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2006
Industry Studies Association
Working Papers

WP-2006-01
http://isapapers.pitt.edu/

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March 27, 2006

Abstract: Ten new steel plants were constructed in the United States from 1989-2001, each taking advantage of new technologies that gave scrap-based minimills access to the market for flat products based on the casting of steel slabs. Earlier, this market was the exclusive domain of ore-based integrated mills. This research brings new evidence to bear on the nature and importance of agglomeration economies, by analyzing industry clusters related to the advent of new slab casting technologies. The analysis is based on direct observation and plant visits to all of the new mills created by the new technologies. We find that industry clusters can play an important role in the process of market entry, and that specific factors related to product and firm characteristics help to determine the nature of agglomeration economies and their effects on firms and regions.

* This study is funded by the Alfred P. Sloan Foundation, New York. The assistance of Paul Flora, Katherine Johnson, Carey Treado, and Gashawbeza Bekele are gratefully acknowledged.

1. Introduction

Current interest in industry clusters as a basis for firm competitiveness and regional economic development is well founded in theoretical and empirical research in the academic literature. Although studies of high-tech clustering prevail (e.g., Romer 1986, Storper 1993, Saxenian 1994, Audretsch and Feldman 1996, Porter 1998, 2000, Newlands 2003, *inter alia*), not all regions are well positioned to succeed in the competition for development in information technologies, biotech, pharmaceuticals, research and development, and similar industries with associated occupations. While recent clustering research has emphasized the synergistic, non-traded interactions associated with high-tech clustering, the more commonly recognized benefits of agglomeration in traditional industry clusters remain (Marshall 1890, Weber 1929, Isard *et al* 1959, Czmanski 1971, Moomaw 1981, Cella 1984, Henderson 1986, Glaeser *et al* 1992, Gordon and McCann 2000 *inter alia*). As such, the promotion of traditional industrial clusters and agglomeration continues to be an important economic development strategy. In fact, the success of such strategies can turn on specific factors related to the product and firm characteristics of the targeted activities because these characteristics help to determine the nature of agglomerations and their impacts on firms and regions.

The analysis presented in this paper is drawn from practical experience in the American steel industry. We study the characteristics of agglomeration associated with ten steel minimills recently constructed to take advantage of new technologies that permitted scrap-based steel producers to enter a new market segment consisting of various sheet and plate products. In the course of market entry, variation in experience across mills exposes the importance of traditional agglomeration economies and also highlights the ways that firms can use co-located facilities as levers for market entry. Moreover, our analysis offers insight by example on the factors that can affect the impact of industrial clusters on host regions. The experience of the plants in our study shows in a tangible way how the nature of the product market, firm strategy, and firm structure all may affect the impact of industry clusters on regional economic development.

The following section describes the technological advance that spurred new investments in the 1990s, and the plants that adopted the new technology. Section 3 places the plants in geographic perspective by describing their locations with respect to the general product markets that they serve. A brief review of perspectives from the agglomeration literature follows in Section 4. We present our methodological approach in Section 5. Our analysis related to agglomeration and steel minimills begins in Section 6, which identifies the relationship between industry clusters and market entry for these new producers. In this section, we highlight the important role in market entry that has been played by service centers and other downstream processors. Section 7 draws implications from our findings concerning regional economic development. Concluding remarks are offered in the final section.

2. New technology and new plants

The restructuring of the American steel industry that began in the 1980's was driven primarily by an environment of stagnant national demand coupled with two competitive forces: low-cost imports and low-cost domestic minimills. Domestic competition is based on two rival steel making technologies, One technology uses basic oxygen furnaces (BOFs) in a process that requires iron ore as the primary ferrous input, while the other uses electric arc furnaces (EAFs) in a process that relies primarily on ferrous scrap (i.e., recycled steel). Before restructuring in the mid-1980s, traditional integrated firms used both technologies (BOF and EAF) to produce steel for a wide range of product markets. Their domestic rivals, steel minimills, are exclusively EAF producers, and at the time of this initial restructuring, they were restricted by the limits of available casting technologies to producing “long” products like rods, bars, rails, and beams (Ahlbrandt, Fruehan, and Giarratani 1996, Ch. 4). While integrated steel mills also produced these products, their comparative advantage lay in the markets for “flat” products, the steel sheet and plate used in a wide range of manufacturing industries.

Table 1 shows steel making capacity by type of plant (integrated and minimill) and by furnace type (BOF and EAF) for 1982 and 2002. The data help to expose the extent and character of restructuring based on this domestic rivalry. The table documents how restructuring partitioned the American steel market by technology. Integrated producers reduced their overall capacity dramatically, but they also virtually eliminated their capacity to make steel using scrap-based electric furnaces. Over the same period, minimills increased their capacity from 34.1 million tons to 59.1 million tons.

[Table 1 Here]

As a consequence of this dramatic change, the product market in the steel industry was partitioned. During the 1980s, scrap-based minimills using EAF furnaces captured the market for long products. Ore-based integrated mills using BOF technology focused exclusively on serving markets for flat products. In effect, integrated producers eschewed competition from their domestic rivals by limiting their product range behind the protection of a technological barrier. At the time of restructuring, the steel slabs necessary to produce flat products could not be cast by EAF producers. However, the resulting division of product markets was not long lasting.

In 1989, the leading firm in the minimill sector, *Nucor Corporation*, adopted an untried technology, Compact Strip Production (CSP), from *SMS/Concast* an international steel equipment supplier. CSP is a breakthrough technology that allows steel slabs to be cast as thin as two inches. The successful implementation of CSP occurred with the construction of the now-famous Nucor plant in Crawfordsville, IN (Preston 1991), and this signaled to other steel makers that entry to the markets for flat products is possible at much smaller scale and capital costs than were previously believed possible.

Spurred by the success of CSP, other competitive new technologies soon followed, and ten new steel mills were constructed in the United States from 1989-2001. The variety of locations associated with these plants offers a unique opportunity to understand the nature and importance of industry agglomeration related to steel minmills. Some of the new minimills were built in established industry agglomerations. Other new minimills were built in regions that had little or no prior steel making activity --- greenfield locations. By studying the experience of individual mills in traditional steel making regions and in greenfield locations insight can be developed on the nature of industry clusters, and we can more fully appreciate factors bearing on the impact of agglomerations on plants and on regions. The analysis reported is based on direct observation and plant visits to Nucor-Crawfordsville and all of the slab-casting minimills that were built after implementation the CSP technology.

Table 2 summarizes information about the ten new steel plants entering the markets for flat products, and it does so by distinguishing between two types of EAF slab mills: sheet producers and plate producers.

[Table 2 Here]

Nucor's success at Crawfordsville led immediately to that plant's capacity expansion from one to two million tons per year, and by 1996 Nucor had constructed two additional sheet mills based on the CSP technology – one in Hickman, AR (1992) and another in Berkeley, SC (1996). Entrepreneurs found the steel industry attractive once again, and a cascade of new ventures materialized over the decade of the 1990's. *Gallatin Steel* (Ghent, KY) was the first non-Nucor mill to enter this market, and it did so by using the same CSP technology adopted by Nucor.

Steel Dynamics, Inc. (Butler, IN), which is widely recognized as one of the most successful thin-slab steel producers, was created by entrepreneurs who as former Nucor employees had played a critical role in the successful start-up of Nucor-Crawfordsville. Capitalizing on that knowledge and experience, Steel Dynamics (SDI) expanded rapidly and extended its business beyond flat products to include new facilities that also produce structural and rail products, bar products, and building products.

In 1996-1997, *North Star BHP* (Delta, OH; now *North Star BlueScope*) and *Trico Steel* (Decatur, AL; now *Nucor-Decatur*) also entered the market for steel sheet, but they did so on the basis of technologies that cast "intermediate" slabs – slabs somewhat thicker than those produced by the original CSP technology. North Star's caster produces a four-inch slab, and together with innovations in its rolling mill the technology in this plant allows for improved reduction and surface quality.

Trico was a joint venture of three large integrated steel producers (*LTV Steel*, *Sumitomo Metals*, and *Corus Group*), but it had serious start-up problems. At start-up, the plant suffered a number of equipment and managerial problems, and was ultimately engulfed in the industry's financial crisis that began in 1998. Soon after the bankruptcy of LTV, one of its parent companies, Trico itself declared bankruptcy in 2001. Nucor Corp. purchased the Trico plant, which now operates as Nucor-Decatur.

Cumulatively, these seven EAF slab producers are capable of shipping at least 14.4 million tons of steel sheet per year, which is equivalent to about one-quarter of all domestic shipments of steel sheet in 2003 (AISI 2003; p. 22, Table 8).

The market for steel plate in the United States is much smaller than the market for steel sheet, but EAF slab-casting technologies also permitted substantial competition in this product market. The first firm to enter was *IPSCO*, a Canadian pipe producer. *IPSCO-Montpelier* (IA) was constructed with the objective of producing plate for IPSCO pipe mills as well as for the wider market. At this plant, the rolling of steel to final products is done in a Steckel Mill that allows the processing of thicker steel slabs and enhances a steel mill's flexibility in terms of product range. Although the technical constraints at IPSCO-Montpelier took several years to work out, IPSCO learned from the Montpelier experience and used a very similar but improved plant design to construct a new plate mill in Mobile AL, which began operations in 2001. Also in 2001, Nucor started up a new slab-cast plate mill in Hertford NC. These three successful plate mills (IPSCO-Montpelier, *IPSCO-Mobile*, and *Nucor-Hertford*) further eroded the market share of traditional integrated mills in flat products. Together, they have a total capacity of 3.5 million tons per year, which is equivalent to nearly 38 percent of the total domestic shipments of steel plate in 2003 (AISI 2003; p. 22, Table 8).[1]

3. Plant locations

Figure 1 shows the locations of slab-casting minimills in the United States, and distinguishes between mills specializing in steel sheet and mills specializing in steel plate. Focusing first on the sheet producers, we find that plants are located exclusively in the Midwest and South. Among these plants, we find a notable concentration in and around Indiana and Ohio, which along with Illinois and Michigan, are arguably the regional core of Midwest manufacturing. The four plants in this concentration are Nucor-Crawfordsville, Gallatin Steel, North Star BlueScope, and Steel Dynamics. They are located directly in a region where there are major concentrations of integrated steel producers who serve the markets for flat-products in automobiles, appliances, and other manufacturing industries.

[Figure 1 Here]

In addition to this concentration, three EAF sheet mills are located on a Southern band, extending from Nucor-Hickman (Arkansas) to Nucor-Decatur (Alabama) and on to Nucor-Berkeley (South Carolina). With this band, Nucor Corporation is positioned effectively to compete within a wide swath of Southern manufacturing industries.

[1] New EAF-based slab capacity actually is understated by our description of these ten plants. Two additional firms began making steel slabs based on EAF production capacity during the study period, but both were previously existing plants that had been purchasing and re-melting steel slabs. Tuscaloosa Steel (Tuscaloosa, AL), which was built in 1985, added steel making and casting capacity in 1996. This mill, which is now owned by Nucor Corp., has a current annual capability of producing about one million tons of steel plate per year, according to company reports. Beta Steel Corporation (Portage, IN) also began operations by purchasing and re-melting steel slabs. In 1997, Beta started its own melt shop and according to company reports now has a capability of producing 800 thousand tons per year of steel sheet. Neither plant was included in our study because their locations were established prior to the advent of EAF slab casting.

The locations of steel plate producers are clearly peripheral to traditional steel producing states such as Ohio, Pennsylvania, Illinois, and Indiana. Two of the plants, Nucor-Hertford (North Carolina) and IPSCO-Mobile (Alabama) are in coastal locations. The third plant, IPSCO-Montpelier (Iowa), which is located on the Mississippi River is just on the western edge of the Midwest manufacturing core.

By taking advantage of variation in the geography of these plants and their product and firm characteristics, explanation can be found in terms of variation among their associated industry clusters. We proceed by focusing first on the agglomeration literature, then on the key issue for these firms, market entry, to analyze the nature and scope of agglomeration economies.

4. Perspectives on Agglomeration

Agglomeration has a long and richly varied history in economics, geography, and regional science literature. While the concept dates back to Marshall (1890), it extends to the present in several threads. We follow Bekele and Jackson (2006) by grouping the theoretical approaches into 6 somewhat overlapping but identifiable categories, all of which form a foundation for the present research. The first two, classical agglomeration theory and flexible specialization, focus primarily on the process of agglomeration. Dynamic externalities, regional competitiveness, and regional innovation systems focus more directly on the relationship between agglomeration and regional economic performance. The new economic geography developed as a means of integrating a representation of agglomeration processes within a more comprehensive and formal model of regional growth and distribution of income and wealth. The following (necessarily) brief review of theoretical frameworks associated with agglomeration is by no means complete, but provides a frame of reference for our empirical results.

Classical agglomeration theory, which laid the bulk of the foundation for the variations to follow, emphasizes external economies of scale, particularly in the form of access to specialized labor pools, shared inputs, and technology spillovers (e.g., Marshall 1890, Weber 1929, Hoover 1937 and 1948, Ohlin 1933). These factors, combined with enhanced interaction among suppliers and buyers are the important determinants of economic activity concentrations. More recent classically oriented studies have focused more closely on localization *versus* urbanization economies, the former related to industry and linked industry concentrations, the latter to urban size, *per se*. Shefer (1973), Segal (1976), Moomaw (1981), Nakamura (1985), Tabuchi (1986), Henderson (1986), Moomaw (1983), and Ciconne and Hall (1996) provide varying degrees of evidence of positive impacts on productivity of both kinds of agglomeration. Classical agglomeration theory further highlighted the importance of interindustry linkages, which brought about a variety of key sector, industry cluster and industry complex studies, many in regional science and based on input-output data (e.g., Isard *et al.* 1959, Richter 1969, Streit 1969, Czamanski 1971, Campbell 1972 and 1975, Roepke *et al.* 1974, Latham 1976, Czmanski and Ablas 1979, Howe 1991, and more recently, Rey 2000 and Rey and Mattheis 2000).

The 1980s witnessed the early stages of a perceived shift in industrial structure from traditional mass production toward a more flexible specialization of industry organization. In addition to a focus on technological changes necessary to flexibility, this approach reflected an attempt to capture so-called untraded interdependencies, by embedding economic within social, cultural, and institutional structures (Brusco 1982, Piore and Sable 1984, Scott 1988 and Storper 1995 *inter alia*). This shifting emphasis launched a transition toward three strands of research emphasizing more strongly the regional socio-economic context of the process of agglomeration. Romer's (1986) work on endogenous growth, which followed from Marshall's (1890) argument and later formalization by Arrow (1962) focused on knowledge spillovers within industries, and led to a theory of dynamic externalities emphasizing the innovation, education, research and institutions, and launched further studies on the role of specialization vs. diversity and monopoly vs. competition in regional growth and development (see e.g., Lucas 1988, Glaeser *et al.* 1992, and Henderson *et al.* 1995). The regional competitiveness school championed by Porter (1990) identified industry clusters as a source of competitive advantage and promoted the identification and formation of clusters as a regional public policy objective. His extensive body of work identified industrial cooperation and rivalry, institutional partnerships, and regional resources and infrastructure as significant components of regional competitiveness, and hence, regional economic performance. Regional innovation systems formed a third theoretical approach focusing on agglomeration and regional growth. In this arena, the "new knowledge economy" and collective learning played central roles. Lundval (1992), Cooke and Morgan (1998), and Malmberg and Maskell (2002) support the exchange of tacit vs. codified information as key determinants of localized patterns of knowledge creation, sharing, learning and innovation.

The new economic geography developed in an attempt to integrate and synthesize the processes of agglomeration and growth within a comprehensive theoretical model to explain the centralization, decentralization, and variations in regional economy (e.g., Krugman 1991, Venables 1996, and Fujita and Thisse 2002). The new economic geography succeeds in establishing a consistent theoretical framework, including treatment of pecuniary externalities, agglomeration *dis*economies as well as economies, increasing returns to scale, and imperfect competition.

With the exception of classical agglomeration research and the new economic geography, which focuses on the behavior of entire regions, the vast majority of agglomeration and industry cluster research and indeed, subsequent policy recommendations and formation has placed high technology activities at the center. Implied, if not explicit in this research, is that the advantages of agglomeration and clustering will be weighted heavily if not exclusively on new high technology industry sectors. While expecting a stronger role for knowledge and information exchange in knowledge and information intensive industry is justifiable, our research reveals a variety of ways in which interindustry and interfirm ties and relationships play a critical role in the success and development of more traditional, heavy industry. We further demonstrate that the potential and role for agglomeration varies not simply among industries, but along sub-industry dimensions of product differentiation and market characteristics.

5. Methodology[2]

We conducted multi-day interviews at each of the new EAF slab casting plant locations between March 2003 and November 2004. A formal or informal expression of support for the project by a respected figure in the industry typically preceded each visit.

[2] This section parallels and draws upon a similar description in our companion paper, “Empirical evidence concerning the economic geography of market entry in the U.S. steel industry: Plant location and the advent of slab casting by U.S. steel minimills.”

In some cases, we had the advantage of individuals who had supported our research on earlier projects, but more often we relied on the head of a major steel industry association to help us identify plant managers and make appropriate introductions. One of our contacts was the multi-plant firm's Chief Operating Officer, who responded generously by committing the participation of the company's plant managers. We then used our site-specific contacts to help identify "co-located" facilities. In most cases, the manager of each steel mill then provided a list of all upstream and downstream firms that had established facilities in the immediate vicinity. We then made direct contact with selected co-located facilities and requested plant visits timed to our visit at the steel plant.

Plant interviews consisted of a structured series of open-ended questions. In all cases we requested and were granted permission to tape record the interviews at all of the study steel mills and at the vast majority of co-located facilities. The questions at the steel mills focused on technology, products, markets (industry and geographic), site-selection process, location factors, relations with co-located facilities, and policies related to human resource management. Questions posed at the co-located facilities were similarly structured, but with much greater emphasis on the nature and benefits of relationships with the minimill. Where appropriate, we used a variety of means to check on matters of fact or assertions of cause and effect. Follow-up telephone calls were used to clarify information received on the ground in some instances. On several occasions we also visited relevant local and regional economic development agencies.

Data analysis proceeded at three levels. First, we reviewed together notes that taken individually as soon as possible following interviews, and in this way brought perspective to bear on core topics from two disciplinary perspectives, economics and geography. Second, recordings from the interviews were transcribed and reviewed systematically based on the topic list, with particular attention to key factors bearing on inter-firm relationships and location decisions. We identified cross-cutting issues in this way, and new threads of analysis developed as the project proceeded. Finally, we met periodically to compare accumulated notes and draw generalizations.

Interview data were compiled from meetings with 68 persons from visits to ten steel plants and twenty-three related upstream and downstream facilities. We had access to every steel minimill plant manager and senior operating personnel, and in the vast majority of site visits, we toured the new steel mill with a highly informed guide. We channel all of this information through our personal experience, which includes site visits, here and abroad, to a wide range of steel production facilities dating back to the mid-1980s.

6. Agglomeration and Market Entry

The technological achievement of Nucor-Crawfordsville is well recognized: It proved that thin-slab casting with the CSP technology was feasible on a commercial scale. However, its achievement goes well beyond the successful implementation of the CSP technology. At start-up Nucor-Crawfordsville had to overcome substantial skepticism: about the feasibility of the technology and also about the quality of the steel that could be produced by that technology.

Inter-firm relationships between integrated steel producers using ore-based BOF technology and their customers in the markets for steel sheet are measured in decades. Inter-firm relationships between steel makers using scrap-based EAF technology and customers in the markets for steel sheet had to be built from scratch. To begin this process, the sheet steel from EAF mills had to be accepted by manufacturers who had relied exclusively on the steel sheet being produced by ore-based mills, and the prejudice was substantial.

Ferrous scrap, the primary metallic input in EAF mills, is sold in "grades" that vary by source, size, and shape. Each grade also is associated with characteristics related to the extent and kind of residual elements such as copper that are mixed with the scrap or integral to it. The size and shape of ferrous scrap can affect the efficiency of melting in a furnace. The extent and kind of residual elements can have significant consequences for the metallurgical attributes of scrap-based steel that translate into properties like strength and formability; they also can affect its surface quality.

At the start-up of Nucor-Crawfordsville, much of the attention by potential customers was focused on surface quality – in particular, residual cracking. The expectation was common that residual elements rising to the surface during the solidification process would render scrap-based steels unusable for a wide range of sheet products and most particularly for high value-added uses. Much of the learning that took place at Nucor-Crawfordsville had to do with the melting of ferrous scrap to cast steel sheet that would be accepted by such reluctant users.

Nucor-Crawfordsville's geographic location is in the heart of a region that is dense with steel using manufacturers. By focusing first on the production of standard grades of steel and working directly with customers over a wide range of existing industries, Nucor-Crawfordsville steadily built its customer base and overcame prejudice by direct experience with its products. The technology was proven, and the product was accepted.

The second Nucor sheet mill, Nucor-Hickman would set a standard for strategic market entry that exposes the critical role played by downstream processors.

Nucor-Hickman had a very limited *local* market as compared to Nucor-Crawfordsville. Located in the northeast corner of Arkansas, Nucor-Hickman has access via the Mississippi River to markets in the Southeast and Southwest (especially Texas) and north to the upper Midwest, but at plant start-up the local market for steel products was thin in comparison to Nucor-Crawfordsville. Recognizing this, the strategic development of Nucor-Hickman relied on building a local agglomeration that would facilitate market entry.

The consequences in terms of economic development are indicative of the success of the strategy for market entry pursued at Nucor-Hickman. At the time of its construction in 1992, the Nucor-Yamato bar mill was already established in a nearby location. However, there were few downstream customers for steel sheet in the immediate region. By 1997, Mississippi County, where the plant is located, experienced an increase of 1,551 in full and part-time employment in steel related industries, along with the addition of 365 jobs in the blast furnaces and steel mills industry.[3] This increase exceeds the total county employment change during the period, offsetting employment losses in other industries. From 1992-1997 the percentage of total county employment attributable to steel and steel related industries nearly doubled, from a 1992 value of 18.3% to 34.6% in 1997. Details are presented in Table 3.

[Table 3 Here]

Base load. The drive to achieve high levels of capacity utilization is one of the keys to understanding the forces of agglomeration in this context. A mill that is large relative

[3] Based on data reported in County Business Patterns (US Census, 1992 and 1997).

to the size of its immediate market will be highly motivated to lock in a certain "base load." A mill with annual capacity in the neighborhood of one million tons that is located in the heart of dense demand need not worry especially about capacity utilization over the long haul. A two-million ton mill located in an area of immediate sparse demand may place a premium on locking in certain minimum capacity utilization. It is more than merely the comfort of the sales force at stake. At the margin, a mill is in a stronger negotiating position on price if its annual capacity utilization is high. Nucor's *Vulcraft* Division, which produces joists and decking for the housing industry, provides such a base load for Nucor bar mills. However, Nucor's entry to the sheet market did not enjoy the benefit of a similar in-house corporate customer of this scale.

Planning to secure the base load at Nucor-Hickman began with the purchase of land. The plant is located on a tract of land in the neighborhood of 5,000 acres. It includes 27 miles of railroad track, and Nucor runs its own locomotives within that acreage. Land was sold to downstream customers, at cost, and Nucor would include a spur from its rail line to the customer. [4]

The nature of steel produced at the plant dictated the type of customer that would be attracted. Nucor-Hickman was built to produce hot-rolled coils or "hot band," and initially it lacked a cold mill for secondary rolling and processing. A cold mill was added five years after the start-up, but only after confidence was gained in the profitability of further investment. Cold-rolling, which uses hot-band as an input, greatly enhances the product range of steel sheet, and increases its value-added.

Two kinds of immediate downstream firms were important to Nucor-Hickman, and they represent the two largest intermediate users of hot band. The first firm recruited by

[4] Interview with Rick Campbell, Sales Manager, Nucor-Hickman, November 15, 2004.

Nucor-Hickman was *Huntco*, a processor that cut hot band to length or slit it to strips for steel-using manufacturers. Intermediaries like Huntco are important to all sheet producers. They have a sales force that taps a wide customer base by cutting and slitting hot band to the needs of particular end products, and their multi-establishment multi-locational structure can provide additional “eyes and ears to the market”. *Friedman Industries* is another steel processor recruited to the Nucor-Hickman campus. Both companies had established ties with downstream firms, and they knew where and how to find markets for hot band. Processors like Huntco and Friedman play a role in the market that goes beyond simple cutting and slitting of steel. In some cases, they can provide rapid feedback to a mill should quality issues arise. Moreover, they are commonly more willing than mills to hold inventories that facilitate just-in-time exchange, and they also may be able to aggregate small orders to provide for more efficient production for the steel mill and for steel users.

As early as 1994 (within two years of start-up), *Maverick Tube Corporation* also was recruited, and Maverick represents the other significant kind of intermediary, firms that use hot band to produce tubes for the oil and gas industries and for other manufacturers. Together, Huntco, Friedman, and Maverick helped Nucor-Hickman establish the base load that provides for efficient capacity utilization – a factor of particular importance for capital intensive manufacturers.

Diversification. The collective range of markets served by Huntco, Friedman, and Maverick helped to mitigate demand uncertainty for Nucor-Hickman. At the time they were recruited to the Nucor-Hickman campus, all of these firms processed hot band. Collectively they served a wide variety of product markets. One means of diversification is to recruit new processors for access to new markets; however, an aggressive firm also can encourage diversification by helping existing processors expand their business beyond traditional market boundaries.

Maverick was very much a commodity producer when it was recruited by Nucor-Hickman, in the sense that the products it produced with Nucor-Hickman hot band were undistinguished in the market. Not long after opening the on-campus plant, Maverick used its relationship with Nucor-Hickman to help change its market position, and it has since become a leading producer of tubular products for energy and industrial applications. Maverick did this by broadening its product range to compete directly with producers of seamless tube and this further diversified the markets for Nucor-Hickman's hot band.[5]

Seamless tube is made by piercing the center of the steel billets that are produced in traditional bar mills. At the time its relationship was established with Nucor-Hickman, Maverick produced a competing tubular product by shaping and welding steel sheet to make tubes with seams. Welded tube is much cheaper than seamless tube. However, substitution between the products is limited by the metallurgical properties of the steel, which can translate into attributes like the strength of the weld and the formability and strength of the steel. The closer the equivalency in such important dimensions, the more direct will be competition between the products. Nucor-Hickman and Maverick used their proximity to develop hot band that could meet this test. Over a 5-6 year period through repeated changes in steel chemistry and physical tests they developed grades of hot band to compete with seamless tube in a large number of end products – up to forty grades in all, covering a wide swath of the value-added range of tubular products.

[5] Interview with Rick Campbell, Sales Manager, Nucor-Hickman, November 15, 2004.

Maverick's presence in terms of tubular facilities in close proximity to Nucor-Hickman (on campus) grew to include six plants as a consequence of this collaboration.

Value-added. Maverick moved up the value-added chain by working with Nucor-Hickman to compete in new markets with hot band. For Nucor-Hickman, there was a second avenue for moving up the value-added chain, expanding into cold strip. In a cold mill, hot-rolled strip (hot band) is processed to reduce thickness and improve formability and surface characteristics, and this allows access to a very wide range of potential markets. In 1999, Nucor-Hickman added a cold mill and expanded its product range to include pickled and oiled sheet, cold rolled, and hot dipped galvanized steels to its product list. This decision came at some cost to Huntco, which by that time had already built a cold mill to process Nucor products. Indeed, Huntco subsequently entered bankruptcy and later liquidated its assets.

After building the cold mill, Nucor-Hickman sought to duplicate the success that it had achieved in market development for hot-rolled products by recruiting processors who specialized in its new product lines. The new plants attracted to the campus as Nucor-Hickman moved into cold mill products represent two of the largest service center chains in the United States. Together they extended the steel mill's range of product markets substantially and helped to secure Nucor-Hickman as one of the nation's leading EAF sheet mills. In turn, the steel industry agglomeration in Mississippi County, AR became one of the largest in the United States.

We found these elements – base load, product diversification, and drive toward higher value-added grades – to be common among EAF sheet producers, although their relative importance varies from plant-to-plant, as does their reliance on service centers in any one of these areas. The three mills that started operation in 1996 help to make this point: Nucor-Berkeley, Steel Dynamics, and North Star BlueScope. Once established, the resulting clusters also led to efficiencies in production and distribution that are characterized by well recognized agglomeration economies.

The Nucor-Berkeley plant is now widely credited as a standard-setting sheet mill, particularly in terms of product development. Like Nucor-Hickman, it followed a successful path from campus design to a rich cluster of co-located facilities. Like Nucor-Hickman, this development also was purposeful in that the Nucor-Berkeley campus was designed to accommodate co-located facilities. Once the land was in place and the basics of rail access and logistics with the plant were set, Nucor-Berkeley was attractive to downstream plants, and campus development was engaged. In all, the Nucor Industrial Park at this site now includes six downstream plants, including four of the nation's largest service center firms. Together, about one-quarter of the steel sheet produced by Nucor-Berkeley is processed through these co-located facilities, and they service a very wide range of industrial end-users, helping to assure the plant's base load and the diversity of end users.[6]

The attractiveness of mill sites to service centers goes well beyond the transportation cost savings associated with proximity to the mill. Service centers can and do advertise proximity as an attribute to potential customers. This can translate into direct advantage for simple "toll" processing, where the mill sells directly to the end user but contracts with the service center for value-added processing. However, proximity for the service center assures access to personnel at the mill as well as access to product. Access to personnel can help a service center be more responsive to demand in that the customer's

[6] Interview at Nucor-Berkeley on March 3, 2003.

metallurgical requirements can be easily discussed at the plant site. Moreover, co-location clearly enhances the potential for mutually beneficial relationships. Repeated interactions provide deep knowledge of individual personalities, skills, and responsibilities that help to establish the valuable sense of trust on which the success of these relationships often depends.

Access to product means that the service center can promise timely delivery to its customers, and this can be especially important in periods of steel shortage, as has been the case in some recent years. Whether proximity can translate to timely delivery also depends on a service center's ability to schedule its orders. At some steel plants, co-located service centers have access to order books and access to the people at the plant who keep those books. Finally, the efficiency of a steel processor depends critically on the order mix of the steel coils that are run through the plant. One plant manager made this point by describing as most critical the sale of time on equipment in order to maximize profit.[7] It is not simply the margin that matters in products. Processors prefer big coils that translate into high-yield runs in order to minimize set-up costs. To the extent that service centers can work with the mill to schedule orders efficiently in this way, both parties (the mill and the service center) can realize better utilization and less down-time.[8]

In terms of the drive toward higher value-added steel, Nucor-Berkeley has evolved into a plant with a large and effective sales force, and partly because of this product development now largely results from direct access between the plant and steel using manufactures. The role of service centers in product development, even in a mill of

[7] Interview at Nucor-Decatur on October 27, 2004.
[8] Interview at Nucor-Decatur on October 27, 2004.

Nucor-Berkeley's scale, may remain important, however. Often value-added development results when a sales staff member from a service center comes back to a mill with a specific steel part that is being made by an end-use manufacturer. The issue may be material substitution or it may be to determine the particular metallurgical properties necessary for part performance. In other instances, the service center may offer a mill broad access to higher value-added products by providing ways to improve material characteristics such as surface quality.

A case in point at Nucor-Berkeley involves its relationship with *Feralloy Corporation's* Charleston Division, which is on the Nucor-Berkeley campus. Steel mills have traditionally been reluctant to guarantee flatness tolerances on finished or unfinished sheet. In 2003, Feralloy installed a state-of-the art leveling system from *Butech, Inc*. (Salem, OH). The new hydraulically controlled cassette-style leveler is designed to process gauges ranging from 0.060" through 0.500" in widths through 72".[9] Feralloy has worked with Nucor engineers to generate a combination of leveling process and steel chemistry that allows the production of steel with "still water flatness" for delivery to the market, and this added to the already impressive record of the mill in terms of product development.

Steel Dynamics, Inc. (SDI) was the only EAF sheet producer to enter the market without the backing of a large corporate parent. The entrepreneurs who started this enterprise brought human capital from their start-up experience, as Nucor employees, at Nucor-Crawfordsville. The partners they approached with the prospect of taking equity positions in the new firm include the principal of a major ferrous scrap broker/processor, *OmniSource*, and the principal of a major steel service center, *Heidtman Steel*. The

[9] Metal Center News Online, May 2003. Interview with Mike Grimmer, Feralloy Corp May 11, 2005.

company they created, SDI, effectively re-establishes an “integrated” structure in the limited sense that one corporate entity can trace ownership links up and down its supply chain. Both upstream and downstream relationships were important to SDI’s market entry.

From SDI’s perspective the equity position taken by OmniSource helped assure access to ferrous scrap and timely delivery. In turn, OmniSource saw the relationship as an opportunity to secure a sufficiently large regional demand to justify investments in scrap processing equipment that would give it additional market advantage in terms of cost competitiveness and product range.[10]

SDI’s relationship with Heidtman Steel touches on all three key factors, base load, product diversification, and value-added product development. In terms of base load, Heidtman takes 30 – 35 percent of SDI sheet production.[11] The close working relationship with SDI allows Heidtman to promise inventory savings, reliable on-time delivery, and attention to its customers’ product needs. Heidtman’s long experience in serving customers for steel sheet gave SDI reach into established market relationships. Heidtman also recognized that it was beneficial for SDI to develop relationships with other processors, where there was little overlap with Heidtman’s market advantage. As a result, SDI’s market reach was extended substantially beyond the contacts it achieved through Heidtman. The product development side of the relationship was stressed by SDI in that the close working relationship with Heidtman allowed both parties to challenge their capabilities in terms of metallurgical properties and processing.[12]

[10] Interview with Mr. Daniel Rifkin, OminSource Corporation, August 6, 2003.
[11] Interview at Steel Dynamics on August 6, 2003.
[12] Interview at Steel Dynamics on August 6, 2003.

North Star BlueScope (NS Bluescope) is the third successful start-up that helps to reveal the basis for clustering activity. This joint venture between *North Star Steel Company*, a division of *Cargill Steel*, and *BlueScope Steel* uses a technology that competes with the original CSP process that has been used in Nucor sheet mills and SDI. By casting “medium” slabs (as compared to the CSP thin-slabs) this plant is able to reach improved surface quality as a result of greater reduction in its rolling mill.

For NS BlueScope, the base load is processed through *Worthington Steel*, a co-located facility with whom NS BlueScope established a long-term supply agreement. Worthington accesses a very wide, long established customer base for flat-rolled steel. Worthington advertises that it services 1200 customers in this market. Worthington takes up to one-third of the steel plant’s output, and in exchange for this steady demand Worthington enjoys a volume discount off market price.[13] Other, smaller processors also are co-located with the plant, but by agreement with Worthington the other processors are not in competing product lines.

The relationship between Worthington and NS BlueScope has been especially important in terms of product development. Working to specifications encouraged by Worthington, NS BlueScope developed steels of particular strength and formability suitable for floor joist and other building applications as well as automotive applications.[14] This gave Worthington the ability to service new needs for established customers and at the same time it broadened the product and value-added range enjoyed by NS BlueScope.

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[13] Interview at NS BlueScope on March 8, 2004.
[14] Interview at NS BlueScope on March 8, 2004.

While base load, product diversification, and the drive toward higher value-added grades are common elements among all EAF producers, the influence of these factors on agglomerations differs between sheet and plate producers. These differences can be attributed to product characteristics, to the steel plate market, and to corporate strategy.

As with steel sheet, there are multiple grades of steel plate. However, a much greater proportion of steel plate can be characterized broadly as commodity rather than value-added product. Because of the smaller set of potential uses for steel plate and the narrower range of processes into which it enters, there is less need for highly engineered, high value-added steel plate.

The market for plate, at around nine to eleven million tons, is roughly one fifth as large as the sheet steel market and geographically is more dispersed and dynamic than the market for sheet. Major geographical concentrations of steel sheet users exert strong locational pull on sheet producers, and hence influence their location decisions. The absence of such concentrations of plate users means that for these producers there is much less market pull on the location decision. A larger portion of steel plate is shipped greater distances than steel sheet. The Nucor-Hertford plate mill, for example, reaches a broad geographical market and identifies its three biggest states as Illinois, Texas, and Pennsylvania.[15] Likewise, an estimated 80% of IPSCO-Mobile steel plate serves a region that extends south and east from Memphis, Atlanta, and Savannah to Mexico with 20% extending beyond this “natural” market.[16]

The dominance of commodity plate coupled with the geographically dispersed market diminishes the need for and value of co-location, which leads to smaller agglomeration

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[15] Interview with Giff Daughtridge August 12, 2004.
[16] Interview with Lester Bridges May 12, 2004. This estimate excludes intra-company product.

effects associated with plate producing steel mills. Whereas sheet producers and co-located steel users can benefit significantly from product development and feedback opportunities, producers of commodity steel engineered to relatively standard specifications have much less need for such interactions. As a result, fewer downstream linkages tend to develop in the immediate area. Rather, the plate mills tend to reach their markets by selling to distributors in dispersed locations.[17]

The importance of access to transportation infrastructure over market pull is underscored by the geographical dynamism of a substantial portion of the plate market. For example, when a mill makes plate for buildings and infrastructure, the steel often will be delivered to the construction location. Also, location of pipe plants is only loosely tied to geography since it is less expensive to transport the plate than the pipe and the location of final demand depends on where the pipe will be installed. Once the pipeline is in place, the next major market site might well be hundreds of miles distant. No single location would be central to such a market.

Corporate strategy can influence the nature of steel plate centered agglomerations. Two examples here include supply chain strategy and pricing strategy. IPSCO provides an example of the former in that its strategy has been not only to examine existing markets for steel but to build their own steel-using production facilities in an area *prior* to putting a steel mill into production. These steel-using facilities were using purchased steel from other mills when they first began production but following mill construction, switched partially to IPSCO steel.[18] In this way, IPSCO-Montpelier effectively

[17] This is sometimes facilitated by developing close relationships with remote service centers, in effect establishing agglomerations once removed (geographically) from the steel mill location.
[18] Interview at IPSCO-Montpelier on June 24, 2004.

established and ensured its base load, providing greater stability to a dynamic market context.

The influence of pricing practices on agglomeration is somewhat more subtle. Service centers that provide value added processing to plate can often find themselves in either direct or indirect competition with the mill itself. A mill selling plate on a delivered price basis can discourage service center co-location in two ways. First, one of the general advantages of co-location is immediately removed – that of reduced transportation costs on material inputs. The service center might well argue that it should not have to pay the same price for plate as customers at more distant locations. Secondly, by co-locating with a mill using a delivered price strategy, the service center may not be able to compete with service centers located in and serving more distant locations.

7. Agglomeration and regional economic development

When one thinks about great steel agglomerations associated with traditional integrated mills, regions like Pittsburgh, PA; Gary, IN; and the Ruhr Valley in Germany spring to mind. Such agglomerations are (or were) massive in terms of the size of individual mills and in terms of the number of competing steel producers that are drawn to a particular place by the coincidence of location factors. Rarely do agglomerations associated with steel minimills follow this pattern. Instead, their size is normally limited by the scale of a single steel mill, two sister mills from a given company, or a similarly small number of mills from competing companies that produce complementary product lines.

The limited size of minimill agglomerations has implications for the symmetry of co-located facilities in terms of downstream and upstream operations. Minimill agglomerations are free from the limitations of large scale upstream investments in the coke plants, sinter plants, and blast furnaces necessary to process coke and iron in integrated steel works. The great integrated agglomerations are hosts to extensive networks of firms that sell goods, services, and equipment to the major steel mills. The scale of the local market as represented by the integrated steel mills justifies great variety and depth in terms of upstream suppliers. Minimill agglomerations are not characterized by depth and variety of upstream operations in the same way.

For minimills, agglomeration economies related to upstream linkages often are represented by oxygen production, ferrous scrap processing, and slag processing activities. Mill services such as maintenance, transportation, and materials handling also may be involved, sometimes on-site on a contract basis.

Industrial gas firms typically locate oxygen production facilities near mill sites. The production process yields not only oxygen for the EAF furnaces but also other gases such as nitrogen. At Nucor-Berkeley, for example, the oxygen facility is a source of industrial gases that are delivered directly by pipeline to other local facilities. Scrap suppliers often co-locate facilities for sorting and sizing ferrous scrap. This provides a local market for the scrap resulting as a byproduct in regional metal fabricating plants. This source of scrap, known as *prompt scrap,* is especially valuable in slab mills because it contains fewer residuals and is more uniform than scrap recovered from obsolete products. Parts stamping plants are important source of prompt scrap, and we were told of initiatives at several mills designed to attract such plants.

Slag is a waste product from the EAF furnaces and minimills typically contract with slag processing firms to process their slag and find markets for it. A co-located slag processor will reclaim ferrous metal contained in the slag and return it to the mill before selling the slag for aggregate in concrete or other uses. Agglomeration economies are achieved by both co-located scrap processors and slag processors by facilitating low transfer costs for the recycling of ferrous metal to the mill.

Upstream operations can be important as an agglomeration factor in particular circumstances (witness the equity structure of SDI, for example), but the character of industry agglomeration for minimills and the potential of such agglomeration in terms of regional economic development depend decidedly on downstream linkages. Whether or not the downstream linkages of a particular minimill translate into rich regional agglomeration, however, will depend on the particular characteristics of the mill and generalization about economic impacts must be conditioned accordingly.

Irrespective of other plant characteristics, the success of a mill's start-up can have long-lasting implications in terms of agglomeration and regional development. A successful start-up can mean operating near capacity limits within 12-18 months of plant construction, with attendant success in terms of product quality. A failed start-up may mean many months of interrupted operations with sub-periods of complete shut down, low product yields, and poor product quality. Of course, the profitability of a steel mill turns on such factors, but start-up problems at a mill also may translate into failure for downstream operations. Steel processors and service centers or major OEM's are dependent on steel mills for timely supply of quality product. When confidence and profitability are shaken by a poor start-up, existing downstream firms may withdraw from the local market and new downstream firms will be reluctant to enter, until confidence is re-established --- a process that may take years and ownership changes to be resolved.

Given the success of plant start-up, the development of agglomerations depends keenly on product and firm characteristics. The relatively concentrated nature of markets for steel sheet as compared to plate means greater potential strength of linkages between sheet producers and downstream firms, as a general rule. As we have explained, EAF slab producers who entered the markets for steel sheet did not have established relationships with sheet-using OEM's – the kind of relationships already enjoyed by their integrated steel competitors. Building those relationships, directly or indirectly, was one of the keys to success for new EAF sheet mills. However, the ways in which such relationships were built varied significantly from plant to plant, and indeed, the importance attached to using downstream processors as a lever for market entry varied by firm and plant.

Regional economic development is shaped in this context. The corporate strategy of a particular firm may focus the attention of a plant on supply to sister mills within the firm. Given the hierarchical nature of the firm, more or less autonomy may be given to individual plants in terms of establishing strategies for market entry. When the new plant must seek local demand for its base load and when the plant is dependent on downstream firms for expanding the breadth and value-added range of its product line, autonomy in decision making can mean great growth in the supporting regional economy. When firm strategy limits external linkages for a plant, the potential for regional development can be more measured. In effect, the nature of the firms, as institutions, helps to determine the nature of economic geography.

Steel Dynamics, Inc. (SDI) is unique among the plants included in this study in that its sheet mill was established as the company's first facility, and it was not part of a larger corporate entity. SDI was created as a stand-alone steelmaker to take advantage of new technology, and it succeeded in doing so. There were no deep corporate pockets to draw upon; SDI succeeded based on the embodied technical and commercial know-how of its principals. Its livelihood depended in part on inter-firm linkages, and this helped to determine its potential as an engine of regional development.

To fully appreciate the characteristics of all other EAF slab producers, the plants must be analyzed within their respective corporate structures. At the time of their construction, North Star BHP, Gallatin Steel, and Trico (now Nucor-Decatur) were parts of much larger corporate entities, and they also were the only EAF slab mills owned by their parent companies. IPSCO-Montpelier and IPSCO-Mobile, which are plate mills, were created by a parent company that also is a major buyer of steel plate. The company that started this revolution in steel making, Nucor Corporation, accounts for five of the ten mills included in this study. The actions and decisions taken by all of these mills have been shaped by their respective firm structure.

By way of example, the influence of firm structure on the economic geography of EAF slab producers can be exposed by differences in the relationships among these plants and related upstream and downstream faculties. Again, SDI is clearest example of such influence. Its principals are drawn from industries with established upstream and downstream activities. In effect, SDI's ownership structure helped to determine its strategy for market entry and the role of industry agglomeration in that strategy. The net result is a commitment to partnerships (formal and informal) as vehicle for market penetration and product development.

As noted earlier, the IPSCO plants have taken a very different path to success with very different consequences for upstream and downstream relationships. The IPSCO plate mills are guided by a clear firm policy of "running steel short." By this they mean that the company's demand for steel by its downstream pipe manufacturing operations and company owned processing centers exceeds the supply of steel from IPSCO plate mills. As a result, when steel markets are slack, IPSCO plate mills can run a good rate of capacity utilization by supplying the company's internal demand. When steel markets are tight, IPSCO plate mills can give preference to their sister pipe mills. IPSCO plate mills also rely greatly on IPSCO processors for market information and product development.

Both company policies, running steel short and working closely with its own downstream processors for market information and product development are important in understanding the way that IPSCO-Montpelier and IPSCO-Mobile develop and maintain relationships with the non-IPSCO downstream facilities related to their plants. Their strategy for market entry did not have local steel processors and service centers as a linchpin. This is not to say that either plant fails to benefit from agglomeration; they do benefit. The role of agglomeration economies in supporting downstream operations of other firms is more limited for these mills than is for some other EAF slab producers.[19]

While the SDI and IPSCO examples are clear reflections of the way that firm policy can impact cluster activity around a mill, the influence of Nucor corporate policy on cluster activity at the plant level is not cleanly defined at all. The principles upon which Nucor has grown include a serious commitment to decentralized decision making. While

[19] Interview at IPSCO-Montpelier on June 24, 2004.

it was even more evident before the company's expansion in the late 1990's, employees still speak of the relationship between plants and the corporate office as akin to the "United States of Nucor."[20] With this attitude, one should expect to find diversity among the plants, and one does. But one also finds clear evidence of best practices traveling from plant to plant. Thus, the success realized by Nucor's substantial steel agglomeration in Arkansas has served as a model for plants to follow, but this was not as a matter of firm policy. Instead, managers who were given the responsibility for new plant start-ups adopted practices that seem to work well elsewhere. For example, Nucor-Hickman became a model for Nucor-Berkeley in terms of campus design and strategic market entry via downstream operations.

In essence, it is important to think about the building of inter-firm relationships within an agglomeration as an investment, and corporate policy can affect the ability and incentive of individual plants to make such investments. As a case in point, a firm may define the very concept of a "good customer" from the corporate perspective, but the concept of a good customer might look very different from the perspective of an individual plant. The product range of a plant will be limited by the plant's technology, whereas the product range for the firm is limited by the number of plants owned by the firm. Because of this, firms can restrict special pricing or service agreements to downstream customers that serve the *firm's* best interest, rather than the best interests of a particular plant. When this happens, the incentive for plant managers to invest in building personal relations with co-located facilities will be diminished.

Firm policy also may extend to information sharing related to production practices and market intelligence, both of which go to the heart of agglomeration economies. If

[20] Interview at Nucor Crawfordsville on July 7, 2003.

plants within a firm share best practices in a formal way, the incentive may diminish for individual plants to build relations with co-located firms precisely because some of the gains to such investment can be achieved via intra-firm relations. Similarly, if corporate policy extends to gathering market information in a strategic way, the value to a plant of downstream firms in an agglomeration as a source of such information may be lessened.

The unique character of agglomeration tendency in each of these three examples (SDI, IPSCO, and Nucor) reinforces the importance of investing in an understanding of product, plant, and firm as basis for explaining agglomeration patterns in this industry. Generalization based on theory is certainly possible and necessary for understanding, but one misses key aspects of explanation unless there is reference to the institutions within which theories translate into reality.

The physical infrastructure built at mill sites support other steel related activities, and this helps to establish the basis for regional development. Industrial parks with zoning, utilities, and transportation access to accommodate the new mill are important examples. Typically site preparation resulted in extensions of water and sewage lines as well as water treatment and high capacity power lines. Transportation access to interstate, rail, and, in most cases, barge docks was provided.

For example, to make the site for the SDI plant viable it was necessary to extend the high voltage electricity transmission line 16 miles, a process which required the agreement of 120 different property owners to provide the required easements.[21] However, now that the right-of-way and transmission lines have been established, economies exist for other electricity users. At the North Star BlueScope site a new interchange and toll booth were installed on the Ohio turnpike and local exemptions to

[21] Interview with Jack Bercaw, Butler County Economic Development Commission, on August 7, 2003.

Ohio weight limit laws were instituted so trucks from Michigan, which has a higher weight limit, could be accommodated. This new transportation access provides transfer economies for the service centers located near the North Star BlueScope site not only for steel obtained from the co-located mill but also for steel brought in from other mills to be processed.

Many facilities that locate near minimills do only some proportion of their business with the mill. Firms that provide trucking or equipment maintenance services draw business in addition to the services provided to the mill. Steel processors with equipment to slit, cut-to-length, flatten, temper, pickle, or galvanize typically process significant tonnages of steel not locally sourced. This is not only based on strategic competitive considerations but also on the necessity of maintaining high rates of capacity utilization for lower average cost. Furthermore, service centers often have customers who require steel which the local mill cannot produce, e.g., unavailable width or gage or stainless. Regardless of the specific reason for partially sourcing non-local steel the impact is the same—tonnage of steel processed will exceed that sourced locally. Hence, many linked industries will stimulate further agglomeration economies.

8. Conclusion

This paper draws on the experience of ten steel minimills that began operations from 1989-2001 in order to take advantage of new technologies that allowed scrap-based steel producers to compete in the markets for steel sheet and steel plate. We find that the character and extent of industry agglomeration related to market entry by these plants is explained by particular product and firm characteristics. In general, proximate downstream processors and service centers can be especially important in facilitating market entry because of the role that they can play in securing a steel mills base load, diversifying its product line, and supporting its drive to market higher value-added products. The significance of such relationships, however, may be limited by the success of a plant's start-up. Firm structure and firm policies also greatly affect the extent and kind of relationships that develop with downstream facilities. While new mills can be expected to have important regional economic impacts, inter-industry linkages will differ substantially between producers of steel plate and producers of steel sheet. Firm polices related to inter-firm sales, product development, and plant autonomy can be critical determinants of a steel mill's potential in terms of regional economic development.

We further confirm that the success and development of a more traditional, heavy industry such as steel processing can be shaped in important ways by clustering and agglomeration economies. This finding will be both encouraging and useful to regional policymakers evaluating and implementing cluster policies in regions that lack the physical and social capital to compete effectively for high technology economic development.

Table 1: Steel making capacity by furnace type and by type of plant, 1982 and 2002 (millions of tons)

	1982		2002	
	B.O.F.	E.A.F.	B.O.F.	E.A.F.
Integrated plants	95.9	13.6	56.6	0.5
Minimills	0.0	34.1	0.0	59.1
Total	95.9	47.7	56.6	59.6

Source: Center for Industry Studies (2003). *Steel Plant Database.* Pittsburgh, PA: University of Pittsburgh. http://www.IndustryStudies.pitt.edu/database.html.

Table 2: A summary of thin and intermediate-slab EAF steel producers in the United States

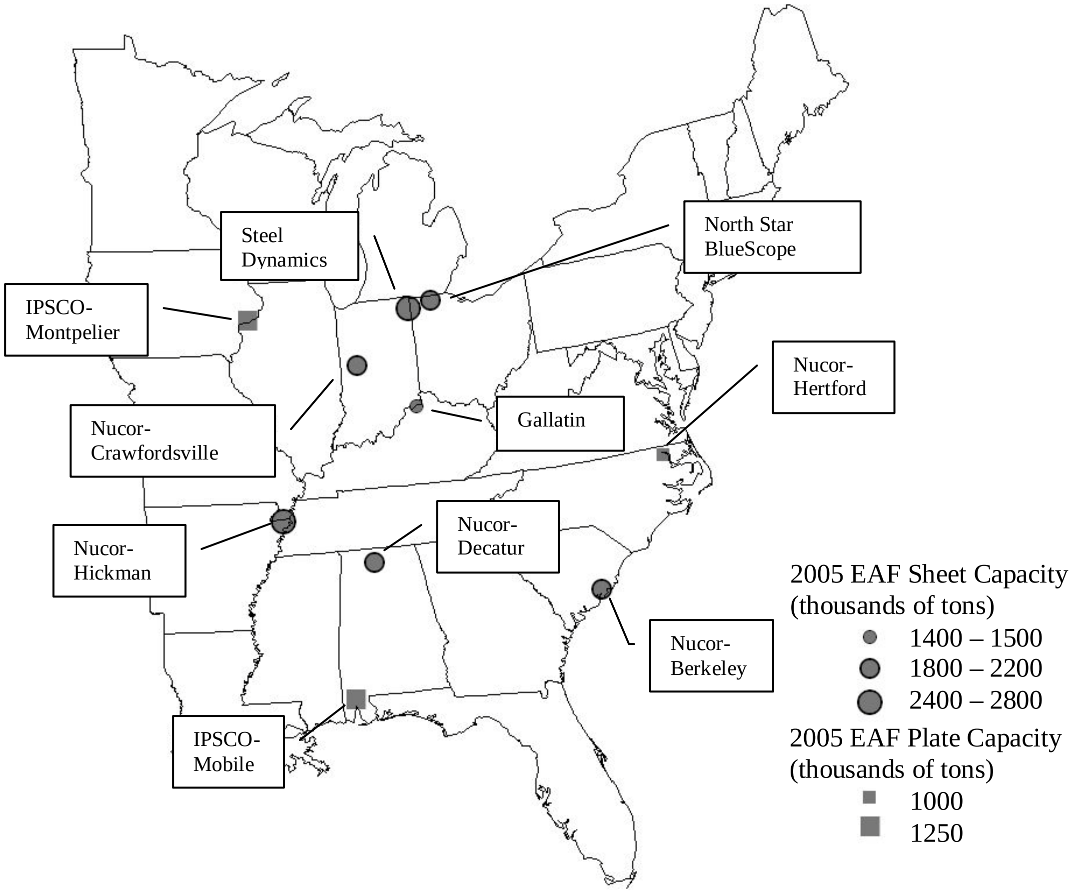
	Plant	State	Start Year	2005 Capacity (000 tons)
Sheet producers				
Nucor	Crawfordsville	IN	1989	2000
Nucor	Hickman	AR	1992	2400
Gallatin	Ghent	KY	1995	1400
Nucor	Berkeley	SC	1996	1800
North Star BlueScope	Delta	OH	1996	1800
Steel Dynamics	Butler	IN	1996	2800
Nucor	Decatur (Trico)	AL	1997	2200
Plate producers				
IPSCO	Montpelier	IA	1997	1250
IPSCO	Mobile	AL	2001	1250
Nucor	Hertford	NC	2001	1000

Source: Company reports and Center for Industry Studies (2003). *Steel Plant Database.* Pittsburgh, PA: University of Pittsburgh. http://www.IndustryStudies.pitt.edu/database.html.

Table 3: Steel and Steel Related Employment, Mississippi County, AR

	SIC	1992	1997	Change (1992 to 1997)
Blast Furnaces and Steel Mills	3312	756	1,121	365
Steel Pipe and Tubes	3317	0	547	547
Fabricated Structural Metal	3441	0	107	107
Special Dies and Tools and Accessories	3544	8	684	676
Motor Vehicle Parts and Accessories	3714	687	908	221
SubTotals	NA	1,451	3,367	1,916
Total County Employment (TCE)	All	7,931	9,745	1,814
Steel and Steel Related Percentages of TCE	NA	18.3%	34.6%	105.6%

Figure 1: The geographic location of slab-casting steel minimills in the United States



Source: Company reports and the *Steel Plant Database*, Center for Industry Studies, Department of Economics, University of Pittsburgh, Pittsburgh, PA.

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