may indicate the geographic expansion of the automotive value chain into emerging regions. States such as Puebla, Baja California, and Tlaxcala also show significant growth, further consolidating their positions within the sector. In contrast, states such as CDMX and Estado de Mexico experienced stagnation or a decline in the number of municipalities specialized in motor vehicle manufacturing.

Taken together, these patterns underscore a dynamic reconfiguration of industrial specialization across Mexican states, with some regions emerging as new hubs of activity while others face relative decline.

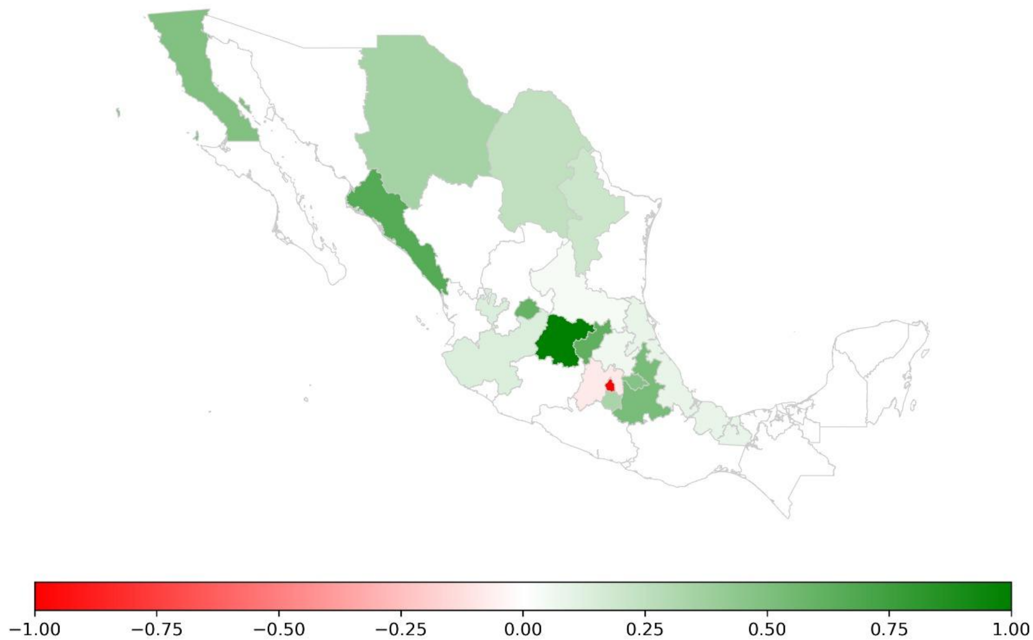
Maps 1 and 2 display the same information as Table 8 but offer a spatial perspective that facilitates the visualization of the evolving geography of industrial specialization in MIG

3341 and MIG 3361, respectively. In both cases, the central Bajío region—particularly Guanajuato, Querétaro, and Aguascalientes—exhibits pronounced increases in municipal specialization, confirming the Bajio's role as a growing manufacturing corridor. The maps also reveal an expansion of the automotive value chain toward states such as Sinaloa, Puebla, and Baja California, signaling a diffusion of industrial activity beyond traditional hubs. Conversely, CDMX consistently appears in red, indicating a persistent decline in specialization in both industries. This sustained downward trend suggests a structural shift away from manufacturing in the capital, likely associated with urban economic restructuring and an increasing orientation toward service-based activities.

Map 1. MIG 3341



Map 2. MIG 3361



Final comments

This study provides robust empirical evidence that geographic proximity significantly contributes to the diffusion of productive knowledge, as measured by manufacturing specialization across Mexican municipalities. Across all the states and MIGs examined, contagion rates were consistently higher for neighboring municipalities than for non-neighboring ones. This reinforces the role of spatial spillovers in regional economic development and highlights the importance of fostering local industrial clusters.

Beyond the Mexican case, international empirical evidence consistently underscores the role of geographic proximity in facilitating the transmission and consolidation of productive knowledge. Studies examining economies in Europe (such as Spain and Italy), the United States, and Asia (notably China and South Korea) show that new industries are more likely to emerge in regions where related capabilities are already in place, supported by dense networks of firms, suppliers, and skilled labor. Taken together, these experiences demonstrate that the spatial clustering of capabilities is not unique to Mexico but rather a recurrent mechanism of industrial development across diverse contexts.

The identification of MIGs 3341 and 3361 as key drivers of national manufacturing exports underlines the strategic importance of supporting their ecosystems, including their input supply industries. The dynamic shifts in specialization patterns—especially the emergence of new regional hubs in central Mexico—indicate an evolving geography of industrial capabilities, shaped by market forces, policy shifts, and cost structures.

From a policy perspective, the findings suggest that promoting inter-municipal cooperation, supporting industrial linkages, and investing in infrastructure and human capital in neighboring regions can amplify productive spillovers. Moreover, understanding the mechanisms behind spontaneous specialization remains an important area for further research, especially for designing interventions in more isolated or lagging regions.

Future research should aim to disentangle the causal factors underlying the observed diffusion patterns, such as the role of supply chains, workforce mobility, firm relocation decisions, and regional policies. Incorporating firm-level and worker-level data, alongside qualitative insights, would help deepen the understanding of how productive knowledge travels and takes root.

Ultimately, conceptualizing productive knowledge as an asset that becomes more diffuse geographically provides a powerful framework for understanding industrial development and for guiding strategies to promote inclusive and sustainable regional growth in Mexico.

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Appendix 1. MIGs according to the NAICS

Table A1.1 MIG codes and definitions according to NAICS

Code	MIG definition	Code	MIG definition
3111	Animal Food Manufacturing	3311	Iron and Steel Mills and Ferroalloy Manufacturing
3112	Grain and Oilseed Milling	3312	Steel Product Manufacturing from Purchased Steel
3113	Sugar and Confectionery Product Manufacturing	3313	Alumina and Aluminum Production and Processing
3114	Fruit and Vegetable Preserving and Specialty Food Manufacturing	3314	Nonferrous Metal (except Aluminum) Production and Processing
3115	Dairy Product Manufacturing	3315	Foundries
3116	Animal Slaughtering and Processing	3321	Forging and Stamping
3117	Seafood Product Preparation and Packaging	3322	Cutlery and Handtool Manufacturing
3118	Bakeries and Tortilla Manufacturing	3323	Architectural and Structural Metals Manufacturing
3119	Other Food Manufacturing	3324	Boiler, Tank, and Shipping Container Manufacturing
3121	Beverage Manufacturing	3325	Hardware Manufacturing
3122	Tobacco Manufacturing	3326	Spring and Wire Product Manufacturing
3131	Fiber, Yarn, and Thread Mills	3327	Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing
3132	Fabric Mills	3328	Coating, Engraving, Heat Treating, and Allied Activities
3133	Textile and Fabric Finishing and Fabric Coating Mills	3329	Other Fabricated Metal Product Manufacturing
3141	Textile Furnishings Mills	3331	Agriculture, Construction, and Mining Machinery Manufacturing
3149	Other Textile Product Mills	3332	Industrial Machinery Manufacturing
3151	Apparel Knitting Mills	3333	Commercial and Service Industry Machinery Manufacturing
3152	Cut and Sew Apparel Manufacturing	3334	Ventilation, Heating, Air-Conditioning, and Commercial Refrigeration Equipment Manufacturing
3159	Apparel Accessories and Other Apparel Manufacturing	3335	Metalworking Machinery Manufacturing
3161	Leather and Hide Tanning and Finishing	3336	Engine, Turbine, and Power Transmission Equipment Manufacturing
3162	Footwear Manufacturing	3339	Other General Purpose Machinery Manufacturing
3169	Other Leather and Allied Product Manufacturing	3341	Computer and Peripheral Equipment Manufacturing
3211	Sawmills and Wood Preservation	3342	Communications Equipment Manufacturing
3212	Veneer, Plywood, and Engineered Wood Product Manufacturing	3343	Audio and Video Equipment Manufacturing
3219	Other Wood Product Manufacturing	3344	Semiconductor and Other Electronic Component Manufacturing
3221	Pulp, Paper, and Paperboard Mills	3345	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing
3222	Converted Paper Product Manufacturing	3346	Manufacturing and Reproducing Magnetic and Optical Media
3231	Printing and Related Support Activities	3351	Electric Lighting Equipment Manufacturing
3241	Petroleum and Coal Products Manufacturing	3352	Household Appliance Manufacturing
3251	Basic Chemical Manufacturing	3353	Electrical Equipment Manufacturing
3252	Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing	3359	Other Electrical Equipment and Component Manufacturing
3253	Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	3361	Motor Vehicle Manufacturing
3254	Pharmaceutical and Medicine Manufacturing	3362	Motor Vehicle Body and Trailer Manufacturing
3255	Paint, Coating, and Adhesive Manufacturing	3363	Motor Vehicle Parts Manufacturing
3256	Soap, Cleaning Compound, and Toilet Preparation Manufacturing	3364	Aerospace Product and Parts Manufacturing
3259	Other Chemical Product and Preparation Manufacturing	3365	Railroad Rolling Stock Manufacturing
3261	Plastics Product Manufacturing	3366	Ship and Boat Building
3262	Rubber Product Manufacturing	3369	Other Transportation Equipment Manufacturing
3271	Clay Product and Refractory Manufacturing	3371	Household and Institutional Furniture and Kitchen Cabinet Manufacturing
3272	Glass and Glass Product Manufacturing	3372	Office Furniture (including Fixtures) Manufacturing
3273	Cement and Concrete Product Manufacturing	3379	Other Furniture Related Product Manufacturing
3274	Lime and Gypsum Product Manufacturing	3391	Medical Equipment and Supplies Manufacturing
3279	Other Nonmetallic Mineral Product Manufacturing	3399	Other Miscellaneous Manufacturing

Appendix 2.

The scatterplots compare neighboring transmitted contagion rates in different subperiods. The positive association shown on both suggest that manufacturing contagions tend to be higher (lower) in certain states regardless of the time period.

Figure A2.1 States' neighboring transmitted contagion rates, first and second subperiods

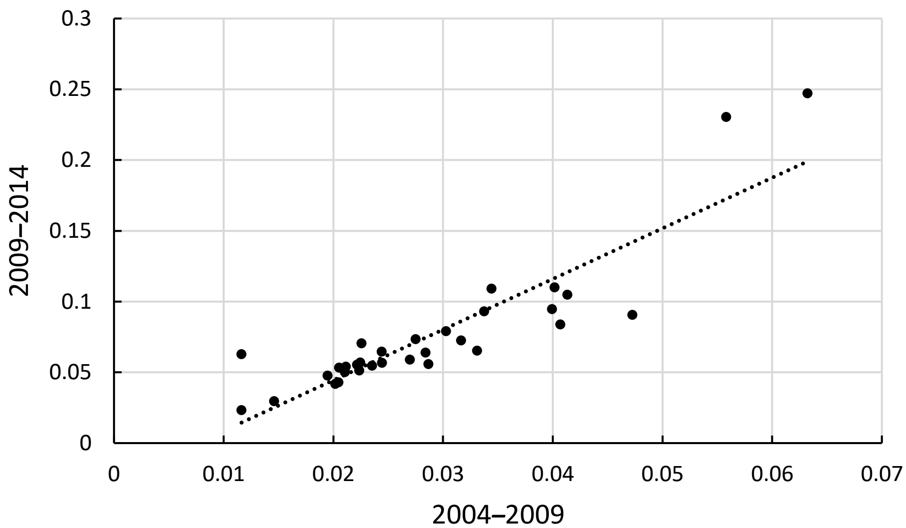
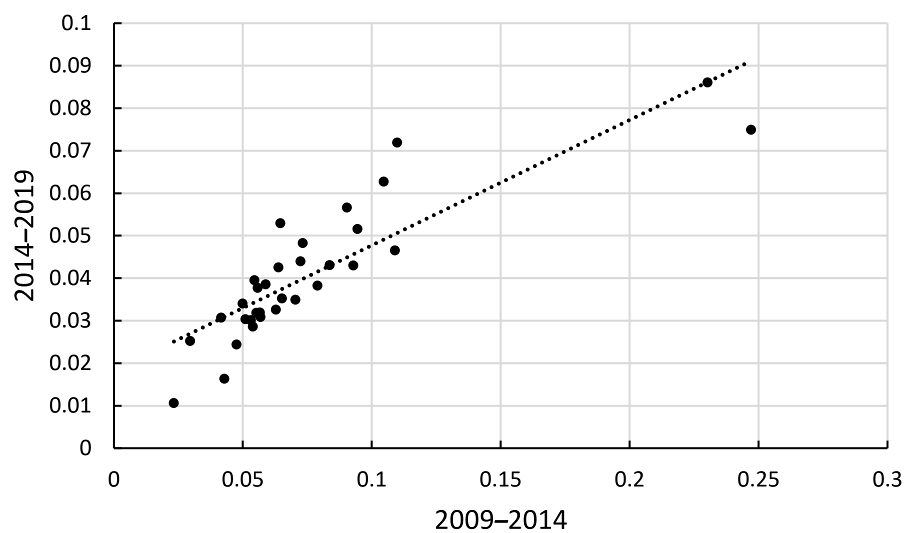


Figure A2.2 States' neighboring transmitted contagion rates, second and third subperiods



Similarly, the rates of spontaneous specialization contagion show positive correlation, suggesting that this type of contagion tends to be consistently higher or lower in certain states, regardless of the time period.