LINKED THROUGH SKILL: LABOR MARKET INTERDEPENDENCE ACROSS THE AUTOMOTIVE VALUE CHAIN

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ABSTRACT

Allison Forbes: Linked through Skill: Labor Market Interdependence Across the Automotive Value Chain
(Under the direction of Nichola Lowe)

This dissertation revisits old questions regarding how to increase manufacturing skills, but with attention to the asymmetrical position of large and small firms in manufacturing supply chains. Small sized firms (under 500 employees) employ roughly half the U.S. workforce, but typically have fewer resources to invest in training their employees compared to their larger-sized counterparts, contributing to recognized labor market inequities.

Power and resource asymmetries between large and small firms are particularly pronounced in the automotive industry. A large body of research on global supply chains provides a foundation for this inquiry into how suppliers might adjust their training practices in response to the constraints and expectations of their automotive clients.

Integrating approaches from cluster- and supply-chain-based research, the dissertation's three papers address three related questions: 1) How is skill dispersed across industries supplying the U.S. automotive industry?; 2) How do supply chain dynamics affect suppliers' ability to train and compensate skilled workers?; and 3) How might smaller companies gain access to training resources in automotive clusters where politics and institutions favor larger firms?

The first paper in the dissertation describes the skill requirements of industries in the U.S. automotive cluster. I show that the relationship between skills and wages is uneven and complicated: wages vary by supply chain tier, but in the opposite direction as skill requirements.

The automotive industry clearly depends on the high-level manufacturing skills of sectors supplying intermediate goods, yet the lower wages in these sectors may impede skill regeneration and upgrading.

The second paper investigates the training decisions of suppliers in a local automotive cluster. I find that cost reduction trends can deter suppliers from investing in training their own production technicians, but also that suppliers can leverage their supply chain position and activate local networks to increase training in spite of negative supply chain pressures.

The third paper addresses a bias in the training system diffusion literature toward larger multi-national corporations. Shifting the focus to smaller multi-national enterprises, I find they are well positioned to activate institutional resources, both global and local, to introduce more accessible training models at their branch plant locations.

For Jamie.

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AHK	German-Mexican Chamber of Commerce and Industry in Mexico
IHK	German Chamber of Commerce
MNC	Multi-national corporation
OEM	Original equipment manufacturer
VWM	Volkswagen of Mexico

INTRODUCTION

Small sized firms employ roughly half the U.S. workforce, but often have fewer resources to invest in training their employees compared to their larger-sized counterparts. Numerous studies have documented this training discrepancy, which contributes to recognized labor market inequities. In response, labor market analysts have suggested directing federal investments in workforce development to support smaller, resource-constrained firms, overlooking the potential for smaller firms to benefit from sustained public investments in regional training systems originally designed to support larger corporations.

This dissertation addresses a noted policy gap regarding the role of technical training in firm and area upgrading by focusing on the complementarities between the labor market demands of large and small firms in global value chains and local industrial clusters. Regional economists note that when large and small companies compete for skilled labor and training resources, large firms most often win. Large firms have more power in their negotiations with the public sector compared to smaller firms and are in a better position to capture limited public resources. While smaller firms may have less initial bargaining power, their greater dependence on public training systems means they are well positioned to partner with workforce practitioners to inform innovations that can further extend service delivery.

This dissertation seeks to answer the following three questions:

1. How is skill dispersed across industries supplying the U.S. automotive industry?
2. How do supply chain dynamics affect smaller companies' ability to train and

compensate skilled workers?

3. How might smaller companies gain access to training resources in automotive clusters where politics and institutions favor larger firms?

By analyzing firms' positions in both global value chains and local labor markets, I seek to understand how related constraints and advantages shape firms' training decisions and their proclivity to connect with and inform the development of regional training resources. I am especially interested in understanding how we can support firms along an entire production supply chain, utilizing relationships between large and small firms to reduce the training gap. Strategies that embed training within a supply chain framework can help state and local workforce practitioners extend support to smaller firms.

Two frameworks are key to my research: a global value chains perspective and a regional economic development perspective. The mechanisms through which training investments lead to small firm training and skill upgrading involve network, political, institutional, and supply chain relationships. These related dynamics motivate my supply-chain-based approach to measuring skill demand in the U.S. automotive cluster. I further explore these mechanisms for skill upgrading through in-depth studies of growing, yet skill-constrained, automotive clusters in the U.S. South and Mexico, and find evidence that smaller companies might benefit from larger companies' training investments.

In examining the skill demand and training activities of smaller companies in automotive clusters, I identify supply-chain-based dynamics that suppress training investments. I also find some promising indications that cluster- and supply-chain-based relationships can disrupt and assuage these negative pressures, creating room for training investments that have the potential to boost firm productivity and job quality.

There is a large body of literature describing how cluster dynamics support smaller firms, and an almost equally expansive literature on how local firms link up to global supply chains, but little research in terms of skill development. In both fields, the market or the market-based responses of the public education system are the mechanisms for training provision. Rarely do we examine how the private sector produces and reproduces skilled labor—this only occurs in studies of firm-internal training practices, not in the context of firm-to-firm relationships. National and international comparative studies likewise focus on how the private and public sector engage each other to invest in education and training, rather than how firms engage each other. The *varieties of capitalism* literature describes skill development regimes at the national level in detail, but obscures local level dynamics, supply chain relationships and international networks.

Of course, we can draw great insight from the existing bodies of research on cluster and supply chain dynamics. The most detailed and descriptive work on supply chains cannot help but examine place-based connections; similarly, the most detailed and descriptive work on cluster dynamics cannot help but examine the extra-local and global relationships that affect the local cluster. But in examining opportunities for smaller firms to invest in training, these intersecting dynamics must be more explicit, and training should be a specific subject of research.

Empirical Context—Focus on the Automotive Industry

This dissertation addresses research questions regarding skill demand and development in the context of the global automotive industry, given the industry's dependence on technical skill, and the hierarchal governance structure that has multi-national and local suppliers operating under significant constraint. Larger lead firms ("Automakers") have substantial power to influence behavior along the supply chain, indicating that the supply chain structure may be central to extending training resources to smaller firms in this industry.

Automakers (e.g., Ford, Toyota) are the primary coordinators of automotive supply chain activity and have the power to direct their suppliers to meet certain performance standards, including suppliers located across international boundaries. Their supplier upgrading programs can be tremendously helpful to participants, but access is limited to their most strategic suppliers. These programs may also have spillover effects that facilitate local firm upgrading when local firms are co-located with automotive suppliers.

Automakers are also powerful in their branch plant locations. They have the power to solicit public training subsidies vis-à-vis their negotiations with subnational state governments and are well positioned to influence the regional training institutions that structure opportunities for upgrading. Automakers are able to solicit fairly large (up to $40 million) training incentives and infrastructure. Their direct (Tier 1) suppliers have also received large local training subsidies.

The increasingly important role of Automakers' Tier 1 suppliers demands our attention. The first paper in this dissertation examines the occupations and occupational skills required by Automakers, Tier 1 suppliers, and Tier 2 suppliers in the U.S., as well as their average wages, in order to identify how skill demand is dispersed across supply chain tiers. The analysis draws our attention to the high level of skill required by Tier 1 and Tier 2 companies, suggesting that Tier 1 suppliers are directly responsible for managing much of the skill in the automotive supply chain.

Like Automakers, Tier 1 suppliers exercise power through their supply chains and in their branch plant locations. Large global suppliers from a number of automotive-producing countries (primarily the U.S., Germany, Japan and increasingly China) make up the global supply chain in new and old automotive regions. Global suppliers' increasingly strategic and expansive role in the automotive industry may even block local firms from upgrading into the automotive value

chain. But it is unclear what role these global suppliers might play in facilitating knowledge and practice transfer to local firms or to their own supply network. Part of the reason we know so little about these suppliers is that they are rarely distinguished in empirical studies, which often refer to them as "follow source" suppliers, because they follow Automakers to all their global locations, usually upon request. These companies seem to operate either under the direction of their clients or their own headquarters location. They seem not to have any agency of their own.

German Automakers and Apprenticeship Practice in North American Branch Plant Locations

Papers two and three in this dissertation evaluate training practices in two different North American automotive clusters. I specifically examine local clusters where the lead firms and many of the first tier suppliers are of German origin, and where these firms have been engaged in processes of apprenticeship program expansion. This focus allows me to observe how foreign multi-national enterprises of various sizes, but of the same industry and national origin, navigate host country politics and institutions to carve out a competitive position in the regional labor market. These cases also allow me to study the attempted transfer of German-style apprenticeship programs, a training practice considered a global best practice by international development organizations, national and state governments.

PAPER 1: A MEASURE OF INTERDEPENDENCE: SKILL IN THE AUTOMOTIVE SUPPLY CHAIN[1]

As policy makers grapple with the evolving conditions of global competition, they are regularly reminded that high skilled workers are in demand. The education sector and workforce development agencies are hard at work to infuse new and returning labor market participants with "21st century skills"—STEM skills, communication, and problem-solving skills—key to the functioning and improvement of U.S. manufacturing operations.

A common assumption is that businesses are uniformly able to leverage the skills of the workforce and reward higher skilled workers with higher wages. But the relationship between skills and wages is actually uneven and complicated. Mediating factors—including firm size and supply chain position—temper and distort the relationship.

Labor scholars often assume that the disconnect between skills and wages, among small firms or nonunion firms, reflects weakened labor market institutions, and, specifically, the lack of worker protections and bargaining ability. This is an important factor, but an equally compounding issue relates to the power that firms have in their buyer-supplier relationships and the degree to which those relationships influence job quality and pay.

By ignoring this uneven landscape, we may be making empty promises to workers and firms that are not able to solicit wages compensatory to their skill levels. Attending to the

[1] This paper will appear as an article in the journal Economic Development Quarterly. The citation is as follows: Forbes, A. (forthcoming) A Measure of Interdependence: Skill in the Automotive Supply Chain. *Economic Development Quarterly.* In a special issue on Manufacturing and Innovation.

pressing macroeconomic demands facing training and education systems, we may overstate the abilities of existing industry to pay for higher-level skills and to improve their own position in the supply chain through skill upgrading. Policy makers, aiming to attract high skill industries and occupations, may overlook ways to utilize and leverage the skills of the existing workforce to advance more inclusive, equitable, and sustainable growth.

We need tools to draw out the relationship between skills, compensation, and existing industry structure. One way to explore this is at the industry level. This study examines how manufacturing skills are dispersed among related industries. Since it is also important to consider how these industries are situated vis-à-vis critical suppliers and clients, this study situates industries by their supply chain position in the U.S. automotive cluster, identifying constraints in this context and suggesting supply-chain-specific solutions.

Simply recognizing this uneven terrain can help local economic and workforce development practitioners identify skill-centered strategies to address strengths and weaknesses in the way that global industries touch down in their local areas. By evaluating skill demand across related sectors, policy makers will be able to see how high- and low-skill, high- and low-wage occupations are critical to supply chain competitiveness, motivating support for firms and workers in more vulnerable sectors. State and local economic development organizations can identify opportunities for these incumbent firms and workers to move into higher value-added positions. Workforce development organizations can complement this work by identifying rewarding career pathways across related sectors, drawing underutilized workers up (or down) the supply chain while building a talent pipeline behind them, even more effectively responding to industry requests to help fill high demand occupations. These actions would improve both the productivity and resilience of manufacturing supply chains.

Analysis of skill demand in a supply chain context also has the potential to sharpen industrial recruitment strategies. States and local areas spend millions of dollars recruiting large, high profile, multinational firms to boost local employment and capacity for innovation, but the local impact on employment and innovation also depends on efforts to localize and develop the supply base of the large firms. Greater familiarity with how skill demand is dispersed across a large firm's intermediate goods suppliers will help local policy makers evaluate the potential for recruitment deals to benefit incumbent firms and workers.

With both public- and private-sector-led skill development efforts in mind, this study presents a skill-centric analysis of publicly available data. Input-output tables, industry and occupation matrices ("staffing patterns"), and descriptions of skill requirements by occupation are leveraged to identify related industries and analyze their skill levels. This approach aims to motivate efforts to upgrade skills across related sectors. It brings lower-tier sectors into focus where they might otherwise be ignored.

The automotive industry is used as an illustrative case of how patterns in buyer-supplier relationships can affect the dispersal of skill and compensation across industries. The automotive supply chain (or "value chain") follows distinct patterns in the dispersal of power, resources, flexibility, technology, and knowledge, generating activities that diverge from patterns in the aerospace, textile, or electronics industries. For example, automotive supply chains are generally organized around and coordinated by the producers of automobiles (e.g., Toyota, Ford) while apparel supply chains are generally coordinated by the buyers of manufactured products (e.g., Nike, Zara, Gap) (see Gereffi & Korzeniewicz, 1994, for early conceptualizations of producer-driven versus buyer-driven value chains).

For many reasons (primarily their brand control and direct relationship with consumers), automakers are particularly powerful clients and have historically captured most of the profits and produced most of the innovation in automotive supply chains. With their powerful positions, automakers exert control over their supply chain partners to increase operational efficiency, demanding cost reductions and quality improvements. There are also many examples of automakers working collaboratively with their most strategic direct "Tier 1" suppliers, which produce sophisticated car components and systems such as drive trains, interior seating and consoles, and electrical systems. Lower-tier suppliers are more difficult to study or to connect directly to the automotive supply chain. These are smaller, more diversified establishments producing smaller, less complex parts and services—metal or plastic parts that fit into larger components and systems—or related tools and machinery.

The next section reviews the literature on the role of occupational skills in economic development. The data and methods described in section three provide a generalized framework to advance a shared understanding of what it means to evaluate skill from a supply-chain-sector perspective, evaluating multiple measures of skill demand. In the section following, I apply these methods to the automotive supply chain in the United States (or the U.S. automotive cluster), then report and discuss the results. I offer concluding remarks in the final section.

Background

Wilbur Thompson and Philip Thompson laid the conceptual framework for situating skill as a focus for economic development policy. In their pioneering work (Thompson & Thompson, 1987), they proposed a shift away from the targeting of monolithic industries for (any) jobs, introducing a method to identify and advance local comparative advantage, which they defined in terms of what people do (their occupations) rather than what they make (their industries). They proposed directing development efforts to the "functional [occupational] strengths of the

home locality" (Thompson & Thompson, 1987, p. 554) and claimed that these human resources would inform a local area's ability to respond to technological change and global competition.

In the 2000s, Ann Markusen and Ed Feser took up the mantle of occupational targeting, advancing the fruitful deployment of occupational databases. Markusen (2004) highlighted how local concentrations of creative arts and design occupations could be targeted for development, enhancing an area's unique occupational advantage. Artists and designers seem to be mobile to the extent that they could be attracted and embedded in place, enhancing localization trends. Most importantly, art and design work provides an excellent example of how a local occupational strength could have a variety of industrial applications, and could range from low to high levels of compensation and job security. Similarly, Ed Feser (2003) provided economic development analysts with a technique to identify "knowledge-based clusters," groups of occupations requiring similar substantive knowledge. These mostly high-wage occupations support innovation in various knowledge-intensive industries.

Further application of these occupational clustering techniques shows that occupational localization trends cannot be predicted by an area's industry mix (Barbour & Markusen, 2007; Renski, Koo, & Feser, 2007), confirming that what people do is different than what people make. Therefore, targeting occupational clusters leads to different economic development strategies rather than focusing on industrial clusters alone (Markusen & Schrock, 2001).

Occupational clustering techniques can prioritize different sets of shared underlying attributes. For example, municipalities seeking to increase income tax revenues can aim to develop high-wage occupational clusters regardless of industry. For municipalities that are home to large populations of lower-wage workers, occupational clustering techniques can identify accessible career pathways across existing industry. Recognizing that the "knowledge-based

clusters" proposed by Feser (2003) and Koo (2005) were not accessible to people in or near poverty, Chrisinger, Fowler, and Kleit (2012) identified clusters accessible to low-wage workers and argued that economic development centered on these clusters could boost growth and reduce poverty. They highlighted the possibility of linking not only displaced workers to jobs requiring their skill profile but also linking workers stuck in dead-end jobs to better jobs in related fields, suggesting that workers can incrementally increase skills and compensation across occupations and industries when work at a single firm or in a single industry does not necessarily ensure advancement. Societal gains are maximized when job openings are accessible to low-wage workers and are paired with strategies that facilitate advancement (Nelson & Wolf-Powers, 2010; Persky, Felsenstein, & Carlson, 2004). Fran Stewart (2017) showed that a higher density of jobs requiring technical skills (high STEM and low soft) was correlated with greater regional well-being, confirming the potential value of production and repair occupations and other accessible occupations identified by Chrisinger, Fowler, and Kleit (2012). Associated with this work is the idea that workers increase their skills and their wages concurrently.

This deep and instructive dive into the occupational analysis that Thompson and Thompson (1987) inspired has expanded our understanding of how occupations are connected to each other, how occupational trends differ from industrial trends, and how the two can be fruitfully cross-referenced. We are now more fully prepared to further build our intuition regarding how compensation and skill requirements vary across industries, and to consider how patterns in buyer-supplier relationships affect the dispersal of both skill and compensation.

A supply chain (or "value chain") framework helps to identify actors with more (or less) resources and power, and more (or less) ability to utilize and advance the skills of existing industry. These dynamics vary by supply chain—automotive supply chain dynamics are different

than textile supply chain dynamics. Each of these globally competitive industries has complex and extended supply networks and follows a distinct pattern in the dispersal of power, resources, flexibility, technology, and knowledge-generating activities. The relationship between skills and wages is important to address in this context because supplier-buyer relationships structure investment opportunities and constraints. A firm's position in a supply chain (with one type of client), as well as across supply chains (diversified clients), determines its ability to negotiate for better contracts. The nature of a contract, particularly if it is short term and cost reducing, can limit a firm's ability to invest in new machinery and skilled labor (Barrientos, Gereffi, & Rossi, 2011[2]; Helper et al., 2011; MacDuffie & Kochan, 1995; Theodore & Weber, 2001; Weber & Schnell, 2003).

Identifying transferable occupational skills and occupational pathways across this increasingly fragmented industrial landscape[3] can help prepare communities for technological and trade disruptions, which may affect local firms and may shift an area's industrial profile. However, this approach has its limits, as many occupations and jobs are firmly embedded within the limits of existing industry, with few options for learning outside of the job site. What are the options for workers and communities attached to existing industry? Where will we learn the "versatility in skill and adaptability in behavior" that "ensures quicker and easier escape from adversity" (Thompson & Thompson, 1987, p. 559)? It is critical to understand how our

[2] Barrientos, Gereffi, and Rossi (2011) describe a variety of labor impacts (voice/representation, safety, wages) from cost reduction pressures and quality expectations created by large, lead firms in their supply chains. They conceptualize the distribution of skill requirements in global industries.

[3] It is broadly recognized that it is harder today for many workers to advance within one company or even one industry than it was 30 years ago. Most companies are no longer vertically integrated and are no longer performing all the necessary operations that bring a product to market, and production activities are spread over many industries and locations.

communities are situated vis-à-vis local industry, global industries, and the supply chains that inform our options for skill upgrading.

In the 1980s and 1990s, scholars began to look closely at how the structure of global supply chains (or "value chains") shape opportunities and challenges for local area upgrading (Dicken, 1992; Gereffi, 1999; Henderson, Dicken, Hess, Coe, & Yeung, 2002; see also Gereffi, Fernandez-Stark, & Psilos, 2011 regarding workforce development). An important observation and critique is that workers do not always benefit from firm or area upgrading (Barrientos, 2007). The quality of jobs created by global trade is highly variable, with some jobs requiring specific skills and paying decent wages, and others characterized by extremely low levels of commitment by employers and high flexibility demanded of workers with low pay (Barrientos, Mayer, Pickles, & Posthuma, 2011; see also Kalleberg, 2011 for similar trends in reference to financialization in the United States). Barrientos identified that different supply chains (or "value chains") have unique patterns of skill dispersal and different trajectories for increasing wages, labor rights, and job security, based in part on variations in cost and quality demands (Barrientos, Gereffi, & Rossi, 2011).

This work to identify tradeoffs between development trajectories is increasingly important when the institutions that have traditionally rewarded skills with higher wages are weakened. Larger firms are generally better positioned than smaller firms to pay their workers better wages (Brown, Hamilton, & Medoff, 1990; Harrison, 1994), but have outsourced parts production and related employment to suppliers. National governments' role in preserving national interests and enforcing labor standards is diminished as corporations increasingly operate across international boundaries and local suppliers make employment decisions in

response to the requirements of their multinational clients (Barrientos, Mayer, Pickles, & Posthuma, 2011).

In general, global competition and the outsourcing activities of multinational corporations seem to push cost reduction burdens to firms further down the supply chain. Small firms in lower tiers of the supply chain may be particularly constrained in their ability to provide quality jobs and job training. Smaller firms in the United States not only pay lower wages, but also invest less in training (Black & Lynch, 1996; Brown, Hamilton, & Medoff, 1990; Harrison, 1994; Lynch & Black, 1998; Osterman, 1995). In 2014, Paul Osterman and Andrew Weaver found that skill shortages were overstated in general, but where they exist may be more acutely felt among smaller firms (Osterman & Weaver, 2014).

Consequently, smaller firms likely have difficulty taking advantage of local labor pools. Chrisinger, Fowler, and Kleit (2012) suggested that local labor pools of low-wage workers should be the subjects of economic development efforts to reduce poverty. They leave us asking how we can increase the number of accessible occupations.

Many states and local areas are also asking how they can invest in people and skills to fortify and restore manufacturing capabilities, rather than place bets on individual companies or invest only in high-skill, high-wage workers. For labor market participants that are not as entrepreneurial or as mobile as Markusen's artists or Feser's knowledge workers, occupational development needs to start with an accurate assessment of where investments in occupational skills will be rewarded. For workers whose labor market entry or re-entry is at stake, we know that education and training programs cannot be separated from work opportunities[4] and work

[4] Investments in training and education should be informed by labor market data regarding work and wages, including employment projections, and conducted in partnership with employers to ensure students and employees are receiving the most up-to-date training. Whenever possible, job seekers should be connected to employer-led training programs that lead directly to employment or advancement. These short-term programs should also be

opportunities cannot be separated from industrial trends, including the way the states and local areas are situated vis-à-vis global industries, global trade, and the powerful dynamics of supply chains.

With the "cross-hairs" of industrial and occupational analysis in focus (Thompson & Thompson, 1987, p. 547), this study introduces a related-industries approach and supply chain framework to evaluate skill dispersal and its compensation in the U.S. automotive cluster.

Data and Methods

The following analysis uses data on industries, occupations, and occupational skill requirements to map skill in a manufacturing supply chain, specifically the skill needed to manufacture the materials and parts that make up passenger vehicles.[5] The data sources will be familiar to economic analysts. Some of the data sources used in this analysis have been in use for decades, reoriented over and again to new priorities and paradigms. Introduced by economist Wassily Leontief in the 1940s, input-output tables aim to capture all economic transactions in the economy. They underlie much modern economic analysis, including industrial cluster studies (see Delgado, Porter, & Stern, 2015) and research on international trade (see Timmer, Dietzenbacher, Los, Stehrer, & de Vries, 2015). National input-output tables provide the basic information underlying economic impact studies produced by the IMPLAN and RIMS impact estimation tools (IMPLAN, 2017; U.S. Bureau of Economic Analysis, 2017).

This analysis uses the U.S. Bureau of Economic Analysis (BEA) Input-Output Tables to identify supply chain relationships, and their intensity and direction. These tables, the result of

sensitive to longer term skill demand and help ensure the labor market is resilient to change and can move to opportunity.

[5] Although the focus here is on manufacturing, a multitude of service industries are also connected to the automotive supply chain.

an impressive data collection program detailed in "The Input-Output Handbook" (Horowitz & Planting, 2009), capture transactional economic relationships between industries in a static representation of supply chains, a snapshot of relationships at one point in time. The major limitation of the BEA Input-Output Tables, for present purposes, is that the most recent year that data are available for detailed industry codes ("benchmark tables")—using 6-digit codes in the North American Industrial Classification System (NAICS)—is 2007. These benchmark tables are updated every 5 years. The 2007 data were released in 2015 and the 2012 data were not available at the time of publication.

Because the detailed "benchmark" (6-digit NAICS level) input-output tables for 2012 were not available, it is worth considering how the massively disruptive 2007-2012 automotive crisis and recession years might have shifted economic transactions between industries. Indeed, one of the reasons given for the bailout was the dependence of automakers on a shared supply chain. The concern was that if one automaker failed, its suppliers might have been unable to sustain operations and might have failed to provide key inputs to other automakers, causing their subsequent failure and magnifying the recession. While complete system failure was avoided, there were bankruptcies, mergers, and acquisitions among Tier 1 suppliers. The shifts apparent in the annual tables (2-digit NAICS level) from 2007 to 2012 are not consequential for the present analysis, in part because the Tier 1 suppliers are grouped together and thus we do not observe the intra-tier changes.[6] As readers are aware, the underlying industry dynamics and relationships are constantly evolving.

[6] The 2007 to 2012 period was highly disruptive to the U.S. automotive industry, but any structural change is not apparent when using the annual BEA national input-output Direct Requirement and Use tables to compare 2007 to 2012. This is likely because the high level of industry aggregation at three-digit NAICS code level masks intra-industry dynamics. According to the tables, during this period gross operating surplus for Automakers and Tier 1 suppliers (3361MV) is reduced, with reduced internal spending and reduced spending on all other manufacturing. Reductions are evenly spread across industries except with a slightly larger drop in spending on primary metal

The U.S. Department of Labor's Bureau of Labor Statistics Occupational Employment Statistics (BLS OES) occupation data are often used in studies of occupational trends and occupational clusters (Markusen & Schrock, 2001; Feser, 2003; Koo, 2005; Renski, Koo, & Feser, 2007; Chrisinger, Fowler, & Kleit, 2012). In this analysis, the BLS OES national reports by industry ("staffing patterns") are used to define the occupational mix of individual industries. The major limitation with this data source is that, for most industries, the industry-specific national- and state-level occupational profiles are only available at the level of 4-digit NAICS. I accept the generalization of occupational mix to the level of 4-digit NAICS, as this is an improvement over many industry studies that generalize at the 2- and 3-digit level. The limitation is further explored in the "Discussion of Data Limitations" section below.

Each occupation included in the occupational mix from the OES national reports by industry is matched to its skill profile in the extensive O*NET OnLine database (O*NET, 2017). Designed to help students and workers evaluate the training and career path that is right for them, the O*NET database describes the skills needed for each of the 800+ detailed occupations. The O*NET database contains measures of required education, related work experience, on-the-job training, STEM skills, and applied learning in a classroom setting provided by an employer, as well as measures that help an individual evaluate "fit" in an occupation (abilities, interests, tasks, etc.). Incumbent workers and occupational experts evaluate and re-evaluate a portion of the skill measures every year and each occupational profile is updated about every 5 years.

Education is a common proxy for skill. While this is a valuable measure, it does not capture all aspects of the "skill" construct. In this analysis, I am concerned with two measures of

manufacturing (331), a one percent drop. Imports of 3361MV are also reduced, exports increase, and domestic output increases slightly. The more detailed 2012 benchmark tables were not available at the time of publication.

job-related skill requirements, education and experience, which are used to assess two different aspects of the broader construct of "skill."

Table 1. Data Sources

Database Name	Database Source	Data Years	Description	Measures Used
BEA Input-Output Tables – Direct Requirements (DR) Table – Use Table	U.S. Bureau of Economic Analysis (BEA)	2007	BEA national Input-Output Tables track trade between U.S. industries by detailed (6-digit) NAICS codes: each industry's role as a commodity producer and consumer (their relationships to each other as buyers and sellers of materials and parts). Tables used are after redefinition of secondary commodities.	– Percent spending on input industries. – Total output and percent of output going to automotive industry.
BLS Occupational Employment Statistics	U.S. Department of Labor Bureau of Labor Statistics (BLS)	2016	The Occupational Employment Statistics (OES) program conducts a semiannual mail survey of approximately 200,000 nonfarm establishments per panel (every 6 months), taking 3 years to fully collect the sample of 1.2 million establishments, to estimate employment and wages for workers in 800 occupations. Occupational data are organized by North American Industry Classification System (NAICS) industry codes to create a national industry-occupation matrix.	National industry-occupation matrix: occupational mix, occupational employment, and wages.
(BLS OES) – National by Industry	Affiliated with the U.S. Department of Labor	2016	The O*NET database contains hundreds of standardized and occupation-specific descriptors on almost 1,000 occupations covering the entire U.S. economy. Every occupation requires a different mix of knowledge, skills, and abilities, and is performed using a variety of activities and tasks. Initially populated by data collected from occupation analysts, it is updated by ongoing surveys of incumbent workers and occupation experts.	Measures of education and experience required by occupation; O*NET Job Zone categorization of each occupation.

For present purposes, a major advantage of combining the BLS OES and O*NET skill measures is that O*NET skill measures are based on the actual tasks that occupations require—the education levels and experience levels workers must have on the first day of work in a specific occupation—not necessarily the education held by current employees in those occupations or employer preferences. Other similar sources not used in this analysis would be useful for other purposes. For example, information gained in surveys of the general population (e.g., U.S. Census Bureau American Community Survey or Current Population Survey) is useful for reporting on the education levels of incumbent workers currently in an occupation, which may reflect supply as much as demand. Job postings that are aggregated into databases by Wanted Analytics and other companies are also resources for information on occupations and their skill demands, but these reflect employer preferences (see Wardrip, Fee, Nelson, & Andreason, 2015 for a discussion of how employers' occupational requirements vary by region and labor supply).

The O*NET database also includes a unique job preparation measure ("Job Zone") based on an evaluation of overall preparation needed for an occupation, considering the required education and experience of workers and other measures of skill (O*NET, 2017). See Table 2 for a description of this measure. It is important to note that Job Zone 3 is the highest-level job zone applied to any production or repair occupations (occupational groups 49 and 51 in terms of Standard Occupational Classification [SOC] codes); this level usually requires 3 to 4 years of formal or informal apprenticeship in a trade. Job Zone 1 is the lowest level: few if any educational requirements and little if any previous experiences are needed. Job Zone 2 jobs usually require a high school education and some unrelated work experience.

It is worth noting that Job Zone 3 includes many of the "apprenticeable" trades and "middle skill" jobs that have been identified as in demand by various advocacy, trade, and industry associations, and academics (e.g., machinists and other skilled production occupations) (see Lerman, 2013).

Table 2. O*NET Measures of Skill, Categorization for this Study

Type of Skill Required	Measurement of Skill Requirement by O*NET	Author's Measure
Education	Six categories: did not complete high school, high school GED or diploma, some college, bachelor's degree, master's or professional degree, doctoral degree	Percent of occupations requiring more than a high school GED or diploma
Related work experience	Five categories: none, less than 1 year experience, 1 to 4 years, 4 to 8 years, more than 8 years	Percent of jobs requiring more than 1 year of related experience
Job zone	Five categories: Job Zones 1 (lowest preparation required) to 5 (highest preparation required) for all occupations; production occupations only categorized as 1, 2, or 3	Percent of jobs categorized as levels 3, 4, or 5

Grouping Industries (Supply Sectors) into Supply Tiers

In automotive industry studies, it is important to distinguish between automakers and their suppliers. This analysis starts with passenger cars and light trucks as the end products in the automotive supply chain and then identifies related industries in the supply chain (industries that contain establishments providing key inputs or "supply sectors"). The 2007 BEA Input-Output Tables and BLS OES staffing patterns data distinguish automakers (NAICS 3361) from their primary systems and parts suppliers (NAICS 3363) within the 336 NAICS group for Transportation Equipment Manufacturing.

The buyer/supplier relationships between industries establish the intensity and direction of trade using two measures: a measure of spending by automakers on the product/industry from the BEA Input-Output Tables, Direct Requirements Table; and a measure of how much of an industry's output was utilized by the automotive sector from the Use Table. In this analysis, industries are considered "supply sectors" if they are receiving more than 1% of spending by automakers and their first-tier supply sectors (or more than ~$2.5 billion annually), or if they are sending more than 50% of their output to automakers and their first-tier supply sectors. These supply sectors are organized into "supply tiers" or Tier 1 and Tier 2 supply sectors. Tier 1 supply sectors are those on which original equipment manufacturers (OEMs) and their final assembly plants rely the most. Tier 2 supply sectors are those on which Tier 1 supply sectors rely the most. Note that for illustrative and analytical purposes, only two tiers are evaluated, but this obscures several intra-tier economic transactions as companies in Tiers 1 and 2 buy and sell to each other within as well as across tiers.

Analyzing Skill by Supply Tier

Each 4-digit NAICS code identified as representing a supply sector is matched to its BLS OES national staffing pattern (or state staffing pattern for state-level analysis). Stripping the data to retain only the detailed occupation categories (6-digit SOC codes), each detailed occupation category is matched to data on skill requirements from the O*NET database. I present education and experience requirements by supply tier. Focusing then on production occupations only, which include both production and repair occupations (occupational groups 49 and 51 in terms of SOC codes), results also include the percent of occupations categorized as O*NET Job Zone 3.

Discussion of Data Limitations

The first major limitation is that the BLS OES data linking industries and occupations, or the staffing patterns data, are only available at the 4-digit NAICS level, meaning that data on

economic transactions at the 6-digit level (e.g., in the BLS input-output tables) are not utilized. This is the most detailed level available for staffing patterns by industry. Regardless of the industry-level detail, using industry data means that establishments participating in automotive production are lumped together with establishments that are not participating in automotive production. Establishment level differences are obscured. In representing skill demand across a supply sector, I assume that automotive-serving establishments have similar staffing patterns as non-automotive-serving establishments, or that automotive-serving establishments are evenly distributed around the industry average.

Another data limitation is that information on occupational skill requirements in O*NET do not vary by industry or by establishment; industry- and establishment-level differences are obscured. I assume that occupations have similar skill requirements across industries, as well as across automotive-serving and non-automotive-serving establishments within the same industry. This means that I assume that the job of maintenance technician requires the same level of education and experience on day 1, regardless of whether the maintenance technician is starting a job at an automaker's vehicle assembly plant with a sophisticated teamwork organization and emphasis on quality production or starting at another manufacturing firm, which may have less sophisticated systems.

In spite of these limitations, the proposed framework is useful, in part to structure and motivate research into these assumptions.

Supply Tier Skill Estimates

Grouping Industries into Supply Tiers

Automakers and Tier 1 supply sectors are highly interdependent in their trading relationships (see Table 3). Automakers are supplied by more than 200 industries but seven of these industries receive 46% of the automakers' spending. These seven industries—

manufacturing of steering, engine, transmission, exterior, interior, electrical, and related parts and systems—make up Tier 1 supply sectors. These sectors are highly committed to automotive production, with 59% of their total output going to automakers or other companies in Tier 1 (Tier 1 companies sell to each other as well as to automakers). Spending by automakers and Tier 1 on Tier 1 supply sectors totals $135.2 billion.

Tier 1 includes many of the global suppliers that increasingly provide whole systems or "modules" of vehicles to final assembly plants. For companies in Tier 1, global sales can reach $45 billion annually (Automotive News, 2016). Companies include multinational firms Bosch (headquartered in Germany) and Denso (headquartered in Japan). These are assumed to have sophisticated establishments producing complex parts using advanced technology.

Research on the global automotive industry suggests that interdependence between automakers and Tier 1 suppliers is an increasing global trend, and also that Tier 1 operations are increasingly consolidated though mergers and acquisitions (Sturgeon, Van Biesebroeck, & Gereffi, 2008). Research on U.S. supply chain relations does not contradict this observation but focuses instead on the different levels of collaboration and trust between supply chain partners and trends led by individual automakers (MacDuffie & Helper, 2007).

Table 3 displays the basic information on supply tiers. The first and second columns describe the supply tier; the third describes the industries included. The amount of spending by the automotive sector and the percent of the industry's total output that goes to automotive production are in columns 4 and 5. Average establishment size and total employment are listed in columns 6 and 7. We can see that a single automaker establishment might make a big

employment impact on a local area, but the combined related employment in Tier 1 and Tier 2 supply sectors is greater.[7]

Tier 2 establishments tend to be smaller, but there are more of them. These include metal and plastic parts providers. The automotive industry is known to be demanding in its quality and cost expectations, expectations that are passed down through supply chain tiers from the automakers. Lower tier suppliers have few opportunities to become direct suppliers to automakers, given the dynamics of the first tier (Sturgeon, Van Biesebroeck, & Gereffi, 2008).

Table 3. Supply Sector Tiers: Automakers, Tier 1, Tier 2 Supply Sectors

1	2	3	4	5	6	7
Tier assign-ment	Tier description	4-digit NAICS codes	Spending by auto assembly and tier 1 suppliers (U.S. billions)[a]	Pct. output to auto assembly and tier 1 suppliers[b]	Average establishment size (employees)	Total employment[c]
Auto-makers	Lead firms, final assembly	3361	NA	NA	521	205,261
1	Automotive systems/parts mfg.	3363	$464.2	59%	102	352,398
2	Parts mfg.	various[d]	$430.0	13%	39	305,111

Source: U.S. BEA Input-Output Tables, 2007; U.S. BLS Quarterly Census of Employment and Wages, 2016.
[a] Calculated based on industry output (BEA Input-Output Direct Requirements Table).
[b] Percent of the industry that is allocated to produce cars or car parts (BEA Input-Output Use Table).
[c] Employment is weighted for each industry included in the tier by percent of the industry output going to automakers and Tier 1 industries.
[d] Industries in Tier 2: NAICS 3261, 3311, 3315, 3321, 3327, 3336, 3344.

[7] There are several small establishments that are included in the associated NAICS code (3361) that are indeed Original Equipment Manufacturers that produce race cars and small vehicles in low volume and do not provide a similar product to the large Automakers. Ninety percent of all Automakers' employees are employed at establishments (manufacturing plants or offices) with more than 1,000 workers; half of all employees in Tier 1 are employed at establishments with more than 500 workers (BLS Quarterly Census on Employment and Wages, 2016).

In Table 3, Tier 2 supply sectors are distinguished by their trading relationships with automakers and Tier 1 sectors.[8] Automakers and Tier 1 companies spend $429.6 billion on companies in Tier 2. However, a majority of this spending is by Tier 1, not automakers, revealing that Tier 1 plays an important role in consolidating parts and services from other suppliers of manufactured goods.

Tier 2 companies provide intermediate inputs to a greater diversity of end products compared to Tier 1, which is highly dedicated to and dependent on automotive industry purchases. Only 13% of Tier 2 output goes to automotive production (see Table 3).

Education and Experience in Automotive Supply Tiers

Tier 1 supply sectors require higher levels of education and experience than automakers, based on the required education and experience levels of their total personnel, including administrative, design, sales, engineering, production, and transportation positions. Tier 1 supply sectors employ a higher percentage of engineers than do automakers—8% versus 4% of total jobs—contributing to their higher overall skill estimates (BLS OES, 2016). These results may be surprising for those of us that think of automakers as driving innovation in the automotive industry and therefore possessing most of the important skills for manufacturing process and product innovation.

[8] NAICS 3363 industries constitute Tier 1; plastic, primary metal, metal product, machinery, computer and electronics parts manufacturing sectors are included in Tier 2. Given the complexity of identifying suppliers at lower tiers of the supply chain, studies often limit their analysis of the automotive industry to the NAICS codes that are most directly related: those that begin with 3363. There are seven detailed NAICS categories that begin with 3363 and represent major blocks of firms and establishments that serve in the top tiers of the automotive value chain. Studies that go beyond the 3361 and 3363 NAICS codes to examine the role of other related industries in the automotive supply chain examine a few but not all the codes included here (NAICS 3261, 3311, 3315, 3321, 3327, 3336, 3344). Helper et al. (2011) include companies from NAICS 3261, 3262, 3321, 3327, 3335 and 3362 in their survey of U.S. automotive parts suppliers. Delgado, Porter and Stern (2015) include industries from NAICS 3315, 3321, 3362 and 3369 in their definition of the automotive industry cluster.

Large firms invest the most in research and development and are granted the greatest gross number of patents; also, they can often adapt to control the highest value-added activities in the supply chain such as the research, design, and development of new products. However, we also know that many large firm capabilities, skills, and knowledge are retained at headquarters locations while satellite offices and branch plants apply more codified best practices to their specialized work. Further, on a global scale, automakers share research and development, design, and production risks and opportunities with their first-tier suppliers (Sturgeon, Van Biesebroeck, & Gereffi, 2008, p. 305-307).

In fact, automotive parts suppliers, both Tier 1 and Tier 2 sectors, require a higher level of "skill," as measured by either education or experience, than automakers. Tables 4 and 5 compare basic skill measures for supply tiers—measures of education, experience, and (in Table 5) O*NET's Job Zone 3, categorization: Table 4 for all positions and Table 5 for production positions.[9] The differences in production worker skills across supply chain tiers are more pronounced.

Table 4. Measures of Skill Required of All Workers by Supply Chain Tier

	Percent of all positions requiring…	
	… more than a high school education	… more than 1 year related work experience
Automakers	27%	41%
Tier 1 supply sectors	40%	56%
Tier 2 supply sectors	43%	60%

Source: Author's analysis of BLS OES (2016), O*NET (2017).

[9] Production workers constitute 81 percent of Automakers' employees, 65 percent of Tier 1 employees, and 40 to 80 percent of total employment in individual Tier 2 industries

Tier 2 includes smaller establishments likely producing smaller, less sophisticated parts than Tier 1, but Tier 2 skill measures are almost as high or higher than Tier 1 for all personnel and production positions. In Table 5, Tier 2 stands out as requiring the highest percentage of skilled production workers as measured by the comprehensive Job Zone 3 category. This measure is particularly well suited to measure skills required in manufacturing as it includes skills acquired through experience, education, and on-the-job training.

Table 5. Measures of Skill Required of Production Workers by Supply Chain Tier

	Percent of all positions requiring…		
	… more than a high school education	… more than 1 year related work experience	…Job Zone 3 skills
Automakers	9%	23%	10%
Tier 1 supply sectors	12%	41%	24%
Tier 2 supply sectors	14%	47%	31%

Source: Author's analysis of BLS OES (2016), O*NET (2017).

The estimates for Tier 2 supply sector skills are based on averages across seven very different industries. To focus in on Tier 2, Table 6 displays skill measure results for industries included in Tier 2, showing little variation in the measure of education, a lot of variation in the experience measure, and a moderate amount of variation in the Job Zone 3 percentage. Some supply sectors require much higher levels of skill (see the results for "3327 – Machine Shops" in Table 6); other supply sectors require lower levels of skill (see the results for "3261 – Plastic Products Mfg." in Table 6).

Table 6. Measures of Skill Required of Production Workers for Industries Included in Tier 2

Industries included in Tier 2 supply sector	Percent of production positions requiring…		
	… more than a high school education	… more than 1 year related work experience	…Job Zone 3 skills
3311 – Iron & Steel Mills	14%	50%	32%
3315 - Foundries	14%	45%	24%
3321 – Forging & Stamping	14%	52%	31%
3327 – Machine Shops	17%	58%	61%
3344 – Semiconductor … Mfg.	14%	39%	15%
3336 – Engine & Turbine Machinery	14%	49%	37%
3261 – Plastic Products Mfg.	11%	41%	16%

Source: Author's analysis of BLS OES (2016), O*NET (2017).

Underlying the difference in skill levels estimated for supply chain sectors are the different mixes of production occupations, shown in Table 7 for automakers, Tier 1, and two examples of industries (one higher skill, one lower skill) from Tier 2. The high percentages of skilled tradesmen employed in Tiers 1 and 2 contributes to the high skill measures. Computer-controlled machine tool operators, machinists, machine maintenance, and tool and die positions are designated as Job Zone 3, requiring the top level of preparation among production positions. These are in-demand occupations that increasingly require experience in mechatronics and advanced materials. As Table 7 depicts, some of the industries included in Tier 2 have a very high percent of skilled tradesmen.

Table 7. Variation in Occupational Mix by Supply Sector: Auto Assembly, Tier 1, Example Industries from Tier 2

Production occupations by supply chain sectors	Auto assembly	Tier 1 supply sectors	Tier 2 high skill example: machine shops	Tier 2 low skill example: plastic products
Assemblers, Supervisors	83%	44%	12%	25%
Machine Maintenance	4%	7%	2%	8%
Computer-Controlled Machine Tool Op.	0%	4%	14%	2%
Machine Setters and Operators	7%	18%	14%	45%
Machinists	0%	5%	39%	2%
Tool and Die Makers	1%	3%	1%	1%
Welders, Cutters, Solderers, and Brazers	0%	3%	5%	0%
Inspectors, Testers, Sorters…	3%	5%	5%	6%
Other	2%	11%	8%	11%
TOTAL	100%	100%	100%	100%

Source: Author's analysis of BLS OES (2016).

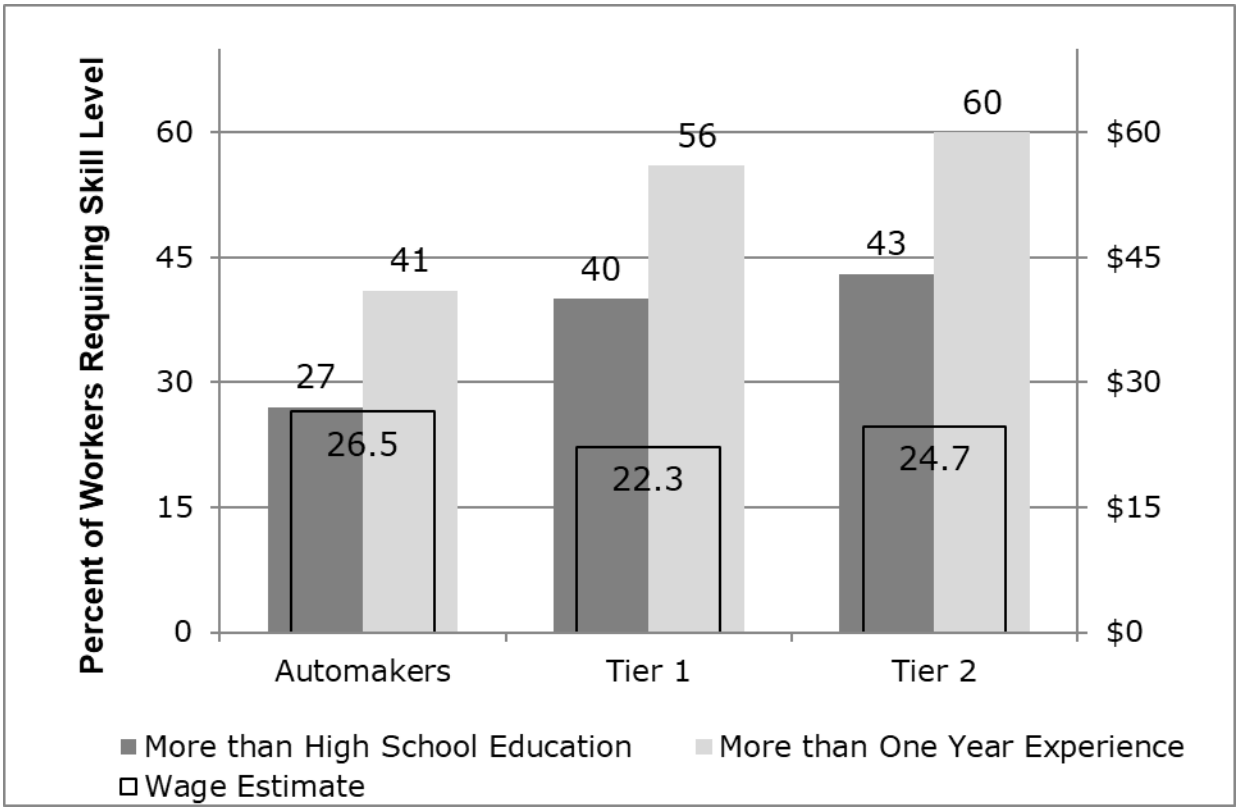
Eighty-three percent of production workers employed by automakers are not skilled tradesmen but rather are experts in assembly ("team assemblers"). These positions generally require a high school education and less than 1 year of related experience, if any at all. Similarly, machine setters and operators employed by automakers (7% of total production occupations) require a similar level of education and experience. Supervisors of team assemblers are registered as Job Zone 3, not because they require more education but because these jobs require more experience and social skills.

Education, Experience, and Wage Estimates

This skill-centric analysis of trading relationships between industries in the automotive supply chain begs the question of how skills are rewarded across supply chain sectors. Given the

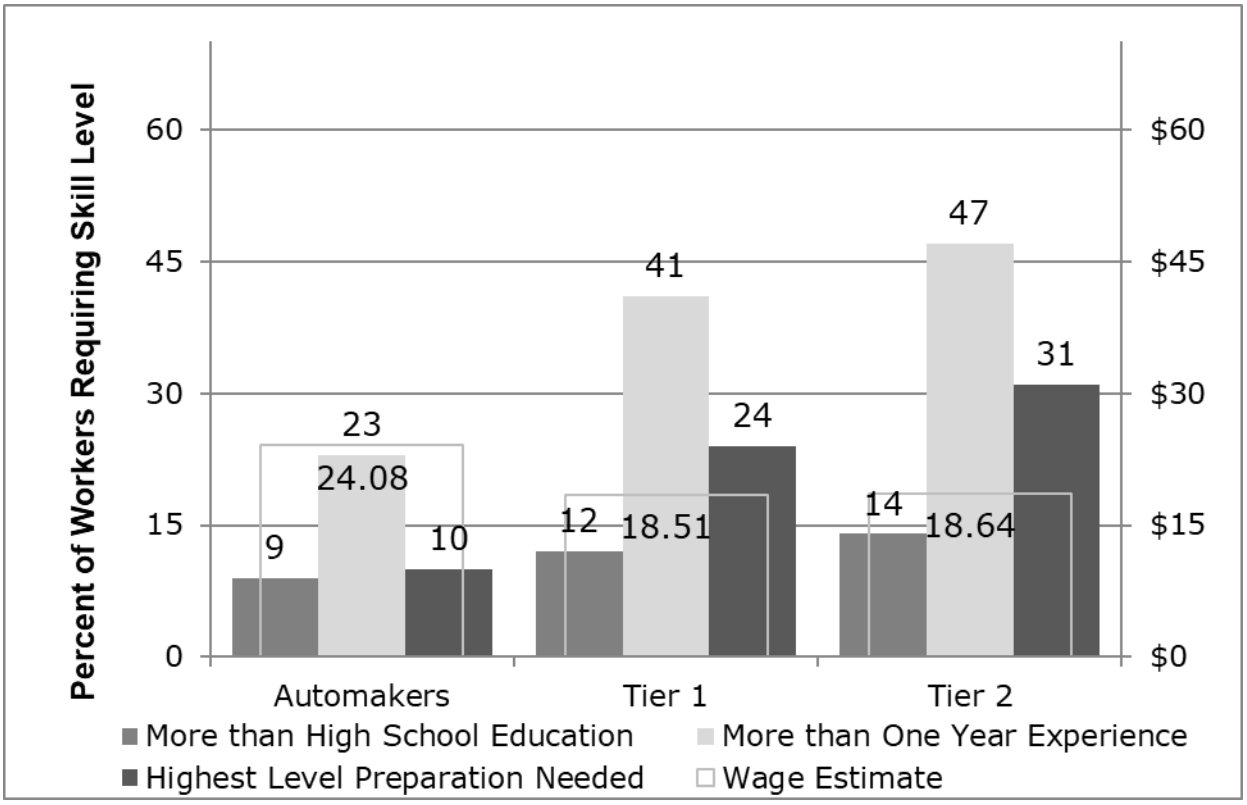
high level of skill required by Tier 1 and Tier 2, in comparison to automakers, it is surprising to see in Figures 1 and 2 that workers' wages in these tiers are lower. Based on national and state-level wage estimates, wages seem not to vary with skill measures but rather with supply tier, in the opposite direction as skill intensity. Figures 1 and 2 show the skill measures and wage estimates for all workers (Figure 1) and production workers (Figure 2).

Figure 1. Skill Measures by Supply Chain Tier - All Automotive Workers



Source: Author's analysis of BEA Input-Output Tables, BLS OES (2016), O*NET (2017).

Figure 2. Skill Measures by Supply Chain Tier – Automotive Production Workers



Source: Author's analysis of BEA Input-Output Tables, BLS OES (2016) O*NET (2017).

These wage estimates suggest that skill is potentially unrecognized or undervalued in Tiers 1 and 2; or, similarly, that workers and firms lack the power to negotiate for wages that reflect their skill levels. In general, we know that automakers generally provide good jobs with higher wages and lower educational barriers to entry where workers are organized and bargain collectively with their employer, while other automakers raise wages and maintain job quality to remain competitive in the labor market and to avoid union organizing (Brown, Hamilton, & Medoff, 1990, p. 30-32, 38-40).

It may also be difficult for lower-tier supply sectors to raise wages if constrained by their contracts. Lower-tier companies might have more precarious contracts with their clients with few channels to communicate or capture opportunities to secure greater profit margins. In this way, the power dynamics in the supply chain may suppress the wages of workers in lower-tier

supply sectors. It is also likely that the supply chain structure allows automakers to capture more profits and to increase workers' wages sufficiently to reduce recruitment and retention costs and stabilize their workforce (how firms reduce turnover with efficiency wages in Osterman, 1995, p. 136).

One also must consider whether supply chain position is being conflated with establishment size: establishments in Tier 1 are smaller on average than automakers' establishments and establishments in Tier 2 are smaller on average than those in Tier 1.

Table 8. Wage Estimates by Supply Chain Tier – All Positions and Production Positions

NAICS description	NAICS codes	U.S. average hourly wage *all positions*	U.S. average hourly wage *production positions*
Automakers	3361	$26.50	$24.08
Tier 1 supply sectors	3363	$22.27	$18.51
Tier 2 supply sectors	(several)	$24.74	$18.64
Employment services	5613	$18.22	$13.92

Source: BLS OES (2016).

The skill and wage levels of production workers in employment services are included in Table 8 as a reference. Employment services tends to employ temporary workers with short-term contracts and lower wages, representing a previously recognized lower segment of the workforce (Kalleberg, 2000; Peck & Theodore, 1998) utilized by automotive companies to increase flexibility during expansions and downsizing and in tight labor markets (Barrientos, Gereffi, & Rossi, 2011; Houseman, Kalleberg, & Erickcek, 2003). The input-output tables show that automakers spend about one tenth of a percent of their budget on Employment Services (NAICS 561300). Tier 1 supply sectors spend a slightly higher percentage than automakers, and

Tier 2 supply sectors spend a slightly higher percentage than Tier 1—but this also reflects that these lower tier sectors spend a greater percentage of their budget on all services due to smaller economies of scale (author's interpretation of BEA input-output tables).

The majority of production workers in Employment Services are in assembly positions, suggesting they are likely utilized by automakers and Tier 1 suppliers. The nature of temporary help services allows automakers to hire workers during production peaks and let them go when production slows (Barrientos, Gereffi, & Rossi, 2011) and adds flexibility in tight labor markets (Houseman, Kalleberg, & Erickcek, 2003). It allows automakers to screen workers for full employment, observing them for 6 months, for example, before offering them a more permanent position.

It is possible that the low wages of the production workers in Employment Services are the result of other low wage industry demand. But if we accept that automakers also pay much lower wages to temporary workers than to regular production workers, then here are several possible conclusions, given the wage differential. One, that wages reflect skill levels: lower skill levels are required during production peaks to augment production, and, if a temporary worker is offered a permanent position, it is because she has gained or has potential to gain critical skills during the 6 months or so of observation. Two, wages reflect the bargaining power of labor in large firms and higher unionization rates or automakers' unique position in the supply chain and their ability to spend to retain their key production staff. If a temporary worker is offered a permanent position, her wages increase, not in relation to skill, but in relation to institutional dynamics.

In summary, a variety of advantages accrue to automakers. Size, brand name recognition, and supply chain control allow automakers to accrue greater revenues and spend

more per worker, regardless of workers' skill levels. Their many advantages might lead to segmentation in the labor market whereby smaller and lower-tier firms are unable to compete with automakers for labor but may compete with each other where co-located.

Skill in the Automotive Supply Chain: State Examples

To investigate the variation in skill measures by state, I chose one state in North America's automotive industry core and one in the periphery. Michigan, specifically the Detroit region, has long been the center of automotive industry research, design, development, and production, and hosts the North American headquarters of the Big Three and many other U.S. and foreign firms. Alabama is in the manufacturing periphery, with younger assembly and parts manufacturing plants, similar to other U.S. southern and Mexican states that welcomed foreign direct investment in the 1980s and 1990s.

In both states, as at the national level, Tier 2 requires the highest percentage of highly skilled production workers (Job Zone 3), Tier 1 is in the middle, and automakers require the lowest percentage of highly skilled production workers (see Table 9).[10] This is despite differences in state population and automotive employment shares. As discussed above, these measures result from automakers' reliance on assembly line positions and Tier 2 industries that rely heavily on skilled trades.

I observed some state-level differences in the skill required by Michigan and Alabama establishments. Alabama's Tier 1 supply sectors have a comparatively lower percentage of highly skilled workers, compared to results in Michigan and to the national results. This

[10] Alabama hosts the vehicle assembly branch plants of Mercedes-Benz (opened 1997), Honda (opened 2001) and Hyundai (opened 2005). Alabama population is about half that of Michigan (roughly 5 million vs 10 million); employment at Automakers in Alabama is a little more than one third of Michigan's employment at Automakers (13,083 vs 36,720 workers); employment in Tier 1 is roughly one fifth (25,533 vs 125,789).

suggests that the dedicated automotive parts and systems being built in Alabama are less skill intensive, or rather that the occupation mix there requires fewer highly skilled and experienced tradespeople. I also note that production workers in Alabama's Employment Services sector are less concentrated in higher skill occupations (Job Zone 3), and thus the wage differential between employment at automakers and at Employment Services is much larger. Although automakers use temporary help agencies and other employment services, the lower wage might also reflect that several other industries are utilizing Employment Services for lower-skill and lower-wage production work in Alabama, or that automakers are not using these services as much in Alabama as in other states.

Wage estimates by tier are shown for Michigan and Alabama in Table 10. In both states, as at the national level, automakers have the highest wages; however, as with Tier 1 skill measures, Tier 1 wage estimates vary by state. In Alabama, Tier 1 wage estimates (and skill measures) are lower than Tier 2; in Michigan, Tier 1 wages estimates (and skill measures) are greater than Tier 2. These results suggest different levels of wage-setting power, institutional differences, and differences in the supply chain position of Tier 1 companies in each state. The historical patterns of how Tier 1 suppliers have chosen their locations to serve various automakers in the region would also be a factor in the divergent skill levels and wage rates. It is interesting to see that wages might drop with skill levels within this supply tier, indicating that skills and wages may have a more typical relationship within individual industries or tiers than across tiers.

Table 9. Measure of Skill Required of Production Workers by Supply Sector Tier – Michigan and Alabama

	Percent production positions requiring Job Zone 3 skills	
	Michigan	Alabama
Automakers	11%	10%
Tier 1 supply sectors	19%	14%
Tier 2 supply sectors	31%	30%
Employment services	15%	9%

Sources: BLS OES (2016), O*NET (2017).

Table 10. Estimated Wages for Production Workers by Supply Sector Tier – Michigan and Alabama.

	State average hourly wage - production positions	
	Michigan	Alabama
Automakers[a]	$25.19	$23.84
Tier 1 supply sectors	$19.86	$16.19
Tier 2 supply sectors	$17.83	$19.00
Employment services	$13.58	$12.17

Source: BLS OES (2016).

[a] Repair and maintenance positions excluded due to data suppression in one state.

Conclusion

An analysis of skill by industry in a supply chain perspective advances our understanding of skill beyond the level of a single organization or a labor market, raising our awareness of how local and nonlocal relationships between firms structure the location and valuation of skill across a supply chain. In the case of the U.S. automotive industry, I observe the strong interdependence between automakers, Tier 1, and Tier 2 supply sectors, not only in their direct economic

transactions but also in the distribution of skill between the tiers. I observe that skill requirements are higher in Tier 1 and Tier 2 supply sectors than for automakers. I also observe that wages vary with supply chain tier but in the opposite direction as skill requirements, demonstrating that average compensation levels do not necessarily reflect the required skill levels of workers.

One should be cautious drawing conclusions, as these observations are based on a descriptive presentation of industry averages based on population estimates, and I do not have accurate industry-level data on the skills that are required. Importantly, the results gloss over issues that qualitative and survey-based research has emphasized: primarily, the degree to which there is variation in work organization that might affect staffing patterns and occupational requirements. For example, larger firms are more likely to adopt measurable high-performance workplace practices, but how that affects measures of workers' skill levels on Day 1 or Day 100 is not well established. The uptake of best practices in work organization (e.g., collaborative work teams, an emphasis on problem solving) may not be correlated with traditional measures of skill, such as education and experience.

Local workforce and economic development practitioners who have one-on-one relationships with employers might further explore these questions with employers, perhaps opening the door for new skill upgrading initiatives. Answering questions on the future of work, regarding the pace of technology adoption and its impact on work requirements, depends not only on recognizing where skill has been located but also how it might be re-located in supply chains and across industry sectors, subjects on which industry experts have deep, contextualized knowledge.

A few questions naturally follow from the finding that automotive supply chains seem to rely on skilled tradesmen concentrated in lower tiers, and yet their skill and experience is not generously compensated. What type of skill and experience is the most valuable? Are some skills gained through experience undervalued, underutilized, or somehow not worth compensating? The global value chain literature suggests that firms in lower tiers of supply chains simply cannot pay more; other literature suggests that skills cannot be leveraged without complementary investments in machinery and training. It follows that these skills—and corresponding "middle skill," "apprenticeable" trades—might be more valuable, but that smaller firms face barriers to compensating these skills. Their failure here may diminish the supply chain's ability to regenerate these skills.

Intermediate goods suppliers may be uniquely able to decipher these issues in the context of the automotive industry, as they are increasingly responsible for managing skilled labor internally and in their supply network. Ignoring the uneven relationship between skills, supply chain position, and wages, they may fail to recognize weak occupational links in their supply chains and overestimate the abilities of other firms to regenerate key skills. Industry leaders, automakers, and Tier 1 suppliers might consider engaging smaller firms more strategically on this issue.

One recommendation for future analysis of education and employment trends is to use multiple measures of skill, particularly when considering the production workforce or other populations that may have low variation in education levels but higher variation in other measures, such as experience or STEM-related skills (see Rothwell, 2013 and Stewart, 2017 regarding the latter). The long-held belief that skill accumulation leads to higher wages and regional growth has depended upon the use of education as a proxy for skill (for a critique, see

Hanushek et al., 2015 or Stewart, 2017). But scholars have recognized that important workplace skills, like teamwork and communication, persistence, and trustworthiness, are not explicitly taught or measured in schools (Heckman & Rubinstein, 2001; Lerman, 2008; Murnane & Levy, 1996). Given the high level of debt students incur at college and variation in college completion rates, research and related policy prescriptions are becoming more detailed and targeted (see Carnevale, Cheah, & Hanson, 2015 for research on the returns to different college majors).

The recommendation to use multiple measures of skill is also relevant to scholars of international development and economic growth as they examine the "skilled" labor component of domestic value added in traded goods and the "skill content" of different products. Alternative measures of skill, such as those utilized in this study and others available through O*NET OnLine, should be sought by domestic as well as international research teams.[11]

Finally, a skills-in-supply-chains framework can serve as a tool for workforce development specialists seeking to identify where workers' skills could be better developed, recognized, and rewarded. In a local labor market context, it provides additional information to evaluate potential career pathways across companies in different sectors of the supply chain, helping practitioners structure further examination into occupational mobility issues, such as how labor flows between large and small firms. It could also help practitioners compare local occupational assets and aspirations to the demands of both existing industry and potential new recruits, planning how to advance the skills of a local area. All these efforts would strengthen U.S. manufacturing supply chains and help pinpoint local comparative advantage.

[11] The various measures of skill utilized in this analysis—education, experience, O*NET job zones—could enhance scholars' evaluation of the shifting skill requirements of various industries and occupations. These details can advance research regarding how technology adoption effects skill requirements as well as where different types of skills are located (and re-located) in supply chains and industry sectors.

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PAPER 2: A SUPPLY CHAIN ANALYSIS OF SKILL COMPETITION AND CO-PRODUCTION

Introduction

Smaller firms are known to underinvest in training their employees. They also tend to pay lower wages than their larger counterparts, making it difficult to attract and retain top talent. Without the capacity to update skills on a regular basis or the ability to retain skilled workers, these firms face a double jeopardy: their small size limits their ability to train their own and to "buy" skilled labor, locking them into an unproductive corner of the labor market where they constitute a dead end for job seekers.

Most research assumes that low levels of training and low wages are due to size-related internal restrictions—reduced resources, poor work organization, or inability to connect to workforce development systems. This paper broadens the lens to consider how top-down buyer-supplier networks can influence whether firms, both large and small, invest in training.

In a supply chain context, more powerful buyers can set cost and quality expectations for a subordinate supplier. Buyers can use formal contract terms or communicate cost and quality expectations less formally, such as through repeated interactions. These dynamics are consequential for economic regions, where inter-firm relationships and related training (dis)incentives can either bolster or undermine the health of local firms. Sometimes intersecting processes of divestment can proceed behind the scenes. If a supplier is expected to focus on cost reductions, it will become difficult to defend investments in human resources. And where buyers and suppliers are co-located, they may compete for skilled labor. This means that, in addition to setting contract terms that make it difficult to invest in workers' skills, buyers may also

undermine co-located suppliers' skill development efforts when they inadvertently recruit talent away from their suppliers. In this regard, the decision to invest in skill development is shaped by both a firm's relative position in a supply chain and the degree of competition for skilled workers within that same network.

This paper explores how supply chain dynamics affect the training decisions of firms, focusing on firms' decisions to provide initial on-the-job training for skilled production technicians, including through apprenticeships. I observe a single concentrated buyer-supplier network in one automotive cluster, drawing insights from industry-level occupational data and 27 interviews with economic and workforce development practitioners and company representatives—human resources directors, owners and branch plant managers. This case shows that the cost-reducing pressures of supply chain dynamics and lean production practices have constrained training resources across the private sector. For some firms, external supply chain pressures lead to divestment from training as well as a disconnect from traditional skill development systems. These industrial dynamics suggest that firms' training decisions may be closely related to their position vis-à-vis clients and product markets, perhaps exacerbating size-related constraints.

I also find evidence that top-down corrections initiated by clients and bottom-up solutions led by smaller and lower-tier firms can counteract some of the training- and wage-suppressing trends that are driven by cost pressures. Likewise, I find that firms that are not entirely captive to the automotive industry and its intensive cost constraints, but which have diversified their client base, have an opportunity to leverage that product market diversification: they can use the greater profit margins to invest in more aggressive and competitive training investments, offer higher wages, or both.

These solutions demonstrate that firms in the same labor market, facing similar cost and quality constraints, can offer a variety of viable training packages, and some distinguish themselves in this respect. Firms that are successful in providing training not only overcome supply-chain related constraints but do so by engaging local education and training institutions like the community college system. A few also engage other local firms. Surprising strategies emerge in this highly competitive but networked environment, including the engagement of younger workers in high school, training candidates that are less in demand by larger and higher-tier suppliers, but which have the potential to benefit from training.

The findings of this paper suggest opportunities for action by economic development practitioners. In the longer term, economic developers can help to build institutions that support supply chain capacity and ingenuity in addressing skill development bottlenecks. More immediately, there is room for extending public sector support for employee training along the supply chain, directing resources to clients and their co-located suppliers. This extension of services following large firm expansion events would help suppliers sharpen their skills when they are both poised for growth (having renewed or expanded contracts) and face reduced risk of losing new staff to their expanding client's hiring efforts.

Even more critically, efforts by economic developers to support skill development along an entire supply chain could capture the attention of suppliers who are willing to invest in training, helping to galvanize more creative supply-side engagement strategies and more meaningful coordination around issues of skill development. More generally, to support constrained firms in raising wages or investing in training or both, local leaders should aim to shift the focus from a discussion that has centered around the tradeoffs between training and wages to consider training and wages as potential complements. It is also important consider

more than just training and wages: firms can distinguish themselves based on their entire employment offer, job quality and fit with existing, new and returning labor market entrants. For some firms, offering and providing training is key to ensuring an enduring and productive fit with employees.

In the next section, I discuss firm-led, on-the-job training trends, considering local- and supply chain-based dynamics. The third section describes the research setting, data and methods. In the following two sections, I interpret the results. The sixth section discusses findings. The last section concludes with policy implications.

Background

In 1964, Gary S. Becker published his influential treatise on human capital, modeling empirical puzzles and rationalizing training and education decisions. Regarding when firms train, he explained that firms invest in training only when the relevant skills are specific to the firm, and not when the skills are transferable to other firms or *general* in nature (Becker, 1964). In the latter case, workers bear the costs and reap the benefits of training. While the general/specific skill model is theoretically compelling, it relies on the strong assumption of a perfectly competitive labor market.

In a *perfectly* competitive market, many firms compete for labor, workers are mobile across firms, firms have perfect information about each worker's ability, and firms communicate demand with wages. If some firms decide to train, other firms will simply lure the training firm's trained workers away with higher wages. (This is because all firms have the same technology and cost structure and hence the same budget for training and wages.) Training will rarely occur under these conditions, since no firm could retain the benefits of training (Becker, 1964; Pigou, 1912). Without barriers to worker mobility, and with transparency in abilities and skills, each

firm also must pay closer to the full marginal product of the worker including increases in worker productivity due to training. It is therefore up to the worker to invest in training.

In *imperfect* or less competitive labor markets, there are a number of conditions which motivate firms to pay for training and reap its benefits. In general, frictions in the labor market allow employers to pay less than the marginal product of labor, making it easier for them to recoup their investment and retain skilled labor (Acemoglu & Pischke, 1999: F119-120). These frictions include barriers to information flows between firms (regarding workers' skills and abilities), matching costs (recruitment and job search) and other limits to worker mobility. Firms will find that, in a less competitive market, it is a good investment to train, and that general skills can be "de-facto firm-specific skills" with limited labor market competition (Acemoglu & Pischke, 1999: F120).

What are the possible training outcomes in imperfectly competitive labor markets? Becker proposed a no firm-sponsored training scenario, based on the idea that firms would not be able to both invest in training and raise wages above market rates, yet this is exactly what some firms are able to do given actual labor market imperfections. Related theoretical and empirical studies show that firms that train benefit from increased productivity without substantially increasing costs, because there is a compression of wages (Barron, Berger and Black, 1997; Dearden & Van Reenan, 2005; Konings & Vanormelingen, 2010). Productivity gains from training outpace wage increases as firms pay below the marginal product of labor. Some firms pay below the marginal product of labor but *above* market wage rates. Other firms, with limited competition for their skilled labor, can pay below *both* marginal product of labor and market rates. Their ability to do so may derive from their *monopsony* power (Becker, 1964; Acemoglu & Pischke, 1999). *Monopsonists*, as they are called, are the only buyer of a specific skill or one of a

few buyers and so they face low levels of labor market competition. They can lower wages if they prefer while still retaining skilled labor (Acemoglu & Pischke, 1999: F119).

Firms also share training costs with workers, such as through reduced wages during an apprenticeship. In such an arrangement, a worker's wages are low during training, then rise steeply as the worker graduates to a master craftsman or another credential. The critical condition for these shared costs is credible contracts, which can support training even with near perfect labor market competition (Acemoglu & Pischke, 1998; Acemoglu & Pischke, 1999; Acemoglu & Autor, n.d.).

Another important consideration in *imperfect* markets is the heterogeneity of firms. Scholars have suggested that firm size and firm strategy are important sources of heterogeneity among firms in the same labor market. Some firms may pursue positions of power over their workers, acting strategically to develop their monopsonistic position and decrease labor mobility. Likewise, other firms adopt High Performance Work Systems, a bundle of competitive human resources and work practices that compel employees to maximize their effort. Theoretically, these firms can afford investments in new machinery, relevant training, competitive wages and benefits because they distinguish themselves in their product markets for high quality products and services (Appelbaum, Bailey, Berg, and Kalleberg, 2000; Batt, 2002). Firms are more likely to pursue this latter strategy in high-wage, high-skill industries; for example, firms in the financial industry train more (Osterman, 1994; Osterman, 1995; Lynch, 1994). Examples of employers deploying this strategy in low-wage industries are rare (see Osterman, 2018 regarding "high road" employers).

Firms with more resources are also more able to invest in training and complementary human resource policies. Larger firms, in general, tend to train more, and scholars explain that

larger firms have a variety of internal advantages and a number of available tactics that help them attract, train and retain skilled labor (Cappelli, 2009, 2012; Osterman, 2018). Smaller firms have deficits in these areas (Brown, Hamilton, Medoff, 1990; Osterman, 1994; Osterman & Weaver, 2014)[12] and their low levels of training are often linked to size-related internal restrictions—limitations to adopting modern work organization or inability to engage productively and consistently with education and training institutions. Even within a similar labor market environment, smaller firms tend to invest less in training relative to their larger counterparts.

A compounding factor may relate to supply chain dynamics, more specifically the position of smaller firms vis-à-vis their downstream clients. Firm size can be correlated with supply chain position, so these factors are sometimes difficult to distinguish. As discussed in the first dissertation chapter, a supply chain (or "value chain") framework can help to identify actors with more (or less) resources and power. Scholars explain that automotive supply chain dynamics are different than textile supply chain dynamics (Gereffi & Korzeniewicz, 1994). In each supply chain, the distinct dispersal of power informs investment opportunities and constraints.

The power dynamics in supply chain relationships often mean that larger companies end up with control over value-added activities as they outsource lower value-added activities and cost constraints to their suppliers. Suppliers, in turn, pass cost constraints to another lower tier of

[12] In general, global competition and the outsourcing activities of multinational corporations seem to push cost reduction burdens to firms further down the supply chain. Small firms in lower tiers of the supply chain may be particularly constrained in their ability to provide quality jobs and job training. Smaller firms in the United States not only pay lower wages, but also invest less in training (Black & Lynch, 1996; Brown, Hamilton, & Medoff, 1990; Harrison, 1994; Lynch & Black, 1998; Osterman, 1995). In 2014, Paul Osterman and Andrew Weaver found that skill shortages were overstated in general, but where they exist may be more acutely felt among smaller firms (Osterman & Weaver, 2014).

suppliers. The result is that firms in lower tiers of supply chains, often smaller firms, are facing formidable pressure to reduce costs, demands which are explicit in their contracts with clients. The global automotive industry is a prime example of a supply chain in which cost reduction expectations arise on an annual basis. The nature of cost-reducing contracts in turn can limit a firm's ability to invest in new machinery and skilled labor (Barrientos, Gereffi & Rossi, 2011[13]; Helper et al., 2011; MacDuffie & Kochan, 1995; Theodore & Weber, 2001; Weber & Schnell, 2003). Scholars have also suggested some specific ways that supplier-client dynamics between firms can limit training, such as when contracts emphasize cost over quality (Cappelli, 2012).

Could these supplier-buyer dynamics affect training decisions equally or more so than firm size or labor market context? If so, how can they be resolved? This paper investigates these questions and shows that it is not size alone, but power dynamics within the supply chain, that affect firms' training behavior. This additional level of variation in firm training behavior can help explain why some firms, both large and small, in high skill industries, end up underinvesting in training. Supply chain pressures can put lower tier firms in a lose-lose scenario, with cost constraints leading to low training and low wages, creating a form of double jeopardy for both the firm and its employees, perhaps the least optimal of all the training scenarios described above.

Taken together, the previous literature motivates the following research questions: How do supply chain dynamics affect firm level decisions about training? Under what conditions can suppliers overcome their supply chain constraints to provide work-based learning? What strategies do they devise that might lend themselves to further institutional or policy support?

[13] Barrientos, Gereffi & Rossi (2011) describe a variety of labor impacts (voice/representation, safety, wages) from cost reduction pressures and quality expectations created by large, lead firms in their supply chains. They conceptualize the distribution of skill requirements in global industries.

Empirical Setting

These questions are addressed through a study of automotive industry suppliers' training behavior in the state of South Carolina. South Carolina has a booming automotive industry, with exports increasing through the Great Recession, and with enviable levels of public-private collaboration in meeting labor demand. The South Carolina Chamber of Commerce is regularly credited for its convening power around workforce development issues. Prominent industry groups such as the South Carolina Automotive Council and powerful multi-national automotive firms have all been involved in establishing South Carolina's much-lauded state apprenticeship program. Apprenticeship Carolina, as it is called, is run by the state's technical or community college system, which, with its 16 campuses, has long been a key asset of the state in its industrial recruitment and development efforts. Larger automotive firms and their most prominent suppliers headline the state's high commitment training programs, while other automotive firms are involved to different degrees.

The density of the automotive cluster in the northwest corner of South Carolina allowed me to observe small- and medium-sized suppliers in the same labor market, but in different supply chain positions. In seeking to understand their skill demands and skill development decisions, I paid particular attention to whether, when and why firms support multi-year on-the-job training programs and apprenticeships in-house. This paper focuses on the training of skilled tradesmen rather than production workers more generally because training and preparation for the skilled trades requires a multi-year commitment. The decision whether or not to train is a highly consequential one for the companies that rely on these skills.

In automotive parts production, Tier 2 supply sectors employ the highest percentage of skilled trades.[14, 15] These sectors include the production of plastic parts, metal parts, metal processing, machinery and tools, and electronic parts. Thirty-seven percent of production workers in Tier 2 require the highest level of production skill development and preparation—compared to 28 percent in Tier 1 and only eight percent at Automakers.[16]

Table 11. Percent of Production Workers Requiring the Highest Level of Preparation by Supply Tier

	Percent Production Positions Requiring the Highest Level of Production Preparation
Automakers*	8%
Tier 1 Supply Sectors	28%
Tier 2 Supply Sectors	37%

Source: Author's analysis of BEA I-O Tables 2007, BLS OES Industry-Occupation Matrices for South Carolina 2016, O*NET Online 2016
*These are national results. Data is suppressed in this category for South Carolina due to the low number of firms in this category.

The high level of preparation required by Tier 2 firms reflects their high percentage of skilled tradesmen—particularly machinists, machine maintenance, and machine programming

[14] Data from the U.S. Bureau of Economic Analysis National Input-Output Tables were used to establish the intensity and direction of economic transactions between related industry sectors at the national level, and these are further confirmed by sub-sector research at the state level.

[15] Data on occupations are drawn from the U.S. Bureau of Labor Statistics Occupational Employment Statistics Industry-Occupation Matrices for South Carolina or "staffing patterns"; occupational skill requirements are collected from O*NET Online. O*NET Online provides a Job Zone categorization, which is a measure of education, experience and other preparation needed for an occupation. Job Zone 3 is the highest level of preparation needed for production occupations. Methods for analyzing occupational skill requirements by automotive supply chain tier have been previously outlined in detail (Forbes 2018, dissertation paper 1).

[16] Tier 1 firms supply automotive parts and systems to branded Automakers (e.g., Mercedes, VW, Ford). Automotive suppliers in these industries include large and medium-sized multi-national companies. Their location and equipment decisions are tied closely to Automaker demand. Tier 2 suppliers have clients in Tier 1. Some of these firms are completely dedicated to automotive production. Others also have clients outside of the automotive industry. As a whole, they are more diversified than Tier 1, and less directly connected to Automakers.

occupations. For small machine shops, these types of positions could constitute 100 percent of production employment. Many of these skilled trades require several years of on-the-job training, usually in formal or informal apprenticeship of two to three years.

In Table 12, I show the distribution of related production occupations across supply chain tiers, with higher skill occupations, each requiring at least two years of related experience, marked with an asterisk. These include machine maintenance, computer-controlled machine operators, machinists, and tool and die makers.

Table 12. Variation in Production Occupations by Tier: Automaker, Tier 1, industries from Tier 2

Occupational Groups	Automakers^	Tier 1 Supply Sectors	Tier 2 High Skill Example – Machine Shops	Tier 2 Low Skill Example – Plastic Products
Assemblers, Supervisors	83%	53%	19%	22%
Machine Maintenance*	4%	8%	9%	11%
Computer-Controlled Machine Tool Op*	0%	10%	3%	0%
Machine Setters and Operators	7%	4%	26%	38%
Machinists*	0%	10%	24%	6%
Tool and Die Makers*	1%	2%	0%	0%
Welders, Cutters, Solderers, and Brazers	0%	1%	6%	4%
Inspectors, Testers, Sorters…	3%	5%	8%	12%
Other	2%	7%	6%	8%
TOTAL	100%	100%	100%	100%

Source: Author's analysis of BLS OES industry-occupation matrix for South Carolina, 2016
*Higher skill occupations, requiring more than two years of related experience
^These are national results. Data is suppressed in this category for South Carolina due to the low number of firms in this category.

Interviewees were selected from firms in Tier 2 automotive supply sectors—firms producing plastic and metal parts, machinery, tools and electronics. I conducted two rounds of

semi-structured interviews in South Carolina's Upstate region. I first interviewed 12 local economic and workforce development staff in May 2016 and then interviewed key decision-makers at more than a dozen automotive suppliers in July 2017. At suppliers, I contacted Human Resource Directors and Plant Managers at the establishment level, based on recommendations by county economic development staff. In selecting firms, I also included a group of smaller suppliers that had participated in the state's registered apprenticeship program. I initially contacted 30 automotive supplier companies with interview requests. Of these, 14 granted interviews, four of which included site visits and plant tours.

Table 13 describes the companies that were interviewed by manufacturing focus and Table 14 describes their employment range, the percent of firm interviewees that were local versus multi-national, and the percent that were dedicated to automotive production (i.e., 100 percent of clients were in the automotive industry) versus diversified across automotive and aerospace or other industries.

Table 13. Count of Company-based Interviewees by Manufacturing Industry

Industry	Count
Electronics	1
Machine Shop	2
Machinery	4
Metal	2
Plastic	5
TOTAL	14

Companies were distributed among plastic, metal, machinery, machine shop and electronics suppliers to the automotive industry. Their level of employment ranged from three to 450 employees. Just under one-third were local firms (vs multi-national) and just under one-third were dedicated to the automotive industry (vs diversified).

Table 14. Interviewee Company Summary Information

Employment Range	Percent local (vs multi-national)	Percent dedicated to automotive (vs diversified)
3 to 450	29%	29%

Each interview lasted between 45 minutes and two hours. For each firm interview, I created a summary of firm statistics and major themes. Interviews covered general, operational and relational themes. Relational themes were further grouped into cluster-based (peer firm or horizontal inter-firm relations) versus hierarchical supply-chain relations.

The comparison of occupational demand across these supply chain sectors in Table 12 points to potential labor market competition as well as to potential areas of collaboration in training, where key occupations require multiple years of training and are in demand by multiple industries. The skill demand overlap demonstrated by the public data presented in Table 12 was apparent in the interview data. For example, *machinist* is a higher skill occupation with a higher percentage of workers in Tier 1 and the Tier 2 high skill sectors. However, coordination in training was not apparent. Presumably both Tier 1 and Tier 2 firms are investing in training these workers and providing them with the experience they need to develop key skills. The degree of coordination with training providers and other firms was addressed in the interviews with Tier 2 firms. I observed intense labor market competition and a variety of different training scenarios.

Results

Uneven Contributions to Buying and Making Skill

For suppliers and economic development practitioners in South Carolina, the regional narrative begins with a branded Automaker's decision to establish a branch plant in the region in the early 1990s. Interviewees explain how the Automaker reinvigorated the region's manufacturing sector following the decline of textile manufacturing, and also paved the way for

the state's expansion into aerospace. The Automaker chose this location in South Carolina because of the region's strong manufacturing tradition and displaced manufacturing workforce.

Interviewees also speak highly of South Carolina's technical college system, a key partner in supporting the industrial transition through engagement with the Automaker and a select group of suppliers. The general ethos is that this region is lucky to have this Automaker to anchor regional manufacturing. Even those that acknowledge significant challenges to supplying the automotive industry note that it is important to retain the business of the Automaker.

Interviewees report that a major challenge for suppliers is attracting and retaining skilled production technicians. Suppliers report difficulty finding skilled machinists, machine maintenance technicians and machine programmers. The growth and increasing density of the automotive industry in South Carolina is a factor—in other words industry growth may be outpacing the supply of labor. New companies moving into the region are automated, lean companies requiring large teams of machine maintenance technicians.

All interviewees experienced supply-chain-based cost constraints and cost-reducing incentives that limited their ability to train and retain trained workers. Suppliers dedicated to automotive clients reported the most constraint in their ability to train and raise wages. Some describe that sustained cost reductions have limited their capacity for training in-house—they were lean and had difficulty freeing up the time of their experienced staff to train new recruits. They also aimed to keep wages low to satisfy the expectations of their clients and multi-national headquarters.

I categorized firms into three groups based on whether they provided in-house training for production technicians and their supply chain position: low train firms that are dedicated to automotive production, medium train firms that are diversified, and high train firms that are

diversified. Table 15 summarizes results from the firm-level interviews, which were completed with firms that had some interest in training, as recommended by local economic development practitioners. Table 16 presents an initial categorization of suppliers into three categories with low, medium and high levels of training.

Table 15. Interviewee Results Summary

Percent that have hosted an Apprentice	Percent with Skill Levels Greater than Industry Average	Percent with Skill Levels Lower than Industry Average	Percent with Wages Greater than Industry Average	Percent with Wages Lower than Industry Average	Wages Not Disclosed
57%	29%	14%	29%	29%	43%

The interview content is further explored in four sections below. Interview analysis demonstrated that overlapping demand and supply chain pressure can lead to not only labor market competition but also to uneven contributions to training in support of regional skill replenishment.

Table 16. Interviewee Distribution Across Three Categories

Low Train and Dedicated	Medium Train and Diversified	High Train and Diversified
29%	43%	29%

<u>Seeking to buy machinery maintenance technicians</u>

With many multi-national companies closely co-located in the region, demands on the community college system are high. When the Automaker arrived in the region, the community college system provided screening and short-term training of workers, and these programs are still some of the first tools that new arrivals use to identify and initiate their first round of hires.

As such, it is not surprising that many of the multi-national suppliers that were interviewed prefer to continue to source labor from the community college system, even though competition for these graduates is intense. Mid-sized, diversified multi-national companies report that they need more skilled production technicians to operate and maintain machinery but are less inclined than the Automaker and the largest suppliers to participate consistently in community college training programs that require on-the-job training commitments, like Apprenticeship Carolina.

Some actors in the region assume market signals will eventually facilitate these firms' increased in-house investments in training, but the combined interviews suggested a longer-term decline in the provision of on-the-job training. Practitioners suggested that companies would increase wages and their training commitments as they feel the pinch of a more limited supply (Interview 8) or when it becomes too painful (expensive or harmful to the company) to avoid these investments. Sometime soon companies will start investing in their workers and "growing their own" (Interview 2).

Yet, companies were already operating under constraint at the time of the interviews—constrained by their supply chain position and lean shop floor staffing. It takes several years to train production technicians, so the expected just-in-time signals that tell companies to start investing in training in-house will likely be delayed at least a few years. And labor market theory refutes the expectation that a more competitive market will induce training; the theory suggests that a more competitive labor market will lead to less training. In fact, there were already indicators that the market is very competitive. Multiple automotive suppliers admitted to luring experienced workers away from other automotive suppliers. One mid-sized company reported: "We're all buying from the same employees." Employees are lured from one place to another with small increases in hourly wages (Interview 10). An economic development practitioner

explained: “They’re going next door and paying $1 more an hour and trading people back and forth” (Interview 2). Scholars warn that this pattern can become a vicious cycle, reducing everyone’s ability to train and retain workers (Becker, 1964; Cappelli, 1998).

Most firms had sponsored apprentices and had experienced the disappointment of losing their investment when a trainee leaves soon after the end of a multi-year training period. All of these companies hope to avoid a repeat experience, but only a few reported having implemented contractual agreements requiring a period of tenure after training.

For some mid-sized multi-national companies, their skill demands matched with the skill supply from local community college programs. Their match with this labor source was helping them to compete in their product markets while offering less on-the-job training. Competition for community college graduates was high, but some companies were able to compete for these graduates, paying mid-level wages, but also making connections through career counselors and course instructors, and offering co-ops and internships (rather than the more time and resource intensive apprenticeships). Meanwhile, other mid-sized multi-national companies struggled to compete for these talented graduates or graduates were not a good fit. Some were in lower wage sectors, some were captive to automotive clients and had little room the maneuver vis-à-vis the education system, some needed different skill sets. Some new transplants to the region had not yet established strong relationships with educational institutions, were paying below market wages, and were reliant on their clients to initiate and make room for improvements.

Making machinery maintenance technicians in-house

The previous section described the preferences of mid-sized multi-national firms to “pay for” or “buy” trained production technicians rather than train them in-house. Most of the firms that are entirely dependent on an automotive client fit in this category. Meanwhile, other multi-national companies and local companies in the area have a more diverse client pool, serve

multiple manufacturing industries outside of automotive production, and tend to do more training. Some provide small parts in high volume, others provide more varied parts and services, fix molds for casting metal and plastic parts, create and fix other metalworking tools. The high-volume parts companies receive five to 30 percent of their business from automotive-related clients. Small metal parts and services companies are either direct suppliers to Automakers or to first tier suppliers of Automakers—with the exception of one toolmaker that had transitioned almost entirely from automotive to aerospace contracts, they receive about half of their business from Automakers and large automotive suppliers.

In seeking skilled production employees, these more diversified companies do train in-house, though not necessarily in coordination with the community college system and sometimes in more informal settings. The firms with high levels of in-house training—mostly small metal parts and services companies, but also including one larger company—value experience and loyalty above all else. With the majority of these companies unable (in their own words) to pay the highest wages or provide robust internal career pathways, they emphasize that employees learn valuable skills on the job. They specifically seek employees that are a "good fit" for their company—for example, employees that will enjoy working at a smaller or more familial company—in hopes that they will be more likely to stay with the company over time.

However, these medium- and high-level training companies report losing even their most meticulously chosen trainees to their largest clients or to other multi-national companies in the area. In fact, almost all the companies I interviewed had a story of losing employees to a large Tier 1 company that had recently expanded its 2,000-employee plant in the region. Experienced production technicians are in high demand by all companies and these technicians can constitute as much as 60 percent of positions in a small, high-skill firm.

Experiencing the challenges of limited labor market supply, high training companies have engaged local leaders, school administrators and young people in local high schools, encouraging students to consider manufacturing careers. To attract young people to manufacturing, these companies must contend with the impression that manufacturing is a dead-end career, or dirty and dangerous work, as it was historically in the local textiles plants. Smaller firms are more explicit about these challenges as well as supply-side constraints, suggesting that their pain is more acute compared to their larger counterparts.

High training companies, which are training in-house, also face additional challenges in adjusting to emerging trends in manufacturing training and education. The state's model of community college training has been growing in popularity since 2008. With low unemployment, job seekers can name their contract terms, and many expect employers to provide financial support for continuing education; young people seeking employment in manufacturing are now also seeking a community college degree, with employer-provided tuition. But larger multi-nationals are likely to recruit such newly credentialed workers directly from the community college system, away from other employers. Any experienced, credentialed worker emerging from an apprenticeship program or community college program will likely be lured away by another company. As one multi-national company explained, "Folks who go to school to be technicians get snatched up pretty quickly" (Interview 19).

Companies doing high levels of training in-house find themselves in a tough spot. Not only is it difficult for these companies to match the wages of the larger multi-national companies in the area and pay for the community college tuition that is increasingly in demand, but they also feel supply-side constraint more acutely, and do not all feel that the college system is serving them well. Smaller companies in lower tiers of the supply chain that do invest in the

community college curriculum, allowing employees flexible hours to attend classes, paying for books and tuition, are more likely to lose their trainees. And some smaller companies simply do not see the value in coursework anyway; work experience is more valuable to them.

While some companies have reimbursement contracts that require trainees to stay a certain period after training (or repay the company-provided college tuition), smaller firms are timid to ask for these contract terms. One company had only one candidate seeking employment with them, and they hoped to make a strong personal connection with that individual, not to pressure her with contract terms.

While smaller companies consider raising wages and offering tuition benefits, they report that they are limited in their ability to attract job seekers and to effectively reward workforce skill and skill development. The next two sections of this paper introduce the effects of external cost constraints on firms in the automotive industry. I first address the experiences and responses of automotive suppliers in general and then those that are dedicated to automotive clients.

Operating under cost constraint

A larger, more powerful client can set cost and quality expectations for a subordinate supplier through a formal contract or more informally through interactions. While there is a risk that a cost focus can limit investments in training and human resources and reduce the quality of a supplier's work, these tradeoffs are often hidden from view. In this analysis, cost expectations by Automakers are explicit. Suppliers have varying abilities to contest the cost expectations and to highlight how they undermine product quality and reliable product delivery.

Local economic development practitioners explained that the cost pressures of the automotive industry put suppliers in the difficult position of balancing cost constraints with their need for skilled labor, particularly as they compete with multi-nationals moving into the area. The Automaker "has the ability to keep the suppliers under their thumb, so to speak, and then the

suppliers are relegated to second position on what they can pay labor," meaning that the suppliers cannot pay as much as the Automaker, or as much as Tier 1 suppliers (Interview 3).

Companies who want to distinguish themselves as a good employer by paying higher wages are constrained from doing just that. Automakers are not unlike Wal-Mart, another practitioner explained, comparing Automakers to the powerful retail buyer able to reduce costs to barely sustainable levels based on its huge buying power and knowledge of cost limits. The Automakers, he explained, "are pretty good at figuring out that the line is as low as it could possibly go" (Interview 2).

For suppliers at lower levels of the supply chain, cost pressures are hard to avoid. Automakers place restrictions on the rate per hour that suppliers can charge, a seemingly non-negotiable contract feature. This directly restricts the wages that suppliers can extract from the rate per hour. These cost-reducing pressures not only come from Automakers but also from Tier 1 suppliers that manage upstream supplier networks. In this regard, the cost pressures facing Tier 1 suppliers are often passed down through the supply chain (Interview 2).

For those suppliers that are diversified among clients and industries, the automotive industry is the most demanding. One supplier explained, "This is not our usual way of doing business, but we do it," making accommodations for automotive industry contracts (Interview A7). Another supplier explained that he leverages other contracts to pay his workers more than automotive contracts allow (Interview A2).

One smaller metal tools supplier had a different reaction to the cost pressures: he decided to exit the automotive industry altogether. It was a risk, he says, moving away from high volume automotive contracts, but the volume was so high that the price was "a big deal, in some cases over everything" (Interview 21). He pursued an opportunity to transition toward aerospace

clients and contracts and says that his exit from automotive allowed a renewed focus on value-driven production and product innovation. “Our tools have a greater value,” he reports, pointing out that the tools his company makes facilitate process improvements for his clients (Interview 21). His company now has more room for innovation.

Diversified companies that choose to continue participation in the automotive industry have to pay lower wages and find other ways to increase staff retention or raise wages and accept losses on automotive contracts. Most choose the latter, balancing losses on automotive contracts with work from other clients. This balancing act would seem to make it very hard to raise wages and develop and grow the business. The likely loss, as Interviewee 21 pointed out above, is in innovation and product improvement, if not in quality.

Captive and operating under cost constraint

Mid-sized multi-national companies not only experience the cost constraints of their automotive clients but are also constrained by the expectations of their headquarters, both expecting the branch plants to keep costs low. Dedicated automotive suppliers seem to experience the most sustained pressure to reduce costs. There are, however, a few opportunities to negotiate cost increases.

Automakers regularly audit their suppliers. While audits give clients insight into potential cost reductions, they also allow clients to identify process and even human resource issues that might affect product quality. When human resource issues became particularly egregious, clients may be convinced to support human resource investments. For example, high turnover among production workers requires constant training and initiation periods and can slow production. If workers are leaving for higher wages elsewhere, the company might consider raising wages. An Automaker can help a direct supplier identify and respond to this issue by signaling their support

for or, or by outright demanding, changes. A direct (Tier 1) supplier may also extend the same vigilance to its own supply chain.

In one case, a multi-national Tier 2 supplier had been struggling with high turnover rates but could not get support from their headquarters to raise wages. An audit by a Tier 1 client pointed to the effect of turnover on product quality. In response, the Automaker required the supplier to address the issue. This provided the supplier with enough leverage to negotiate with their headquarters for wage increases. The audit and client concern were the evidence needed for a compelling argument, and wage increases were approved.

Tier 1 suppliers are in a unique position to help Automakers connect the dots between production bottlenecks and supply-chain related human resource issues. They pass costs down from Automakers through to their own suppliers, but this also gives them a vantage point from which to recognize and focus the Automaker's attention on issues caused by cost constraints. Some Tier 1 suppliers have used their close relationships with Automakers to draw attention to the problems that cost pressure can create for Tier 2 suppliers—not simply by constraining wages, but also by undermining competing demands for product quality. In one case, the involvement of Automaker and a Tier 1 supplier helped galvanize major improvements to internal work organization at a Tier 2 supplier; the multiple parties negotiated solutions that were manageable for all parties.

These mechanisms for negotiation between buyer and supplier may become increasingly necessary as some automotive industry suppliers have been in cost-reduction mode for decades and there is not much more efficiency to be gained. It is difficult for some companies to find additional costs to cut. Regarding the option of raising wages to attract talent, one interviewee asked: "Where are you going to get a little bit more margin? What more can you do? … There

are definitely tighter and tighter requirements of the supply base" (Interview 5). His response suggested not only that it is difficult to raise wages, but that the only option might be to squeeze further cost reductions from lower tier suppliers.

Some mid-sized suppliers have reduced all possible waste—including training capacity. Even if mid-sized multi-national companies wanted to train highly skilled production technicians in-house, they might not be able. Several company representatives explained that their companies are too lean and automated. While their machinery requires attention and maintenance by skilled professionals, the leanness of the plant means that they cannot spare the time of a skilled professional to train others (Interviews A1, 16, 18). With other companies, it was apparent from their staffing structure that they lacked both high skill capacity and the middle rungs of the training ladder that otherwise could facilitate the internal advancement of production workers, who could learn new skills incrementally while on the job. Instead, only basic production operators and a few high skill technicians were employed.

A limitation is that these trends and the ability of Tier 1 suppliers to address them is that Tier 1 suppliers can only address what they see. While audits are commonplace, identifying the connection between quality issues and human resources issues is not. Luckily, their mediation is not the only option for advancing skills and wages along the supply chain.

Smaller companies make a move—bottom up solutions

Smaller firms are devising innovative strategies to retain and reinvest in their skilled workforce. An especially innovative approach involves a group of smaller suppliers that have banded together to improve recruitment and retention efforts, working across manufacturing industry lines to include firms that have multiple supply chain affiliations.

In the 1990s, a national association of metalworking organized a local group of metalworking companies in Greenville, South Carolina, in a new training initiative. The local

cluster was, at the time, transitioning from textiles to automotive production and local companies needed new skills. The local companies each registered apprenticeship programs and began training new staff under the apprenticeship model. But the national association's leadership left the local consortium with little local organization. While one company emerged as a champion of apprenticeship, each company toiled separately without the benefit of learning from the others' challenges. The businesses struggled, not only with the training challenge, but also in their various markets; at least half of the shops were closed by 2016. Those that continued were discouraged by the reduced power of the consortium, the increasing challenges of serving the automotive sector, and their inability to retain trained employees.

In their wake, another promising constellation of manufacturing firms has emerged, and this group has several sustaining features. Like the previous group, there are one or two firms that are very active, engaged and leading work across the education and industry sectors. One of these is an automotive supplier. But, unlike the previous group, a local business association, representing companies from different industries, and not a national single industry entity, supports group members. This new group is also closely aligned around supporting and growing a local technical high school. Group members have institutional roles vis-à-vis the county industry association, the county's manufacturing association, and the technical high school. They serve on the boards and have formed an unofficial advisory group to the high school. The industry association addresses both economic and education issues and the goals of the manufacturing association are educational, social and economic, in that order.

With aggregated demand and institutional engagement, these firms are more visible in the local labor market and positioned centrally in the flow of labor from area high schools to area employers and community colleges. They recruit young scholars and technicians to the local

vocational high school and to work at their companies, even staying engaged in years when they are not personally hiring. Year after year, with their help, the vocational high school has increased its applications and enrollment. Their central position in the local skill development system that helps them keep an eye on each other, boosting accountability while also increasing their mutual understanding and trust. Firms here can win by training, not by poaching.

This new group has a track record of success. First, group members refer talented trainees and employees to each other when employees are looking to optimize their fit in the local cluster. They seek to find the best fit for trainees and employees within the local area, not necessarily within the boundaries of their plant. Second, group members refer business to each other when customers are looking for a specific niche service or product. This then encourages the companies to specialize and further develop their niche business offerings. Activities that bring the companies together, such as their local organizational affiliations, allow them to pinpoint their niche employment offer.

Poaching by larger companies is still an issue, but instead of retreating from training, the smaller firms are doubling down on their unique ability to train workers. Instead of seeing larger companies as threats, the smaller companies seek their participation. One of these smaller firms explained that “big companies write the check and we get our hands dirty” (Interview 8), indicating that the larger companies will make financial contributions to the local vocational school and will provide the equipment for training. The owners and managers of the smaller companies are more likely to be on site, in the classroom, giving lectures and coaching students on how to use the equipment.

The way these smaller companies position themselves also helps assuage some of the tensions introduced by the increased drive toward community college education in

manufacturing, and the increasing expectation that employers pay for workers' education and credentialing. Working with the high school allows local firms to meet students that are college bound and seeking these benefits, but also to reach students who may be a better long-term fit for their small shops, who are passionate about the industry, working with their hands, and looking for a vocational path to work. One of the firms in this group accommodates both of these pathways and individualizes trainees' development plans, a practice that could be more difficult for a larger firm, depending on the flexibility of their human resources staff.

Discussion

Analyzing firms' training decisions in the context of their supply chains shows how supply chain position and firm size inform skill demand. With varying ability to train, to reduce costs and to contest cost reductions, overlapping demand for production technicians can lead to uneven contributions to training in support of skill replenishment. The trend among mid-sized multi-nationals is away from multi-year commitments to training production technicians in-house (e.g., apprenticeships) and toward increased reliance on the community college system. Firms providing a high level of on-the-job training have a hard time making a match with the community college and enabling workers to gain an industry-recognized credential while also protecting their training investment.

Where firms advance strategic and targeted investments in training and skill development, they seem to reduce their exposure to zero sum labor market competition. Where multiple high skill firms offered unique training packages in coordination with each other, they seemed to increase the provision of training across firms. In one example, firms worked together to cast a wide net for training candidates, offering their various training and employment pathways as a menu from which potential employees could pick and choose, helping to improve the final employer-employee matches and support investments in training.

Some firms, however, fail to leverage their ability to train into business development. Others, without in-house training capacity, and captive to automotive clients, struggle to keep their wages at a competitive level. Some of these firms seemed on the verge of withdrawing from the skilled labor market, focusing business strategy in another direction, turning to further automation, shrinking or closing shop. Firm size did not seem to define these trajectories—firm exposure to supply-chain-based cost constraints and hierarchies were more strongly correlated. For dedicated automotive suppliers, interventions by their clients helped firms increase wages, address limits to training, re-invest in workers and remain in the supply chain.

In many of the examples of successful training, firms recognized their supply-chain related constraints and sought support for various targeted recruitment and training strategies. Some engaged with clients to identify workable solutions, and their results ranged from wage increases to organizational restructuring. Firms that activated supply chain and other inter-firm relationships to increase training investments also adopted multi-pronged training strategies to take advantage of local education and training institutions to engage local labor pools. These strategies were sometimes surprising. For example, firms that had the capacity to train did not necessarily seek to attract the most in-demand talent, but rather they attempted to make a productive match with undeveloped talent. This allowed them to keep wages low while still providing a competitive offer to trainees and future employees.

Importantly, in spite of the annoyance of poaching by firms offering higher wages, the decision to train appears disconnected from wage setting practices. For firms competing for skilled production technicians in very competitive labor markets, wages were set in response to area wage surveys, not necessarily in response to poaching experiences, and never as a proactive high-wage strategy in coordination with training. All firms reported they aimed to set their wages

at mid-level, about average for the area. Training, on the other hand, was provided strategically and cautiously, where firm capacity provided the opportunity to train, and was not limited by lean manufacturing practices or by automotive contracts.

While cost constraints reportedly limited the firms to paying wages below their preferred wage rates, wages were less determinate of firms' ability to make successful training investments than other factors. Rather, cost constraints loomed large: firms reported that the cost cutting processes they have endured for decades (and exhausted) help to explain a reduced tendency to support shop-floor training. The limited use of training contracts also caused these companies difficulty and forced them to manage risks that could have otherwise been resolved.

The heterogeneity of firms is important, particularly where variation by supply chain position (diversified or dedicated to automotive) informs not only the decision to train in house but also broader regional labor market dynamics. There was evidence of competition across firms of larger and smaller size, higher and lower supply chain position, with higher and lower levels of in-house training, etc. These differences informed the flow of labor from, for example, supplier to client (from lower to higher wages, and from lower to higher tier suppliers), which tends to pull talent away from training companies. This problematic spillover of skilled labor from supplier to client or from smaller to larger firms may be counterintuitive to researchers accustomed to seeking evidence of spillover from larger to smaller firms. While smaller firms may intercept or slow the flow of labor to larger firms, it is unlikely they will be able to reverse the flow.

Also, some firms are in a more direct relationship with their automotive clients. Supplier audits and higher levels of communication among larger firms allow companies to identify problems related to cost constraints. Tier 1 suppliers play a mediating role with lower tier

suppliers: they pass cost restrictions down to their suppliers and highlight related issues of constraint to their clients, sometimes connecting production quality and process issues to deficits in human resources. Their ability to address bottlenecks in the talent pipeline is limited by how far down the supply chain they can see and whether they would recognize if a human resource issue was causing a problem. These efforts might not reach the smallest firms, lowest tier suppliers, and diversified members of the supply chain if Tier 1 suppliers do not see them as their responsibility, or do not see them at all.

Some high skill intensity firms may feel forced to close up shop entirely while others double down on the unique training experience they can provide. Some firms have responded to cost and quality expectations by pooling resources, recognizing a shared vulnerability to real and persistent labor market challenges.

Policy Implications

Building on research regarding the influence of inter-firm networks for growth and innovation strategies, this paper examines how inter-firm networks affect decisions related to workforce skill and training. This paper also adds to research on co-location or "clustering" dynamics by considering how skill development decisions of individual establishments within a localized supply chain are linked together.

The costs of doing business in the lower tiers of the automotive supply chain are apparent. In spite of these challenges, there are a number of solutions that firms described deploying to support their investment in training. More innovative strategies include tempering constraint through client diversification, gaining access to advocates higher up the supply chain, and working together through collective action to come up with intra-supplier solutions. These various workarounds offer a means for institutionalizing a new set of training supports and strategies.

This analysis challenges the assumption that we must always turn to larger firms for labor market solutions. Rather, smaller firms have the capacity to introduce solutions to address reported "skill gaps." These small firms can offer collaboration as a real solution, grounded in their acute understanding of and intimate experience with labor shortages and the consequences of low-level commitments to training. The only way for companies to escape the skill gap is through the recognition that they depend on their clients, suppliers and competitors, large and small, for information, coordination and, ideally, collaboration and co-investment in the skill development system.

That said, Tier 1 suppliers play a critical role. To keep larger firms from cannibalizing their own supply chain or undermining local skill development efforts, interventions might need to be explicitly tied to specific supply chains, so that clients are more aware of their suppliers' interdependence. Tier 1 suppliers and mid-sized multi-national firms with diversified clients and community ties are in a good position to convene these conversations. Supply chain mapping efforts could link the bottom of the supply chain to the top, demonstrating the limited reach of current supplier development and audit programs, and drawing attention to initiatives that support lower tier companies. Unable to quantify their interdependence on local labor pools, co-located firms will likely continue to poach each other's labor without regard to the negative impact on training investments and, in the longer term, replenishment of skilled labor pools.

Organizing and advocacy campaigns have been successful in engaging large clients and convincing them to ease restrictions on their suppliers, where greater compensation for products can be directly translated into higher wages or training. These seem to work best on a local level (e.g., Mt. Olive Pickle) rather than on a global scale, where they have been less successful (Barrientos, 2007).

Two local program interventions could help smaller firms and lower tier suppliers take advantage of both cluster and supply chain dynamics. The first is the alignment of public sector training funds with supply chain development programs. State and local training funds are often awarded to large firms when they arrive or expand at an establishment site. But this is often done without regard to the parallel expansions required in their supply chains, including among co-located suppliers (and potential suppliers).

Given that larger firms with generally higher wages seem to easily attract labor from smaller firms and from their own suppliers, it makes sense to invest in suppliers and smaller firms, particularly high skill/high training firms, which may be the net producers of skilled labor. When the largest Tier 1 companies locate or expand in an area, with skill requirements similar to local companies and lower tier suppliers, they attract skilled labor away with higher wages. Just as training funds are provided to these largest of suppliers upon establishment or expansion in an area, plans should also be implemented to help local companies regenerate the labor they will likely lose to the larger firm.

The second recommendation is for lower tier suppliers and local companies, particularly high skill/high training firms, to be provided the resources to rebuild their local vocational training programs. Local companies can collaborate with local high schools not only to expose students to manufacturing career opportunities, but also to facilitate the build out of hands-on learning programs, which can motivate students to complete high school. This will help them differentiate their offering and position themselves for further growth.

Efforts to integrate training with other services for smaller firms are underway.[17] Economic and workforce development strategists can further sharpen their training interventions when they consider participating firms' supply chain position and size. Each industry has a unique pattern, but industries generally leave lower tier firms and their workers in the most vulnerable and least mobile positions. Greater attention should be paid to how and when recognition of a skill gap can lead to recognition of skill interdependence and a coordinated response.

Existing place-based solutions for "skill gaps" tend to embrace the individualism rather than interdependence of employers, defaulting to the public sector for coordination activities. By relying on the public sector and its well-established selection of training and education solutions, economic development strategists risk ignoring potential roadblocks and synergies related to inter-firm relationships. This paper explored examples of firm coordination to support investments in training or retaining production technicians. Strategies to bolster and extend these activities should be considered in future workforce-planning efforts.

[17] Training is included in the strategic planning and implementation of 15 Manufacturing USA locations nationwide (previously "National Manufacturing Innovation Network") and increasingly integrated into firm-specific services provided by NIST's Manufacturing Extension Network (MEP) programs in every state.

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PAPER 3: SUPPLYING SKILL: THE ROLE OF SMALL MULTI-NATIONAL FIRMS IN TRAINING PRACTICE TRANSFER

Introduction

When large Original Equipment Manufacturers (OEMs) establish a branch plant location, they often need to create training systems to produce a skilled technical workforce. This investment in training is needed to ensure high quality, consistent products for export or to meet domestic demand. Further increasing workforce skill in their overseas locations, OEMs also transfer training and other practices to a select group of top supplier firms, sometimes inviting them to participate in joint training programs.

But the role of OEMs in diffusing global training practices to firms at lower levels of the supply chain is less certain. Scholars often focus their attention on the OEM and their relationship with core suppliers, failing to recognize the underlying challenges or barriers to further training diffusion. Furthermore, this myopic focus on OEMs means scholars risk overlooking alternative channels for pushing global training standards throughout the entire supply chain.

This paper reorients the focus from OEMs and their top suppliers to their next level of smaller, multi-national suppliers. Like OEMs, these smaller multi-nationals also have some internal capacity to invest in workforce training abroad. But their lower position in the global supply chain and exposure to local labor markets also means they can create a stronger bridge between the foreign and the local. Branch plants of foreign-owned suppliers are not only connected to the OEM, but often source from local manufacturers, meaning they are in a pivotal

position to influence skill development practices within their own supplier networks. Their role in supporting practice transfer is especially important given the proprietary nature of most OEM training programs. Furthermore, their smaller size means they may be more inclined than OEMs to engage public educational institutions. This suggests that smaller foreign-owned suppliers can embed the training standards of their home countries within public and private training programs abroad.

To demonstrate the role of smaller multi-nationals in diffusing globally competitive training practices, this paper features the experiences of two German automotive suppliers that set up German-style apprenticeship programs in Mexico. The findings shed light on practice transfer processes in general as well as on the nature of smaller multi-national enterprises and their potential contributions to local skill development systems. Still, the transfer of global training practices by smaller suppliers is not straightforward or conflict-free. As this study illustrates, relational and entrepreneurial work is needed on the part of these smaller multi-nationals to establish new institutional models and structures.

This research suggests that OEMs are not the only companies that can anchor skill development programs. In a local setting, smaller multi-national enterprises can have enough clout, capacity and interest to affect program development and change. They are well positioned to diffuse training practices to local firms as they are closer in size and located more proximally to local suppliers compared to their OEM counterparts. Broadly speaking, the findings of this research suggest opportunities for economic and workforce development practitioners to engage smaller multi-nationals when they establish a new plant and bring them in as strategic partners in the development of local skill development systems.

Background

The largest multi-national corporations (MNCs) control a substantial number of subsidiaries and vast supply chains, and their branch plant location decisions often dictate the allocation of resources across countries and local areas. Understandably, a firm's size and supply chain position are central to the way we understand its power and industry influence. Still, it may also be important to reckon with smaller-sized and even lower-tier firms' capabilities and power, rather than simply equate smaller firm size and lower supply chain position with powerlessness and low ability, as we often do.

Berger (2013) and her colleagues at MIT have explained that U.S. firm size is declining as firms outsource employment-generating activities in order to focus on their core competencies. Similar trends have been documented in Mexico: larger firms have been outsourcing employment-generating activities to smaller firms since the 1990s (Bensusán, 2012). This means that supply chains are longer and the distance between large MNCs and their lower tier or more peripheral suppliers—in terms of direct interactions and technological sophistication—is greater. Sturgeon, Van Biesebroeck & Gereffi (2008) note that, as large firms disperse production activities, vertical supply-chain-based power is being re-consolidated in new ways. Specifically, they point to the rise of the "global supplier" in the automotive industry (Sturgeon, Van Biesebroeck, & Gereffi, 2008: 305-307; see also Rutherford & Holmes 2008: 525; Ivarsson & Alvstam, 2005).[18] While "global suppliers" tend to crowd out local firms from

[18] Across industries, companies find it increasingly difficult to enter or move up in global supply chains, primarily because MNCs increasingly use established preferred suppliers or "follow source suppliers" (who follow from other sites) (Ivarsson & Alvstam, 2005). The structure of the automotive industry is particularly problematic in this way (McDermott & Corredoira, 2010; Sturgeon, Van Biesebroeck & Gereffi, 2008; also Giuliani et al, 2005; Humphrey & Memedovic, 2003; Contreras & Carrillo 2010; Contreras & Carrillo 2011; Pietrobelli & Staritz 2013; Contreras et al 2012).

supply chain participation, they may also introduce new dynamics in support of local learning and upgrading (Pietrobelli & Staritz, 2013).

The expansion of global supply chains suggests both shifts in multi-national firm power and effects on local learning processes. Allen (2003) explains that where global dynamics and relationships are embedded in local spatial configurations, an expansive view of firm power is necessary. As supply chains extend outward, the distribution of power also becomes more "fluid" and "territorialized" (Rutherford and Holmes, 2008, 2014). Horizontal rather than hierarchical relationships can take shape; that is to say, firms can gain power *through* their interactions *with* each other rather than amass power *over* others.[19] Where horizontal relationships take shape at the lower end of the supply chain, increased associational and facilitative power can draw in greater support from institutions, including those that might otherwise serve only larger multi-nationals (Ramirez & Rainbird, 2010: 699).[20] In other words, as power gathers further down the supply chain, smaller firms can work together to "mobilize resources across scales" (Rutherford & Holmes, 2008), including intensifying their engagement with public institutions and government-funded programs, leading to the development of new programs, policies or even institutional structures.

Employee training is one of these program and policy areas where supply-chain based actors can play a role alongside local and global institutions in supporting supply chain development. Within firms, training practices may be coordinated between headquarters and

[19] The understanding of how power is exercised in the Global Value Chain literature, and Global Production Network literature to a large extent, is that of a hierarchal power between firms in global value chains. One firm has power over another: an ability to determine terms of contracts and control behavior.

[20] Ramirez and Rainbird (2011) explain that technical training programs are viable pipelines for transferring codified knowledge to a broad array of actors including between clusters/nodes in and across global value chains, evoking the definition of associational power that is "the ability to mobilize resources across scales" (Rutherford and Holmes, 2008).

branch plants (from headquarters in the home country to a branch plant in the host country); within supply chains training may be pushed by some actors along the supply chain—for example, by client to supplier (MacDuffie & Helper, 2007; Dyer & Singh, 1998; Dyer & Hatch, 2006; Hatch & Dyer, 2004). Training can also be coordinated among smaller firms or with institutional actors outside the supply chain, as when the state or private training organizations are engaged to provide training services for a multi-national corporation (McDermott & Corredoira, 2010: 313-314).

Large multi-national corporations are known to have many options for developing and deploying training resources. Their prominence enables them to attract the attention of state and local actors and influence them to create new public programs (Coe, Hess, Yeung & Dicken, 2004). A multi-national corporation may simply wield its power over regional supply chains to leverage a state commitment to vocational training. When public institutions are in a stronger bargaining position, however, they may force multi-national corporations to negotiate for state support (Coe, Hess, Yeung & Dicken, 2004). However, large multi-national corporations often have internal training capacity, meaning they can avoid direct negotiation with public institutions and train in-house.

In comparison, smaller firms are more resource constrained and more likely to be dependent on institutions for vocational training. For smaller multi-national firms that relocate overseas, this institutional dependency can come with its own unique set of challenges, particularly if the firm has a training practice that they want to transfer to their new host community. For this to be successful, the firm must contend with established employment and work preparation practices in the local community, and, especially when engaging public training institutions, likely must secure support and from local gatekeepers. In this respect,

training program implementation in overseas locations is not simply a case of wholesale transfer of a firm's most effective training practices, but rather is necessarily a negotiation with socially embedded practices and engagement with established actors and norms for firm-to-firm and firm-to-institution coordination.

This raises a number of questions. How do smaller multi-nationals transfer their best training practices to a branch plant location? What kind of partial or hybrid practices might smaller multi-national companies introduce to a local area? How do smaller multi-nationals engage local institutions in an institutional environment that often favors larger firms? Finally, as supply chains extend out and are reconsolidated and territorialized in new ways, will local firms be crowded out of learning and knowledge exchange, as scholars suggest, or are there ways to extend these opportunities down the supply chain?

Empirical Setting, Data Collection and Analysis

This paper focuses on two training program development efforts by smaller multi-national companies. These cases were developed through interview-based research conducted in Puebla, Mexico, between 2014 and 2016. The author sought to understand how German branch plants had adapted home country training practices in a foreign environment. Both cases were selected because they involve a local automotive cluster where the OEMs and many of the first-tier suppliers are of German origin.

The City of Puebla, Mexico, is located 75 miles east of Mexico City and some 170 miles from the eastern port of Veracruz, in Mexico's central automotive corridor. The local automotive cluster in and around Puebla is anchored by Volkswagen's production plant, which produces cars for the Mexican, U.S., and E.U markets. The region has been upgrading its functional, process, and product capabilities since vehicle assembly began at Volkswagen of Mexico (VWM) in 1964. VWM underwent major restructuring in the 1990s, and invested in an upgrade to the

Puebla facility in 2008. From the 1990s and through the early 21st century, VWM, like other foreign automakers, recruited home country and other "follow source" suppliers to co-locate with their assembly plant in order to provide large car parts and critical services in short time frames. By 2014, about 40 suppliers were located in close proximity to the VWM assembly plant, with at least 200 other direct suppliers located within a day's drive. At the time this research was being conducted, further regional investments were underway in anticipation of Audi's new plant opening in Puebla in 2016.

This dense cluster of automotive parts suppliers makes Puebla a rich setting in which to observe multi-national companies of all sizes and a promising arena for the introduction of foreign training practices. As VWM expanded, so did its internal training systems. Established as a separate organization in 1996, but still operating on-site at the plant, the Volkswagen Institute provides employees with executive, management, and language courses and operates a technical training school.

Attempts by VWM and the State of Puebla to coordinate public and private training resources had started but stalled in the late 1990s. This vision of public-private coordination would be achieved with Audi's arrival, when a state-administrated training center opened outside the Audi plant in 2016. Between the late 1990s and 2016, other firms, including VWM suppliers, set their intentions on the adoption of German-style vocational training at their branch plant locations in the Puebla cluster and were engaged in processes of program expansion beyond the boundaries of their single firm. Focusing on these firms and their efforts allowed the author to observe the bumpy process of practice transfer across countries with different skill development norms and institutions.

The author conducted 53 semi-structured interviews and collected 60 brief, structured survey-style responses between August 2014 and July 2015 in the central Mexican states of Mexico, Puebla, Tlaxcala and Guanajuato. The majority of the interviews and observations took place in and around the City of Puebla, Mexico. Interviewees were identified through a snowball sampling method, beginning with prominent organizations, through which the author identified three cases of training practice transfer from Germany to Puebla. One additional training program was identified through a survey of news articles. In total, 12 interviews were conducted with staff at two OEMs and 11 were conducted with staff at six supplier firms. To better understand the regional training norms, the author conducted eight interviews with industry or employer associations; seven with public universities; six with private universities; three with state officials; and five with other training providers and experts. Eight company interviews included plant visits; four included training site visits. Interviews lasted between 45 minutes and two hours.

Interviews explored the activities of and connections between firms and educational institutions. In comparing the various models of training and public-private partnership encountered, the author primarily considered the length of training programs and the mix of classroom, lab, and on-the-job learning. Additionally, the author considered: the mix of general and specific training offered; the age and education of trainees; the structure of mentorship for trainees in the school and in the company; the qualifications trainees received; and the financing of training programs. In interviews with company representatives, the author sought to understand company training norms in terms of internal recruitment, screening, hiring, and training practices for production workers and production technicians, as well as how those practices have changed over time. The author also inquired about the use of external recruitment

or training partners, the practice of apprenticeship, and, where utilized, the process of apprenticeship practice adaptation and implementation, assessing the support that companies had in setting up their programs.

Field notes and interviews were transcribed and each interview was tagged with the interviewee's professional position, previous professional experience and employer information. Summaries for each interview were created and major themes identified; key words were created for major themes and used to re-evaluate all interview content during final analysis. Findings were organized and further developed around these themes. Sixty brief, structured interviews with workers from various firms also contributed to a broader understanding of the local training practices. These were summarized in one report and were found to be generally congruent with the main analysis and findings.

The Dual Formation Model for Skilled Production Workers

There are a variety of "best practices" in work organization, business operations, supplier management and client relations that are important for companies aiming to compete in global industries. This paper focuses on an area of improvement that is relevant to companies of all sizes in various industries in a variety of countries, yet is often taken for granted: the training of technical tradesmen and tradeswomen. Across manufacturing sectors, critical "production technicians" include machinists and machine maintenance technicians. These and other technical workers have the skills to efficiently operate and maintain machinery and tools. Scholars and policymakers pay attention to the training and preparation of these workers in part because addressing the economic demand for technical skills has the potential to dovetail with efforts to reduce high post-Recession unemployment rates experienced by young adults (Hoffman, 2011).

International interest in closer engagement between the education sector and employers has inspired emulation of the "dual formation" model exemplified by the German system.[21] Pilz & Li (2014) and Euler (2013) describe the basic elements of a German-style dual formation or "apprenticeship" program, emphasizing operational elements—training locations, standards, teacher qualifications, student population, and trainee certifications—as well as governmental elements—multi-stakeholder joint decision making, funding, and oversight – and the program's economic, social and individual development goals.[22] The key to achieving the operational elements—teacher certifications, trainee certifications, funding and oversight—is that these are co-determined by public and private stakeholders. Given the difficulty of replicating the German system of governance, including labor representation, scholars simply emphasize the public and private sector coordination. Still, a much higher level of public-private coordination and a much greater engagement by employers and employer associations is required to sustain the *dual formation* process of education than most countries (other than Germany, Switzerland and Austria) have been able to achieve. In *dual formation* systems, the learning process at the work site is as important or more important than learning in the classroom. Employers must provide mentorship and structured on-the-job training, and they must also ensure that classroom lessons are advanced and classroom theories are applied at work. Likewise, vocational schools must do their part to ensure that classroom lessons are relevant to work applications; teachers must have

[21] The "dual formation" model exemplifies global best practice in employee training, as evidenced by vocational education recommendations by the Organization for Economic Cooperation and Development to its member countries; European efforts to advance dual formation training practices throughout the region; and a number of bilateral practice transfer agreements by Germany with other countries.

[22] Euler's work (2013) is based on expert evaluation regarding the potential for practice transfer, drawing from the import and export history of the German apprenticeship model. The criteria from Pilz (2015) is evaluative, developed specifically to identify key aspects of the "Berufskonzept" (apprenticeship or occupational development) practice at individual establishments.

enough recent industry experience or exposure to make the connections clear and compelling. This is a challenge for many countries with vocational schools that operate independently from industry.

Another critical distinction is that the German apprenticeship system engages young people in high school in their initial vocational training and early career preparation, easing young people's transition from enrollment in secondary school to work. Engaging young people, their schools and teachers, their parents and communities, requires a high level of trust, buy-in and coordination between multiple actors, public and private. In some countries and communities, this level of engagement in vocational education requires a shift in norms and priorities, given the emphasis placed on college and more general educational requirements. Another way of judging whether a *dual formation* educational process has been achieved, in addition to the degree of employer participation, is the degree to which *the public* sees initial vocational education as a valid educational and career pathway (Euler, 2013).

Scholars find that in spite of German government efforts since the 1960s to help companies implement the system abroad, there have been few cases of a large-scale or complete transfer. This suggests an opportunity to study attempted transfer cases, failures, and partial adaptations to understand how firms activated their agency and power in the diffusion process.

Two Firms and Their Training Programs

In the late 2000s and early 2010s, two smaller multinationals took steps to adopt elements of the German-style apprenticeship at their branch plant locations in Puebla, Mexico, in order to address the difficulties they encountered in recruiting and retaining skilled workers. Both companies, Wawa and Mecha, are suppliers to Volkswagen with a global headquarters in Germany and only a few other branch plants outside of Germany.

Table 17 describes the two companies. Compared to other multi-national firms, Wawa and Mecha are small, with only about 400 and 100 employees at their Puebla locations and 1,000 and 6,000 employees worldwide, respectively. Their sizes and supply chain positions make these firms uniquely constrained in some ways and uniquely capable in others. This section of the paper describes each firm's efforts to develop employee-training programs at their branch plant location, setting explicit intentions to transfer a German dual formation model.

Table 17. Summary Information for Wawa and Mecha

Company	Wawa	Mecha
Headquarters Country	Germany	Germany
Locations Outside Germany	1 Mexico (first international location), 1 USA, 1 Czech Republic	2 Mexico. 2 U.S. 1 Brazil. 7 Asia. 9 E.U. and other (14 Germany)
Year Established in Mexico	1993	2005
Products	plastic parts	machinery
Global Sales	$245 million	$1233 million
Global Employment	1,900	6,570
Employment in Mexico	440	160
Employment at Study Site	440	100
Clients	OEMs	OEMs and Tier 1

Incremental Program Development in the Periphery—Wawa

In spite of Wawa's previous experience with apprenticeship programs at its headquarters in Germany, the apprenticeship program at Wawa's plant in Puebla developed incrementally

over several years. Volkswagen requested that Wawa establish a branch plant location in Mexico in the early 1990s, around the time that VWM was restructuring and outsourcing and when Mexico was loosening its local product sourcing requirements and more aggressively pursuing foreign direct investment. This was Wawa's first plant established outside of Germany, officially a joint venture with a local Mexican company. Wawa established its plant about 70 miles from VWM, taking over a factory on an industrial site in a small town.

Wawa's first employees in Puebla were transitioning from agrarian work and had never worked in a factory. By the 2000s, the plant had upgraded its machinery and required more skilled labor for machinery maintenance as well as more skilled production technicians. Struggling to make do with intermittent visits from technicians headquartered in Germany, the company decided to train their own technicians. But by the 2000s, young people in the area were not attracted to manufacturing careers, nor were they interested in staying in the small town.

Illustration 1. Volkswagen and Wawa locations in and near Puebla, Mexico

In response to these challenges, Wawa set out to establish an attractive new employee recruitment program. Managers drew on expertise from headquarters and worked directly with a former consultant to Volkswagen and Mercedes-Benz, a Master Apprentice trained in Germany who ran a training school[23] and consulting business (herein "The Training School") in nearby Mexico State.[24] Unable to host a more substantial on-site training program, Wawa sent apprentices to The Training School for several weeks of intensive hands-on training every year. Wawa graduated its first class of apprentices in 2008; the first class of students trained in collaboration with the local high school graduated from the apprentice program in 2015.

The German Chamber of Commerce (IHK), through the newly staffed IHK office in Mexico City, helped Wawa pursue schoolteacher and plant mentor training and certification, and, soon after, offered this suite of services to other companies. The consulting services of The Training School continue to provide individualized support and initial training capacity to firms in Puebla and across the country. These certifications and programs give Wawa increased credibility in its local efforts, ensuring a high standard of quality is maintained *and* helping attract trainees and gain the trust of local communities.[25]

[23] The Training School is a private training firm that has developed curriculum and a school in Toluca, Mexico, to support dual education systems, or apprenticeship, based on the German model. The school was developed in Mexico for this precise purpose, the idea sparked from VWM's activity to develop its own school in the 1990s. The Training School supports the IHK/AHK certification, functions as a testing as well as a training site, and provides ongoing support to firms in Puebla, Tlaxcala and nationwide.

[24] The German-Mexican Chamber of Commerce and Industry in Mexico (CAMEXA or AHK) is an official administrator of German training and certification. CAMEXA has a small staff dedicated to promoting and implementing the German dual education system in Mexico and has celebrated the development of local apprenticeship programs as an organizational priority. CAMEXA plays a key role in a pilot apprenticeship program with Mexico's Secretary of Public Education. (The Training School plays a background role.) The organization is in charge of training the trainers that will support new programs across the country.

[25] The IHK credential, which apprentices gain when they pass a final exam, was not recognizable to most companies in Mexico, but it gave apprentices the very real benefit of a credential recognized by German companies worldwide. Not all companies in the local area have pursued the IHK test and credential, but its formalization helped position Wawa in the local labor market, validating the program's value, and providing an excellent marketing tool.

By 2015, Wawa had achieved many of the programmatic elements of a dual formation program. The company had an established recruitment process, a designated mentor to train apprentices, both school-based and company-based learning sites, and established training curriculum and internal company rotation schedules for apprentices. On-site training facilities were minimal but sufficed. Wawa identified a dedicated space for the apprentices by simply pulling together a few desks in the plant's administrative building. This small change made a big difference in the culture, allowing students to connect with each other for lessons after training separately across the production site.

After Wawa and the local public school adjusted their own internal systems and resolved their coordination issues, they worked together to promote the intensive, high-commitment training model to other employers. They recruited several local businesses: in 2015, at least five other companies welcomed a new class of apprentices. By recruiting other companies, Wawa and the school had created a de facto cost sharing and demand-aggregating multi-firm training platform. When interviewed, local participants, Wawa representatives most of all, spoke to the economic, social, and individual development goals of the program.

A perhaps unexpected barrier was local company capacity. Local, single-establishment companies that could not afford the consulting services of The Training School and had little experience that was applicable to training young people and related internal capacity development. While Wawa managers had been trained in the apprenticeship system in Germany, Mexican owners and managers had few reference points and struggled to adopt and sustain the high-commitment training model. One owner of a participating local company explained that he was personally dedicated to providing training and had benefited from his own initial training as an employee in a large chemical company, but it was difficult for his local single-establishment

company to dedicate sufficient in-house capacity to train and mentor the apprentices and to ensure the financial sustainability of the training investment.

Where the Wawa program falls short of the German model is in its lack of joint determination of apprentice qualifications; qualifications are established separately by school standards, company training standards, and then the imported IHK standards. Given the missing element of joint determination, the Wawa case does not constitute a complete transfer of a German dual formation system. Despite this gap, the Wawa case does suggest that a German-style apprenticeship can be implemented with adaptations, meeting company needs, engaging young people, and providing a structure for individual trainee development that becomes particularly important in a foreign context.

Meanwhile, on the other side of the automotive cluster, another Volkswagen supplier and German multi-national was busy addressing a related but distinct set of challenges.

Private Sector Response in the Core—Mecha

As Wawa set up its program in the geographic periphery of the automotive cluster, Mecha was building a training program in the core. In an industrial park across the street from the Volkswagen plant, a number of Volkswagen's large, multi-national parts and systems suppliers were struggling to meet increasing production demands: the plants had sufficient machinery, but were struggling with a shortage of human capacity to operate and maintain the equipment.

Illustration 2. Volkswagen and Mecha locations in the state of Puebla, Mexico

The industrial park did not have a shortage of skilled workers per se, but industrial park residents were engaged in a vicious cycle of employee poaching. Competition was so aggressive that companies were posting recruitment messages on billboards across the street from their neighbors. In an effort to end this destructive cycle, area employers, all German automotive parts and service providers, agreed to start talking about ways to address their shared challenges. They all were familiar with the German apprenticeship system and were more or less familiar with each other. Not only did their parent companies share multiple global locations, but CEOs also attended the same international conferences.

Mecha offered to set up a German-style training program in collaboration with the other automotive suppliers and eventually launched an independent training school. Like Wawa, Mecha believed that an apprenticeship program would address its shortage of skilled production technicians, serving as a recruitment tool, a skill development system, and generating mutually beneficial commitments from trainers and trainees. In the context of the industrial park, an apprenticeship program would also reduce direct labor market competition between companies,

establishing training and employment protocol for their investment in workers, a deterrent to continued system abuse.

Mecha was in the unique position of already being a service provider to several of the concerned automotive companies in the park, at times even providing training services to other companies' employees. Mecha imported, installed, and helped maintain critical equipment in these plants and already had senior staff with a high level of production expertise in-house. So, like Wawa, but with more explicit intentions from the start, Mecha offered a cost-sharing and demand-aggregating multi-firm training platform. Instead of partnering with a public school, however, Mecha launched its own private school, which was operating independently by 2014.

In comparison to Wawa, the platform Mecha designed was more formal and uniform across firms. Mecha essentially provides a *turnkey* solution: any member company can plug into the program, provided they can support their own in-house on-the-job-training and mentoring and provide stipends and benefits for trainees. Mecha equips the training center, coordinates recruitment, and trains students in the classroom and the lab. Training specializations offered include tool mechanics (industrial mechanics technology in die-casting and stamping) and industrial mechanics (machine and systems technology). The programs each require three years of training, with 60 percent classroom and 40 percent on-the-job training. At the end of the training, students are tested and certified as technicians by the German Chamber of Commerce and Industry (IHK).[26] They finish with the IHK certification and a two- to six-year contract with a participating sponsor company.

[26] The German exam and certificate are from the Chamber of Commerce and Industry in Germany, coordinated in Mexico by the Mexican-German Chamber of Commerce and Industry, as established by Germany's professional education law of 1969.

Mecha initially launched with six companies committed to sponsor apprentices, and began promoting its dual training school, Entre, to training candidates. In the program's first year, six companies—all Volkswagen suppliers and Mecha clients—took on two to seven apprentices each. Thirty total apprentices were enrolled. Seven additional companies joined between 2012 and 2015. Each company supports up to eight new apprentices each year. In 2014, 90 apprentices had enrolled over three years, 19 to 36 entering each year.

Internal capacity was not as prominent an issue among these multi-national companies as it was for the local firms that were participating in the public school program with Wawa. The German multi-nationals were familiar with the program offerings and large non-German multi-nationals that joined later were able to conduct their own learning and capacity-building processes. The private school model was, however, not without its own challenges. Member companies paid membership fees to sustain the school, but some companies also convinced Mecha they had to permit them to take breaks (off years), allowing them to avoid paying for an ongoing service, and only plug in when convenient, reducing the reliability of the training program revenue. The public school model avoided this challenge as school-based training was publicly funded.

By 2014, Mecha, like Wawa, had utilized the IHK standards and qualifications and achieved many of the programmatic elements of a dual formation program. Mecha's school, Entre, was more loyal to the *dual formation* model and German-style apprenticeship, with better integration of on-the-job training with classroom education, given that the training school and employers were highly coordinated, almost inseparable—participating employers had launched the training school and the school was run by one of those employers. The high-level initial commitments by top area companies met the spirit of the high-commitment German-style

apprenticeship. But the school had no public funding or formal public partnership and fell short of the German model in this respect. In this respect, Wawa's program, with public sector participation, more strongly demonstrated a commitment to not only economic but also social and individual development goals for apprentices, another element of the *dual formation* model. Mecha participants did not attest as directly to social or individual development goal. See Table 18 for a summary of these differences.

Table 18. Characteristics of Dual Formation Programs Launched by Wawa and Mecha

Anchor Firm	Wawa	Mecha
School Site	Local high school	Private training school, hosted on site in industrial park
Key Participating Firms	Wawa, otherwise participation varies	Launched with six automotive suppliers
Program Purposes	Firm internal training, high school capacity building, student success	Firm internal training, client service, reducing industrial park competition for skilled labor
Commitment to Economic and Social Goals	Multi stakeholder commitments sustain program; local area upgrading and student success are explicit goals	Student and business satisfaction are important to business model
Teacher Training and Certification; Apprentice Learning Standards and Testing	German Chamber of Commerce (IHK) and The Training School Consultancy	
Firm Participation Requirements	Responsible for apprentice and related expenses	Membership fees locked in for years; responsible for apprentice and related expenses
Potential for Networked Sites to Extend Practice	School systems; coordinated school sites	Business model for industrial parks
Firm-to-firm relationships —program development —program expansion	 —relational —relational	 —relational —formal, modular

Revisiting the cases in 2018, the author finds that Wawa and Mecha continue to sustain their local programs and, presumably, their advantages within them. Since helping to establish these programs, technical assistance providers at the German Chamber of Commerce (IHK) and The Training School consulting company have taken on central roles in a national initiative to further adapt and extend the dual formation model across Mexico. Wawa and Mecha became accidental activists at the national level, as they sought to defend their programs and solicit their expansion as the national task force and then the national initiative was developed.

While both models had the potential for expansion across multiple sites, clearly one was better situated for roll out through the public school system. Mecha's private model was not picked up by a national partner, in spite of its more replicable turnkey model for training as service provision.

Conceptualizing the Case Comparison

International business scholars have suggested it is rare for firms to make an intentional effort to transfer training practices in a manner that is faithful to home country practice (Kostova, 1999). Vocational training scholars report it is rare to see a successful practice transfer (Euler, 2013; Pilz, 2015). But the two firms studied in this paper demonstrate that a degree of dual formation practice transfer is indeed possible.

While the "partial" practice transfers fall short of a complete transfer of the German apprenticeship system, these examples offer insight about firm behavior, power, and potential. Reflecting on the roles of Wawa and Mecha in this study, the smaller multi-national firms acted first as entrepreneurs and then as *anchors* to dual formation programs. As entrepreneurs, they adapt global best practices; as anchors, they provide a hub for further development. Each *anchor firm* is deeply involved in program development and expansion.

The anchor firms' supply chain positions support their efforts at establishing German-style apprenticeship programs. Both firms are branch plants of multi-national suppliers in the global automotive industry. Their clients produce cars for the advanced and highly competitive U.S. and European markets. And their clients require technological and social sophistication in product and service delivery. They both have access to global best practices and management resources, but they lack the capacity to develop robust training systems in-house in the branch plant location, making them more dependent on local institutions and external partners than larger multi-national companies. The firms' shared country of origin means that they launched their programs with a similar reference point and notions of best practices in training: both Wawa and Mecha believed that a German-style apprenticeship program would address a local shortage of skilled production technicians and establish beneficial protocols for participating firms.

Both firms also rely on substantial institutional and organizational supports to set up their programs. They activate these supports through relational work across local and international networks. Each draws resources from the home country as well as from the host country. To maintain their programs, both firms rely on continued support from The Training School and IHK, which draw updated technical requirements and testing materials from those established by German government, labor unions, and business chambers. IHK programs include a Train the Trainer curriculum and apprentice testing programs. While standards developed in Germany might not be a perfect fit for Mexico, these standards are nonetheless a valuable resource, providing structure, clear goals, and guidelines for quality assurance to emerging and expanding programs.

While technical assistance providers help the firms transfer elements of the German system, other adaptations are necessarily the purview of participating firms. Practice transfer, therefore, relies both on the codified elements of the German system *and* the local re-development of a German-style apprenticeship system, requiring substantial entrepreneurial work by well situated multi-national firms. The differences between the Wawa and Mecha programs suggest that a variety of practice transfer scenarios potentially stem from their competitive positions in global supply chains. Even with similar origins, networks, and resources, the anchor firms' motivation and program design varied by location as well as product and market orientation. Each anchor firm's geographic location in the industry cluster (periphery vs. core) and labor market position in its micro geography (rural area vs. industrial park) influenced its German-style apprenticeship program design. In the periphery location, the firm's high skill demand, larger comparative size, and ability to pay higher wages than other companies helped the anchor firm draw benefits from program development and expansion. In the core location, skill demand and the potential to expand existing client services were motivating factors. Each company built on its initial orientation in extending the programs. Wawa dabbled in more social entrepreneurship while Mecha's approach was more commercially oriented.

Left out of this paper's analysis of German-style apprenticeship programs in the Puebla automotive cluster is an older, OEM-initiated dual formation program established at the Puebla VWM plant, which was formalized in 1996 as the Escuela de Becarios at the Volkswagen Institute. Compared to the style of most dual formation programs in Germany, the VWM program is a misfit, as it failed to establish 1) an independent training school with public sector support, and 2) access to regular on-the-job training during the initial training period. Volkswagen originally aimed for its training program to be supported by the state but

negotiations for such support were unsuccessful. VWM's first external partnership in training program development was in 2009, when they established an engineering degree at a private university. But in 2014, their vocational training service had still only been extended to top strategic suppliers. Now it seems that efforts by Wawa and Mecha, along with increased scrutiny from the IHK and the Mexican government, might nudge Volkswagen to modernize its program at the Escuela de Becarios to meet the IHK's training and testing standards.

With this broader context, we can see that VWM's "failure" to fully transfer a German-style dual formation system to Puebla allowed some of its smaller suppliers to elevate and advance certain elements of a dual formation system and introduce some innovations while increasing their own local reputation and visibility.

Conclusion

We often write about small multi-national enterprises as if they are purely subordinate to their larger client OEMs, but power is relative, and the agency of smaller-sized firms lower on supply chains should not be ignored. Critical examination of smaller multi-national enterprises, including follow-source suppliers, reveals that they are influential in some locations and practice areas. The two examples provided in this study suggest that smaller multi-national firms can be influential in their local labor markets and micro-geographies (e.g., industrial park in the cluster core or rural town in the cluster periphery). Within these local contexts, their comparatively large size and access to global resources can anchor local training efforts. As they act in their own best interest, drawing inspiration and resources from abroad, they create a bridge between the global and the local—connected to global corporate networks, but still reliant upon local alliances. Their ability to accrue benefits from their investment improves their staying power, enhancing their ability to anchor a program in the long term.

The broader international recognition of German-style apprenticeship as a best practice since the Great Recession, and the expansion of relevant institutional supports outside of Germany, make it increasingly possible for German firms to accomplish this type of practice transfer to branch plant locations. Non-German firms experience more difficulty adopting and transferring German-style apprenticeship, but may still be successful. A generalization of the case study findings in this paper to clusters across North America's automotive manufacturing periphery (the U.S. South and Mexico) is also possible. Both "global suppliers" (co-locating with OEMs worldwide) and "follow source suppliers" (asked to co-locate in specific locations) are increasingly prominent in various supply chains. An injection of foreign "follow-sourcing" suppliers (suppliers required to co-locate with clients) affected all clusters beginning in the 1990s, leveling the playing field regarding what is possible in each of these regions, particularly regarding the behavior and skill demands of follow-source suppliers.

Had VWM succeeded in the 1990s in forging an agreement with the State of Puebla to create a German-style apprenticeship system, the local history might have been very different. Its failure to completely adopt and extend this now globally recognized best practice model to the local area created an opening for entrepreneurship by smaller firms and their technical assistance providers, who in turn established their prominence in local and eventually even national skill upgrading systems. This sequence of events demonstrates that once a practice is introduced, a local anchor organization can act as an agent or policy entrepreneur in the host area to advance or reconstitute the practice and further facilitate practice transfer between co-located firms.

The process of practice transfer is not only incremental, with each program building on the previous efforts of others and iterating across program development stages, but is also evolving with the expansion of global supply chains. The emerging potential for the diffusion of

training practices from headquarters to branch plant (or home to host country) is, in part, a function of increasing foreign direct investment and increased institutional supports for transfer in branch plant locations. The largest MNCs play a role, preceding their follow source suppliers in the branch plant location, and sometimes creating a surplus of technical assistance in the region that indirectly influences suppliers' behavior. While transferring global best practices in labor management from an OEM's headquarters to its branch plants and supply networks has not previously been successful (Barrientos, 2007; Locke, 2013), this case of training practice transfer shows that smaller multi-nationals and their branch plants can serve as hubs for the introduction of new practices. Headquarters and powerful clients may motivate and incentivize practice transfer, but branch plants and suppliers themselves need to initiate and sustain critical local partnerships and international networks.

This ability to bridge the global and the local is important given the increasingly asymmetrical relationships between larger multinationals and local suppliers. Smaller multi-nationals are well positioned to addressing this gap by imitating their clients and collaborators: activating the support of organizations both global and local, expanding their programs and introducing their practices to other companies and interested organizations in the region. By adapting a system first introduced by their larger client through the co-production of public and private training programs, Wawa and Mecha extended their locational advantages as well as their visibility, allowing them to accrue benefits by sustaining the training programs.

Policymakers and scholars should be careful not to discount the potential for smaller multi-national enterprises to break down barriers to, and introduce new mechanisms for, practice transfer. While there is no assurance that smaller multi-national corporations will be more collaborative and locally embedded than their larger more powerful clients, it is possible that

they will enact power and influence in different ways. In at least two cases, their anchoring and extension activities helped to extend training services further than expected, engage other locally-based firms, and create new infrastructure and networks for vocational training in the branch plant location.

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CONCLUSION

The outsourcing of employment-generating activities from larger to smaller companies puts the relationship between skill and wages at risk. This dissertation suggests ways to restore that relationship, drawing attention to firm-to-firm dynamics in global value chains and local clusters.

This dissertation explored whether smaller firms require skilled labor and how they acquire it. I examined these questions in the context of the U.S. automotive industry and in two sub-national automotive clusters in South Carolina and Puebla, Mexico. Integrating approaches from cluster and supply chain-based research, my findings demonstrate how power and resource asymmetries between firms can affect local skill development systems and firms' prospects for upgrading in global supply chains.

The first dissertation paper addressed how skill is dispersed across industries supplying the U.S. automotive industry. This exploration was necessary because there is conflicting information about the skill requirements of large and small firms. In the automotive industry, brand-name Automakers control most of the value-added activities in their supply chains: they spend the most money on research and development and they receive the most patents. But their plants are also the most automated, raising questions about the kinds of skills they require of production workers. Smaller, lower tier automotive suppliers—such as machine shops and metal product producers—are known to require highly skilled trades people, but they tend to train

through informal, internal systems in ways that make skills hard to measure and reward, and they pay lower wages.

To investigate these trends, I grouped industries into two supply tiers. The industries most utilized by Automakers were included in Tier 1; those most utilized by Tier 1 were included in Tier 2. Overlaying these tiers with their occupational skill requirements, I found that the lowest tier requires the greatest percentage of workers with more than a high school degree and more than one year of related work experience. I also found that the relationship between skills and wages is unclear: wages vary by tier, but in the opposite direction as skill requirements. The results for Tier 1 are particularly interesting as these intermediate goods suppliers seem to control much of the skill in the supply chain, through direct employment and sub-contracting, while their skill measures and wage rates vary by state.

The second paper in this dissertation further investigated issues of skill demand and compensation, focusing on the training decisions of lower tier automotive suppliers in South Carolina's Upstate automotive cluster. I replicated the method from the first paper to show skill and wage requirements by supply tier for South Carolina and found similar results. Drawing insights from interviews with company representatives and county economic development staff, I found that supply chain dynamics negatively affect smaller companies' abilities to train and compensate skilled workers. Cluster dynamics can both exacerbate and assuage these negative supply chain pressures.

To identify how improved training practices can be extended to smaller companies, the third dissertation paper investigated how smaller multi-national enterprises have developed apprenticeship programs in their branch plant locations. Although better training practices among smaller companies are often derived from larger multi-national corporations, I demonstrated that

smaller multi-nationals have agency in their own right and are well positioned to introduce new training models in a foreign environment. They are more flexible than their larger counterparts, but also have more resources than smaller, local firms. With the appropriate institutional supports, smaller, multi-national enterprises can adapt the training programs of their larger clients and extend the reach of both public and private training programs to benefit firms at the lower end of the supply chain.

Policy Implications

The relationship between occupational skills, wages and supply chain position is critical to understanding why some firms succeed at investing in local skill development systems while others fail. Economic and workforce development policymakers and practitioners receive vast amounts of information on each of these issues—skill demand, employee compensation, and supply chain dynamics—but rarely have an opportunity to weave these issues together to inform strategies for local development. These connections are important if we are to advance effective human-centered economic development strategies. Each of the individual papers in this dissertation has identified strategies that can help guide local development.

The first paper showed that smaller firms in lower tier supply sectors of the U.S. automotive industry require a higher percentage of skilled tradesmen than Automakers, but do not translate higher skill demand into higher wages. The automotive industry clearly depends on these skills, yet these lower wages risk impeding skill regeneration and upgrading. Economic and workforce development practitioners can use this analysis to begin or reinvigorate skill-centric conversations with employers in high- and low-skill sectors. Industry leaders can use it to demonstrate the extent to which larger firms rely on the skills of their supply network and to motivate investments in skill development across the supply chain.

In the second paper, I reported how larger firms rely on the skill investments made by their suppliers. Because some suppliers have the technical knowledge to generate their own trainee pipelines in house, I recommended dedicating funding to provide local manufacturing firms with the resources to rebuild vocational training programs. To sustain their investments in these programs, suppliers must ensure these programs help them create a competitive advantage to grow and advance their businesses. To further address the risk of poaching by larger companies, I also suggested that economic development practitioners link public support to supplier development programs in advance of client expansion events, in order to help suppliers retain their core workers. The success of this strategy depends on suppliers having clear opportunities to grow and expand their businesses.

In the third paper, I reported that smaller multi-national companies can be key to helping draw down critical resources for building local skill development systems. I recommended expanding technical assistance provision so that these firms can build such programs across various global locations. I also proposed that economic and workforce development practitioners engage multi-national companies when they establish a new plant, bringing them in as partners in the development of local skill development systems. These multi-national companies have the resources and, because of their industry prominence and ability to pay higher wages than local companies, will reap the benefits of this engagement. Given the large investment that is required when moving to a new location, it is critical that these companies are successful in their first few years.

Limitations of the Research

The first paper presented an analysis of publicly available data at the national level. While the method is replicable across various supply chains, the automotive example is particular to the automotive industry and cannot be otherwise generalized. A major construct

validity issue was discussed in detail, regarding the measurement of "skill." Two measures were used—education and experience—to capture different elements of the construct.

The limitations to using publicly available data to evaluate skill requirements by industry and supply chain tier include: 1) delays in the publication of the benchmark (detailed) national input-output tables by the Bureau of Economic Analysis; 2) Bureau of Labor Statistics Occupational Employment Statistics occupational "staffing patterns" are only available for four-digit NAICS codes and require the assumption that staffing patterns do not vary across establishments within industries; and 3) O*NET data on skill requirements by occupation do not vary by industry, requiring the assumption that skill requirements for occupations do not vary across industries. The third limitation is the most egregious because it is difficult to address and makes it challenging to assess very important differences between large and small firms in the same supply chain across different industries (e.g., between Automakers and machine shops).

The greatest limitation to the case studies presented in papers two and three is external validity, which is limited by the focus on manufacturing sectors related to the automotive industry and the focus on growing automotive clusters anchored by a large German Automaker. Some recommendations regarding inter-firm dynamics will likely be applicable across industries and clusters, while others will not. In the latter category are those recommendations that rely on a foreign branch plant or a concentration of branch plants to introduce a new training practice. Otherwise, the potential for the diffusion of training practices from supplier to supplier, including from foreign to local, is a function of supply and demand environments (institutional supports in the home and host area) and the ability of an anchor organization to act as an agent or policy entrepreneur in the host area. Supply chain position, local labor market position, local and global networks and ability to mobilize resources will inform the orientation of the anchor

organization. Non-German firms would have more difficulty adopting and transferring German-style apprenticeship, but it is not precluded.

A unique local history can also reduce external validity, but a generalization of the case study findings to clusters across North America's automotive manufacturing periphery (the U.S. South and Mexico) would not be misguided. The unique factor in the Puebla case was Volkswagen of Mexico's adoption of German training practice at its own plant in the 1990s. Still, an injection of foreign follow sourcing suppliers affected all clusters from the 1990s, leveling the playing field regarding what was possible in each of these regions, particularly regarding the behavior and skill demands of follow source suppliers.

Directions for Future Research

This dissertation offers a structured approach to a complex issue. It provides planners with additional information regarding the interaction between global and local actors in economic development by demonstrating how the relationships between firms can contribute to and undermine local skill development ecosystems. Additional research can bring clarity to some of the outstanding issues that have been raised.

In the longer term, the tools I introduce and the findings I reported can help local areas better prepare for the inevitable disruptions from trade and technological change. This dissertation highlights the fact that much of our knowledge regarding skill demand is based on trends in skill supply (e.g., higher returns to higher education) as well as the hiring and compensation trends exhibited by larger firms (also higher returns to education). We often overlook evaluation and planning efforts to update the skills of the workforce in smaller firms, assuming that investments made by and in larger firms will "trickle down." There are a number of barriers to this process, both institutional and resource-based; in reality, neither public

programs nor skills tend to “trickle down” from larger to smaller firms. Instead, skills and skill development investments may require substantial draw-down efforts.

In order to make progress on longer term planning issues, additional data collection and evaluation is needed. This dissertation shows that a firm’s orientation toward skill investment is related to its supply chain position. Supply chain and cluster-based case studies have enriched our understanding of how this key variable affects individual firm decisions and intra-regional dynamics. Unfortunately, this is difficult to measure at the firm or establishment level. Information about supply chain position is missing not only from publicly available data, but also from other survey-based research. (For example, helpful questions are missing in the Georgia Manufacturing Survey; automotive industry surveys by Sue Helper are an exception, as they have included a few questions about clients and suppliers).

In order to make near term progress investigating intra-industry variation in “staffing patterns” (occupational mix), existing establishment-level survey data from the Bureau of Labor Statistics could be matched to information on each establishment’s supply chain position. This would help us understand, for example, whether automotive-serving establishments are different from non-automotive-serving establishments in the same industry. Conducting this research at the state level is feasible and has the potential to inform nationwide survey construction, improving the chances that questions about supply chain position are attached to establishment-level data in future data collection efforts.

Advancing our understanding of how occupational skill requirements differ across industries and establishments requires either direct observation, access to expert analysis, or the use of job posting descriptions. This information would help us understand whether the skill requirements of a machinist at an Automaker are different from the skill requirements of a

machinist in a lower tier supply sector. If there were major differences, O*NET and other skill databases would need to be updated.

Given the similarity in the data used across North America, efforts for more comprehensive data collection could be coordinated. This would allow for more comparative research. For example, future research on skill development at the sub-national and industry level in the U.S. and Mexico could focus less on process and more on outcomes so that progress across clusters can be quantified and compared. This work does not necessarily require updating national databases; surveys, interview projects and case studies could be advanced on a more reasonable timeline.

There is also additional work needed to ensure multiple measures of skill are used in national and international assessments of the "skill content" of products and trade in value added goods, where researchers are interested in assessing changes in skill requirements and comparing skill requirements across countries. This is particularly important in studying manufacturing industries and production workers. Research should continue to demonstrate the limitations of standard proxies for skill, like formal education or wage level, as well as to develop alternative and more encompassing measures.