CREATING A PLUG-IN ELECTRIC VEHICLE INDUSTRY CLUSTER IN MICHIGAN: PROSPECTS AND POLICY OPTIONS

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Introduction

Significant changes in the automobile market and industry have created conditions that are increasingly favorable to the mass commercialization of the electric vehicle. Major advancements in battery technology and accompanying cost reductions, as well as increased demand for fuel-efficient products, have driven interest and investment in the development of wide spectrums of technologies and business models that advance the automobile's electrification.

Mass commercialization of an electric vehicle will revolutionize the competitive landscape of automobile production and challenge any remaining competitive advantage of the Detroit automobile production cluster. Indeed, as argued on the front page of the *Wall Street Journal* in a discussion of the Chinese BYD Company's strategy for building vehicles to compete with Detroit, electric vehicles may level the vehicle production playing field entirely:

> Few products are as complex to develop and produce as gasoline-powered automobiles, which are assembled with thousands of precisely-engineered parts. But electric cars use only basic motors and gear boxes, and have relatively few parts. Aside from perfecting the battery itself, they're far easier and cheaper to build . . . .[1]

If technology and market trends continue to favor transport electrification, there will be a significant challenge to Detroit's longstanding competitive advantage in automobile production. Failure to adapt to the new market landscape is likely to erode Detroit's competitive advantage and have corresponding negative implications for the regional economy.

The electrification of transportation also presents tremendous opportunities for automakers in Michigan to leverage their skilled workforce,

1. Norihiko Shirouzu, *Technology Levels Playing Field in Race to Market Electric Car*, Wall St. J., Jan. 12, 2009, at A1.

supplier networks, and engineering human capital in the development of the next-generation automotive product. Further, it presents opportunities for the United States as a whole to reduce dependence on oil imports, rapidly improve the efficiency of transportation energy usage, and reduce greenhouse gas emissions.

This Article seeks to examine how policy can be used strategically to foster the development of a plug-in electric vehicle ("PEV") industry cluster in Michigan. The tendency for certain industries to localize in particular regions has captured the interest of much economic research and policy discussion in recent years. The trend toward the clustering of new industries has stayed strong despite the acceleration of globalization. Attention to clusters has proven to be an enduring theme in economic development circles for nearly thirty years. Clusters generate synergies that make industrial activity greater than the sum of contributions by individual players.

In this Article, we review a broad array of literature on the development of economic clusters in general, assess the key elements of the PEV value chain, and summarize interviews with several major players along the electric vehicle value chain. Our goal is to look beyond simply "buying" jobs with tax subsidies, and to identify ways in which targeted policy support can spark a self-perpetuating, high-technology PEV economic cluster centered in the State of Michigan.

The remainder of this Article is organized as follows. First, in Part I, we review the literature on industrial clusters in order to identify the broad features of clustering behavior. In Part II, we explore the factors that lead industries to cluster in the first place, apply this analysis to the case of the automobile industry in the twentieth century, and assesses the likelihood of development of PEVs within one or more industrial clusters. Part III turns to the key characteristics of successful clusters. Part IV explores the factors Michigan will need to successfully build a PEV cluster and examines the range of policy options that have been used to support cluster development in various locations around the world. Part V pulls the foregoing analysis together by presenting a set of policy recommendations that may support the creation of a successful PEV cluster in Michigan.

I. The History of Cluster Research and Theory

Johann Heinrich von Thünen first theorized about the localization of economic activities, seeking to understand the impact of grain prices on agricultural production. In *The Isolated State*, he put forth a model that documented how agricultural production and land use would agglomerate around a central city, arguing that the agglomeration of economic activity was driven by transportation costs to the city's center.[2]

2. J. H. von Thünen, The Isolated State 110–13 (1826).

Alfred Marshall was the first to theorize on the agglomeration of related industries, explaining co-location of firms in terms of the positive externalities associated with firm proximity. Marshall identified (1) markets for specialized labor skills, (2) improved industry-specific inputs, and (3) localized knowledge flows as tangible positive externalities that firms could tap through agglomeration. These *Marshallian externalities* have proven consistently important concerns in the literature addressing economic clusters.[3]

Paul Krugman, who was awarded the 2008 Nobel Prize in Economics for his work in economic geography, formalized and modernized Marshall's theories, initiating a new strand of literature of "New Economic Geography", which seeks to explain the emergence of industry agglomerations based on increasing returns to scale and transportation costs, emphasizing linkages up and down the value chain from suppliers to firms, and from firms to consumers. The theory explains agglomeration by first noting that increasing returns to scale will drive geographical concentration of production: Chevy Tahoes, for example, are more easily produced in one centralized national facility rather than 50 smaller facilities in each state across the nation. The theory also notes that material transportation costs increase the appeal of production locations that are close to consumers and suppliers. This concentration of production tends to attract labor inputs, further driving consumption and making the location increasingly attractive for producers, thus creating a positive feedback loop. This centripetal agglomeration force also has a corresponding centrifugal force that drives the industry apart: agglomeration may drive up land rents, concentrate environmental pollution, or empower labor unions, thereby driving up production costs. Furthermore, if transportation costs for the finished product are excessive, then centralized production becomes infeasible and clustering will not emerge.[4]

Another strand in the cluster literature focused on the role of innovation systems and entrepreneurship in cluster economies. By concentrating intellectual capital in a given area, industrial districts came to be seen as fostering the spillover of technological knowledge between firms and institutions as positive externalities.

A. *Cluster Analysis: Synthesis and Application Literature*

In the 1980s, competitive industrial districts captured the interest of economic researchers. The "Third Italy" was one of the first such industrial district phenomena to be investigated in depth: the thriving industrial districts in Italy's central Emilia-Romagna region had established and sustained global competitiveness in traditional industries of shoes, furniture, tiles, and

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3. Alfred Marshall, Principles of Economics 268–343 (9th ed. 1890).

4. Paul Krugman, Geography and Trade 36–54 (1991); Armin Schmutzler, *The New Economic Geography*, 13 J. Econ. Surv. 355, 362–63 (1999).

musical instruments despite stagnation and recession in other Italian regions. Much of this research emphasized the role of social capital within the north-central Italian regions and brought together economic and political perspectives to explain the unique economic model of the Third Italy. For example, the long history of local relationships in the regions of the Third Italy facilitated the exchange of tacit knowledge without requiring the formal contracts often used in the United States. This lowered the transaction costs of industrial organization and supported growth in regions with high social capital.[5]

In 1990, Michael Porter's *Competitive Advantage of Nations* highlighted various external factors that contribute to firm performance: his *diamond* framework relating factor input conditions, demand conditions, related and supporting industries, and firm structure, strategy and rivalry is probably the most commonly cited development in the literature. The book explored the specialization of regions and nations according to strengths, rather than diversification, which was the prevailing U.S. development objective at the time. It also discussed government policies that would increase competitiveness at the national level and established the aforementioned competitive framework that Porter uses to consider cluster competitiveness. While citations to Porter's *Competitive Advantage of Nations* are ubiquitous in the grey literature regarding clusters, the book is highly anecdotal, lacking specific citations and empirical data, and relies heavily on Porter's observations and resulting theories.[6]

Research on competitive regions in Germany, the United States, Japan, New Zealand and Norway proliferated throughout the 1990s. Particularly influential was Annalee Saxenian's study of the diverging paths of Boston's Route 128 and Silicon Valley's industrial clusters, each of which had been compared to Detroit's decline. Saxenian concluded that Silicon Valley achieved greater flexibility and higher rates of collaboration than Route 128 and expressed skepticism about whether government efforts to protect or promote strategic sectors during times of rapid technological and market change could be successful.[7]

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5. *See* Richard M. Locke, Remaking the Italian Economy 145–73 (1995); Robert D. Putnam, Making Democracy Work 83–120 (1993); Thomas P. Lyon, *Capitale Sociale e Crescita Economica in Italia 1970–1995*, *in* Lo Sviluppo Locale: Storia, Economia e Sociologia 229, 229–59 (C. Carboni & M. Moroni eds., 2007); Michael J. Piore & Charles F. Sabel, *Italian Small Business Development: Lessons for U.S. Industrial Policy*, *in* American Industry in International Competition 391, 400–02 (John Zysman & Laura Tyson eds., 1983).

6. Michael E. Porter, The Competitive Advantage of Nations 89 (1990); *see, e.g.,* Thomas Andersson et al., The Cluster Policies Whitebook 16–18 (2004), *available at* http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.118.7546&rep=rep1&type=pdf.

7. *See* Annalee Saxenian, Regional Advantage 165 (1994); *see also* Andersson et al., *supra* note 6, at 39 (citing Saxenian for the proposition that R&D clusters grow faster than the economy in general).

The most comprehensive summary of cluster performance and policy to date has been *The Cluster Policies Whitebook* ("Whitebook"), which investigates "whether, when, and how policymakers can and should attempt to enable or strengthen clustering."[8] The Whitebook clarifies the cluster concept by identifying elements that define a cluster, demonstrating the importance of and factors that lead to innovation, and evaluating various policy frameworks for fostering cluster success, including broker, demand-side, international linkage, training, and policies. The Whitebook also takes into account the various stages in the life cycle of clusters and different categories of clusters. The Whitebook project emerged following the 2003 publication of The Cluster Initiative Greenbook, which provided survey-based data on 238 self-reported cluster initiatives.[9]

B. *Cluster Mapping Projects*

Data in the cluster field have grown considerably in the past ten years. There are currently three significant cluster mapping projects that are attempting to document the location of clusters and the policies and programs that support them. The most robust resource for cluster data is at Michael Porter's Institute for Strategy and Competitiveness at Harvard University. The Institute's *U.S. Cluster Mapping Project* uses Standard Industrial Classification ("SIC") codes to sort data on employment, establishment, wages and patent inventor locations into various geographic levels, including states, economic areas, metropolitan areas, and counties. Thus, clusters are empirically determined by the concentration patterns of SIC-coded data. Due to SIC-code data limitations, this resource is only available for the United States.[10]

The *European Cluster Observatory*, modeled after the U.S. Cluster Mapping Project, also uses SIC coding to observe trends. The project is based at the Center for Strategy and Competitiveness at the Stockholm School of Economics with support from the European Union's INNOVA initiative, which fosters entrepreneurial innovation across the EU.[11]

The Competitiveness Institute, a non-profit organization based in Barcelona, Spain, has set up a *Cluster Initiatives Database* that sorts cluster initiatives by location, industry, and programmatic type, providing high-level indicators on the budget, employees, the number of businesses encompassed, and sales figures as well as contact information for the organ-

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8. Andersson et al., *supra* note 6, at vii.

9. *Id.* at 19.

10. *Cluster Mapping Project*, Harv. Bus. Sch. Inst. for Strategy & Competitiveness, https://secure.hbs.edu/login/isc-cmp-us/index.html (last visited Apr. 14, 2011). The North American Industrial Classification System (NAICS) is the successor to the SIC code system and was designed to facilitate comparison of industries throughout North America.

11. *European Cluster Observatory Overview*, Eur. INNOVA, http://www.europe-innova.eu/web/guest/eu-cluster-observatory/overview (last visited Apr. 14, 2011); *About*, Eur. INNOVA, http://www.europe-innova.eu/web/guest/about (last visited Dec. 12, 2011).

izations that run a given cluster initiative. In contrast to the *U.S. Cluster Mapping Project*, this data is self-reported and organized by initiative rather than raw industry agglomeration, thus excluding clusters that lack organizing bodies (such as Silicon Valley) and perhaps including cluster initiatives that lack true industry agglomerations.[12]

II. Will the Electric Vehicle Industry Cluster?

A. *Why Do Industries Cluster?*

Some, but not all, industries cluster. Whether an industry will benefit from agglomeration is determined by several criteria discussed below.

Economies of Scale

Industries with economies of scale will benefit from shared infrastructure, labor pools, and knowledge transfer in clustered contexts. The more businesses choose to locate in a cluster, the more supporting services (e.g., worker training, transportation, and intermediate goods) will be available. These agglomeration economies were first noted by Alfred Marshall and later formalized by Paul Krugman as a "pooled market for workers with specialized skills" and "non-traded inputs specific to an industry in greater variety and at lower cost."[13]

Tacit Knowledge

Tacit knowledge—knowledge that is not easily codified—requires informal interactions for transfer and generation of new ideas. Tacit knowledge is most important during the early stages of an industry's life cycle. This tacit knowledge is related to the local knowledge spillovers and positive externalities theorized by Alfred Marshall and documented in the 1990s. This phenomenon is widely cited as an underlying reason for the success of Silicon Valley and the high level of new business formation and innovation that happened there.[14] According to one authority on the history of Silicon Valley,

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12. *Cluster Initiatives List*, TCI Network, http://www.tci-network.org/cluster/initiatives (last visited Apr. 14, 2011).

13. Krugman, *supra* note 4, at 36–37.

14. Neslihan Aydogan & Yiu Por Chen, Social Capital and Business Development in High-Technology Clusters: An Analysis of Contemporary U.S. Agglomerations (2008); David B. Audretsch & Maryann P. Feldman, *Innovative Clusters and the Industry Life Cycle*, 11 Rev. Indus. Orgs. 253, 270 (1996), *available at* http://www.rotman.utoronto.ca/feldman/papers/audretsch&feldman1996innovationcluster.pdf; Neslihan Aydogan & Thomas P. Lyon, *Spatial Proximity and Complementarities in the Trading of Tacit Knowledge*, 22 Int'l J. Indus. Org. 1115 (2004).

> [I]nformal conversations were pervasive and served as an important source of up-to-date information about competitors, customers, markets, and technologies. Entrepreneurs came to see social relationships and even gossip as a crucial aspect of their businesses . . . such informal communication was often of more value than more conventional but less timely forums such as industry journals . . . . [L]ocalized accumulation of technical knowledge enhanced the viability of Silicon Valley start-ups and reinforced a shared technical culture . . . with a shared language and shared meanings . . . .[15]

Fast Feedback

High-technology industries that need to quickly bring a product to market or make changes to an existing product must keep research and development ("R&D"), suppliers, and manufacturing functions close together. This enables the challenges of manufacturing to be appropriately incorporated into the R&D process, and new R&D products to be quickly brought into production. When industries need to quickly move a product to market, seamless communication between these functions is critical. This can be observed in the success of Intel Corporation, which achieved early success by taking advantage of a superb manufacturing capacity that allowed it to transfer new products from R&D to manufacturing almost immediately, and months before others could copy the knowledge.[16]

Value of Standardization

Product standardization can be facilitated when major players along the value chain work together to form common standards, which can drive economies of scale. The success of standardization can be observed in the affordable production of the standardized 18650 laptop computer battery.[17]

Cost of Transportation

Transportation costs play an important yet subtle role in clustering. Very high transportation costs inhibit clustering because production must occur in close proximity to customer demand to minimize the need for transportation. If supplies are difficult to transport while the final product is relatively easy to transport, then clustering becomes more appealing. This is consistent with Krugman's argument that clustering is increasingly found in the service

15. Saxenian, *supra* note 7, at 33, 37.

16. Interview with Minyuan Zhao, Assistant Professor of Strategy, Ross Sch. Bus., Univ. of Michigan, in Ann Arbor, Mich. (Feb. 20, 2009); *see also infra* Interviews Conducted (detailing the specifics of the interview process).

17. Stanley Besen & Joseph Farrell, *Choosing How to Compete: Strategies and Tactics in Standardization*, 8 J. Econ. Persp. 117 (1994); Interview with Ralph Brodd, President of Broddarp of Nev., Inc. (Feb. 13, 2009); *see also infra* Interviews Conducted (detailing the specifics of the interview process).

sector (e.g., financial services in London, Tokyo, and New York) rather than the manufacturing sector.[18]

Industry Maturity

The tendency for innovative activities to spatially cluster is linked to the stage of the industry's life cycle. When an industry is in its emerging stages, knowledge is elusive and changes rapidly, making it beneficial for companies to be in close physical proximity to one another. The theory of knowledge spillovers suggests that geographic proximity matters most in contexts where tacit knowledge plays an important role in generating innovation. In contrast, evidence suggests that during the mature and declining stages of the industry life cycle, further increases in an industry's geographic concentration tend to yield to more dispersed innovation activity, suggesting "that new ideas need new space, at least during the mature and declining stages of the industry life cycle."[19] The greater dispersion of innovation during the mature and declining life-cycle stages suggests that the positive agglomeration effects of the early stages of the industry life cycle may be replaced by congestion effects during the later stages.[20]

B. *Why Did the U.S. Auto Industry Cluster in Detroit?*

In order to better understand the future of the Detroit automobile production cluster in the absence of significant changes in the value chain or policy intervention, we evaluate the drivers that caused the industry to cluster in Detroit initially. As described below, the level of agglomeration in Detroit has experienced much variation over time.

More than half of automakers in the 1890s were dispersed along the Northeast corridor between Philadelphia and Boston, but Detroit quickly attracted and retained the strongest automakers due to Michigan's established expertise in the production of carriages and steamship engines. There were 125 automakers in Michigan during the first decade of the twentieth century, and 42% of all cars were made in Michigan by 1904. By World War I, 80% of auto assembly occurred in southeast Michigan and nearly all auto-related production was clustered around surrounding Midwestern states.[21]

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18. Krugman, *supra* note 4, at 65–67.

19. Audretsch & Feldman, *supra* note 14, at 254.

20. Andersson et al., *supra* note 6, at 21; Audretsch & Feldman, *supra* note 14, at 271; David B. Audretsch & Maryann P. Feldman, *R&D Spillovers and the Geography of Innovation and Production*, 86 Am. Econ. Rev. 630, 639 (1996); Aydogan & Lyon, *supra* note 14, at 1120.

21. Thomas H. Klier & Daniel P. McMillenic, *Evolving Agglomeration in the U.S. Auto Supplier Industry* (Fed. Res. Bank Chi., Working Paper No. WP 2006-20, 2006), *available at* http://www.chicagofed.org/digital_assets/publications/working_papers/2006/wp2006_20.pdf (last visited Apr. 17, 2011); James M. Rubenstein, *The Evolving Geography of Production—Is Manufacturing Activity Moving Out of the Midwest? Evidence from the Auto Industry* (1996),

Shortly after World War I, the Ford Motor Company determined that the cost of shipping the Model T from its centralized Detroit assembly plant was greater than the cost of shipping parts to branch assembly plants at major population centers, leading the company to introduce a decentralized "branch plant assembly system" for Model T production. As GM and Chrysler imitated this innovation, Michigan's share of vehicle assembly dropped from 80% to 40%. Parts manufacturing remained concentrated in Detroit, and these parts were shipped to assembly plants near population centers where they were assembled for sale to consumers. The regionalized branch plant assembly system was possible because the various models produced under one nameplate, such as Chevrolet, differed in only minor details—there were no significant differences within these brand identities.[22]

Reclustering of Assembly Plants Since the 1960s

Increased foreign competition in the 1960s led to significant increases in product variety. With a greater variety of products relative to overall demand, it made less sense to have multiple assembly facilities for each product, pressuring the auto industry to reconsolidate. Because the output for any given product came from only one plant, the distribution cost-minimizing location for that plant was the interior of the country, specifically the I-75/I-65 corridor that runs from Michigan's Upper Peninsula to Miami (I-75) and Chicago to Birmingham (I-65).[23]

Two important punctuations facilitated this reconsolidation of assembly plants. The oil embargo of the late 1970s drove many automakers to shutter coastal assembly plants in favor of the Midwest, and the introduction of just-in-time production systems made it critical for suppliers and assembly plants to be in close proximity to minimize inventory and working capital costs.[24]

Foreign automakers set up several production and assembly facilities in the United States in the 1980s, focusing their investment in Tennessee and Kentucky, and more recently in Alabama and Mississippi, at least in part with the intention of avoiding Detroit's powerful labor unions. This migration southward deepened the I-65/I-75 corridor into the South. Labor-intensive production in particular has migrated southward in recent decades,

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available at http://www.chicagofed.org/digital_assets/others/events/1996/the_midwest_economy/1996_midwest_economy_structure_and_performance_ruben.pdf (last visited Apr. 17, 2011); Thomas J. Sugure, *Motor City: The Story of Detroit*, The Gilder Lehrman Inst. of Am. Hist. (Mar. 2007), http://www.gilderlehrman.org/historynow/03_2007/historian6.php.

22. Rubenstein, *supra* note 21, at 4–5.

23. *Id.* at 5–6.

24. Klier & McMillenic, *supra* note 21, at 2.

leaving higher value-added production such as engines, transmissions, and large stampings more heavily concentrated in the Midwest.[25]

Supplier Plants Declustering and Subsequent Reclustering

While Michigan, Ohio, Indiana, Illinois and Wisconsin contain 77% of currently-operating supplier plants that were built before 1960s, they contain only 47% of the plants built since 1970. The supplier plants largely shifted towards the Southeast since the 1960s, almost certainly driven by the prospect of lower wage costs. GM pursued the southern-shifting strategy, but unions were able to organize in these areas, stifling GM's labor cost-saving strategy. Foreign automakers, however, have seen considerable success in avoiding unionization in the Southeast region.[26]

Re-clustering of these suppliers resumed, however, in the 1990s. Twenty-two of the thirty-five U.S. supplier plants that opened between 1990 and 1995 were located in the Midwest, primarily outside the Detroit metropolitan area in southwestern Michigan, northeast Indiana and northwestern Ohio. This recent re-clustering has been driven by the combination of lower inventory levels and lean manufacturing requirements for tight linkages between assembly and supplier plants, driving tighter spatial linkages between suppliers and assemblers. These forces, as well as the need for proximity to corporate offices, research facilities, and assembly plants offered by the Detroit-area, were weighed against the low land cost, uncongested access to long-distance interstate highways (I-69, I-80, I-90, I-94, I-96), and a fresh non-Fordist labor force, resulting in investments in the Michigan region, but outside of metropolitan Detroit.[27]

In substantial part, clustering has been driven by affiliation with the Big Three automakers—Ford, General Motors, and Chrysler. Parts suppliers with historical connections to the Big Three automakers, such as Delphi, have located closer to Detroit's assembly facilities, while independent suppliers and those affiliated with foreign automakers have spread out farther, clustering more around assembly plants in the Southeast.[28]

Clustering is also driven by the type of part supplied. The Midwest contains three quarters of engine and brake plants and about two thirds of body, trim, and drivetrain plants. On the contrary, the Midwest contains only nine percent of tire plants and about one-third of cooling, interior, and

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25. Thomas H. Klier, *Agglomeration in the U.S. Auto Supplier Industry*, 23 FED. RES. BANK OF CHI. ECON. PERSP., no. 1, 1999, at 18, 18–19; Klier & McMillenic, *supra* note 21, at 6–7.

26. Klier, *supra* note 25, at 7–10.

27. *Id.* at 30–31; Thomas H. Klier, *Geographic Concentration in U.S. Manufacturing: Evidence from the U.S. Auto Supplier Industry* 30 (Fed. Res. Bank of Chi., Working Paper No. WP98–17, 1998), *available at* http://www.chicagofed.org/digital_assets/publications/working_papers/1998/wp98_17.pdf (last visited Apr. 17, 2011).

28. Klier, *supra* note 27, at 8.

mechanical plants.[29] The traditional automotive value chain has been broken into the following components, which are driven to cluster in varying degrees by very different factors, discussed below.

Engine and Engine Components

Automakers produce nearly all of their own engines, and they do so in close proximity to final assembly sites in the Midwest. Engine components (pistons, valves, cylinder sleeves, camshafts, fuel, and exhaust systems) also remain in the Midwest. Reasons for the high degree of agglomeration include:

- Few new engine component factories have been built in recent years;
- Proximity to main customers is critical; and
- Engine manufacturing requires a highly skilled workforce with experience in engine manufacturing.[30]

Cooling Systems

Only one-third of plants that make cooling equipment are located in the Midwest, and only one-sixth of cooling equipment plants built since 1970 are located in the Midwest. New York, Tennessee, Missouri, and California are centers of production. Reasons for the low degree of agglomeration include:

- Air conditioning industry is a relatively new industry;
- Air conditioning industry is relatively stand-alone; and
- There are a large number of foreign players.[31]

Electrical Systems

More than half of electronic systems plants are located in the Midwest (Kokomo, IN, and Warren, OH), but recently plants have followed low labor costs in the Southwest and Mexico. The continued high degree of agglomeration may be attributed to Delphi's size as the largest supplier of automotive electrical and electronics components.[32]

Drivetrain

Two-thirds of current drivetrain plants are in the Midwest. Nearly all transmission plants for the Big Three automakers are located in the Midwest, but less than half of all new drivetrain plants are located in the

29. Rubenstein, *supra* note 21, at 9.
30. *Id.* at 10.
31. *Id.*
32. *Id.* at 11.

Midwest. The migration out of the Midwest is detectable in all new construction of drivetrain component plants, with transmission components and axles being least likely to locate there.[33]

Brakes

Brake production is a highly-skilled operation that remains heavily clustered in the Midwest. Half of all new plants, however, are in the Southeast and built by foreign market entrants.[34]

Other Mechanical Components

Thirty percent of existing plants and ten percent of new plants are located in the Midwest. These components are made in large batches of small, standardized parts that are not usually needed for just-in-time delivery, limiting the need for clustering.[35]

Body

Body stamping plants are mostly located in the Midwest because body panels are bulky, fragile, and must be stamped near final assembly plants due to transportation challenges.[36]

Interior

Thirty-three percent of airbags and forty-one percent of seats are made in the Midwest. The low degree of agglomeration for these industries is likely due to the low levels of production skill required for these parts, and the low levels of integration with the more central vehicle components.[37]

Trim

Two-thirds of trim plants are in the Midwest, and they have not drifted towards the Southeast. The lingering high degree of agglomeration is often attributed to the proximity to Midwestern raw material sources and markets.[38]

Tires

Only two of the twenty-three original equipment tire plants are in the Midwest. Seventeen are in the Southeast. The low degree of agglomeration likely results from the following:

33. *Id.* at 12.
34. *Id.* at 14.
35. *Id.* at 14–15.
36. *Id.* at 15.
37. *Id.*
38. *Id.* at 17.

- Tires are particularly low-value-added products that are less integrated into the automotive production process.
- Because labor costs represent a high portion of tire production costs, non-union and low-cost Southeastern labor is attractive.[39]

Summary of Critical Drivers of Location Decisions

Summarizing the agglomeration drivers discussed above, the critical drivers of location decisions for auto parts suppliers include:

- Highway access;
- Proximity to corporate offices;
- Proximity to research facilities;
- Less than one day driving time to assembly centers;
- Land costs; and
- Labor quality.

The opening of several new assembly plants in the Deep South in the 1990s has squeezed Midwestern suppliers by putting them more than one day's drive from many plants that require just-in-time delivery. While it is widely understood that the auto industry continues to be a strong regional cluster, it appears that the local cluster within Michigan has been weakened considerably by the appeal of the southern regions of the corridor.[40]

C. *Will the Electric Vehicle Industry Cluster?*

An evaluation of the PEV supply chain indicates that it is highly likely that the industry will cluster. Figure 2 provides information on the key components of the PEV value chain. The essential parts of the PEV value chain that distinguish it from the value chain for the traditional internal combustion engine ("ICE") are:

- Energy storage, including battery R&D, manufacturing and assembly, and ultracapacitors;
- Power electronics and control equipment and software, including thermal management for battery packs;

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39. *Id.*; Klier, *supra* note 25, at 19.

40. Klier, *supra* note 25, at 19; *see* Thomas H. Klier, Senior Econ., Fed. Res. Bank of Chi., & James M. Rubenstein, Professor, Miami Univ. of Ohio, The Supplier Industry in Transition—The New Geography of Auto Production, Presentation at Fed. Res. Bank of Chi. Detroit Branch Conference (Apr. 18, 2006), *in* Chi. Fed. Letter, *available at* http://www.chicagofed.org/digital_assets/publications/chicago_fed_letter/2006/cflaugust2006_229b.pdf.

- Grid interface electronics; and
- Electric motors.[41]

Below we discuss the key factors that drive clustering as they relate to these essential components of the PEV value chain. We place particular emphasis on energy storage and the associated power electronics, the areas where the greatest advances in technology are anticipated.

Tacit Knowledge

The pace of development in battery technology and power electronics and controls, is often faster than industry journals can cover. Interviews with battery producers as well as power electronics and controls producers indicate that conversations around new business models and technologies play a major role in conveying information in these spaces.[42]

Fast Feedback

Interviews with battery and power electronics and controls manufacturers are mixed regarding the value of proximate R&D and manufacturing capacity. One interviewee suggested that this close relationship was critical to "put out fires" and quickly move products to market in response to customer demands. Another interviewee cited advances in communication technology as effectively bridging much of the distance gap. Interviewees agreed that technology could not fully bridge the distance gap, but disagreed as to the relative costs at issue.[43]

Value of Standardization

Advanced batteries, power electronics and controls, and electric motors are likely to seek standardization due to the economies of scale that can be generated. The success of standardization can be observed with the 18650 laptop computer battery, which has become standardized and can be affordably produced. Some experts disagreed about the value of all forms of standardization, arguing that manufacturers would be hesitant to completely standardize because differentiation between products is critical in this space.[44] It is likely that a mature advanced vehicle battery market will be characterized by a high level of standardization.

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41. Interviews with Industry Experts (2009); *see also infra* Interviews Conducted (detailing the specifics of the interview process).
42. Interviews with PEV Supply Chain (2009); *see also infra* Interviews Conducted (detailing the specifics of the interview process).
43. *Id.*
44. Brodd Interview, *supra* note 17; Industry Experts Interviews, *supra* note 41.

Economies of Scale

Like the traditional internal combustion vehicle, the anticipated mass production for the electric vehicle is expected to drive very large economies of scale and benefit substantially from network effects and agglomeration. High capital and upfront R&D costs, particularly in advanced battery development, mean that the industry will depend heavily on economies of scale for profitability. According to one interviewee, "[f]or success in this industry, the successful companies will be global due to the enormous upfront costs of manufacturing equipment and R&D."[45]

Cost of Transportation

Interviews with battery producers indicate that these products are very expensive to ship due to their weight and careful handling requirements. Therefore, it is attractive for battery pack assembly operations to be located within a 300-mile radius of their customers, the automakers. According to one industry expert, "[s]hipping these batteries across international boundaries is untenable. It is not tenable for the cells to be shipped overseas long-term—they are fragile, heavy, and expensive, and the U.S. market is too vast: seventeen million units. Without the cell development, we are not really in the game."[46] Electric motors were cited as less expensive to ship, but equally beneficial to have within a day's shipping distance. Power electronics and controls were not noted to have transportation-related benefits.[47]

Industry Maturity

While the mature automotive industry may tend to drive innovation away from its core, as witnessed by the emergence of electric car commercialization efforts outside of Detroit (e.g. Tesla in California or BYD Co. in China), the advanced automotive battery, power control electronics, and electric motor industries that support electric vehicle development are entering a growth phase that will tend to re-concentrate innovation. Each of these industries was classified as "nascent" by the interviewees. While these industries have seen maturity in previous applications (electric motors for stationary applications, power electronics for various small electronics, advanced batteries for laptops), the system requirements of electrified transportation differ radically, and those requirements must be brought to manufacturing scale and incorporated into the vehicle interface.[48] This spotlights the opportunity and challenge that the emergence of the PEV presents to Michigan.

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45. PEV Supply Chain Interviews, *supra* note 42.
46. *Id.*
47. *Id.*
48. *Id.*

The set of drivers listed above, taken together, will tend to cause the PEV supply chain to cluster. If Michigan is unable to accommodate these innovations, the innovative core will develop elsewhere.

III. What Are the Drivers of Successful Clusters?

Cluster policies and initiatives occur in a variety of different cultural, political and industrial landscapes, making it difficult to create best practices knowledge that is externally valid.

A primary challenge to researching cluster policies is that of determining what counts as a cluster policy. Policies labeled under various headings including regional, industrial, innovation, and science policy are often, in effect or intent, cluster policies in as much as they contribute to the creation of an environment of cooperative innovation among stakeholders in a region. Further, because clusters are strongly embedded in the overall economy, they are greatly affected by various policies that are not explicitly focused on economic development or competitiveness at all, such as tax and intellectual property law.[49]

A second challenge is that "cluster initiatives" rarely correlate well with the cluster ideal identified by the academic literature. In practice, clusters appear to be designated based on political momentum and limited choices rather than economic rationale or the opportunity for legitimate competitive advantage. Several initiatives have sought to overcome this by identifying clusters through more deliberate methodology, including the SIC codes and County Business Pattern data in the Cluster Mapping Project at Harvard University and "locational gini coefficients."[50]

A third challenge is that even when cluster policies and initiatives can be identified, their impact is empirically difficult to document. The measurement challenges facing cluster impact assessments are driven by several factors.

First, cluster policies tend to be driven by support for multiple clusters and projects, making it difficult to disaggregate the impact of policies tailored for one cluster from those tailored for another in the same regional or national jurisdiction.

Second, cluster policies generally combine a range of different types of policy measures within a single program, making it difficult to disaggregate the effects of specific policies. Because few cluster programs share the same mix of policy initiatives, evaluation efforts are difficult to generalize.

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49. European Commission Expert Group, Final Report of the Expert Group on Enterprise Clusters and Networks 10 (2003), *available at* http://www.bth.se/tks/ctup.nsf/(WebFiles)/728464CC5D72546BC1256F4A00590E1B/$FILE/EuropeanClusters%20eu.pdf.

50. Krugman, *supra* note 4, at 129.

Third, cluster policies focus heavily on fostering innovative capacity, which itself faces significant measurement challenges.[51]

In addition to these external validity and impact measurement challenges, the idiosyncratic nature of clusters means that some of the general characteristics that are identified as prevalent in many clusters may be useless, or even undesirable, in other clusters.[52]

Despite these challenges, extensive research efforts of varying quality have been placed on determining the characteristics of successful clusters. The existing literature returns to several key characteristics of clusters.

Clusters are by nature self-reinforcing. Their "gravitational" force tends to attract the inputs of innovation and talent as well as produce these characteristics as outputs. Although these feedback loops and the aforementioned measurement challenges make it nearly impossible to document causality between any specific factor and cluster success, certain characteristics are present to a greater extent in successful clusters. Each of these characteristics is explored below in greater detail. This Article discusses the theoretical literature that seeks to explain and document these mechanisms and identifies the cluster initiatives that have successfully implemented programs to support them. The measurement and development of these characteristics in the region will advance the development of Michigan's electric vehicle cluster.[53]

A. *Presence of Functioning Networks and Partnerships*

Formal and informal knowledge flows within a cluster are a critical underpinning of success that is cited throughout the research literature.

Theory: Localized Knowledge Spillovers

By concentrating intellectual capital in a given area, industrial districts foster the spillover of technological knowledge between firms and institutions. These spillovers are pure externalities that result simply from the close proximity of related firms. Due to their ethereal nature, localized knowledge spillovers are challenging to document, and they remained largely theoretical until recently. It has been demonstrated that the clustering patterns are not fully accounted for by economic activities alone, suggesting that the benefits of local knowledge spillovers may justify this additional agglomeration. Economists used patent citations—a rich data source of documenting the intellectual history of innovations and their geographical

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51. Philip Raines, Senior Research Fellow, European Policies Research Ctr., Univ. of Strathclyde, The Challenge of Evaluating Cluster Behavior in Economic Development Policy, Presented at the International RSA Conference, Evaluation and EU Regional Policy: New Questions and Challenges (May 31, 2002), *available at* http://www.eklaster.org/old/_files/stale/RAINES.PDF.

52. Andersson et al., *supra* note 6, at 30.

53. *Id.*

locations—to demonstrate the existence of local knowledge spillovers by showing that knowledge flows were more localized than would be predicted by industrial agglomerations alone. Agglomeration has also been demonstrated to affect private and university R&D investments,[54] as well as industry employment.[55] Critics have challenged the econometric validity of these studies, but have not directly demonstrated the absence of local knowledge spillovers. Local knowledge spillovers have become a key aspect of New Growth Theories, which seek to explain regional variations in growth rates based on region's differing capacities to exploit knowledge spillovers.[56]

Example: Austin

Sematech, an Austin-based R&D consortium of U.S. semiconductor companies, was formed in 1987 to counter the perceived threat posed by Japanese semiconductor firms. Sematech's unique challenge was that its sponsors (AT&T, IBM, Intel, and Texas Instruments) were not based in Austin, limiting the role of casual contact in fostering knowledge transfer. The consortium has attributed most of its success in transferring knowledge to human factors. In order to support knowledge transfer, the consortium used "assignees", representatives from sponsoring firms who would spend time in Austin, participate in research activities, and take ideas back to their respective firms.[57]

Example: Silicon Valley

Early institutional innovations in Silicon Valley built an early and strong relationship between academia and industry. These institutional innovations included the establishment of the Stanford Research Institute, which was focused on practical rather than basic science; the Honors Cooperative Program, which connected engineers at local electronics companies to Stanford's classrooms; and the Stanford Industrial Park, one of the first such parks in the country.[58]

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54. Luc Anselin et al., *Local Geographic Spillovers Between University Research and High Technology Innovation*, 42 J. Urb. Econ. 422 (1997).

55. Edward L. Glaeser et al., *Growth in Cities*, 100 J. Pol. Econ. 1126 (1992).

56. Philippe Aghion & Peter Howitt, Endogenous Growth Theory 106 (1997); Krugman, *supra* note 4; Audretsch & Feldman, *supra* note 20; Stefano Breschi & Francesco Lissoni, *Localized Knowledge Spillovers Versus Innovative Milieux: Knowledge "Tacitness" Reconsidered*, 80 Papers in Regional Sci. 255 (2001); Glaeser, *supra* note 55; Adam B. Jaffe et al., *Geographical Localization of Knowledge Spillovers as Evidenced by Patent Citations*, 108 Q.J. Econ. 577, 577–98 (1993).

57. Thomas H. Davenport & Sven C. Völpel, *The Rise of Knowledge Towards Attention Management*, 5 J. Knowledge Mgmt. 212, 219 (2001).

58. Saxenian, *supra* note 7, at 23.

Application to Michigan

Partnerships between companies in this market are challenging due to a *winner-take-all* perception and the sense that the parties are racing against one another to successfully commercialize the EV. Interviewees in power electronics, batteries and electric motor production viewed the hesitancy for cross-company collaboration as well justified, attributing this attitude to the nature of the industry, rather than the state of Michigan. One industry expert stated, "I see very little space for 'precompetitive collaboration' in the automotive drivetrain. Whoever wins the race for the next generation of automotive buyers is going to knock it out of the park. It is very important to have cooperation between industry and academia, and industry and federal labs, but private-sector-to-private-sector collaboration is not likely. Any company that has the financial wherewithal to do it alone, will do it alone."[59]

While pre-competitive collaboration was approached with skepticism, interviewees tended to agree that functioning networks and partnerships up and down the supply chain would be critical in the development of electric vehicles. Battery R&D, cell manufacturing, and cell pack assembly firms all have an interest in co-location with automobile assemblers due to the resulting savings in selling, general and administrative expenses ("SG&A") and logistics, as well as the ability to quickly understand and respond to production challenges. According to one strategic decision-maker at a major lithium-ion battery manufacturer, it is critical that there be a close relationship between various components of the value chain in this space:

> There is a great deal of sharing and transparency that will be needed to make this successful. You are sharing a great deal of confidential and propriety information between customer[s] and suppliers at a level that I have not seen before with power electronics or audio or some of the other system-level components of cars that an electronics supplier would share.

Others stated that "[t]his cannot be done in a black box," and "[t]he level of understanding and sharing on both sides must be pretty transparent to be successful. You have teams working almost like they are in the same company."[60]

The current status of Michigan's networks and partnerships receives mixed reviews from individuals involved in various components of the value chain. The Big Three automakers have developed strong supply chain networks across the Midwest auto corridor, and battery manufacturers that are in partnership with the Big Three automakers report high levels of collaboration and information sharing, acknowledging both public-facing collaboration efforts and confidential business partnerships that are in devel-

59. PEV Supply Chain Interviews, *supra* note 42.
60. *Id.*

opment. However, the size of the Big Three automakers makes it difficult to sell to them. One battery manufacturer states that "[f]or us it has worked out very well . . . but it's tough to supply to the automotive industry because they are big companies and you have got to get to the right person. A lot of approvals need to happen to get something from the outside into the vehicle."[61]

B. *Strong Innovation Base, Supporting R&D Activities when Appropriate*

Innovation is increasingly seen as the critical and defining cornerstone of successful clusters. The relevance of innovation extends beyond R&D activities, encompassing technology application, management system design, marketing, packaging, labor development, and every other aspect of business. A large body of literature studies the factors that contribute to innovation in business, but it is generally agreed that innovation requires supporting institutions as well as interaction between various actors in the innovation process.

Theory: National Systems of Innovation

The literature on national systems of innovation explores the links between various value-creating activities and the importance of coordinating mechanisms that can facilitate collaboration and cooperation. Due to their dynamics, system characteristics, and interdependencies, clusters can be viewed as innovation systems operating on a sub-national scale. Literature regarding the building of successful innovation systems has had a significant impact on cluster policy strategy.[62]

A region's capacity to innovate is a primary driver of its productivity: maintaining and increasing a region's standard of living requires steady productivity growth, which requires innovation. Several factors are prevalent in countries with the most innovative firms. Education programs directed towards industry, export-supporting macroeconomic policy, and R&D partnership structures correlated with innovative industries.[63]

A firm's innovative capacity depends on its capacity to organize complementary knowledge in strategic production networks with customers, competitors, and their specialized suppliers. There are three traditional rationales for government intervention into this market-driven phenomenon, discussed below.

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61. *Id.*

62. *See* Theo J.A. Roelandt & Pim den Hertog, *Cluster Analysis and Cluster-Based Policy Making in OECD Countries: An Introduction to the Theme*, *in* BOOSTING INNOVATION: THE CLUSTER APPROACH 9, 9 (Org. for Econ. Co-Operation & Dev. Ed., 1999).

63. MICHAEL E. PORTER, CLUSTERS OF INNOVATION: REGIONAL FOUNDATIONS OF U.S. COMPETITIVENESS (2001), *available at* http://www.compete.org/images/uploads/File/PDF%20Files/CoC_Reg_Found_national_cluster.pdf.

Creation of Favorable Framework Conditions

The government can prevent collusive and anti-competitive behavior and generally facilitate smoothly functioning markets through regulatory reform.

Positive Externalities

R&D and knowledge creation bring positive externalities. Because the social rate of return of investment on knowledge creation is larger than the private rate of return, government should facilitate increased investment. This is likely to be the case in energy, the environment, infrastructure, or large-scale innovation projects. Small and medium-sized enterprises are often unable to capture the benefits of increased linkages and knowledge sharing.

Government's Role as a Player in Some Markets

Government is also a player in the market and may be able to "pull through" innovation through effective procurement policies to fit its needs.[64]

Application to Michigan

A key core competency is Michigan's high concentration of universities and intellectual capital, particularly with regard to engineering and automotive development. Academic research and interviews with battery experts indicate that partnerships with universities and national laboratories are expected to be critical for the commercialization of battery technology. Though Michigan lacks a national laboratory, the national laboratory system in the United States has developed partnerships across various geographies, and such partnerships will help to ease funding and institutional barriers between these research entities. The State of Michigan is currently brokering a Cooperative Research and Development Agreement ("CREDA") partnership with the Oak Ridge National Laboratory and Michigan-based players in the automotive and battery value chain, with a focus on the development of PEVs.[65]

C. *Strong Skills Base*

Successful clusters develop and nurture a strong skills base, both in management and the labor force. There is strong qualitative evidence, based on interviews with relocating companies within clusters, suggesting that labor skill is a primary reason for location and relocation.[66]

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64. Roelandt & den Hertog, *supra* note 62, at 17.

65. Brodd Interview, *supra* note 17; PEV Supply Chain Interviews, *supra* note 42.

66. EcoTec Research & Consulting, A Practical Guide to Cluster Development (2003), *available at* http://www.dti.gov.uk/files/file14008.pdf.

Theory: Labor Market Pooling

By concentrating an industry's firms in one geographic location, an "industrial district" fosters a pooled market for workers with specialized skills. Because peaks and lulls in each company's demand for labor will not be perfectly correlated, the dense concentration of labor can smooth out those extremes, so companies are more likely to find labor needed in times of high demand, and workers are more likely to find work in times of low demand. For companies to derive these labor-pool risk-mitigation benefits from cluster localization, they must first possess economies of scale that lead them to operate in few locations rather than many dispersed locations.[67]

In a recent study of six high-tech clusters, highly skilled technical labor has been identified as a necessary precondition for growth in the information communication technology-based entrepreneurial clusters in Israel, Taiwan, Ireland, India, Silicon Valley, and Cambridge.[68]

Example: Silicon Valley

With regard to technical skills, Stanford University and the University of California, Berkeley developed strong programs to train electrical engineers. California's state and community colleges offered strong technical programs, linkages to local firms, and an associate of science degree in semiconductor processing. Gordon Moore, a member of the "traitorous eight" who left Shockley Semiconductor Laboratory to form Fairchild Semiconductor, is widely regarded as a founding father of Silicon Valley. Moore asserts that the development of a skilled class of "technologist-managers," the first of their kind, was a critical component of the successful launch of Silicon Valley.[69] According to Moore, "Rather than representing simply a discrete shift in management style or technique, the proliferation of technologist-managers is emblematic of a widespread human-capital deepening. This new human capital, which could only be developed through experience, linked technical possibility to market need."[70] Moore does not imply that this particular form of human capital is critical for the development of all clusters, but it was critical for the development of Silicon Valley's semiconductor industry.[71]

Because high-tech clusters present significant challenges in commercializing scientific and technical advancements, they present new marketing

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67. *See* KRUGMAN, *supra* note 4, at 39.

68. *See* Timothy Bresnahan & Alfonso Gambardella, *Old-Economy Inputs for New-Economy Outputs: What Have We Learned?*, *in* BUILDING HIGH-TECH CLUSTERS: SILICON VALLEY AND BEYOND 343 (Timothy Bresnahan & Alfonso Gambardella eds., 2004).

69. Gordon Moore & Kevin Davis, *Learning the Silicon Valley Way*, *in* BUILDING HIGH-TECH CLUSTERS: SILICON VALLEY AND BEYOND 4–7 (Timothy Bresnahan & Alfonso Gambardella eds., Cambridge Univ. Press 2004).

70. *Id.* at 13–14.

71. *See* SAXENIAN, *supra* note 7, at 42; Moore & Davis, *supra* note 69, at 13–14.

and management challenges. Many nascent clusters rely on adapting and importing this management capability. While Silicon Valley initially grew by having its scientists and engineers learn the second skill of management, it gradually developed more sophisticated experiential training and mentoring systems. Repatriation has also played a critical role in the development of management talent: many native engineers and scientists have left their homes to gain skills in high-performing clusters such as Silicon Valley bringing critical management skills upon their return.[72]

Universities have been an important source of skilled labor in Cambridge and Silicon Valley since the 1960s, but they are not the exclusive way to achieve the necessary high-skills technical labor input. For example, Israel's military and technical institutes have been key suppliers of technical skills to its Silicon Wadi high-tech cluster. Immigration is also seen as a key source of high-skill technical labor in Israel, Silicon Valley, Taiwan, and India.[73]

Application to Michigan

Michigan's skilled manufacturing workforce remains one of its greatest strengths. However, the skills required for the production of PEVs differ from those required to develop the traditional internal combustion engine. Interviews with battery manufacturers indicated a high level of receptivity to existing training programs and an interest in further developing training programs to bring engineering talent into the region. Battery producers cited the Master of Energy Systems Engineering graduate program at the University of Michigan, the Michigan Alternative Energy & Renewable Energy Center at Grand Valley State University, and the Alternative Energy Initiative at Lansing Community College in collaboration with the National Alternative Fuels Training Consortium as valuable resources. Some interviewees commented on the strength of Michigan's general engineering expertise, calling it the best in the United States or second only to California. Michigan retains strong human capital regarding automotive and project management experience and has a growing foundation of battery expertise. Overall, Michigan's intellectual capital was rated very highly with regard to the production of PEV components.[74]

However, there was consensus among interviewees that Michigan lags behind Asian competitors in battery engineering intellectual capital. According to one interviewee, "Chinese/Korean investment levels in vehicle electrification give them a huge advantage." Battery producers indicated the need for more engineers and scientists, particularly with lithium-ion experience. Korea, China, and Japan were described as having intellectual capital

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72. Moore & Davis, *supra* note 69, at 13–14.
73. *Id*. at 47.
74. PEV Supply Chain Interviews, *supra* note 42.

that far outpaces the United States in this area of engineering. One interviewee stated that other locations in North America, including the states of Indiana, Ohio and California, as well as the Massachusetts Institute of Technology, the University of Waterloo, the University of Toronto, the California Institute of Technology, and The Ohio State University, have intellectual capital in battery technology development competitive with that of Michigan.[75]

Additionally, the mechanism of labor market pooling as an external economy of clustering relies heavily on labor market mobility and the transferability of skills. According to one interviewee, "[t]here must be an exchange of knowledge workers who are able to move from one firm to another and vote with their feet on the competing technologies."[76] Michigan's traditional work culture is highly immobile. The continuation of this immobility into the PEV production chain may compromise the way that skilled human capital can be leveraged to the benefit of the economic cluster.[77]

Lastly, some interviewees indicated that the general perception of Michigan as a strong union state is a potential detractor to new business development. This view did not surface in the majority of interviews, and it was cited as a driver of perceived higher costs, rather than actual higher costs of business.[78]

D. *Presence of Large Firms*

Large firms have been documented as important players in some clusters. This is most likely in "value chain clusters" such as Detroit, which have extended input-output or buyer-supplier chains comprising multiple sectors or industries. The mechanism underlying the relevance of large firms is their role in stimulating important cluster features, including hierarchically-structured assembler-supplier relations, extensive sub-contracting, the coexistence of several firms with complementary skills, and the existence of several integrated manufacturers. Large firms also play a key role in diffusing knowledge to small and medium-sized enterprises by generating spin-off startups. In addition, they provide a critical route to market for small and medium enterprises, facilitating their access to world markets.[79]

Application to Michigan

Michigan's Big Three automakers have historically played this role in creating Detroit's internal combustion engine cluster and are likely to continue to do so in their commercialization of the electric vehicle. This is

75. *Id.*
76. *Id.*
77. *Id.*
78. Industry Experts Interviews, *supra* note 41.
79. ECOTEC RESEARCH & CONSULTING, *supra* note 66, at 41.

unlikely to change despite the current financial and organizational challenges facing the industry, which are likely to make it more difficult for the Big Three automakers to catalyze the development of PEV technology. The importance of large firms does suggest that retaining original equipment manufacturers in Michigan will be critical in ensuring Michigan's successful development of the upstream components of the PEV value chain.

E. *Entrepreneurship: New Firm Formation and Firm-Building*

Theory

Firms that pioneer important innovations that generate new markets are likely to grow. With this growth will come forward and backward linkages creating additional demand for new entrepreneurship. Pioneering firms also provide a local source of training for managers and entrepreneurs.[80]

Application to Michigan

Though Michigan's start-up rate is relatively high for the Midwest region, it is about average relative to the rest of the nation. The Kauffmann Index of Entrepreneurial Activity, which rates the percentage of the adult, non-business owner population that starts a new business each month, places Michigan at the middle of the pack relative to other states. Of the fifteen largest Metropolitan Statistical Areas (MSAs), Detroit's entrepreneurship rate ranks tenth: compared to Detroit's 0.30%, Phoenix-Mesa-Scottsdale ranked first with 0.58%. Michigan is not currently a true leader in new firm formation.[81]

Site Selection ranked Michigan third nationally for its 296 corporate facilities expansions. While this number has been cited with pride by the State of Michigan, the fact that the data are not weighted by the number of corporations or state population makes it difficult to compare across states.[82] Nevertheless, Michigan's advancement in the recent rankings from ninth to third provides at least circumstantial evidence that Michigan has experienced some improvement in entrepreneurship.

80. Bresnahan & Gambardella, *supra* note 68, at 349.

81. Robert W. Fairlie, Kauffmann Foundation for Entrepreneurship, Kauffmann Index of Entrepreneurial Activity 14 tbl.10, 15 tbl.11 (Apr. 2008), *available at* http://www.tntechnology.org/uploads/files/Kauffman_Entrepreneurial_Activity_1996_2007.pdf.

82. Mark Arend, *Eyes on the Prize*, Site Selection (Mar. 2009), *available at* http://www.siteselection.com/issues/2009/mar/Cover.

F. *Financing*

Theory

Venture capital plays a critical role in commercializing early stage technologies. The role of venture capital is highly integrated with the functioning and management of the invested company, so venture capitalist investors prefer to make seed investments in operations that they can interact with on a regular basis. In regions where private venture capital is scarce, there is keen interest in the question of whether government can step in as a substitute. Lerner studied this question using data on the largest such program in the U.S., the Small Business Innovation Research ("SBIR") program, which disbursed over $7 billion to small firms between 1983 and 1997. Lerner found that compared to matched firms that did not receive SBIR grants, SBIR recipients enjoy substantially greater employment and sales growth, especially in high-tech industries. However, this relationship holds *only* in regions with substantial private-sector venture capital disbursements. This suggests two important conclusions: (1) where venture capital is plentiful, SBIR funding serves as a valuable signal of quality to private venture capitalists, and (2) where there is a scarcity of venture capital, SBIR funding may be captured by politically connected firms with weak growth prospects. The role of government funding in signaling quality receives further support from the finding that firms that receive multiple awards grow no faster than those that receive a single award.[83]

Application to Michigan

Traditionally, Michigan has not been a hotbed of venture capital, at least in part because the Big Three automakers were able to generate adequate investment capital internally. Ann Arbor has developed relatively strong sources of venture capital associated with commercializing technologies emerging from the University of Michigan, and there is also some venture capital activity in Oakland County, but the rest of the state remains weak in this area relative to coastal regions. The major battery production companies interviewed did not report suffering from an absence of venture capital in the region, citing their ability to access venture capital elsewhere. However, these companies conceded that the relatively low levels of venture capital in Michigan relative to California and Boston remain a handicap for smaller firms. Smaller firms and generalists who were interviewed cited the absence of local venture capital as a significant handicap. According to one interviewee:

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83. Josh Lerner, *The Government as Venture Capitalist: The Long-Run Impact of the SBIR Program*, 72 J. Bus. 285 (1999).

> It is very common for venture capitalists [outside of Michigan] to request that these companies move to the coast: part of it is that the VCs take a high level of ownership in the companies and they need face-to-face, meaningful real-time management, which is tough to do from a remote location. This applies most to second or third-year prototype product stage companies.[84]

Detroit Rennaissance has established a forty million dollar fund to seed venture capitalists in the region, but the initiative is taking time to grow. Some interviewees suggested that the State of Michigan may be able to partially substitute for private venture capital, and that structuring the financing as grants rather than investments may be needed to allay the awardees' fears that government may subsequently change the terms of its investment. Nevertheless, Lerner's results suggest that government venture funding is best seen as a complement to private sector venture capital, not a substitute.[85]

G. *Sophisticated Local Demand*

Theory

According to Michael Porter, a nation's firms can gain competitive advantage if its local buyers are the most sophisticated and demanding. Proximity to these sophisticated buyers helps the firms better understand the needs of its customers, and when the customers are other firms, this presents opportunities for collaborative innovation. Such buyers pressure firms to meet high standards for quality, features, and service. A corollary of this concept is the notion that when local demand anticipates the demand of other regions, local firms are advantaged. Porter illustrates this concept at the national level by using the Japanese advantage in energy efficiency, which was incubated by Japanese concern over energy costs that preceded the oil embargos of the 1970s.[86]

Example: Silicon Valley

Geographic proximity to a wide range of sophisticated potential customers was one of the primary drivers of Silicon Valley's extremely fast time-to-market—prototyping products sixty percent faster and shipping them forty percent faster than firms in other parts of the United States—and is in part attributed to the close networking of customers and producers.[87]

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84. PEV Supply Chain Interviews, *supra* note 42.
85. *Id.*; Lerner, *supra* note 83, at 312–15.
86. Porter, *supra* note 6, at 89.
87. Saxenian, *supra* note 7, at 114.

Application to Michigan

The ability to learn from the experience of early PEV buyers is likely to be important for industry advancement, especially with respect to challenges associated with the connection to the electric grid. Unfortunately, Michigan currently lacks a high level of demand for electric vehicles. Increasingly aggressive energy and automotive legislation in California is one cause of the sophisticated demand for efficient automobiles in California. This demand, which is not yet matched in Michigan, may be a driver for Ford Motor Company's plug-in hybrid electric partnership with Southern California Edison.[88] To the extent that political lobbying by the Big Three automakers has prevented Michigan from adopting aggressive legislation on vehicle efficiency, these companies themselves may be responsible for some of the difficulties in sparking a PEV cluster in Michigan.

H. *Timing of Value Chain Development*

Theory

Successful high-tech clusters have demonstrated cooperation with existing firms in the short run. In fact, short-run complements can pave the way for long-term substitutes. High-tech clusters in Israel, Taiwan, Ireland, and India established linkages to more established centers of technology, fostering the transfer of organizational models and managerial capital. It is critical that clusters position themselves in product spaces that are complementary to the principal existing sources of supply rather than competing directly with those sources.[89]

Application to Michigan

Interviewed stakeholders indicated a belief that the development of the Michigan cluster must proceed in an order that acknowledges and leverages the existence of expertise outside the region. Specifically, with regard to the development of advanced batteries, battery pack assembly must precede cell manufacturing, which must precede electrode production, which must precede raw material production.

The logic for this ordering follows from three factors, discussed below.

Investment Requirements

Because economies of scale may be more important for production processes farther up the value chain, more volume and more stable demand is required. This makes the investment untenable until there is an established and steady demand.

88. Industry Experts Interviews, *supra* note 41.
89. Bresnahan & Gambardella, *supra* note 68, at 348.

Quality Requirements

At key stages of the PEV value chain, raw materials must be of very high quality, and their production will require certification in some form. Firms in the downstream segment of the market will be understandably wary of new firms entering the market far back up the value chain where assessing their input quality may be more difficult.

Set-Up Time

The production processes further up the value chain may require significant time to set up.[90]

IV. Policy Actions that Effectively Support Clusters

In the last decade, dozens of cities, states, regions, and nations, as well as the World Bank, the Organisation for Economic Co-operation and Development ("OECD"), and the European Commission, have adopted cluster strategies in various forms as tools for economic development. Because so many municipal bodies of varying sizes and political dispositions have adopted these strategies, there is a broad umbrella of strategies and government intervention tools.[91]

In this section, we seek to identify policy mechanisms that have successfully developed and upgraded economic clusters. As explained in Part III, empirical evidence of the success of these strategies is nearly impossible to document, so we must rely heavily on theory and anecdotal evidence.

Michael Porter's *Competitive Advantage of Nations* lays out a broad framework for regional competitiveness that is supported by observation. We rely heavily on Porter's research and anecdotes, supplemented with others from the literature. While Porter's framework was initially created to discuss the competitiveness of nations, it has been used extensively to consider competitiveness of regional economic clusters.[92] Porter's broad framework is deployed below to examine areas of government policy intervention that support cluster competitiveness.

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90. PEV Supply Chain Interviews, *supra* note 42.

91. Michael J. Enright, *The Globalization of Competition and the Localization of Competition: Policies Toward Regional Clustering*, *in* The Globalization of Multinational Enterprise Activity and Economic Development 303–331 (Neil Hood & Stephen Young eds., 2000).

92. Porter, *supra* note 6, at 89.

A. *Factor Creation Policies*

Education and Training

Education and training systems provide competitive industries with the critical supply of human capital. For industries in which university-trained engineers and scientists are needed, it is not sufficient to simply produce a pipeline of trained knowledge workers; rather, they must be trained with "an eye to industry needs."[93] The contrasting examples of the United States and Germany on one hand, and France and Great Britain on the other hand, illustrate this nuance. The university systems of the United States and Germany were considerably more responsive to the needs of industry during the emergence of their highly competitive science-based industries.[94]

The type and level of training appears to have a significant correlation with industry success in a given country. For example, the United Kingdom has demonstrated strong competitiveness in pharmaceuticals and military electronics, sectors which depend on advanced scientific research, but has not seen success in manufacturing sectors, which depend on engineering and vocational skills. This is reflected in the education and training profiles of the countries: while most OECD countries have workforces with similar proportions of graduate degrees, Germany and Switzerland have almost sixty percent more home graduates in engineering and technology than the United Kingdom, while the United Kingdom has more graduates in arts and pure science. In the United Kingdom, only twenty-five percent of the workforce has intermediate vocational qualifications, compared to sixty-three percent in Germany.[95]

While Stanford is traditionally cited as a critical input to the development of Silicon Valley, the University of California, Berkeley was also a critical center for research for semiconductors and computer science, and by the mid-1970s trained as many electrical engineers as Stanford or MIT. California's state and community college systems were also important inputs to Silicon Valley's intellectual infrastructure. The region's six community colleges offered outstanding technical programs, including linkages to local firms and the nation's first two-year associate of science degree in semiconductor processing.[96]

Science and Technology: Research and Development Policy

The relationship between the research conducted and the industrial firm appears to be a critical component of innovative performance. Direct

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93. Richard R. Nelson, *A Retrospective*, *in* National Innovation Systems 511 (Richard R. Nelson ed., 1993).

94. *Id.*

95. Philip Cooke & Kevin Morgan, The Associational Economy: Firms, Regions, and Innovation 26 (1998).

96. Saxenian, *supra* note 7, at 42.

interactions between firms and university faculty and research projects correlates with strong innovative performance, as demonstrated by agricultural experimentation in the U.S. and machinery production in Germany. These relationships go beyond university research into industry-specific questions and involve partnerships, information dissemination, and collaborative problem solving. Such partnerships appear to be much more critical components to innovative performance than direct government support of R&D.[97]

The impact of defense, space, and nuclear power R&D on advancing innovation in the commercial markets is controversial. U.S. defense-related investments in the 1960s are commonly accepted to have contributed to the nation's subsequent industrial competitiveness in aerospace and electronics, but similar R&D investments by France and Great Britain did not appear to lead to commercial spillovers. One critical driver of commercial spillover success appears to be the extent to which the government-sponsored research is opening up broad new generic technologies rather than the development of highly specialized systems.

Evidence suggests that the presence of strong research universities and public laboratories is correlated with the innovative capacity of a nation's firms, but this varies among industries. Fine chemicals, pharmaceuticals, and agriculture are highly correlated with strong research programs, and electronics also appears to be generally correlated. While innovation in the automobile industry historically does not appear to have benefitted from proximity to research universities, electric vehicle development is likely to more closely resemble the high-tech industries where this correlation is observed. Our interviews with battery experts corroborated this academic research and indicated that partnerships with universities as well as national laboratories will be critical for advanced battery commercialization.[98]

Capital

Although the automobile industry is highly globalized, the financial system may also play a role in fostering systems of innovation. Research suggests that in European and Asian countries, it is easier to raise patient capital for innovation. This has been attributed to the close relationship between banks and industry, as shown by Germany's Deutsche Bank or the Japanese *keiretsus*. The United States has a limited number of government programs to support new business ventures. As discussed in Part III, research on the federal government's SBIR program indicates that the program's participants tended to grow faster and attract more venture capital over time than comparable non-participants. However, the direct role of government in the capital markets remains highly controversial, especially if

97. Nelson, *supra* note 93, at 513.
98. Brodd Interview, *supra* note 17.

government capital is deployed in an attempt to substitute for, rather than complement, private venture funding.[99]

Contrary to popular belief, Silicon Valley's venture capital industry emerged as a product of its robust base of technology companies, not a cause. The early venture capital community largely consisted of successful early entrepreneurs, such as Eugene Kleiner and Don Valentine of Fairchild, who re-invested their profits into promising local start-ups. Due to this dynamic, in which many of the venture capitalists were highly familiar with the industries in which they invested, financiers took an active role in advising entrepreneurs on business plans and strategy.[100]

Information

Publicly-organized business services may inadvertently crowd out the demand for privatized services or stifle the development of private business services that are critical to the development of a cluster. Considering this risk, it is important that the business services provided are true public goods that the market will fail to provide, including the diffusion of basic information.[101] Information-gathering and information-sharing structures can play a role in strengthening demand for the cluster's services. For example, complaint systems that are publicized may create an added stimulus for improvement.

Infrastructure

Because major international competitors in PEV production, such as China, have less developed electricity and automotive infrastructure than the United States, these countries have the potential advantage of leapfrogging to infrastructure systems that will enable a sophisticated rollout of PEVs. For a successful transition to PEVs, the U.S. system must place a political priority on using public funds to upgrade infrastructure systems where the capital markets fail to produce these upgrades. A modernized electricity grid, as well as the advanced battery systems that it feeds, can be viewed as part of that infrastructure system, warranting state investment. According to one interviewee, "[t]he instability of the capital markets makes it impossible to properly capitalize electrification businesses at present. The normal sources of investment are either unavailable or too poorly funded to support American technology development. When you couple that with the prices of labor and recreating infrastructure, that becomes compounded."[102] Government investments in infrastructure must play a role in bridging this gap if the U.S. is to emerge as a leader in PEV deployment.

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99. Cooke & Morgan, *supra* note 95, at 27; Lerner, *supra* note 83, at 285, 297.
100. Saxenian, *supra* note 7, at 39.
101. Andersson et al., *supra* note 6, at 57.
102. PEV Supply Chain Interviews, *supra* note 42.

B. *Demand-Side Policies*

Demand-oriented policies can support or hinder the competitiveness of a region's cluster. Policies must meet certain specifications in order to foster competitiveness. Because the desired end result is a cluster's innovation and competitiveness, demand-side policy should seek to improve the quality of domestic demand, rather than merely becoming a guaranteed buyer. Porter advises the following strategies:

- Create streamlined pro-innovation regulatory standards affecting the cluster to reduce regulatory uncertainty, stimulate early adoption of new products and technologies and encourage upgrading;
- Sponsor independent testing, product certification, and rating services for cluster products/services; and
- Act as a sophisticated buyer of the cluster's products and services.[103]

Government Procurement

Public procurement strategies can work for or against industry competitiveness. According to Porter, if government purchases become a guaranteed market or external suppliers are excluded from competition, the procurement policy will actually hinder innovation, limiting the capacity of local firms to compete in external markets. While some government procurements are now subject to international trade agreements, procurement policies can still be an effective strategy to support the development of a competitive cluster in some circumstances. Porter identifies several characteristics of government procurement, discussed below, as supportive of improved industry competitiveness.

Early Demand

Policies should provide early demand for advanced new products or services, pushing local suppliers into growth areas. (Of course, this approach runs the risk of inaccurately "picking winners" among technologies.)

Demanding and Sophisticated Buyers

Government procurement must maintain "stringent product specifications and seek sophisticated product varieties" rather than just accepting the offerings of the local suppliers.

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103. Porter, *supra* note 6, at 631.

Procurement Reflects International Needs

Government purchases should determine purchasing specifications with an awareness of needs outside the nation or region in order to encourage the cluster to develop competitive advantage to address those needs.

Competition

Government purchases should be competitive. With respect to national competitiveness, Porter writes that "shutting out foreign firms altogether . . . will most likely mean that domestic firms will remain domestic."[104]

Japan's state telecommunications monopoly, Nippon Telephone and Telegraph, maintained several suppliers for each product to ensure robust domestic competition. The company also ordered next-generation systems rather than the systems that Japanese producers already made. This approach to government procurement helped to position Japanese firms to succeed in the international telecommunications market in the 1980s.[105]

American defense investments after World War II stimulated investment in core technologies that became the basis for a national competitive advantage in electronics and aerospace. This is particularly clear in the development of Silicon Valley, where firms such as Lockheed Aerospace, General Electric, and Hewlett-Packard received substantial military grants, and Boston's Route 128, where the federal government accounted for half of the sales of firms in 1962. However, modern defense procurement may present several limitations as an economic development tool. The highly specialized nature of modern defense procurement minimizes the spin-off potential of much of the investment. Outside the aerospace industry, there are substantial limitations in the similarity of product, process, and competitive advantage demanded by defense versus commercial industries, although there may be synergies between Department of Defense needs for hybrid tanks and trucks and domestic market demand for hybrid vehicles. Lastly, defense buyers' hesitation to outsource abroad will thwart international competition for these products, leading them to be less innovative and competitive.[106]

Regulation of Product and Process

Stringent standards for product performance, safety, and environmental impact can contribute to the upgrading of competitive advantage. Regulations that anticipate international standards are particularly beneficial and give firms a head start in the development of products that will be needed in foreign markets. To illustrate this argument, Porter uses the examples of

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104. *Id.* at 644–46.
105. *Id.* at 645–46.
106. *Id.*; SAXENIAN, *supra* note 7, at 17.

Sweden's tough environmental protection and safety standards, which cultivated an environment in which Atlas Copco became a strong name in the production of quiet compressors for use in urban areas, and Japan's Energy Conservation Law of 1979, which set standards for energy usage in appliances and automobiles that set the stage for the Japanese competitive advantage in these products. Japan's Ministry of International Trade and Industry has pressured firms to come to consensus on basic standards, enabling firms producing television sets and fax machines to focus on features. This contrasts to the process of setting technical standards in the United States and Europe, in which firms often jockey for regulation-based competitive advantage.[107]

On the other hand, regulation can easily undermine competitive advantage if the regulation lags or is anachronistic. German limitations on biotechnology research in the 1980s hampered its agrochemical and pharmaceutical industries, and the ten-year lag in U.S. approval of aseptic food packaging enabled German and Swiss suppliers to become the dominant suppliers of this technology.[108]

Stimulating Early and Sophisticated Demand

Porter argues that incentivizing buyers to be early adopters of sophisticated products is a better strategy for driving innovation than direct subsidies to firms because it forces firms to continue to be attentive to consumer needs. It also stimulates competition. This can be observed in the success of the German and Spanish feed-in-tariffs in sparking the development of solar business in those countries. Porter observes this phenomenon in the Japanese government's prioritization of music education, which led every public school to purchase a piano, and focused industry attention to the development of inexpensive and mass-produced pianos. This early and sophisticated demand prefigured the worldwide market growth in these products and enabled Yamaha and Kawaii to assume international leadership. Likewise, Scandinavian nations established the Nordic mobile telephone program in order to establish mobile telephone systems in their countries before they were universal, enabling Nokia to assume an international position when the industry grew.[109]

C. *Policies to Improve the Context for Firm Strategy and Rivalry*

Macroeconomic Fiscal, Monetary, and Trade Policies

Policies that encourage firms to export are critical determinants of industrial innovation. Most countries with firms that do not compete on the

107. Porter, *supra* note 6, at 652–53.
108. *Id.* at 649.
109. *Id.* at 651–52.

world market lack a high level of competition. Exceptions to this rule include countries with very large home markets, such as the United States, but the exception is increasingly invalid as economies are increasingly integrated. Export-encouraging macroeconomic fiscal, monetary, and trade policies have been found to correlate with high levels of national innovation.[110]

Ensuring Inter-Firm Competition

Porter has observed that firms that do not have to compete at home rarely succeed abroad. The absence of domestic competition hampers innovation, but also enables the firm to receive special treatment from government in the form of protectionism, further degrading the incentives for innovation. Strong antitrust policy a plays a critical role in ensuring lively inter-firm competition, and policies that protect inefficient or lagging competitors should be abolished. The theory on this topic contrasts markedly with the views of many players in Michigan's developing PEV race who view collaboration and the elimination of duplicated work as a potential source of efficiency. Porter argues that the inefficiency of competitive duplication is a critical byproduct of the race for innovation and competitiveness and should not be undermined. Clearly, a balance is required between competition and collaboration within any cluster, and the extent of collaboration is likely to be a function of the degree of complementarities between the knowledge created by different firms in the industry.[111]

D. *Policies to Foster Related and Supporting Industries*

Establishing Cluster-Oriented Free Trade Zones, Industrial Parks, or Supplier Parks

While this is clearly consistent with basic research findings on the value of geographical proximity, it is only a useful policy if it can be executed effectively. There are numerous examples of science parks that have failed. As a result, some authors have expressed skepticism about the value of most science parks and counsel caution on the part of governments trying to spark new clusters.[112]

Sponsoring Forums to Bring Together Cluster Participants

The relationship between the research conducted by universities and industrial firms appears to be a critical component of innovative performance. Direct interactions between firms and university faculty on research projects correlates with strong innovative performance, as demonstrated by

110. Nelson, *supra* note 93, at 12.
111. Aydogan & Lyon, *supra* note 14, at 1130 (finding that a greater degree of complementarities facilitates the exchange of knowledge); Porter, *supra* note 6, at 663.
112. Saxenian, *supra* note 7, at 165–66.

agricultural experimentation in the United States or machinery production in Germany. These relationships go beyond university research into industry-specific questions and involve partnerships, information-dissemination, and collaborative problem solving. Such partnerships appear to be much more critical components to innovative performance than direct government support of R&D.[113]

Brokering Policies That Support Coordination Across Sectors

Governments may be able to usefully broker policies concerned with building a framework for dialogue and cooperation between firms, relevant public sector actors, and nongovernmental organizations. The following policies and tactics are examples of such policies, though there is no consensus on their efficacy.

Public authorities have helped to build links between firms by creating meeting places, facilitating networking, creating export networks, and coordinated purchasing, branding, and joint marketing initiatives.

Public authorities can use tactics to strengthen science-industry linkages, such as incentive structures that promote linkages between university research and industry, intellectual property reforms that provide incentives for university researchers to collaborate with industry, industry-university partnership efforts, and the provision of support services for technology-based firms.

Public authorities can collect and organize relevant statistics related to the cluster, detailing and communicating the composition of the cluster, its constituents, and its development over time. This can enable improved awareness among firms.[114]

Fostering Manufacturing and R&D Proximity

Silicon Valley's loss of the memory supply business in the 1980s has been attributed in part to the region's turn toward traditional models of mass production, which relied on centralized manufacturing facilities, located at significant distances from R&D operations, producing high volumes of product. This isolation of engineering and manufacturing failed to produce opportunities for interactive learning and improvement that were produced by Japanese organizations. Likewise, inferior quality and higher defect rates of U.S. semiconductor producers relative to Japanese competition have been directly attributed to the 1980s trend of increasing geographic distance in Silicon Valley's semiconductor value chain, which decreased the sharing of proprietary product or process information, shifted the business cycle bur-

113. Nelson, *supra* note 93, at 511.
114. Porter, *supra* note 6, at 680–82; *see infra* Figure 1.

den to the supply chain, and resulted in underinvestment in capital equipment.[115]

V. Recommendations

In this final section, we draw upon the theoretical literature, empirical evidence, and input from local participants in the PEV business to suggest policies that might spark the development of a PEV cluster in Michigan. It should be understood that all of these recommendations come with significant caveats. We have emphasized throughout this Article that the literature on clusters is notoriously anecdotal, with a scarcity of solid empirical work based on large numbers of data points. Nevertheless, the importance of clusters for economic development is clear, as is the urgency of action to spark economic growth in Michigan. This state has reached a point where a bias toward bold action rather than caution seems appropriate.

A. *Bring Cell Manufacturing to Michigan*

Interviewees agreed that battery cell manufacturing will be a critical component of the value chain that must be developed within a one-day shipping distance from automobile assemblers. Furthermore, following Krugman's logic regarding transportation costs, the fragility and high cost of battery cells transportation over long distances will lead them to cluster near other components of the automobile value chain. One industry expert interviewee estimated that a mature PEV industry in the United States would support three to four major cell manufacturing plants. It is likely that Michigan will compete with neighboring states for this component of the value chain when the demand from battery pack assembly is sufficient to support an increase in production capacity. Interviewees showed near-universal agreement that the type of tax subsidies that currently apply to pack assembly should be extended into cell manufacturing. In this vein, the signing of Michigan's House Bill 4515 and Senate Bill 319 in April 2009 empowered the Michigan Economic Growth Authority to dedicate an additional $220 million in tax credits for the construction of battery-cell manufacturing facilities, bringing the total amount of tax credits for this sector to $555 million.[116]

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115. Saxenian, *supra* note 7, at 91–92.

116. Press Release, Governor Jennifer M. Granholm, State of Mich., Granholm Signs Legislation Positioning Michigan as Leader in Advanced Battery Development and Manufacturing (Apr. 6, 2009), *available at* http://www.michigan.gov/granholm/0,1607,7-168-23442_21974-212181--,00.html.

As discussed, tax incentives will need to be complemented by other value-added partnerships and programs mentioned below, in order to avoid a race-to-the bottom among states competing for industrial investment.[117]

Since the initial draft of this Article was written, the state has made considerable progress in attracting investment commitments for battery cell manufacturing, as well as pack assembly. The tax credits mentioned above have stimulated substantial investment commitments from battery manufacturers. A123 Systems has announced plans to invest $600 million in a plant in Livonia, Michigan, which will eventually employ 5,000 workers. KD Advanced Battery Group—a joint venture between Dow Chemical, Kokam America, and Townsend Ventures—has announced a $665 million investment that will create 885 jobs. A partnership between LG Chem and Compact Power is building a manufacturing facility to supply the Chevy Volt, which will involve investment of $244 million and create 443 jobs. Johnson Controls, partnering with Saft, plans to open a manufacturing plant that will require an investment of $220 million and create 498 jobs.[118]

Furthermore, the state has successfully sought stimulus funding from the federal government for battery manufacturing. According to a White House press release:

> Reflecting the state's leadership in clean energy manufacturing, Michigan companies and institutions are receiving the largest share of grant funding of any state. Two companies, A123 and Johnson Controls, will receive a total of approximately $550 million to establish a manufacturing base in the state for advanced batteries, and two others, Compact Power and Dow Kokam, will receive a total of over $300 million for manufacturing battery cells and materials. Large automakers based in Michigan, including GM, Chrysler, and Ford, will receive a total of more than $400 million to manufacture thousands of advanced hybrid and electric vehicles as well as batteries and electric drive components. And three educational institutions in Michigan, the University of Michigan, Wayne State University in Detroit, and Michigan Technological University in Houghton in the Upper Peninsula, will receive a total of more than $10 million for education and workforce training programs to train researchers, technicians and service providers, and to conduct con-

117. Brodd Interview, *supra* note 17; PEV Supply Chain Interviews, *supra* note 42; *supra* Part IV.D.

118. *See* Nathan Bomey, *Michigan Lands Four Advanced Battery Production Facilities with Plans to Hire Thousands*, MLIVE.COM (Apr. 14, 2009, 12:05 PM), http://www.mlive.com/business/ann-arbor/index.ssf/2009/04/michigan_lands_four_advanced_b.html.

> sumer research to accelerate the transition towards advanced vehicles and batteries.[119]

Thus, the first key step toward attracting critical components to the PEV supply chain to Michigan seems to have been taken successfully. The challenge at this point is to put in place a set of complementary policies, which we detail below, that will help to foster a sustainable competitive advantage in the battery sector.

B. *Increase Partnerships with National Labs, Universities, and Industry*

Interviewees cited the need for more streamlined partnerships with national labs that would facilitate funding and research collaboration with other critical parties.[120] Partnership relationships with National Labs to create intellectual property relationships that align with the needs of industry are a critical component to funneling funding and research energies into PEV development. The CREDA in development with Oak Ridge National Laboratory is a step in the right direction, and such partnerships and collaborations should continue to be cultivated.

C. *Develop Local Venture Capital*

While the larger global players in the value chain unequivocally stated that local venture capital did not matter in their location decisions, local venture capital is a critical component to the development of small and medium-sized businesses with advanced technologies and prototypes that are often bought up or integrated into the larger global players. The innovations in these small- and medium-sized enterprises struggle to move beyond the prototype stage without sufficient investment. If Michigan is to have a vibrant and innovative PEV cluster, it is critical that new ideas can be incubated and grown without dependence upon funding from established industry players. Government funding could play an important role, recognizing that such efforts are more likely to be effective if they are matched by funding from the private sector.

D. *Build a Competitiveness-Driven Cluster Initiative Program to Coordinate Initiatives*

Successful cluster initiatives tend to have cluster actors who understand that the root cause of competitiveness is productivity and innovation, rather than protectionism or subsidies in the long-term.[121] An organization that

119. Sebastian Blanco, *Obama Announces Battery Grants: Big Three, Michigan, Li-ion Companies Come Out Winners*, Autoblog Green (Aug. 5, 2009, 12:50 PM), http://green.autoblog.com/2009/08/05/obama-announces-battery-grants-big-three-michigan-li-ion-comp.

120. PEV Supply Chain Interviews, *supra* note 42.

121. *See* Porter, *supra* note 6, at 619–25.

achieves long-term sustainable advantage will not be focused on the acquisition and development of subsidies or grants or other rent-seeking behavior. Ideally, a cluster initiative should reflect the actual boundaries of the regional cluster, rather than the state's boundaries, allowing the incorporation of important players in nearby states. In addition, the initiative should preferably have private sector leadership and operate independently of government, so it maintains long-term view and is not subject to political cycles. Creating a private sector consortium that could enhance the public sector efforts of the Michigan Economic Development Corporation, and coordinate with relevant private-sector actors in states such as Indiana and Ohio, may be a valuable step forward.

E. *Develop Sophisticated Local Demand for PEV Products in the State of Michigan*

Sophisticated local demand has been found to be a key driver in national competitiveness. If government procurement policies are used to support this demand, they must take an aggressive posture, demanding high performance standards from producers. Whether a powerful government "pull" is possible in Michigan, given its relatively limited public procurement programs for vehicles, is unclear. Incentive programs and regulations can also be used to foster consumer demand for PEV products within the State. Interviewees cited higher levels of demand along the West Coast as one rationale for hybrid-car and alternative drive-train investments taking place in California.[122] Policymaking in this area must be careful to avoid "picking winners" by selecting technologies that are too specific, and should instead focus on end-use performance rather than specific technological inputs.

F. *Long-Term Education Investments*

Several interviewees cited Michigan's poor secondary school performance as one of the most substantial long-term concerns handicapping the state's long-term intellectual capital potential.[123] Investments in science, mathematics and engineering education will provide the critical base for long-term competitive advantage in the engineering and production of PEV technologies.

Conclusion

We believe these steps are worthy of exploration by Michigan policymakers and offer a real opportunity to enhance the State's capacity to create a successful cluster of plug-in electric vehicle manufacturing.

122. PEV Supply Chain Interviews, *supra* note 42.
123. *Id.*

Interviews Conducted

Several formal and informal conversations were conducted with industry experts. Formal and semi-structured in-depth interviews were conducted with strategic decisionmakers from the following companies (Interviews with PEV Supply Chain):

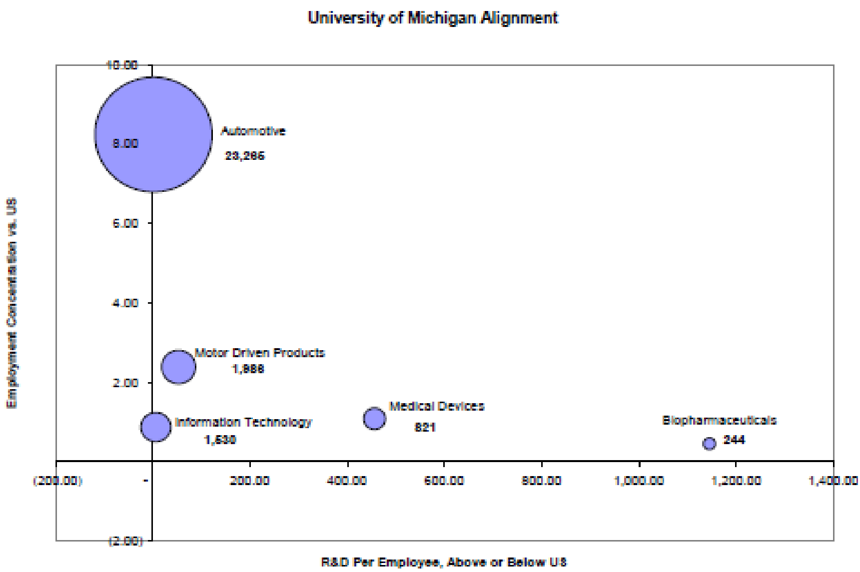
- Ford Motor Company
- Robert Bosch, LLC
- LG Chem / Compact Power, Inc.
- A123 Systems
- Denso
- Magna
- Sakti3
- General Motors did not respond to requests for participation
- Johnson Controls—Saft did not respond to requests for participation

Formal, in-depth, semi-structured interviews were conducted with the following industry experts (interviews with PEV industry experts):

- Ralph Brodd, independent automotive and battery consultant, author of "*Factors Affecting U.S. Production Decisions: Why Are There No Volume Lithium-Ion Battery Manufacturers in the United States?*"
- David Cole, Center for Automotive Research
- Skip Pruss, Michigan Department of Energy, Labor and Economic Growth
- Brett Smith, Center for Automotive Research
- Levi Thompson, Professor of Chemical Engineering at University of Michigan
- John Voorhorst, Voorhoorst Consulting LLC
- Minyuan Zhao, Assistant Professor of Strategy at the University of Michigan Stephen M. Ross School of Business

Appendix

Figure 1: University of Michigan Alignment of R&D Resources and Outputs[124]



124. Nat'l Sci. Found., Academic Research and Development Expenditures: Fiscal Year 2001, Section B: Detailed Statistical Tables, 157 tbl.B-39 (2003), *available at* http://www.nsf.gov/statistics/nsf03316/pdf/sectb.pdf; *Cluster Mapping Project*, Inst. for Strategy & Competitiveness, Harv. Bus. Sch., http://data.isc.hbs.edu/isc (last visited Dec. 5, 2011) (using cluster data for 2001).

FIGURE 2: KEY COMPONENTS OF PLUG-IN ELECTRIC VEHICLE VALUE CHAIN

Value Chain Links (similar to those defined by FreedomCAR)			PEV	Conventional Vehicle
Energy Storage	Batteries		5-15 kWh capacity (or more) Deep cycle requirements	<1.5k Wh
		Battery Components		
	Ultra Capacitors		Size and integration requirements T.B.D.	N/A
	Other Concepts	Hydraulic	Size and integration requirements T.B.D.	N/A
		Flywheel	Size and integration requirements T.B.D.	N/A
		Compressed Air	Size and integration requirements T.B.D.	N/A
Power Electronics and Control	ECM "Computers"		Complete vehicle integration and grid interface communications required	Similar processing requirements
	High Power Control Devices		Several high-current, high-voltage devices required	Fewer components required, generally lower power requirements
	Thermal Management		Electronic device and electrical machine thermal management required	Less stringent requirements as applied to existing electronics
	Motors/Generators		25-75 kW machines	500 W generator 1.5 kW starter motor, short duration
	Components	Magnets	All possible value chain component supply requirements for Michigan	Similar components required but to different specifications
		Windings		
		Cases		
		Bearings and Gear Sets		
		Assembly		
Range Extender	IC Engine		25-100 kW (depending on vehicle and system configuration)	Much larger required (250 kW)
		Petrol		
		Diesel		
	Other Concepts	Fuel Cell	Possible electrical generation source	N/A
		Battery Swap stations	Possible "quick charge" technique	N/A
		. . .		
Grid Interface	Hardware infrastructure		Standard 110 volt (or 220 volt) plug-in. Availability may be limited at some homes or businesses	N/A
	"Smart" infrastructure		Communication to "grid" for optimal charge timing	
Vehicle System Integration	Total Vehicle Efficiency Improvement			
		Weight reduction materials	Carbon Fiber, Composite, Mg, Al	Similar drivers for economy
		Drag Coefficient improvement		Similar drivers for economy
		Rolling resistance reduction		Similar drivers for economy
		. . .		
	Auxiliary System Integration			
		HVAC power source/efficiency improvement	Potential need for auxiliary fuel fired heater, high efficiency A/C	Similar drivers for A/C efficiency
		Steer by wire		Similar drivers for economy
		Brake by wire	Potential need for auxiliary brake actuation	
		Engine cooling by Wire		Similar drivers for economy
		. . . .		
Vehicle Performance Test & Validation	Emissions (including aux. HVAC)		Low duty cycle engine operation affects startup emissions and catalytic converter operation	
	Performance		Consumer perception of new technology (feel) to be optimized	
	Durability		Real World durability of batteries, electric machines, power electronics and auxiliary equipment	