Reconstructing Clusters:

Augmenting regional clusters with intellectual property and labor force skill specializations

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Abstract

Patent counts and patenting rates are the go-to measures for regional innovation, productivity and competiveness. For this reason, more attention needs to be focused on to the types of technology developed in a region and the technology embedded in the products and services in which a region specializes.

Knowledge spillovers are an accepted driving force for agglomeration economies but too little attention has focused on the types, or categories, of that knowledge. Just as there are regional concentrations of industries and occupations, there are relative regional concentrations of knowledge and intellectual property that are expressed in the technology categories of patents. We estimate regional technology concentration as a complement to industry structure and assess the degree to which technology classes are associated with industry concentration/specialization across 2640 U.S. counties that have a track record of patenting between over time.

Regional concentrations of occupations are also an accepted dimension of agglomeration economies. Occupations, however, consist of a set of skills put into practice to create products and services. Occupations may co-locate, reinforcing the forces that make industry clusters more productive and competitive, but relatively little is known about how occupations, and the skills that inhabit occupations, are interdependent. We embed skill interdependence – a latent relationship – into the identification and definition of clusters.

This research addresses the deficient in the conceptualization and measurement of clusters. By examining and appropriating measures for the latent inter-relationships and dependencies associated with occupational skill sets, in addition to the discovery of regional technology concentrations, we make the operationalization of clusters more complete.

Keywords: industrial structure, agglomeration economies, manufacturing, patents, technology, skills

Introduction

How clusters—the term of art for agglomeration economies—are defined and measured has been well debated in the literature. Michael Porter has argued for decades that competitive forces drive productivity and that the geographic concentration of related firms intensifies the competitive forces and results in benefits associated with integrated supply chains, specialized labor force skills and knowledge spillovers (1990, 1996). How one defines the geographic boundaries matters too. Is it micro or macro geographic boundaries? What constitutes a cluster can also lack precision (Martin and Sunley, 2003). Therefore, we propose cluster dimensions beyond the measurement of input-output relationships, labor force and industry co-location.

In this paper, we examine the interplay of the standard set of cluster definitions and metrics – that can be distilled in Porter's Cluster Mapping Project measure of *between cluster relatedness* -- with regional technology concentration and regional skill set concentration.

The motivation for this work is that industry structure is constantly changing – sometimes quite a lot with globalization, offshoring and increasingly complex and long supply chains – and as a result, a cluster composition of industries in any one region may, or will likely, change as well. A cluster definition in 2005 may not be in evidence in 2020 as regional industry concentration adjusts to local, regional and international competitive dynamics. Moreover, industries that grow up together in one region may reflect a different balance of industrial concentration in another.

A secondary motivation is that the set of employment and occupational concentrations together with input-output relationships isn't up to the definitional and empirical task. Knowledge spillovers from industries and occupations is an agglomerative operating principle, but these latent spillover factors are not easily measured. Moreover, there has been recent work using network analysis that measures the unseen interdependence of occupations and skills (Shutters and Waters, 2020). In addition, there is evidence that the development of intellectual property – IP – and research and development activities and patenting outcomes can be geographically distant from production, depending on the industry and the IP technology. Patenting and producing may collocate in some instances but the trend appears to warrant the spatial distinction between patent making and patent using.

This research will augment the determination and definition of clusters using patent data by broad technology categories and labor skills interdependence. Using twelve broad technology IP categories which are a further refinement and more granular than the six categories of Hall et al. (2002), we can estimate the concentration of patent technology types and match industry concentration by U.S. counties. Using the notion of skills tightness, or interdependence, we add an additional dimension for occupational knowledge and, if one may say, occupational input-output relationships. Skills tightness measures the regional latent "transactions" between occupations. In other words, which occupations/skills are co-located. These new dimensions will enhance the standard practice of using industry input-output, employment and occupation concentrations in a region, for example, as practiced by Delgado et al. (2016) and Feser et al. (2005).

Data and Method

For employment by industry data 2001 to 2018, we use an internal "QCEW-Complete" whereby we estimate any suppressed data in the Bureau of Labor Statistics QCEW datasets. (These data are available upon request.) Annual patent data from 2001 to 2020 is from the USPTO. We deploy crosswalks that use algorithmic links between NAICS descriptions and USPC and CPC patent classification that assign probabilities associated with NAICS industry and a patent technology matches (Goldschlag et al., 2016, Lybbert and Zolas, 2014). Skills by county are based on occupational headcounts, estimated from the BLS Occupational Employment Survey – OES –and industry staffing patterns together with occupational characteristics from O*NET.

We first conducted exploratory factor analysis with STATA using the concentration, or proportion, of employment by 4-digit manufacturing industries and business services. Most manufacturing industries are considered traded in the Porter framework, as is the business services cluster. The latter collection of industries, or the business services cluster, has been growing in scale and relative concentration across the U.S. structural landscape. We performed factor analysis on both 2002 and 2018 employment concentration by industry. (2002 was used because 2001 was a recessionary year.) In this way, we could assess the latent relationships between industries and evaluate the extent of the change in industry profile from 2002 to 2018. We hypothesized that business services, which includes research and development and engineering services, and several manufacturing industries were related and co-located – that is, interdependent. Other manufacturing production/industries could be geographically distant from technology/IP development and dependencies.

Initial findings

In Figure 1, we see that business service industries explain most of the variation in the dataset (proportion of employment by industry by county, N=2642). Business services, which may be better categorized as "tradeable" instead of definitively traded, are well diffused across most regions and counties in the U.S. and that is reflected in a constellation of high scores. Factor 2 appears to describe the auto sector interrelatedness and concentration. Eigen values make a steep drop, although Factor 3 appears to describe the textile industries and their co-location. While their score would not otherwise warrant a mention, in Factor 1 it appears that computers, communications and electronic components are positively associated with the business services of computer systems design and management, scientific, and technical consulting.

Figure 2 compares the factor scores for 2002 and 2018 industry concentration. As mentioned above, there have been many industry structural transformations in those intervening years, including offshoring, the lingering effects of the Great Recession and the energy boom. These shifts in the underlying industry structure with these initial analysis point to the need to update and recalibrate cluster definitions based on regional specific characteristics. Feser and colleagues (2005) use regional value chains – simply put, the marriage of input-output relationships and industry employment concentrations – to identify clusters in a specific regional context.

Figure 1: Exploratory Factor Analysis, Manufacturing and Business Services, N=2642

	Eigenvalue	3.61	1.28	0.77	0.76	0.69
	Difference	2.33	0.51	0.01	0.07	0.01
	Cumulative	0.35	0.48	0.56	0.63	0.70
Variable		Factor1	Factor2	Factor3	Factor4	Factor5
v3131	Fiber, Yarn, and Thread Mills	-0.0414	0.0969	0.3601	0.0488	0.0779
v3132	Fabric Mills	-0.0498	0.0814	0.369	0.0403	0.0728
v3133	Textile and Fabric Finishing and Fabric Coatin	-0.0204	0.0704	0.2915	0.0312	0.0591
v3141	Textile Furnishings Mills	-0.0042	0.0793	0.2603	0.0267	0.0668
v3149	Other Textile Product Mills	-0.0144	0.0304	0.0226	0.0338	0.048
v3151	Apparel Knitting Mills	-0.0129	0.1075	0.0258	0.3963	0.0446
v3222	Converted Paper Product Manufacturing	-0.0077	0.167	0.0567	0.0045	0.0095
v3231	Printing and Related Support Activities	0.0681	0.202	0.0341	0.0181	-0.0017
v3241	Petroleum and Coal Products Manufacturing	0.0096	-0.0051	0.0419	-0.1245	-0.0695
v3251	Basic Chemical Manufacturing	-0.041	0.0291	0.1182	-0.2259	-0.0871
v3252	Resin, Synthetic Rubber, and Artificial Synthe	-0.0125	0.004	0.1424	-0.178	-0.04
v3254	**Pharmaceutical and Medicine Manufacturing**	0.1028	0.0545	0.0544	0.0199	0.0128
v3255	Paint, Coating, and Adhesive Manufacturing	0.0645	0.1456	0.0555	-0.0075	0.0186
v3256	Soap, Cleaning Compound, and Toilet Preparatio	0.0749	0.0793	0.0257	-0.0152	0.0412
v3261	Plastics Product Manufacturing	-0.0451	0.2645	-0.0182	-0.0093	-0.0205
v3262	Rubber Product Manufacturing	-0.0378	0.1269	0.0424	-0.0598	0.0752
v3271	Clay Product and Refractory Manufacturing	-0.0235	0.0463	0.032	-0.0536	-0.0632
v3272	Glass and Glass Product Manufacturing	-0.0215	0.1733	-0.0168	-0.0493	-0.0151
v3315	Foundries	-0.0391	0.2194	-0.0411	0.0111	-0.0097
v3321	Forging and Stamping	0.0042	0.2814	-0.0989	-0.0709	-0.1541
v3327	Machine Shops; Turned Product; and Screw, Nut,	-0.0493	0.3421	-0.1307	-0.0638	-0.0532
v3328	Coating, Engraving, Heat Treating, and Allied	-0.005	0.2605	-0.0544	-0.1483	-0.0649
v3335	Metalworking Machinery Manufacturing	-0.0124	0.33	-0.1188	-0.0639	-0.057
v3336	Engine, Turbine, and Power Transmission Equipm	0.0137	0.0961	0.003	0.0277	-0.0088
v3339	Other General Purpose Machinery Manufacturing	-0.0523	0.1409	-0.1113	0.328	-0.0375
v3341	Computer and Peripheral Equipment Manufacturin	0.1726	0.0351	-0.0673	0.0297	-0.0583
v3342	Communications Equipment Manufacturing	0.2297	0.0183	-0.0692	0.0181	-0.02
v3343	Audio and Video Equipment Manufacturing	0.0396	-0.0045	-0.04	0.0069	-0.0262
v3344	Semiconductor and Other Electronic Component M	0.1559	0.1027	-0.0953	0.0513	-0.0861
v3345	Navigational, Measuring, Electromedical, and C	0.0694	0.0397	-0.0548	0.0056	-0.0439
v3346	Manufacturing and Reproducing Magnetic and Opt	0.1251	0.0148	-0.0283	0.0117	-0.0204
v3351	Electric Lighting Equipment Manufacturing	0.0143	0.1701	0.0282	-0.0178	-0.0978
v3359	Other Electrical Equipment and Component Manuf	0.005	0.1781	0.005	-0.0138	-0.0826
v3361	Motor Vehicle Manufacturing	0.0332	0.0737	0.0412	-0.0401	-0.0156
v3362	Motor Vehicle Body and Trailer Manufacturing	-0.0711	0.0812	-0.0577	0.0629	-0.0131
v3363	Motor Vehicle Parts Manufacturing	-0.0627	0.303	-0.0045	-0.0532	-0.0547
v5411	Legal Services	0.5344	-0.0492	0.0196	0.0217	0.0507
v5412	Accounting, Tax Preparation, Bookkeeping, and	0.485	0.0274	0.0205	0.0061	0.0182
v5413	Architectural, Engineering, and Related Servic	0.3427	-0.0201	0.0045	-0.0894	-0.0552
v5414	Specialized Design Services	0.552	0.0124	-0.0277	0.018	0.0134
v5415	Computer Systems Design and Related Services	0.6652	-0.0406	-0.0413	0.0174	-0.0113
v5416	**Management, Scientific, and Technical Consulti**	0.7279	-0.0576	-0.0288	0.0074	-0.0012
v5417	Scientific Research and Development Services	0.3083	-0.0033	-0.0732	0.0034	-0.0532
v5418	Advertising, Public Relations, and Related Ser	0.5729	0.0224	-0.0289	0.0375	0.0539
v5419	Other Professional, Scientific, and Technical	0.2593	-0.0065	-0.0378	-0.0208	-0.0423
v5511	**Management of Companies and Enterprises**	0.4089	0.0902	0.0187	0.0465	0.0594
v5611	Office Administrative Services	0.3763	-0.0552	0.0025	-0.0114	0.0249
v5613	Employment Services	0.3794	0.3164	0.1863	-0.0264	0.0702
v5614	Business Support Services	0.2887	0.0204	-0.0351	0.0235	0.0192

Figure 2: Exploratory Factor Analysis, Patent Technology Categories, Manufacturing and Business Services, Factor Comparison Example, N=2642

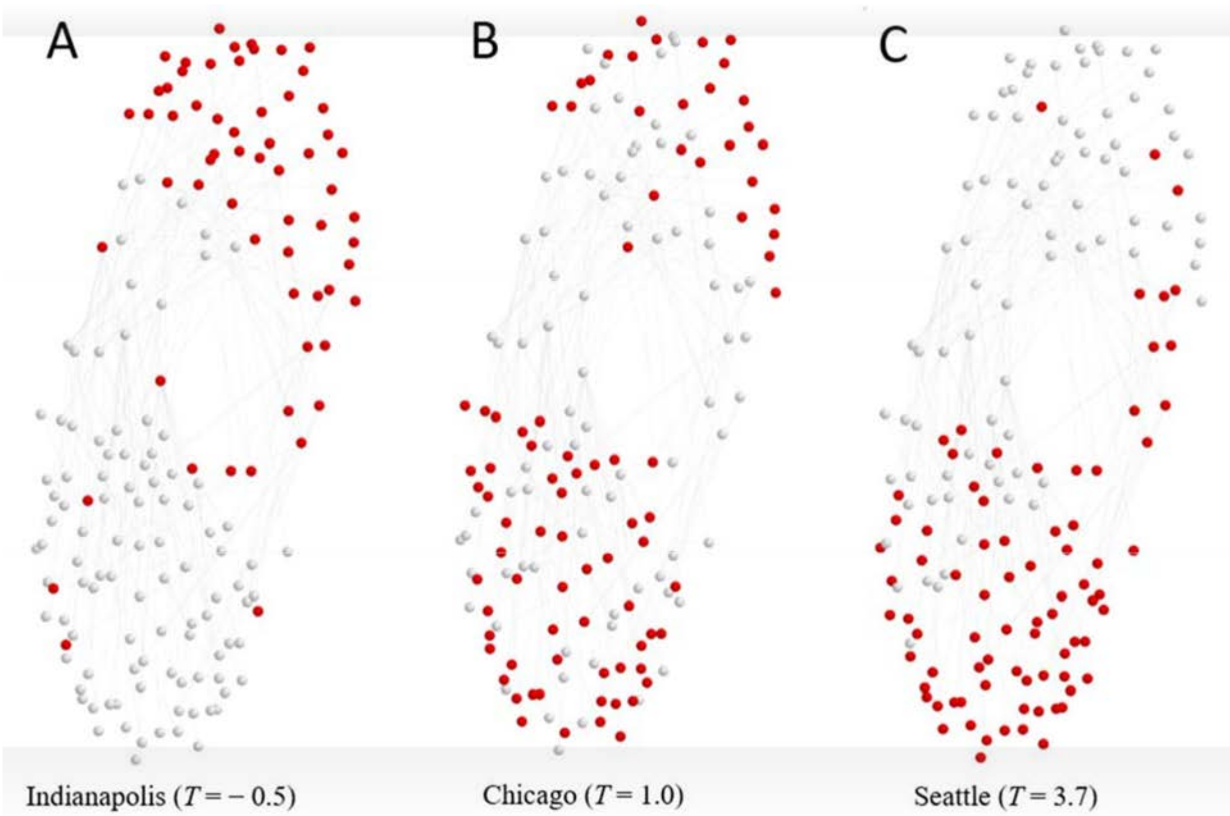
		Factor1 - 2002		**Factor2 - 2002**
	Factor1 - 2018		**Factor2 - 2018**	
chem1	0.0652	0.0819	0.0284	-0.0761
commun2	0.3107	0.342	0.0622	0.0382
compit3	0.3773	0.3756	-0.0569	-0.1093
biotech4	0.174	0.1929	-0.0416	-0.0062
electron5	0.0939	0.1033	0.3725	0.2992
mechan6	-0.171	-0.2062	0.3087	0.1661
trnsprt7	-0.1667	-0.1871	-0.189	-0.0937
agres7	-0.1763	-0.1907	-0.3315	-0.2515
cnstrc9	-0.2004	-0.1916	-0.168	-0.067
meddvc12	0.2252	0.2421	-0.079	-0.0417
Fiber, Yarn, and Thread Mills	-0.0353	-0.0329	0.1087	0.0949
Fabric Mills	-0.0413	-0.0387	0.1029	0.1256
Textile and Fabric Finishing and Fabric Coatin	-0.0152	-0.0058	0.0942	0.144
Textile Furnishings Mills	-0.0031	0.0034	0.0714	0.0665
Other Textile Product Mills	-0.0136	0.002	0.0235	0.0311
Apparel Knitting Mills	-0.0065	0.0005	0.1025	0.0944
Plastics Product Manufacturing	-0.0447	-0.0312	0.2196	0.3323
Rubber Product Manufacturing	-0.0322	0.0076	0.0925	0.1477
Clay Product and Refractory Manufacturing	-0.0192	-0.0087	0.0454	0.055
Glass and Glass Product Manufacturing	-0.0161	0.0098	0.1541	0.1718
Foundries	-0.0317	-0.0191	0.1951	0.1628
Forging and Stamping	0.0027	0.0037	0.2565	0.2987
Machine Shops; Turned Product; and Screw, Nut,	-0.0508	-0.0204	0.2899	0.2975
Coating, Engraving, Heat Treating, and Allied	-0.0094	0.0001	0.219	0.1822
Other Fabricated Metal Product Manufacturing	-0.0432	-0.0407	0.0576	0.076
Agriculture, Construction, and Mining Machiner	-0.0987	-0.0989	-0.02	-0.003
Metalworking Machinery Manufacturing	-0.0174	-0.0119	0.2918	0.2983
Computer and Peripheral Equipment Manufacturi	0.1855	0.1728	0.0252	0.0132
Communications Equipment Manufacturing	0.2342	0.1564	0.018	0.0173
Semiconductor and Other Electronic Component	0.1635	0.1263	0.088	0.0503
Manufacturing and Reproducing Magnetic and O	0.1216	0.1759	0.0098	0.0285
Electric Lighting Equipment Manufacturing	0.0208	0.0395	0.1599	0.1111
Other Electrical Equipment and Component Man	0.0058	0.0447	0.1503	0.2
Motor Vehicle Parts Manufacturing	-0.0659	-0.0416	0.2628	0.3006
Legal Services	0.5191	0.4052	-0.0581	-0.0425
Accounting, Tax Preparation, Bookkeeping, and	0.4667	0.4247	0.0028	0.007
Architectural, Engineering, and Related Servic	0.3334	0.3559	-0.0301	-0.0936
Specialized Design Services	0.5473	0.5766	-0.005	0.0063
Computer Systems Design and Related Services	0.6546	0.4996	-0.0527	-0.0595
Management, Scientific, and Technical Consulti	0.7132	0.5972	-0.0651	-0.059
Advertising, Public Relations, and Related Ser	0.5586	0.5124	-0.0033	-0.0031
Other Professional, Scientific, and Technical	0.2717	0.2029	-0.0029	-0.0077
Management of Companies and Enterprises	0.3999	0.3297	0.0485	0.0581
Office Administrative Services	0.3698	0.3615	-0.0535	-0.0313

Next Steps

A region's changing industrial structure over time and the potential dominance of regional occupational specialization over industry specialization calls for a rethinking of the dimensions the factors and forces that drive the economies of agglomeration today and into the future.

Our next step is to operationalize the network closeness among skills in a region. An example of how skills tightness represents a region's specializations – broadly defined – is shown in Figure 3. Indianapolis is largely within the sensory-physical cluster of skills – network A. Not surprising considering that the state of Indiana is the most manufacturing intensive state in the U.S. Chicago is more evenly split between cognitive and physical clusters of skills – network B. Seattle is dominated by the socio-cognitive cluster of skills – network C.

Figure 3: Three representative MSAs within the national skills interdependence network



Source: Shutters and Waters (2020). Normalized tightness scores – T– of each city is shown in parenthesis.

Given that patent counts and rates are the go-to measures for regional innovation, it is surprising that more attention has not been given to the types of technology formalized and documented in a region's patents and embedded in the products and services with which they are associated. We will address this deficient in the conceptualization and measurement of clusters in the U.S. In addition, we will also examine and appropriate measures for the latent inter-relationships and dependencies associated with occupational skill sets. By combining these additional dimensions with the familiar cluster constructs of input-output and industry and occupational co-location we should provide a more complete and up-to-date picture of the regional competitive landscape.

References

Delgado, M., Porter, M. E., & Stern, S. (2016). Defining clusters of related industries. *Journal of Economic Geography*, *16*(1), 1-38.

Feser, E., Sweeney, S., & Renski, H. (2005). A descriptive analysis of discrete US industrial complexes. *Journal of Regional Science*, *45*(2), 395-419.

Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2001). *The NBER patent citation data file: Lessons, insights and methodological tools* (No. w8498). National Bureau of Economic Research.

Martin, R., & Sunley, P. (2003). Deconstructing clusters: chaotic concept or policy panacea?. *Journal of economic geography*, *3*(1), 5-35.

Jaffe, A. B., Trajtenberg, M., & Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *the Quarterly journal of Economics*, *108*(3), 577-598.

Porter, M.E. (1990), *The Competitive Advantage of Nations* , Free Press, New York, NY.

Porter, M. E. (1996). Competitive advantage, agglomeration economies, and regional policy. *International regional science review*, *19*(1-2), 85-90.

Shutters, S. T., & Waters, K. (2020). Inferring networks of interdependent labor skills to illuminate urban economic structure. *Entropy*, *22*(10), 1078.