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ARE THE GEOGRAPHIES OF INNOVATION AND PRODUCTION CONVERGING OR DIVERGING? AN ASSESSMENT OF HIGH TECH EMPLOYMENT IN REGIONAL ECONOMIES IN THE US

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ABSTRACT

To understand the processes of growth and change within regional economies researchers periodically engage in the evaluation and categorization of those regions. The resulting typologies serve to shape perceptions regarding key industries (e.g. biotechnology, IT) and successful regions (e.g. Silicon Valley, Boston). However, these discourses of knowledge production and localized innovation rarely connect to the underlying narratives of regional growth and decline either in theory or in practice. Since 2007, there is a renewed interest in mapping the long-term economic trends in US regions motivated by questions about the origins and effects of the global recession.

To merge the discussions of the spatial distribution of innovation and production, I turn a theoretical framework provided by the emerging discussion of "evolutionary economic geography" (EEG). EEG provides an analytical approach to regional economies which balances innovation against job creation rather than privileging technology over production.

First, I begin by tracing six regions through a set of historical analyses of regional economies used to develop influential typologies. I then trace those regions through the "typology of innovation districts" project to ascertain their current position as innovative regions relative to other US regions. Finally, I analyze these six regions using recent employment data. The findings indicate that the geographies of innovation and production may be diverging rather than converging in the US presenting a challenge for regional development policy.

Keywords: regional innovation systems, resilience, evolutionary economic geography

1. INTRODUCTION

In order to understand the processes of growth and change within regional economies researchers periodically engage in the evaluation and categorization of those regions (generally metropolitan statistical areas, or MSAs, in the US context). The resulting typologies shape perceptions about key industries (e.g. biotechnology, IT) and successful regions (e.g. Silicon Valley, Seattle, Boston) (Noyelle and Stanback 1983; Markusen 1996; Pollard and Storper 1996; Drennan 2002; Clark, Huang et al. 2010). In recent years, analyses have focused primarily on questions related to firm growth, technological change and innovation rather than deindustrialization, job decline and industrial restructuring. These discourses of knowledge production and localized innovation rarely connect to the underlying narratives of regional growth and decline either in theory or in practice.

However, there are a growing number of exceptions (Markusen 2004; Christopherson and Clark 2007; Taylor 2009). Motivated by questions about the origins of the global recession, a renewed interest has emerged in mapping economic trends in US regions. Since 2007, the emphasis on innovation systems rather than production jobs has begun to shift. A gap in comparative empirical work coupled with evidence of the uneven effects of the recession underscore the importance of understanding and explaining the relationship between geographies of innovation and production.

Unfortunately, policy responses---a reaction to job losses---have largely repackaged the stimulus and job creation policies of the 1980s . These policies have largely ignored decades of empirical work and theorizing about knowledge economies, learning regions, and regional innovation systems (Gertler and Wolfe 2002; Gertler 2003; Asheim and Coenen 2006; Bercovitz and Feldman 2006). However, it is plausible that the research on regional innovation and knowledge production of the last two decades could contribute to a broader understanding of regional economies in periods decline as well as in periods of growth. Further, a more nuanced understanding of the interactions between geographies of innovation and production may be critical to shaping effective job creation policies in a knowledge economy.

In order to merge the discussions of the spatial distribution of innovation and production, I turn to a theoretical framework provided by the emerging discussion of "evolutionary economic geography" (EEG) (Boschma and Martin 2007; Grabher 2009). EEG provides an analytical approach to regional economies which balances innovation against job creation rather than privileging technology over production. It also takes seriously the history of places and the subsequent industrial path dependencies and forms of institutional "lock-in" that shape capacities to absorb and diffuse technological change across process and product innovations. Finally, the EEG approach emphasizes a dynamic rather than static approach to regional economies.

As is often the case, the operationalization of such an expansive theoretical framework is challenging due to data limitations (particularly the availability of historical data on research and development endowments at the regional scale) and ensuing complications in research design. In spite of this, in this paper I begin that empirical project of evaluating regional economies using a dynamic approach that focuses on both innovation and production.

First, I begin by tracing six regions through a set of historical analyses of regional economies used to develop influential typologies (specifically the Noyelle and Stanback (1983), the Markusen (1996)). I then trace those regions through the "typology of innovation districts" project to ascertain their current position as innovative regions relative to other US regions (Clark, et. al (2010)). Finally, I analyze these six regions using recent employment data. By tracing these six regions using both historical and recent employment and innovation data, I take up the empirical challenge posed by evolutionary economic geography and the policy challenge posed by the recent global recession.

Ultimately, mapping the evolution of these six regional economies produces findings that counter the assumption---prominent in economic development practice---that investments in innovation lead to co-located commercialization and production of those innovations. In other words, for regions in the US, the findings indicate that the geographies of innovation and production may be diverging rather than converging. This conclusion presents a challenge for regional development policy.

2. Regional Typologies, Innovation, and Transition: The Question of Evolution in the Economic Base

Regional development policies have recently shifted focus from an emphasis on growth and competitiveness to a broader understanding of the relative resilience of regional economies and policy responses to rapid transitions in technologies, markets, and exogenous economic shocks. The emphasis on sustainable regions rather than economic growth extends research on learning regions and the "innovative milieu" to a broader conceptualization of embedded institutional adaptive capacities (Crevoisier 2004). It also revisits the use of natural systems models as frameworks for understanding economic growth and distribution (Swanstrom 2008; Clark and Christopherson 2009).

This trajectory, prominent in urban planning and regional studies, mirrors recent developments in economic geography which have stimulated debates about an evolutionary economic geography (EEG) integrating several streams of theory and empirical work on firm-level, regional, and network (industry) dynamics (Boschma and Martin 2007; Boschma and Frenken 2009). In particular, the EEG framework synthesizes a set of complex and parallel projects including work on: 1) the embedded and localized nature of innovation (technological change); 2) life cycle issue of regions, industries and firms (path dependencies and lock-in); and 3) the role of "socioeconomic culture" or institutional infrastructure in regional development (organizational “routines” of coordination and control) (Grabher 2009). Participants in the debate note “there is a need to relate technological change and innovation to the social relations among groups of actors, particularly capital, labor, and the state, raising questions of social agency and power.” (MacKinnon, Cumbers et al. 2009, p. 131).

As is often the case in theoretical debates, there is a call for further empirical work designed and deployed to address some of the more problematic elements of the theories in question. Boschma and Frenken call for both qualitative and quantitative work targeted at an effort to synthesize “institutional and evolutionary approaches in economic geography” (Boschma and Frenken 2009, p. 156). Others echo the call for policy-relevant and theoretically sophisticated empirical work (Markusen 1999; Martin 2001; Clark and Christopherson 2009; Christopherson 2010).

The empirical analysis of regions and the attempt to categorize them follows from an extensive theoretical discussion about the character and evolution of regional economies and their relative position in the national and global markets. These analyses have sought both to accurately describe the current position of regional economies and also to provide some predictive basis for understanding future prospects (and possible policy interventions). Recently, the discussion of future prospects evolved into a debate about reactive capabilities, adaptive capacity, and regional resilience (Chapple and Lester 2010; Pendall, Foster et al. 2010).

Such terms describe the endogenously-developed assets of the region which determine (at least in part) its ability to react and adapt to short-run exogenous shocks or long-run transitions in markets (Grabher 2009). Thus, they illustrate a significant shift in regional economic development theory, policy, and practice from an export-oriented approach focused on investment in basic industries to one that privileges investments in institutional capacities and indigenous institutions (Pike, Rodríguez-Pose et al. 2006).

In recent years innovation metrics served as increasingly frequent measures of regional development and in the evaluation of policy. The question of how regions become places where innovation thrives and high-technology industries grow has dominated studies of regions (Kaufmann and Todtling 2000; Doloreux and Dionne 2008; Rutherford and Holmes 2008). It is well-established that firms co-locate to take advantage of agglomeration economies related to their production process (e.g. common infrastructure and labor markets, locally-embedded technologies, production processes, and institutions, and reduced transportation and transaction costs) (Storper 1997; Clark, Feldman et al. 2000).

This theory is rooted in an institutional and evolutionary discourse which recognizes the power of regional path dependencies, the importance of specialized regional labor markets, and the dominance of embedded and localized institutional networks (Christopherson and Clark 2007). This literature draws its empirical grounding from a body of “critical case studies” in regional studies, economic geography, and sociology (Storper and Christopherson 1987; Florida and Kenney 1992; Saxenian 1994; Treado and Giarratani 2008). The theories of the spatial organization of production have engaged the spatial distribution of *innovation* as well (Moulaert and Sekia 2003; Boschma 2005; Simmie 2005). Frameworks such as industry clusters, learning regions, and territorial innovation systems shifted the discussion from co-location of producers to co-location of innovators.

Empirical evidence, both from critical case studies and from an emerging quantitative literature, indicates that the geography of innovation differs from the spatial distribution of production. In particular, knowledge spillovers have a complicated geography, spanning both highly localized and broadly distributed networks. And yet, much prior research finds that information flows, even of published information, are geographically constrained (Jaffe, Trajtenberg et al. 1993; Feldman 1999; Gertler 2003). This ambiguity about the geography of knowledge spillovers has produced a broad debate about both the theory and metrics used to analyze innovation processes and patterns.

Boschma (2005) points out that the relationship between proximity and innovation itself is somewhat under-theorized. Arguing that physical proximity is not the only type of proximity at play in regional firm networks, Boschma disaggregates "proximity" into institutional, social, conceptual, cognitive, and geographic categories. Physical proximity produces both positive and negative outcomes for firms and networks, with attendant implications for regional resilience. In balancing risks and costs of production (and innovation), geographic proximity reduces uncertainty and resolves coordination problems while at the same time producing lock-in and introducing unintended spillover effects (Boschma 2005). The consequences for small firms embedded in agglomeration economies can be decidedly mixed. The assumption that geographic proximity to large firms or a location in a highly concentrated firm network benefits small firms and increases overall regional resilience increasingly is contested in theory and subject to evaluation in empirical work.

To the extent it is recognized, the limits to regional innovative capacity are explained with reference to endogenous characteristics of the region, such as inadequate supportive institutions and/or technological or political "lock-in" (Todtling and Trippl 2005). These approaches, although providing significant insights, leave a model of cooperation, collaboration, and trust among firms as the norm rather than the exception.

And yet the industrial district model, derived largely from empirical work in Italy, has never been an easy fit in the US (Storper and Walker 1989; Gray, Golob et al. 1996). In part the variation in regulation at the state level and general decentralization of regulation makes the regional differentiation at the scale of the state a significant difference between the US and other countries (Gilson 1999; Stone 2004).

Thus, counter arguments and alternative hypotheses recently gained ground. These arguments focus on political, legal, and policy environments which shape regional economies and the role of firm strategies in establishing rules, norms, and power asymmetries within firm networks (Dicken and Malmberg 2001; Christopherson and Clark 2007; Pike 2009). While industry cluster effects build on the idea of a "commons" (in skills, knowledge, institutions), in the US, a culture of competitiveness which privileges property rights over collaboration works against this notion of developing a commons as a path to shared innovation and economic growth. Using evidence from firms operating in Silicon Valley and Route 128, Florida and Kenney demonstrated that US firms, even when agglomerating, do not reap the advantages of geographic proximity expected from the industrial district paradigm. Instead firms focus on establishing organizational practices which produce captive suppliers and competition based on cost rather than quality of innovation (Florida and Kenney 1990).

The question of how regions in the US "innovate" remains a controversial one in management, policy, and economic development. Saxenian provided initial evidence for flexible production in the US context and a successful example of the emergence of high-technology regions (Saxenian 1994). In part her analysis foreshadowed a framework for regional innovation systems, one based on a model shaped by the original empirical work presented by Piore and Sabel in 1984 and the "possibilities for prosperity" that their flexible specialization model proposed for regional economies (Piore and Sabel 1984). Applying that model for innovation and flexible production in the United States is an ongoing empirical and theoretical project with many iterations adapted for both traditional industrial and high-technology contexts (Markusen, Hall et al. 1986).

This article approaches the question of how the geographies of innovation and production have converged or diverged in regional economies within the US through the analysis of six "hard cases" spanning both the high-technology context and the category of older industrial regions (OIRs). By focusing on difficult cases which ranked relatively high in innovation measures, I look back at how these regions were assessed historically, as production centers and places of research and development. The analysis is organized around a core question at the intersections of regional development and innovation policy: whether and to what extent do geographies of production and innovation overlap and, further, is there evidence of convergence or divergence overtime?

3. The Data: The Stubborn Borderline Cases in the US

3.1 Case Selection and Methodological Approach

First, in order to provide historical context on the regions, I revisit a series of typologies developed to categorize and explain the broad processes of growth and change in US regions (and the data behind them). From these typologies, I selected six regions for further analysis. Finally, I analyze the selected cases using recent data on employment and innovation.

The empirical analysis relies on evidence from US regions using three major data sources and two previous typologies. First, it revisits the typologies proposed by Noyelle and Stanback and the data behind their analyses (Noyelle and Stanback 1983).

Second, I use "triadic" patent data applied to US regions to develop a "typology of innovation districts" (Clark, Huang et al. 2010). That analysis modified Markusen's (1996) "typology of industrial districts" using data on innovation (or invention) rather than employment. Finally, I use employment data (2001-2008) to assess these six "hard to categorize" regional economies in the US: Albany, Austin, Madison, Milwaukee, Rochester, and Toledo.[1]

These difficult cases were selected because of 1) their presence in both Noyelle and Stanback's analysis 30 years ago and their presence in the recent analysis resulting in the "typology of innovation districts" and 2) their frequent presence in critical case studies of regional resilience and transformation of both older industrial regions (OIRs) and high technology economies (Sternberg 1992; Chapple, Markusen et al. 2004; Gargano 2006; Christopherson and Clark 2007; McCann 2007).

The analysis begins with the typologies developed by Noyelle and Stanback and the data presented in their 1983 book, *The Economic Transformation of American Cities*. Noyelle and Stanback analyzed all the MSAs in the US in order to better understand the processes of regional growth and change occurring across the country. They collected and analyzed data on employment, industry mix, institutional endowments, logistics, location, and capital. Their rankings were often dominated by the largest MSAs (in terms of population), partially obscuring the capacities of smaller and mid-sized MSAs. For this analysis, I selected only mid-sized and smaller MSAs originally present in the Noyelle and Stanback analysis in order to avoid the overshadowing of larger regions.

Although regional comparative case studies of US regions often focus on the top performing cities in terms of employment concentration in select industries or dominance in other metrics---patents, high-tech firms, regional GDP, etc…, the focus in this article is on regions that are present across the historical analyses but not dominant in population. As a consequence, there is little overlap between the selected regions and other recent studies of US regional economies (Saxenian 1994; Pollard and Storper 1996; Florida 2002). The issue driving this analysis is the emerging relationship between innovation and production geographies and the question of proximity.

The second typology I rely on emerges from a modified methodological approach to Markusen's "industrial districts" typology, delineating regions by innovation measures rather than their distinct characteristics using employment data and the characteristics of firm networks. This "typologies of innovation districts" approach forwards the argument that regional economies depend not only on endowments (producers, networks, skilled labor, strong institutions), but also on capacities (influenced by policy) to leverage innovation in response to changing technology, markets and resource environments (Clark, Huang et al. 2010).

The empirical analysis of US regions presented here is organized around these existing frameworks for analyzing data (Markusen 1996; Boschma and Lambooy 2002; Todtling and Trippl 2005). This historically-grounded methodological approach guides the analysis of the current data on these six regions and contextualizes the discussion within an ongoing debate about the factors that produce variation in regional growth trajectories and the specific role of innovation capacity in that development. In particular, this analysis focuses on the question of the geographic relationship between employment and innovation.

3.2 The Historical Analysis

In their analysis, Noyelle and Stanback developed a hierarchical typology of US MSAs based largely on population size and industrial specialization. The broad distinction in terms of regional function was between "Service Centers" and "Production Centers" with subcategories based on role in the national economy and specialization. The six cases fall into the category identified as "specialized service centers." Within this category, Milwaukee, Rochester, and Toledo are identified as "Functional Nodal" regions and Albany, Austin, and Madison are identified as "Government-Education" regions. Noyelle and Stanback categorized the regions based on a comprehensive analysis of all US MSAs and an array of metrics based largely on regional economic data from the 1970s.

Table 1 displays the institutional endowments related to research and development (Fortune 500 firm headquarters, industrial research labs, research universities, and medical schools) present in each region in 1950s and the mid-1970s. This information provides indications of both innovation and institutional capacity as represented by both private and public research and development infrastructure.

Table 1: Regional Private and Public Research and Development Capacities

Specialized Service Centers (selected)		National HQs Fortune 500 Firms, 1959	National HQs Fortune 500 Firms, 1976	Industrial Research Labs, 1956	Industrial Research Labs, 1975	Largest 4 Year Universities	Medical School, 1974
Functional Nodal							
	Milwaukee	7	11	62	71	1	1
	Rochester	2	4	34	36	0	1
	Toledo	6	7	24	23	2	1
Government-Education							
	Albany	2	1	25	23	0	1
	Austin	0	0	3	18	1	0
	Madison	0	1	9	16	1	1

In addition to the evidence on the "institutional infrastructure" in the regions (Table 1), Noyelle and Stanback's research provides important information about the role of these regions as employment centers in specific industries with a significant emphasis on research and development during the period. Their research evaluated the distribution of employment by four industry sectors for the set of MSAs: SIC 371: Motor Vehicles and

Parts; SIC 365-366, 367: Electrical Appliances and Electronics; SIC 372-376: Aerospace and Ordinance; and SIC 381-387, 357: Office, Scientific, and Measuring Equipment.

They then sub-divided the employment concentrations in these industries by function designating regions as Administrative Centers, Research Centers, or Production Centers in each industry category. Although the Centers were dominated by large population regions that fell into the categories of national and regional nodal nubs, a category not analyzed here, Milwaukee, Rochester, and Toledo (functional nodal regions) appeared as leading regions in several categories (see Table 2).

Table 2: Regions with Research-Based Industrial Specializations

Administrative Centers			
	SIC 371: Motor Vehicles and Parts (of ten)	#5 Toledo	
	SIC 381-387, 357: Office, Scientific, and Measuring Equipment (of ten)	#3 Rochester	
Research Centers			
	SIC 371: Motor Vehicles and Parts (of ten)	#8 Milwaukee	#9 Toledo
	SIC 365-366, 367: Electrical Appliances and Electronics (of seven)	#7 Milwaukee	
	SIC 381-387, 357: Office, Scientific, and Measuring Equipment (of ten)	#2 Rochester	
Production Centers			
	SIC 371: Motor Vehicles and Parts (of ten)	#4 Milwaukee	
	SIC 38: Office, Scientific, and Measuring Equipment	#1 Rochester	

Source: Noyelle and Stanback, 1983

It is notable that any of these small and mid-sized regions ranked in the top of any of these categories. More notable are the regions that cross categories. Rochester registers as a Production, Research, *and* Administrative hub during the period in SIC 381 (a research specialization that region retains). Milwaukee and Toledo also appear in these rankings. In both cases, they appear in SIC: 371: Motor Vehicle and Parts category twice. Milwaukee ranks as a Research and Production center while Toledo ranks as a Research and Administrative Center. Interestingly, both are ranked in the research category, indicating a significant specialization for mid-sized cities.

It is also interesting that none of the Government-Education Centers in the analysis: Albany, Austin, or Madison appears in the industry rankings although all three are discussed as research hubs in current regional development discussions. Although there were major limitations in this analysis due to data disclosure issues and the nuances surrounding the aggregation of MSAs for megalopolis regions, the identification of these mid-sized regional economies as Research, Administrative, and Production Centers in key industries in the late 1970s does provide context for understanding the industrial paths and historical endowments of these places.

3.3 The Innovation Measures: Triadic Patents

The analysis using innovation metrics builds off of a project which produced a typology of US regions based on innovation capacity (e.g. Hub and Spoke, Satellite Platform, Marshallian, Lesser Marshallian, and University/Research Center). The result is a typology that takes into account triadic patents per capita, the relative proportion of patents by size of firm (small vs. large), and the density of university patents.[2]

In this analysis, Madison ranked as a "Marshallian district" with more than 10 percent small firm patents and a high per capita patent rank. Toledo ranked as a "Lesser Marshallian" district, a region with a high proportion of small firm patents without a high ranking of per capita patents. Rochester, Austin, and Albany all appeared as "Hub and Spoke Districts" with a small proportion of patents coming from small firms although they reported a high proportion of per capita patents. Milwaukee fell in the middle of the distribution, ranking high enough to appear in the top eighty regions in the US but not remarkable in terms of patents by firm size or per capita within that group. None of the six regions fell into the "satellite platform" category characterized by low patents per capita and low small firm patents.

Although high rates of triadic patents per capita were found in regions such as Rochester and Albany, the rate of small firm patents varies significantly across these innovative regions. For example, a relatively high percentage of patents come from small firms in Madison and Toledo while relatively few patents come from small firms in Rochester, Albany, or Austin. The "High tech" regions associated with university research and emerging technologies (Austin, Albany, and Madison) and the older industrial regions (Rochester, Milwaukee, and Toledo) fell at the high and the low ends of the measures.

Table 3: Triadic Patent Data and Innovation Typologies

MSAs	MSA Population 2000	MSA GDP per Capita 2006	Percent Small Firm Patents	Patents per Capita	Dominant NBER Technology Class
Albany--Schenectady--Troy, NY	875,583	$36,523	1.34%	17.02%	resins
Austin--San Marcos, TX	1,249,763	$42,904	4.60%	6.96%	semiconductor
Madison, WI	426,526	$48,353	11.43%	8.21%	biotechnology
Milwaukee--Racine, WI	1,689,572	$44,923	6.10%	4.85%	nuclear/x-ray
Rochester, NY	1,098,201	$37,032	0.90%	40.34%	misc/chemical
Toledo, OH	618,203	$34,945	25.00%	1.94%	materials processing & handling

Source: Clark, et al 2010

3.4. The Employment Analysis (2001-2008)

The employment analysis is disaggregated into 1) manufacturing employment, 2) high-technology manufacturing employment, and 3) employment in high-technology services. These subsectors are defined operationally by NAICS codes using the AEA definitions of High-Tech Manufacturing (NAICS 334) and High-Tech Services (NAICS 54). While these NAICS definitions do not perfectly capture the concepts, they are broadly used in the analysis of high-tech firms and employment.[3]

During the period, employment declines were common. Nevertheless, Madison and Austin showed employment gains while declines ranged from 1 percent to 9 percent in the other regions. Overall manufacturing employment declined in all regions between 8 percent and 29 percent. High tech manufacturing, however, increased in three regions while high tech services increased in five regions.

In terms of earnings, manufacturing wages increased more than high-tech services wages in all regions except one (Albany). In fact, given that a 22 percent increase would be consistent with inflation, only Albany significantly exceeded stagnant wages for high tech services. Austin and Rochester lost ground.

Table 4: Employment and Wage Data 2001-2008

	Percent Change in Emp in All NAICS Sectors	Percent Change in Emp NAICS 31-33	Percent Change in Emp NAICS 334	Percent Change in Emp NAICS 54	Percent Change in Avg Earnings (All NAICS)	Percent Change in Avg Earnings (NAICS 31-33)	Percent Change in Avg Earnings (NAICS 334)	Percent Change in Avg Earnings (NAICS 54)
Albany	-1%	-20%	-31%	12%	22%	32%	27%	35%
Austin	14%	-10%	-4%	25%	18%	42%	44%	15%
Madison	7%	-8%	3%	25%	27%	25%	35%	22%
Milwaukee	-1%	-16%	-8%	4%	24%	25%	30%	23%
Rochester	-4%	-29%	0%	3%	20%	27%	36%	16%
Toledo	-9%	-24%	63%	-13%	17%	26%	n/a	23%

4. Analysis: An Emerging Model or Persistent Outliers

Returning to the primary questions: 1) Does revisiting these typologies and the data behind them guide the analysis of current employment and wage data and, in particular, 2) Does the innovation systems and knowledge production research provide any insights into the various patterns of growth and change in these regional economies? Obviously, the sample size here is quite small and the cases were selected for their relative lack of compatibility with dominant models of regional growth and change rather than ease of categorization. In spite of this, these cases do reveal some notable contrasts.

4.1 Proxies and Measures of Long-Term Research Capacities

The idea that historical institutional development capacity bears on the future regional innovation outcomes, and the specific character of that innovation, is supported by this research. For example, the regions with the lowest levels of small firm patents---Rochester, Albany, and Milwaukee---are also the regions with significant numbers of industrial research labs in 1956 and 1975. The exception is Toledo which has a high number of small firm patents in 2003 and a large number of industrial research labs in 1956 and 1975.

In general, the presence (and number) of industrial research labs in this mid-century period seems to be a more important indicator (in terms of variation) than the other institutional endowments (including the presence of large universities or Fortune 500 companies). One hypothesis is that the industrial research labs are a better measure of innovation *and* commercialization capacity than the presence of universities (innovation) or large firms (commercialization) alone.

Following from that point, it should be noted that not all metrics are created equal. In particular, it is not clear that production and research capacities are best analyzed as delinked categories. Predictably, regions with historical production and research capacities seem to retain those capacities over time. However, the underlying industrial specialization does matter (autos in Toledo and Milwaukee vs. scientific equipment in Rochester). While the important role of industry specificity is not a new finding, there has been an increasing tendency to analyze technology specializations apart from their production capacities. Returning to conceptualizing and operationalizing technology classes and production capacities together reveals the critical importance of those overlapping functions for the viability of the regional economy.

4.2 Divergent Geographies of Innovation and Production

The current employment and wage data point to two possible conclusions that challenge much of the conventional wisdom behind innovation systems and technology policy. First, in these regions, increases in high technology production jobs do not closely correspond to increases in high technology service jobs (or vice versa). Of the six regions, five show high-tech production and high-tech service employment moving in opposite directions. In a broader study of twenty-two regions during the same period, only one region showed high tech manufacturing and service employment moving in the same direction (Saginaw, MI, downward) (Christopherson and Clark 2010). Broadly speaking, the geographies of innovation and production do not seem to overlap in these cases. This indicates the need for a diverse set of policies for economic regional recovery and job growth rather than innovation strategies alone.

Second, the wage data tell an interesting story. Although conventional wisdom assumes that high technology services are high paying, this data indicate that in many regions high technology manufacturing jobs earn higher wage increases than high-tech service positions. In fact, only in Albany did the wages for high-tech services exceed that of high-tech manufacturing. In Austin, high tech manufacturing monthly wages were more than $1500 higher than high tech services. And perhaps also surprisingly, in neither the new high-tech region Austin, nor the old high-tech region Rochester did overall wage growth keep up with overall inflation.

Finally, although several of these regions may once have qualified as examples of Markusen's Satellite Platforms---dominated by large firm branch plants with no particular specialization of its own---none would easily fit that category today (Markusen 1996). All six are either 1) holding onto an established specialization: Rochester and optics, Milwaukee and Toledo and advanced manufacturing, or 2) in training to establish a new specialization: Madison and biotech, Austin and IT, Albany and nanotech. This adds an interesting dimension to the question of how policy can leverage established or emerging industry or innovation specializations in order to contribute to job growth and wage gains. The process of regional resilience seems not to be a direct outcome of either research or production alone.

5. Conclusions: Theory, Policy, and Quality Job Growth

After two decades of research on innovation systems and high-tech regional economies, the application of that work to policy remains elusive. Drennan makes the point in *The Information Economy and American Cities* that, for predicting the viability of a regional economy over time, the presence of information sector specializations matter more than Sunbelt vs. Snowbelt location or whether a region is an emerging city or older industrial region (Drennan 2002). Indeed, specialization characterizes all six of the regions analyzed in this study. However, the difference is that high-technology services and high technology manufacturing do not converge on single regions specialized in a sector. Instead, sites of production and sites of innovation appear to be diverging.

This divergence produces a dilemma for policy. In economic development policy the increased emphasis on innovation systems and knowledge economies supports a model of investment in research and development, technology transfer, and university innovation and "centers of excellence" (Christopherson and Clark 2010). Such a model assumes regional innovation leads to high-tech production. Further, the ensuing production is implicitly assumed to occur *in the region*. This analysis complicates that assumption. It appears some regions are becoming specialized in the knowledge economy but without a co-located network of producers and suppliers engaged in the commercialization and production of those innovations.

This finding does not contradict the research on high-tech regions or regional innovations systems, but it does present a problem for policy. Investments in research and development cannot be assumed to produce jobs and certainly not a diverse set of jobs ranging across the occupational categories and educational and skill levels present in most regional economies.

Because innovation systems were never focused on job creation, their contribution to economic development policy and the corollary discussion about regional economic recovery may be quite limited. The models that support innovation systems neither address the broad based issues of employment loss in a recession nor a response to regional differentiation in the character and impact of that job loss.

Although regional specialization has long been associated with the sustainability of regional economies, the delinking of innovation activities from production activities follows along an established pattern of vertical disintegration in which different stages of the production process are sited in different places. The challenge then, is to recognize this delinking and subsequent role of policies and practices that consciously link innovation and production rather than assume their inevitable co-location. In the end, the image of Markusen's satellite platform regions---those places with "branch plant" production sites divorced from the innovation hubs that incubate the ideas that they manufacture---looms large in the discussion. Perhaps surprisingly, the opposite model---those regions with little production but extensive research and development capacities---seem to be developing as well. The implications for a new uneven development, a version produced for the knowledge economy rather than industrial economy, are becoming increasingly clear.

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[1] LEHD and REIS http://lehd.did.census.gov/led/ and http://www.bea.gov/regional/index.htm

[2] In our analysis we use a random sample of 9,060 triadic patents with an invention priority date from 2000 to 2003, and with at least one US addressed inventor, drawn from the population of 32,390 triadic patent families in the OECD triadic patents database. A triadic patent comes from a patent family containing a US-granted patent and a European Patent Office and Japanese Patent Office patent application. Firms and individuals applying for triadic patents tend to view their market as "global" (i.e. spanning three major economic regions). We use the US Patent and Trademark Office field designating patents as belonging to "small entities" (independent inventor, a small business concern [less than 500 employees], or a nonprofit organization), along with assignee data, to code inventors as belonging to large firms, small firms or university/non-profit research organization for the spatial analyses.[2]

[3] (AEA Defining the High-Tech Industry (Feb. 2003)).