Governing Capitalist Economies

Performance and Control of Economic Sectors

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CHAPTER 5

Industry as a Form of Order

A Comparison of the Historical Development of the Machine Tool Industries in the United States and Germany

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This chapter compares the historical development of the machine tool industries in the United States and Germany. Its focus is on the self-regulatory arrangements that these industries constructed and how these arrangements influenced their strategies of adjustment, repeatedly, over time. The machine tool industries in Germany and the United States make an interesting case because, with the exception of the current period, both industries performed extremely well throughout the twentieth century, yet both have been organized in radically different ways and have followed different developmental trajectories. In the U.S. industry, all aspects of production are incorporated within the institutional framework of independent firms in and among whom the mechanisms of authority and price are chiefly used to govern. In Germany, production is governed by a complex network of public and private institutions (including firms) in which mechanisms of price, authority, and trust interact in complex, yet highly flexible, ways.

The chapter will argue that these various governance mechanisms in production are the consequence of the existence of different forms of industrial order in these countries. An industrial order is the peculiar social, political, and legal framework constructed over the course of the industrialization process that shapes the way that producers serving given product markets collectively define the legitimate boundaries of industrial practice. Such frameworks exclude certain types of behavior, make others possible, and establish procedures for dispute resolution within a community of transacting parties. An industrial order is thus not a governance mechanism, such as a market or a hierarchy; it is the politically and socially constructed framework that creates the conditions under which particular repertoires of governance mechanisms emerge and are employed. In this respect, industrial orders have more in common with modern political constitutions than with particular governance mechanisms (see Holmes, 1988; Ackerman, 1988; Hardin, 1989).

The argument begins with a brief theoretical discussion of the notion of industrial order. The two following sections then develop the notion of industrial order through a comparison of the two machine tool industries: The U.S. case will be presented first, the German second. Finally, a conclusion will discuss the implications that the notion of industrial order has for our understanding of the current predicament of the U.S. machine tool industry.

Industrial Order

The argument about industrial order made in the comparative cases below attempts to address a dimension of the boundary between the economy and society that has been exposed by, yet left unexamined in, current sociological critiques of neoclassical theories of governance mechanisms and the firm. The basic divide in the current debate between neoclassical economists and economic sociologists on the theory of the firm is that the latter view individual economic transactions as contingent upon and defined within larger social contexts, whereas the former do not. Neoclassical economists (e.g., Williamson, 1985; Jensen and Meckling, 1976; Grossman and Hart, 1986) focus on individual transactions among self-interested maximizers and view various governance mechanisms as mutually exclusive (uniquely efficient) alternative solutions to the problems of uncertainty and risk posed by discrete choice situations. Inefficient solutions are inevitably revealed to be so, at least in the long run. Contingency and structuralist sociologists (e.g., Stinchcombe, 1985; Bradach and Eccles, 1989) maintain with considerable legitimacy that this orientation assumes away precisely what is most significant in shaping economic exchanges, that is, the way in which noneconomic relations and transactions shape economic ones.

Eccles and White (1988), for example, show that, owing to the power and role calculations of individual managers, multidivisional corporations often use the market as a mechanism of control when neoclassical theory would predict they would use hierarchy, and vice versa. The economists go wrong, Eccles and White argue, because they take the boundary between the economy and society completely for granted. For Eccles and White, the contours of this boundary are crucial: Individual agents in industry, as well as their interests and evaluations of risk and uncertainty, are literally defined by the social contexts of power and value in which they are embedded.

Sociological theories of the firm have gone some way in applying these insights to a theory of governance mechanisms. Rather than as mutually exclusive, most efficient options, ranging on a continuum between market and hierarchy, the sociologists view the governance mechanisms employed by "embedded" agents as institutional techniques for achieving control or avoiding risk. Such techniques, moreover, can be deployed in diverse, often overlapping ways. Indeed, according to Stinchcombe (1985) and Bradach and Eccles (1989) governance mechanisms are deployed both in ways that complement one another (e.g., combining franchising and vertical integration) and in ways that can make one a substitute for another (e.g., hierarchical contracts in large-scale,

deep-sea oil drilling projects). Which mechanisms are deployed in a particular situation and in what ways, they argue, depend upon the context and strategies of the transacting parties within it—what Bradach and Eccles refer to as the "broader architecture of control mechanisms" (1989:115).

Given the explanatory importance attributed to it, it is ironic that the sociologists have not yet addressed systematically the problem of how context or "architecture" is structured or how such structures may vary. Bradach and Eccles recognize the problem, but have no solution for it. They end their illuminating essay by pointing out that explanations for "when and why different mixtures of control mechanisms occur" still need to be developed (1989:116). The notion of industrial order as developed here is an attempt to get at the relationship between particular repertoires of control or governance mechanisms and the background architecture of social and political relations that make them possible.

The argument is that industries exist within specific frameworks of order that emerge historically and are partially created by the members of the industry themselves and partially established for them by historical currents at other levels of society. These frameworks are not identical to the boundaries of a firm or group of firms. Rather, they are ground rules for acceptable practice, created in the turbulent organizational and strategic ambiguity of the formation of an industry, which give rise to particular kinds of firms with a specific array of available governance mechanisms. In this view, industrial orders have a relationship to the agents within them that is analogous in some generic respects to the relation between a modern liberal constitution and its citizens. In particular, I believe there are three characteristics that constitutions and frameworks of industrial order share in common: exclusionary rules, dispute adjudication procedures, and identity creation.

First, like modern constitutions, industrial orders involve rules that prevent or bind members of the industry from engaging in specific practices. These exclusionary rules, however, encourage and in many ways even enable participants to act in other ways considered to be more desirable by the collectivity.[1] Thus as we shall see, in the U.S. machine tool industry, rules against collusion inhibited cooperation and encouraged the stabilization of competition through merger. In Germany, rules against broad technological diversification blocked merger as a strategy and encouraged cooperation as a stabilization measure.

Second, frameworks of order in industry, very much in the manner of constitutions (Hardin, 1989:113–15), establish general procedural guidelines (and institutions) for the adjudication of disputes among members. The norm councils in the German machine tool association in which members coordinate their specialization strategies is an example of institutionalized dispute adjudication. In the United States, dispute adjudication followed the rules of the market: It occurred through merger and was guided by the principles of survival of the fittest.

Finally, I want to suggest further, as some constitutional theorists do about constitutions (e.g., Ackerman, 1988), that the emergence of a framework of order in industry not only crystallizes the strategies of actors but it also either

constitutes or validates general kinds of shared beliefs about the character and boundaries of the industrial community.[2] Industrial orders are generally the outcome of political and social conflicts among competing conceptions of industry and its relationship to society. Once established, industrial orders represent the institutionalization of such a view: People think about firms and their relationship to society differently within different forms of industrial order. This is important because crisis in an industry can provoke actors to engage in difficult reexamination of the boundaries between their own community and the rest of society.

Thinking of an industrial order as analogous to a modern constitution is helpful in characterizing the kind of role that I claim an industrial order plays in an industry. In the manner of a constitution it establishes a framework of order within which, among other things, particular repertoires of governance mechanisms emerge. Yet there are, to be sure, several limitations on the usefulness of the constitutional analogy that should be mentioned to avoid confusion.

First, unlike constitutions, the principles of industrial order are not typically written down, at least not in one place. They exist more as ways of collectively conceptualizing an industry and of institutionalizing acceptable practice within one. They must be discovered, therefore, through careful historical and ethnographic reconstruction. Second, such frameworks do not come into existence in one grand deliberative act, such as a constitutional convention. They are constructed piecemeal over time through an evolving dialogue and struggle over the way that acceptable practice in the industry should be defined. Finally, the boundaries of an industrial order are less sovereign than those of a polity framed by a constitution. Industrial order is often interpenetrated with principles of order outlined within actual constitutions as well as the rules that define and govern practice within the broader social communities in which industries are embedded.

All of these things make frameworks of industrial order more difficult than constitutions to identify and circumscribe precisely. The existence of an industrial order can nevertheless always be verified, I suggest, in two ways. One is to view the way in which two groups of producers making the same types of products in different places react to the same technological and international market pressures. If both successfully respond to the challenge, yet their reactions substantially differ, as did, we shall see, the mid-twentieth-century U.S. and German machine tool industries to the rise of large-scale mass production, then it strengthens the claim that the frameworks of order in each industry were different. Particular strategies of adjustment appeared obvious to those in one context of order that were made virtually unthinkable in the other—and vice versa.

The second way to identify the existence of industrial order is to identify rules that exclude certain governance mechanisms from the repertoire available to a community. The continued salience of those rules in situations where their absence could reasonably be considered to enhance the performance of the industry is a good indication of the existence of an industrial order. The current

experience of the U.S. machine tool industry, which eschews both cooperation and participation in trust relations in a competitive environment that has shown these practices to be highly successful elsewhere, provides a test for the existence of industrial order. The current experience of the U.S. industry, as the conclusion to this chapter makes plain, also points to the kinds of issues involved in redefining industrial order. For the U.S. industry to adjust successfully in the current environment, it must recast the principles of industrial order that define it in a way that makes currently unavailable forms of governance possible to deploy. To do this, however, following the argument above, it will be necessary for industry members to reflect on their shared assumptions about what firms are and on the boundaries of their own community.

The U.S. and German Machine Tool Industries in the Twentieth Century

In the presentation of the machine tool case, the experience of the U.S. industry will be followed by the German. Each of the historical accounts of industrial development will have parallel structures. The industries will pass through three periods of change: an initial period of industry and industrial order creation in the late nineteenth and early twentieth centuries, and then two periods of adjustment within the twentieth century.

Industrial Order in the U.S. Machine Tool Industry

The production of machine tools in the United States has a very long and proud tradition. During the early nineteenth century, there was no independent machine tool industry, as such. Machine tools were constructed by firms engaged in industries that used them, such as weapons producers, textile mills, and locomotive works. Nevertheless, it was during this time that the most distinctively American innovation in machine tool technology took place. With government support, machinists working in armories developed the technological capacity to machine parts that resembled one another so exactly that they could be used interchangeably (Smith, 1977; Hounshell, 1984). The capacity to machine interchangeable parts was an essential technological precondition for the development of high-volume or "mass" production. Such machines were highly productive when used in the manufacture of standardized parts and were also labor-saving.

Although there is some disagreement concerning the precise time, the emergence of companies devoted exclusively to the production of machine tools occurred in the last two decades of the nineteenth century (Robertson, 1966; McDougall, 1966). The emergence of the industry in its modern form is completely bound up with the rise of the modern corporation and the related development of mass-producing industries: sewing machinery manufacturers, bicycle makers, office machinery producers, farm equipment and construction machinery makers, and, especially after the turn of the century, automobile producers (Chandler, 1977). Regional clusters of machine tool producers grew up in and around clusters of these industries in northern Illinois and southern

Wisconsin, Detroit, Cincinnati, Cleveland, while the former nineteenth-century centers of general machine tool production in the Connecticut River valley, Providence, Rhode Island, and Philadelphia fell into relative decline (Wagoner, 1968, chapter 3).

There is much debate about this transformation of the U.S. political economy, but recent evidence clearly indicates that the triumph of the corporation and mass production was in no way economically or technologically inevitable. On the contrary, the mass-producing corporation was the victor in a broadly political contest with an alternative, more regionalist, small producer, and republican vision for the emergent industrial society of late nineteenth-century America (e.g., Berk, 1987; Hattam, 1990; Livingston, 1986; Sklar, 1988). Only when a legal and institutional framework conducive to its development was established was the victory of modern corporate capitalism assured. Formation of the modern machine tool industry was at once shaped by the construction of this framework and was a microcosm of the types of conflicts that constructed it. Three significant aspects of this framework were expressed in the industrial order of the machine tool industry: exclusionary rules favorable to volume producers, procedures for dispute resolution based on market power, and a shared understanding that industry was a term of art for a grouping of sovereign hierarchically centralized firms.

Imposition of Exclusionary Rules

In the context of this general transformation of the American political economy, two different strategies for organizing production competed with one another to define order in the machine tool industry. On the one side were those machine tool producers who attempted to follow the strategy of their mass-producing customers, that is, to focus on the production of a narrow range of standard products that could be produced in volume (Buxbaum, 1920; Wagoner, 1968; Brown, 1957). Such standardized American machine tools were generally semi-dedicated: Although they were not single-purpose machines, they had a limited range of flexibility. Rather than build broad machining capacity into a single machine, these producers tended to make separate machines. The simple machines made up for what they lost in complexity and flexibility with labor savings, precision, and high-volume efficiency (Rosenberg, 1972; Woodbury, 1972). On the other side were craft production-based producers following a strategy of broadly diversified production with an emphasis on customization (Wagoner, 1968, chapters 2, 4). Such producers attempted to cover demand both from the old craft/industrial sectors and from the newer volume producers by emphasizing production flexibility and quality in meeting the precise production needs of the customer.

During much of the latter half of the nineteenth century, market characteristics were still sufficiently plastic to allow producers pursuing both of the above strategies to compete successfully in the market. Most recent research seems to show that neither strategy was technically superior to the other (e.g., Robinson and Briggs, 1991). The level of demand for most types of special machines was sufficiently large so that individual standardized volume producers could justify

specializing production on a narrow range of machinery. Their earnings during boom times were usually enough to tide them over the rather dramatic cyclical swings that plagued the industry. Similarly, demand was robust enough to allow diversified customizers to spread resources across a broad product palette, offering an array of machines that they could deliver with modifications according to user wishes. Reliance on productive flexibility and skill enabled producers to find orders for some type of machinery even during downturns in the business cycle.

Although successful enough in a growing environment, the two strategies did not coexist harmoniously with one another. Each had particular vulnerabilities, and their differences ultimately gave rise to conceptions of acceptable practice and competition that destabilized those of the other.

The specialized volume production strategy was vulnerable in two ways. On the one hand, because by and large at the end of the nineteenth century direct control over the production process and the division of labor was in the hands of skilled workers, would-be volume producers found that their ability to achieve efficient economies of scale in production was blocked by worker control (Montgomery, 1979). On the other hand, in those cases where they succeeded in shifting their resources behind the specialized volume production strategy, such producers became extremely vulnerable to competition and the threat of market fragmentation. In a competitive market, it was always possible for diversified customizer competitors to offer a machine with precisely those capabilities that a standardized machine lacked. Volume producers could only respond to such challenges by offering to customize as well, but this then undermined their efforts to standardize and achieve economies of scale in production. Thus, among volume producers the desire gradually grew to establish a framework of order, or rules for acceptable conduct both in production and in competition, that protected them from such challenges. In its most radical guise, their strategy aimed at redefining the boundaries of industry in ways that completely eliminated the challenges posed by worker control and what they and their allies in other industries called "excessive" competition (Livingston, 1986; Sklar, 1988; Montgomery, 1979; and Wagoner, 1968, chapter 4).

Diversified customizers had an alternative strategy, different vulnerabilities, and, hence, wanted to construct an alternative type of order. Unlike the volume producers, the customizer's strategy was not blocked by the presence of powerful skilled workers in production. On the contrary, because the diversified and customizing strategy that they pursued depended upon a great deal of flexibility in production, these producers relied heavily upon strong, autonomous, and cooperative skilled workers. Indeed, republican "producerist" social and political traditions tended to draw class boundaries in ways that created affinity between the skilled and the small-scale manufacturer (Hattam, 1990). Also unlike the volume producers, the customizers were not threatened by market fragmentation—they thrived on it. A market of many desires, in their view, was a market of many possible contracts.

The vulnerability of the diversified customizer strategy lay not in market fragmentation but in market chaos. Downturns in the business cycle within a

community of highly flexible producers always sent producer chasing after producer, nervously underbidding one another and seeking to win a dwindling pool of machine tool orders. This problem of underbidding among the generalists was compounded by the fact that the volume producers could win orders by dumping machines from their inventory on the market at cut-rate prices. The result in either case was the collapse of market prices. The classic solution to market breakdown of this kind is for participating producers to cooperate on the bidding process and collectively agree to put a floor on prices to preserve market order (i.e., construct a kind of dispute-adjudicating cartel). As we shall see below, this is precisely what the German producers did. Yet, in the United States the diversified customizers proved unable to implement successfully this kind of cooperation or establish it as a legitimate form of market order.

There are two central reasons for this. First, the customizers needed the cooperation of the specialist volume producers in the construction of those kinds of cartels. But volume producers had little incentive to cooperate with the customizers. They desired a *different* form of industrial order that excluded customization as a practice. Second, as time went on and the balance of power in American politics shifted toward an accommodation of large-scale corporate organization, the political and legal terrain in which the industrial economy was embedded became increasingly hostile to the vision of order shared by customizing industrial producers (Sklar, 1988). This was most crucially true in the way that court interpretations of legitimate competition and market order changed. Traditionally, the types of arrangements that the diversified customizers needed to organize cooperation had been permissible under common law (Hovenkamp, 1991, chapter 21). But, in the new corporate and progressive political order, older and classically liberal, or republican producerist, readings of restraint of trade and freedom of contract gave way to interpretations that viewed cooperation among producers almost exclusively as harmful collusion (Hovenkamp, 1991, chapters 20, 22).

Dispute Adjudication

Blocked by rules that excluded the practices needed to construct a framework for stable cooperation, diversified customizing production had to play by rules congenial to the volume producers. Essentially this meant that all disputes on the market concerning price or the character of technology were resolved through a contest of strength. Customizing firms, as a result, were either competed out of business by the financially more robust volume producers, or they were bought out by the same producers. In any case, the customization strategy followed a path of gradual decay in the early twentieth-century machine tool industry. Bludgeoned and decimated from brutal competition during downturns, surviving producers emerged weakened in the next upturn. Slowly, over many iterations of the business cycle, their ability to offer tools of sufficient quality to compete against the standardized tools of volume producers began to disappear. Healthy firms were frequently bought out by richer volume producers because that was the only way the former could protect their assets from the

ravages of the business cycle. Weaker generalist firms either collapsed, or, as we shall see, turned to subcontracting.

Ultimately, the decline of diversified customization redefined the community of machine tool producers. The industry gradually developed an increasingly concentrated industrial structure dominated by specialized companies producing standardized machine tools in relatively large volume. Individual machine tool companies came to be associated with particular types of machines—such as the Gleason company and bevel gear machinery, or the Landis Tool Company and cylindrical grinders—because they dominated the U.S. market for that particular machine. This process had advanced far enough by the mid-1920s that Wagoner claims there were no more than four firms producing the same product in the entire industry and frequently far fewer (Wagoner, 1968:272–73).

Even though this dynamic of concentration shaped relations among individual producers in an important way, there are two reasons why it could not progress as far in the machine tool industry as it had in other branches of capital goods manufacture in the United States, such as textile and shoe machinery (Herrigel and Kazis, 1989; Kaysen, 1956). First, tremendous increases in the level of demand in the first quarter of the twentieth century, owing to the emergence of new industries, in particular the automobile industry, and large military orders during World War I far outstripped the ability of any single producer to cover all of demand completely, even for special types of machinery. In this context, smaller companies, which were either blessed with talented owners, such as the Lodge & Shipley Company in Cincinnati, or could find a profitable niche with an excellent product, such as the Bryant Chucking Grinder Company in Springfield, Vermont, could maintain their position among the leading firms in the industry (Geier, 1949; Broehl, 1959).

Second, because business cycles were far more dramatic in the machine tool industry than they were in other industries, firms were reluctant to increase their production capacity a great deal during periods of peak demand. Instead, they ceded a portion of demand to smaller, often less competitive companies. The structure of the industry in this way grew to be increasingly dualist, divided between a core of leading manufacturers and a secondary sector of smaller and more fragile producers. In many cases the smaller firms that absorbed surplus demand at the peak of the cycle produced their own tools; many other small firms specialized in producing tools for larger producers under contract. Many firms survived by doing both. In all cases, these producers rarely made enough money in boom periods to tide them over business cycle troughs, much less to commit resources to training, research, or product development to pursue systematically a strategy of fragmenting the larger firm's market (Brown, 1957: 413–14).

Consolidation of the Volume Producer Conception of the Firm and Its Relationship to Society

These exclusionary rules and procedures for dispute adjudication basically validated the standardized volume producer conception of the firm and of the

appropriate boundaries between industry and society. For them, the relative rigidity of high volume standardized production meant that profitability could only be achieved when as much uncertainty as possible could be weeded out of production and the market. Volume producers, therefore, placed great value on control (Noble, 1977). The hierarchical firm and the prerogative of its management were not only the practical organizational vehicles they used to achieve their ends of control; they also became the prestigious symbols of a new social order and of legitimate private authority (on this, see, classically, Veblen, 1906/1978, passim, and 1923, especially chapters 5–8).

Correspondingly, extra-firm influences on production, such as from suppliers, customers, or public bodies, were devalued in the developing understanding of good industrial practice. Such intrusions from the outside were viewed as disorderly, or collusive, or threatening, and in all cases obstacles to efficient production. As development within the new framework of order progressed, and producers with alternative conceptions of order slowly went into extinction, the machine tool industry lost all the vestiges of whatever republican, producerist community self-image it may have once had. Its members now understood themselves, not as a community, but as a collection of independent, nearly autonomous firms, each of which, like fathers in a bourgeois family, possessed absolutely sovereign authority over production.

Governance Mechanisms

As the framework of order in the industry increasingly affected producers in this way, it also became clear that it led them to rely on a narrow repertoire of governance mechanisms: primarily authority and price. Other governance mechanisms, such as cooperation, as we saw, had been self-consciously excluded, legally and practically, from the realm of acceptable practice. Still others, such as trust, could not emerge in an industry of producers that drew such rigid and strict boundaries between themselves and the rest of society.

The role of market mechanisms in governing the industry has already been discussed with reference to dispute adjudication. But the importance of hierarchy in the industry is very clear from its organizational development. By the mid-1920s, nearly all aspects of production, the organization of work, vocational training, product development, and market coordination had been taken off the market or ripped out of cooperative relations with others and incorporated exclusively inside the hierarchical and centralized structures of the firm. Large producers abandoned the traditional practice of purchasing parts from artisinal suppliers because they feared that the suppliers would gain access to proprietary information and use it to compete against them.

This kind of mistrust ultimately led to the decline of the artisinate in many manufacturing industrial districts, such as Cincinnati (Ross, 1985). Volume-producing firms wrested control over the labor process from skilled workers so as to be able to implement products and production processes that utilized simpler, more standardized machinery and less skilled, less expensive workers (Montgomery, 1979). These two developments, in turn, led to the total transformation of vocational education in the industry. Traditionally training had

been organized by the artisanate (Ross, 1985; Montgomery, 1979). With its decline, companies made halting efforts to pick up the system themselves, but their production plans changed the type of workers that they needed (Elbaum, 1989; Jacoby, 1991). Ultimately, in those cases where the firm could not completely design away the need for skill, they wound up either stealing skilled workers from other companies or instituting informal on-the-job training regimes (Wagoner, 1968:346–47; BMMTPT, 1953).

The desire to standardize products, increase the scale of production, and vertically integrate ultimately brought product development almost completely in-house. Because producers wanted to avoid customization, innovation in the machine tool business rarely took place in direct response to communication with customers. Firms innovated during business cycle downturns: In an effort to create demand for their products, companies brought out new variations of their special machines, which made the old models obsolete (Brown, 1957: 411–12).

Finally, as production, training, and product development were brought increasingly under the control of individual companies, all vestiges of extra-firm forms of cooperation among machine tool producers disappeared. One can see this in the evolution of the activities of the trade association, the National Machine Tool Builders Association (NMTBA). The association was formed in 1902 in an effort by customizers to establish an institution that would foster cooperation on pricing in the industry to guard against harmful market behavior. But, with the general defeat of such efforts to create an alternative industrial order, the role and purpose of the trade association completely changed. Instead of attempting to foster cooperation among companies, the association was transformed into a public relations and lobbying organization (Wagoner, 1968). Within the framework of order in the machine tool industry, individual firms exclusively governed production.

First Adjustment Period: Mechanical Automation and the Military

By the middle of the 1920s, the framework of industrial order was firmly in place, and the industry whose development it shaped was extremely successful. Technologically, the kinds of special machines produced in high volume by the U.S. industry were unrivaled anywhere else in the world for their quality and sophistication. British, French, and German volume producers all looked to the United States for their specialized machine tools because their own industries did not produce machines capable of doing efficient high-volume work (Soltau, 1930). But at the very time that the American machines were being revered and (partially) imitated abroad, the industry that produced them began to undergo important changes at home. Two developments in the middle decades of the twentieth century—from roughly the mid-1930s to the mid-1970s—set processes of adjustment into motion. These were the implementation of mechanical automation in mass-production industries, and government–military interest in machine tools. As we shall see, the character of adjustment was importantly shaped by the framework of order that the period just described had put in place.

Mechanical automation completely transformed demand for machine tools in the United States. In the place of the independent, stand-alone, standardized, labor-saving machinery that the machine tool industry offered, nearly all mass producers, from automobiles to consumer electrical products, began to implement completely customized systems of linked machine tools in their production processes (Brown, 1957; Noble, 1984; Burawoy, 1979). Although these increased the productivity of the mass-producing user industries immeasurably, the various forms of mechanical automation these users demanded could not themselves be produced in volume, or even in small batches. In most cases they were contraptions completely customized for the particular needs of the user.

These changes in the character of demand were compounded by demand from the military, particularly after World War II with the development of the aerospace industry. Although they did not mass-produce in the same manner as the industries demanding mechanical automation, the military, and the prime defense contractors who did their manufacturing for them, consistently demanded production equipment from the machine tool industry with extremely special characteristics; for example, that used special metals and other (cutting) materials, or possessed particular dimensions and precision required for the manufacture of a military product (Melman, 1985).

RESPONSE. Both of these changes forced machine tool builders to move away from standard products to more customized ones and to relate to their customers in a different way. Because machine tool manufacture was governed primarily by hierarchically organized firms, the capacity to change in the industry was determined by the relative resources at the disposal of individual companies, rather than, for example, the collective resources at the disposal of the industry or of particular regions. This ultimately led to even greater concentration in the industry and the decimation of the secondary sector of small and medium-sized firms.

Greater concentration in the industry resulted from the high costs involved in the bidding process and subsequent construction of large-scale mechanical automation systems (LSMAS). To win an order—say, for a transfer line at an automobile company—machine tool producers had to invest considerable time and money in research, tooling, and machinery simply to be able to make a competitive bid. If they did not win the bid—which always went to the lowest bidder—then they were stuck with the investment. Moreover, the production of such systems had to be done in a fundamentally different and more costly manner than the standard tools that the firms in the industry had made their stock and trade. The LSMAS could not be produced in volume, nor could they be standardized. Customers wanted very particular constructions that would automate their particular production processes. However, to customize a system in this way, the machinery producers needed skilled workers, which they did not readily have—nor, as a result of previous developments, did they have access to a public system that could provide them. Hence, movement into the market for LSMAS involved extremely costly investments in training that firms had to bear entirely on their own.

Within the framework of order in the industry, large companies simply had a greater capacity to deal with these increased costs than did the smaller number of smaller producers within the core of the machine tool industry (Marx, n.d.). Generally, they had the capital needed to absorb the additional costs of entry and then still had enough left over to spread their risks by diversifying their businesses. Large firms such as Cincinnati Milacron, Giddings and Lewis, or the Ingersoll Milling Machine Company diversified in a number of ways: They broadened their product palettes so that they were not dependent upon a single line of machinery, and they offered both customized and standard products.

In contrast to the large firms, smaller companies within the core sector of the industry became increasingly trapped in a scissors situation. They could not afford to carry the bidding and training costs required to compete in custom markets, nor were they, owing to the exclusionary rules that framed the industry, able to cooperate by pooling together their resources. Yet at the same time, the larger the bigger competitors became, the more efficiently they could produce the standard items that remained in their product palette. Hopelessly outmatched, many smaller and medium-sized firms sold out to larger companies such as Milacron to get access to capital, or they merged their operations with one another to improve their capital base and gain economies of scale.

Either way, given the upheaval in the definition of markets and thus the possibility of disputes among firms, mergers and acquisitions were a constant feature of industrial practice in the machine tool industry throughout the postwar period: From 1944 to 1958 there were an average of eight mergers or acquisitions per year. The Bryant Chucking Grinder Company, for example, was purchased by the Ex-Cell-O Corporation in 1958. Between 1958 and 1968, the average number of mergers rose to 13.5 per year (Research Management Corporation, 1969:60). During the late 1960s and early 1970s, as growth in the main user industries began to slow down, this same dynamic began to affect even many of the large firms. Major mergers occurred between two Cleveland companies—National Acme and Cleveland Twist Drill—to form Acme Cleveland in 1968 and between the Cross Company of Fraser, Michigan, and the Kearny and Trecker Company of Milwaukee to form Cross and Trecker in 1978. Other firms sold out to larger manufacturing conglomerates such as Textron, Litton Industries, Colt, White Consolidated, and AMCA International of Canada. Indeed, by 1982, of the top fifteen companies in the industry, all were large, diversified machine tool producers, and at least nine were either themselves conglomerates or were owned by larger conglomerates (Holland, 1989).

This process of concentration among core firms in the industry was paralleled by the gradual decimation of the secondary sector of small and medium-sized firms. This followed from the way in which the increased costs involved in LSMAS production changed core firms' evaluations of risk. In the business of large-scale customization, cumulative knowledge became a competitive advantage. The more business that firms did with particular automobile producers, for example, the more they came to know about the auto manufacturer's purchasing and production strategies in general. This made it easier for companies to

anticipate customers' needs and the possible paths of technological evolution in machine tool demand. Large firms jealously guarded these informational advantages. Old conjunctural subcontracting practices were abandoned because they were viewed as unsafe: Proprietary information could possibly "leak out" to the subcontractor this way and create the possibility that large LSMAS customers could use this to their advantage by playing smaller producers off larger ones to lower bidding prices. Over time, large machine tool producer efforts to keep this from happening killed the small secondary-sector subcontractor. The increasing irrelevance of these producers in the industry comes through clearly in the statistics. Wagoner (1968:272) reported that, in 1947, the largest sixteen companies in the industry accounted for 43.2 percent of the industry's shipments, measured by value. In 1957, Brown (1957) claimed that the top forty companies in the machine tool industry accounted for 70 percent of the output in the industry. By 1981, however, the largest fifteen companies accounted for 73 percent of total shipments (CMTI, 1983).

All of these changes followed from the firm-dominated strategic calculus that the framework of order in the industry created. Significantly, the calculus made for an extremely successful industry. Large American producers pioneered many of the pathbreaking technologies employed worldwide in LSMAS. Their close work with the military in the development of special machinery produced many advanced forms of automation technology, including numerical control (Noble, 1984; Holland, 1989, chapter 3). Throughout the postwar period the industry was consistently among the largest and most technologically sophisticated in the world.

Second Adjustment Period: The End of Mass Production

The U.S. machine tool industry was singularly incapable of adjusting to the new forms of market competition that emerged in the 1980s. Two factors combined in this decade to transform completely the U.S. machine tool markets. First, firms engaged in the mass production of standardized goods found that their markets had become saturated. Partly as a cause and partly as an effect of this, markets that had once been stable began to fragment and break up. Competition from producers in Japan, Europe, and many newly industrializing countries caused the pace of technological change (particularly in microelectronics) to accelerate in all industries, including machine tools. Product life cycles shortened dramatically at the same time that the costs of developing the new technologies began to increase (Piore and Sabel, 1984). Second, as an immediate response to increases in the level of risk that firms confronted on their markets, producers sought to reduce their fixed costs in manufacturing by subcontracting work to outside suppliers. On the one hand, this allowed them to be less vulnerable to a dramatic loss of market share at any point; on the other hand, the use of specialist subcontractors enabled them to spread the costs of development in specialized technologies (see Sabel, Kern, and Herrigel, 1990).

These changes qualitatively transformed the demand for machine tools in both of the areas of U.S. strength. Instability and rapid technological change

in previously stable markets caused demand for rigid forms of LSMAS to evaporate completely. In its place, user firms demanded more flexible machine tools that, with the aid of computer numerical control, could be repeatedly reprogrammed to operate on a variety of production tasks. Moreover, in most cases user firms continued to demand customization, insisting upon special adjustments and features on the machinery itself or in its operating software. At the same time, with the decentralization of manufacturing operations, the demand for standard machine tools with computer numerical control (CNC) increased dramatically. Small and medium-sized specialist supplier firms and job shops found that computer numerical control standard machines were more precise and flexible than conventional machines. Moreover, as the price of CNC technology declined and as the level of work done by small and medium-sized companies in decentralized manufacturing networks increased, the market for all varieties of standardized CNC lathes, milling machines, and machining centers grew to be astronomical.

RESPONSE. American machine tool companies have not been successful in entering these new markets. They have ceded the high end to Japanese, German, Italian, and Swiss manufacturers and the low end to Japanese, Taiwanese, and, to a smaller extent, German and Italian producers. The share taken by imports in the total U.S. market for machine tools has been over 50 percent since 1984 (Holland, 1989; Friedman, 1988). American producers have had difficulty adjusting because the principles of order that shape the industry—no cooperation, dispute resolution through merger, and companies defining themselves as firms radically independent of one another and of society—led producers initially to overlook changes in the character of demand and then subsequently prevented them from responding competitively.

In standard machine markets, as we have seen, U.S. companies traditionally organized production on the assumption that there would be little competition in their product area. Production processes were rigid and vertically integrated, and companies eschewed customization. The larger and more diversified that firms became in the postwar period, the more entrenched these practices in standard machinery production became. American companies made a great deal of money off their military and mechanical automation operations and tended to let their standard machine operations evolve at a very slow rate. As a result, they lost touch with the market.

Japanese producers recognized the potential demand in the small metalworking sector in the mid-1970s, but it took U.S. producers until the early 1980s to respond with a downsized CNC unit of their own—White Sundstrand produced one of the first American CNC machining centers in 1980—and when they did, the response followed the logic of the old production practices exactly. Rather than produce a range of machining centers with different electric motors and gearboxes to fulfill different needs (perhaps saving on costs by purchasing the different motors from subcontractors), White Sundstrand chose to make one highly flexible machine that could be easily produced with traditional volume methods entirely in-house. The company soon discovered that this could

not compete with Japanese firms that were producing a broad variety of different types of well-engineered, general-purpose tools that they could easily and quickly tailor to the needs of a particular customer (Ong, 1983).

The story of blindness and rigidity in the custom machinery market is more subtle but just as devastating. American firms developed production and product development strategies in both commercial and military markets that were bureaucratic and risk-avoiding just as competition and technological change in the industry began to reward risk-takers. The picture of the U.S. commercial machine tool markets during the 1960s and 1970s is one of increasingly large, bureaucratically organized machine tool sellers, in concentrated markets, courting even larger, more bureaucratically organized buyers. Successful machine tool companies knew that purchasers were reluctant to take risks on promising new technologies with no track record because the internal reward system in the largest corporations punished failed innovations. Machine tool salespeople, who needed to sell because of their own internal reward structures, learned to offer what they knew would sell: usually older and well-tested technologies. With little competition or trust within or among sellers or buyers, there was no pressure to act otherwise (*American Machinist*, 1986).

Military work compounded this propensity to avoid risk, only here the result was the development of incredibly advanced machining technologies. Government procurement in machine tools, as well as tremendous amounts of government-funded R&D in the industry, went overwhelmingly to the largest firms in the machine tool industry. Military contractors demanded extremely advanced machining techniques and consistently encouraged machine tool firms to push the frontiers of automation technologies. Contracts were always long term and extremely lucrative. The government paid for performance and was willing to overlook costs. Thus, whereas in commercial markets firms actively sought to minimize risks on the market, in military markets there was virtually no risk involved (Melman, 1985).

The problem, of course, was one that has turned out to be common among many large hierarchically structured American corporations (e.g., Boynton and Victor, 1991). When commercial purchasers of customized machine tools fell into crisis and began to demand advanced forms of production technologies, American machine tool producers were in no position to respond because their divisions producing advanced technology had little connection to those producing for civilian markets. Making linkages between them took time—precisely what the tumultuous and rapidly changing market environment did not allow—and the possibility of turning to cooperation with outsiders was mistrusted and in any case not considered to be in line with the principles of order that governed the industry. Years of bureaucratic conservatism, concentration, and vertical insulation left U.S. machine tool companies, despite their many resources, frozen in their tracks. European and Japanese producers, who organized their business in a different way, turned out to be far better at innovating and delivering advanced commercial technologies at acceptable prices.

Before asking the question of whether or not the firm-based form of industrial order in the United States will be able to recover from its present crisis, it will be interesting to look more closely at the evolution of industrial order in the German case. German machine tool producers followed a different path of development in the twentieth century, which has made it possible for them to take advantage of current machine tool market opportunities.

Industrial Order in the German Machine Tool Industry

The Germans have a tradition of machine tool production equally as long and distinguished as that in the United States. An independent industry producing machine tools probably emerged slightly earlier in Germany than in America. The first company to specialize entirely on the production of machine tools was founded in the 1850s, and there was a wave of new companies in the 1870s following the unification of the German Reich. Most early nineteenth-century German machine tools were imitations of British and American designs, but by the early years of the twentieth century German companies were producing machines that the rest of the world imitated (Buxbaum, 1919). The actual tools that German firms produced tended on the whole to be heavier and far more flexible and general purpose than their American counterparts. Where U.S. producers continually sought to restrict the amount of machining operations that a single machine could accomplish, Germans tended to build more and more operations into their machines (e.g., Mommertz, 1981:140).

The Germans made more flexible machine tools because they sold in very different markets than existed in the United States. The quality of demand in Germany differed because the political, legal, social, and economic background conditions in Germany were far less favorable to the emergence of large-scale mass production than they were in America. German markets were fragmented by different regional, political, and economic boundaries and traditions not only within the Imperial Reich itself, but throughout Europe. This kind of fragmentation made it difficult to sell standardized products, and most producers, large and small, did not.

Indeed, in a way that is ironic only when compared to the United States, high-volume manufacturing was a niche phenomenon in Germany. Among machine-tool-using industries it was found primarily in weapons production and in the relatively small industries involved with the production of sewing machines, bicycles, office equipment, and, beginning in the 1920s, automobiles. But even in the case of these volume-production industries, the contrast with mass production practiced in the United States was dramatic. In 1929, for example, Germany was fifth in world motor vehicle production with a total output of 149,000 units. That same year, the U.S. industry produced 5,358,000 units (Overy, 1975). No auto manufacturer in Germany produced more than ten vehicles per day in the 1920s; no American firm produced less than forty vehicles per day (Soltau, 1930).

This peculiarity of German growth is significant because it means that the kind of struggle between incompatible visions of industrial production that plagued late nineteenth-century America and split the machine tool industry into two warring camps never emerged in Germany—at least not in the late nineteenth and early twentieth century when the industrial order in the machine tool industry came into being. The absence of mass production as an option

in most industries made low-volume, flexible, specialty-product-oriented production an uncontested strategic orientation among both users and producers of machine tools, large and small.

It is true that beyond a common orientation toward customization and craft-based production, real practical and organizational differences existed between large and small firms in Germany. But these differences were prevented from becoming a source of conflict through the regional political and economic structure of the Imperial Reich. Large firms were primarily a regional phenomenon in *fin de siecle* Germany, and they were located in the Ruhr Valley, central Prussia, old court and trading cities (such as Hanover, Kassel, Augsburg, and Munich), and the Saarland.[3] Firms were large in these regions because they could draw on very little preindustrial infrastructure of artisans or home producers as suppliers. They were forced to produce everything that went into their product themselves (Kocka, 1980). In regions where there was a rich preindustrial infrastructure—for example, Württemberg, the Kingdom of Saxony, southern Hesse, or Baden—industrialization occurred within that structure, and the size of firms continued to be quite small. Moreover, most of the regions of small firms, with the exception of the Rhineland, were located outside of Prussia in states that entered the German Reich beginning only after 1866. One of the conditions of entry was that these regions retain sovereignty over their tax, education, and industrial policies. This structure effectively blocked all important background framework changes that could have made large and small producers play by the same rules (Herrigel, 1990, chapter 2).

Thus, in effect, industrializing Germany was replete with regional economies, each dominated by different sectoral mixtures of highly specialized, low-volume producers. Producers of different types of specialty machine tools emerged because they serviced different kinds of local demand. For example, producers in Württemberg made small precision machine tools for the fine mechanical and special machine industries in that region; producers in the Kingdom of Saxony manufactured machines suited for use in the local general machine and woolen textile industries; those in Berlin specialized in producing machine tools for the electromechanical, heavy machine, and weapons industries. So it went. The major centers of machine tool production coincided with the major agglomerations of industrial production in Germany. The largest concentrations of machine tool producers were, moreover, located in the regions dominated by small and medium-sized producers (Buxbaum, 1919).

Given this varied political and economic background in Germany, the problem posed to producers during the period in which the modern German machine tool industry was created proved very different from that which U.S. producers confronted. The Germans needed to discover a way to establish a framework of order within and among communities of highly flexible craft producers.

The Framework of Order

IDENTITY. Producers constructing a framework of industrial order in Germany thought about the boundaries of both the company and of industry in an entirely

different way from their volume-producing American counterparts. The problems inherent in following a craft production-based strategy of customization led machine tool producers to assume that reliance on other firms and on other institutions in society was a necessary part of industrial practice. These bonds of mutual dependence engendered the belief that machine tool producers were part of a community.

Reliance on other producers was an unavoidable part of the strategy of customization. As a practical matter in the densely populated industrial districts of small and medium-sized firms it was extremely difficult to centralize production completely and to customize continuously at the same time. Vertical integration of craft production meant that a firm had to hire enough skilled workers to produce all elements of their machines in-house. The business cycle made this a risky strategy because it was fatal to lay off workers during downturns. Once let go into the labor market of the industrial district, such workers invariably would be lost to other firms. The best way to avoid this kind of disruption was simply to limit levels of employment by procuring special parts from the outside. Producers could use such purchases either to supplement their own capacity in periods of peak demand, or simply to provide materials that the firm was unable to produce itself—such as foundry castings. Either way, subcontracting was preferable to investing in more productive capacity than the market could absorb (Soltau, 1930; Pastor, 1937).

Moreover, the same logic that made these firms subcontract made them become subcontractors as well. Because companies were not completely autarkic as producers, they often did work for other machinery producers on a subcontract basis because they had more appropriate machinery, or simply temporary excess capacity. The ability to complete a custom order often depended upon the knowledge that a company could get something done at another machinery manufacturer within the region.

All of this meant that producers tended to think of themselves not as a group of independent firms coincidentally lumped in a common category because they produced the same technology, as was the case in the United States. Rather, they understood themselves to be a community of producers. The mode of interaction that underlay this self-conception, not surprisingly, resulted in a different, more egalitarian, industrial structure than was the case in the United States. Instead of dualism between large and small firms, there was a great deal of interdependence among firms of comparable size. Seventy percent of those employed in the 332 establishments in the industry in 1926, for example, worked in firms with fewer than 500 employees. Sixty-three percent of all employees worked in establishments employing between 30 and 500 workers. Only 20 percent worked in companies employing more than 1000 workers.

Predictably enough, the large firms in the industry were those that produced "American style" machine tools—mostly turret lathes and milling machines. Five manufacturers dominated that segment—Ludwig Loewe and Fritz Werner of Berlin and Wanderer, Pittler, and Reinecker in Saxony. These companies prospered primarily on the basis of demand from state arsenals and other

volume-producing industries. They had been able to gain market power in their segments by licensing the designs of particular American machines useful in the mass production of weapons (Buxbaum, 1919; Ludwig Loewe & Co., 1929; Dominik, 1938). Companies were even able to standardize their machines and produce in series. The interesting thing about these firms, apart from the special character of their demand, is that they remained relatively isolated from the other smaller specialty producers in the German industry. Because their machines were so closely modeled after American designs, the firms never fostered a secondary sector of second- and third-rate producers as had companies in the United States. The reason: The segment of the market at the peak of the business cycle that the large German producers could not serve was generally serviced by American imports (Soltau, 1930; Pastor, 1937; Mengel, 1931).

The mutual dependence and sense of community that bound producers in the German industry together was enhanced by the multiple ways that these producers were also linked to a variety of institutions in society. The same kinds of risks associated with craft-based customization that led producers to rely on one another also led them (often in cooperation with craft producers from other local industries) to attempt to socialize many of their costs by constructing a broad infrastructure of institutions providing services to all producers. Four institutions in particular were important.

The first important institution was an extensive public system for vocational education. Emergence of the German dual system of industrial training in 1897—which combined practical training in actual workshops with public vocational training—represented a victory of an alliance of industrial craft producers and artisans over the forces of liberalism in Germany. Artisan organizations were entrusted by the state with the authority to oversee and organize the education of skilled workers. In return for a material and functional basis for survival, along with political legitimacy for their organizations, artisans trained skilled workers and thereby ensured that the costs of training highly skilled workers would not have to be borne by individual companies in the industrial sector (Schriewer, 1986).

The second important institution consisted of regional and national research institutes dedicated to the technological concerns of industry. The various German states sponsored the development of technical universities dedicated to the dissemination of advanced technologies into the economy. The Technical University of Berlin and, later, technical schools in Aachen and Stuttgart developed very important laboratories dedicated to technical research on problems related to the machine tool industry. Services provided by the technical universities were further complemented by more locally based institutes for applied technology (now known as *Fachhochschulen*). The most important of these for the machine tool industry were located in Esslingen, Chemnitz, and Remscheid. Initially, these institutes were established by the producers themselves, often with other metalworking-machinery-user firms, to address in a cooperative way the applied technological problems of common concern and to educate technicians and engineers. Although financial support gradually was taken over by the state, these regional institutes became a crucial source of external know-how for small and specialized individual firms.

Third, small and medium-sized manufacturers also created a cooperative banking system to improve their access to capital. Much like small manufacturers in the United States at the time, German small producers were disadvantaged in the national capital markets because they provided smaller returns on investment than did the larger and rapidly growing Ruhr and Berlin combines. But unlike the Populists in the United States, the broadly based late nineteenth-century cooperative banking movement in Germany succeeded in establishing a system that pooled the resources of local small industrialists and artisans for collective investment needs. These "banks" actually were institutions that mediated between individual small industrialists and artisans and the money and credit markets controlled by the larger banks. In 1895, the Prussian state government helped create a Central Bank for Cooperative Societies (*Central-genossenschaftskasse*) in Berlin, which pooled capital from the local cooperative banks so as to provide even more clout in the credit markets to the economic and social interests served by those banks (Heiligenstadt, 1910; Gemming, 1911).

Finally, at the turn of the century, the machine tool industry formed its own trade association, the *Verein Deutscher Werkzeugmaschinenfabriken e.V.* (VDW) Aside from the many political and service tasks that this association performed for the industry, it grew to be intimately involved in the coordination of research. Most precompetitive research projects among firms that were members of the association were managed and coordinated by the association. Also important, the VDW ran the Leipzig (later Hanover) trade fair for machine tools, the largest in the world (Kappel, 1966).

Exclusionary Rules and Dispute Adjudication

By itself, the fact that producers understood themselves to be part of a community that included not only other producers but also important supporting institutions was not enough to provide stability in the industry. The major problem that producers faced was the tendency for competition among firms to degenerate into competitive pricing, underbidding, poaching, and so forth during cyclical downturns. The threat of market chaos, described earlier among the American customizers, needed to somehow be conquered before the German industry could stably reproduce itself.

This problem plagued German machine tool producers—along with the rest of the mechanical engineering trades—a great deal in the three decades preceding World War I. Beginning in the early 1900s, efforts were initiated by the general machinery industry trade association Verein Deutscher Maschianbau Anstalten (VDMA) to regulate competition through the construction of industry-wide guidelines for delivery and payment. These conditions did not attempt to set prices or limit production in the industry—both the range and the variation of products were too vast for that—but they did seek to remove the terms of sale, form of payment, and delivery from competition.

The problem of poaching was directly addressed through the creation of specialized confederations, or "finishing associations" (Liefmann, 1932). Here member firms agreed to specialize in one or several lines of machinery while ceding other lines to other members of the association. The consensus in these agreements was that all parties agreed not to poach on other members'

technologies, even in bad periods of the business cycle. The Germans rarely codified these specialization arrangements into formal cartels because the evolution and change in technology was so completely fluid that the construction of a legal arrangement would only have substituted rigidity for instability. Even so, the kind of arrangements they established would have been illegal under U.S. antitrust law. Instead of binding one another legally, firms simply agreed to commit themselves to continual negotiations over the definition and demarcation of markets (RDI, 1929; Muellenseifen, 1926; Schultz-Mehrin, 1926).

This arrangement solidified a framework of order in the industry. First, poaching practices and technological diversification were by agreement excluded from the industry. This not only had the positive effect of preventing the breakdown of market competition but it also stimulated innovation in the industry. By forbidding diversification in economic downturns, the associations forced companies to remain innovative in their chosen specialty or leave the industry. Second, because the commitment to specialize and not poach was simultaneously a commitment to engage in continuous negotiation with other producers about the terms and boundaries of that commitment, a procedure for the adjudication of disputes in the industry was thereby established.

Ultimately, the process of adjudicating disputes was institutionalized in the Norm Council of the VDW trade association. All manufacturers in the industry sent representatives to this council where they engaged in negotiation that defined the relationship between their various specialties. Once agreement was reached, all received the right to attach the association's quality stamp to their machines—at once a symbol of technical quality and industrial order. This institutionalized practice of negotiation was a crucial condition for the reproduction of the community identity in the industry. Because it effectively eliminated merger as a mechanism of stabilization, the system of permanently negotiated specialization blocked the emergence of firms with disproportionate market power.

Governance Mechanisms

Within this framework of industrial order, normal interaction in the industry virtually conflated the boundaries between individual company and society. Correspondingly, the industry governed itself with overlapping mixtures of market and hierarchy: A firm making a customized machine for a customer—in which customer, client, and other suppliers collaborated on the design—were linked together exclusively by neither contract nor authority but by both of these together. In addition to these, the framework of order in the industry also created conditions under which certain types of governance could only occur through relations of trust and loyalty.

For example, the interpenetrated division of labor between the individual specialized craft firm and the infrastructure of the industry as a whole was self-reinforcing in a way that made trust crucial. The more specialized that each firm became, the more that the pursuit of its particular interests required loyalty to the common understandings of appropriate market behavior, which the framework of order had created, and defense of those superordinate institutions—

training institutes, banks, trade associations, and government agencies—that safeguarded the interests of the industry as a whole. If participants in the system did not believe or trust that others would embrace the same cooperative rules of the game that they did, the entire system simply would not work.

First Adjustment Period: Mass Production and Mechanical Automation

The system described above began to fall into place during the 1920s. By that time, German machine tools were already renowned for their high quality, flexibility, and durability. By 1913, Germany had become the second largest producer of machine tools in the world, behind the United States, and the world's biggest exporter. During the first third of the twentieth century, the United States, Britain, and Germany regularly accounted for over 80 percent of the world market in machine tools. American firms served the world with standardized, semi-dedicated, labor-saving machinery for volume producers, while the Germans provided general-purpose machines to low-volume and specialist producers (Froehlich, 1914; Mengel, 1931; Pastor, 1937; Levy, 1933).

Differences in technology and export orientation between the two countries reflect the fact that German producers concentrated on markets where there were highly skilled workers and little mass production, whereas the American producers did precisely the opposite. This division of labor, already unstable in the 1920s as a result of changes wrought by the war, changed over the course of the following four decades. The Nazi economic recovery program, preparation for war, and, finally, the reconstruction of Europe and the formation of the Common Market transformed both German and European markets. Various market conditions were created that made mass production on a Europe-wide basis possible with a pervasiveness and at a scale that had never before existed (Piore and Sabel, 1984). Market conditions in Europe and the United States began to converge in the post–World War II period. Demand for LSMAS and "American-style" labor-saving machinery dominated the order books of machine tool producers.

RESPONSE. The German industry proved surprisingly able to adapt to the new character of machine tool demand. Even though the ravages of war and the division of Germany caused the collapse of the five largest American-style machinery-producing firms mentioned above, the number of firms in the West German industry exceeded the number from 1926 by over 100 in 1970. Employment in the industry grew to 125,000 workers in 1970. Indeed, there is much evidence to suggest that the industry became even less concentrated during the postwar period—particularly after the formation of the European Common Market (Baumann, 1964; Daley and Jones, 1980). By 1970, the West German machine tool industry was not only the world's largest exporter of machine tools but also the largest absolute producer of machine tools in the world.

As in the U.S. case, the framework of order in the industry shaped the character of German adjustment. This was true in two ways. First, because they could spread costs across an array of firms and supporting institutions, the

relatively smaller German producers were not overwhelmed by the large costs associated with the production of LSMAS. Second, the framework of order had created a dynamic of practice in the industry that simply prevented certain kinds of costs that had plagued their U.S. counterparts from emerging.

As an example, training costs in Germany were partially absorbed by the dual system of vocational training. Moreover, German tool makers, unlike their U.S. counterparts, were already richly supplied with skilled workers because their previous strategy had not been devoted to their elimination. Furthermore, many R&D costs were absorbed or shared through the continuous exchange of know-how with other firms in noncompeting lines, with faculty members and students at the regional research institutes, and through joint "precompetitive" research projects at technical universities organized and administered by the VDW.

Significantly, firms also continued to learn from their suppliers. Although most manufacturers preferred not to subcontract the pieces of the machinery which carried the "know-how" of the firm, many companies did maintain long-term trusting relations with suppliers. In contrast to producers in America, West German companies were not as aggressive about trying to eliminate the threat of competition from suppliers to protect their proprietary knowledge as customizers. They preferred to coordinate and control competition rather than eliminate it. New entrants did not survive long without entering into the complex process of negotiation within the industry over the definition of relationships among firms and technology. In this way they were included in the community of producers. This obligated them to abide by the principles of order that governed it. But, importantly, it also made adherence to some of the principles, such as the use of trust as a governance mechanism, possible as such: Newcomer identification with the community established a sense of common fate without which trust and cooperation would be impossible.

Second Adjustment Period: Crisis of Mass Production

As in the U.S. case, the machine tool industry in Germany suffered considerable turmoil when the long postwar boom in the international economy came to an end. Market saturation, new competitors—above all the Japanese—new technologies, high development costs, and rapidly changing markets all transformed the character of demand in the industry as well as the conditions under which competition took place. The difference between the German and American case is that the German industry was able to recoup its initial losses. Much of this, again, can be explained by the character of order in the industry.

Several developments combined to throw the industry into crisis. First, domestic investment in machine tools in West Germany stagnated throughout the 1970s. In 1975, domestic investment in capital goods, including machine tools, was 7 percent below the level of 1970 in the electromechanical industry, 22 percent below the level in the machinery and automobile industries, and more than 35 percent below 1970 levels in the metal products sector of the economy. Moreover, machine tools declined as a percentage of total capital goods investment throughout the 1970s in West Germany, from 41 percent to 35 percent (Horstmann, 1984).

Innovation in the industry slowed down as a result of this stagnation. Because the demand for machine tools was far lower than the potential supply, prices were driven downwards. Companies, especially small and medium-sized ones, found little incentive, and as the decade wore on, they had increasingly little capital for experimentation with design. This tendency to avoid the risks and costs involved with technological innovation in the 1970s was compounded by a shift in the direction of West German exports. To compensate for stagnation in the more advanced industrial markets, German producers found that they had to enter markets in Eastern European and in developing nations more extensively than they had ever before. The demand in these markets was not terribly sophisticated, and firms found that increasing portions of their output was in machinery that had been in their product palette for a considerable period of time (Borst, 1976; Horstmann, 1984).

When investment demand for machine tools began to pick up at the end of the decade in West Germany and in the broader EEC, the Germans were initially unable to compete with Japanese producers in markets for CNC equipment. In 1980, some 73 percent of the domestic demand for computer numerical control equipment was supplied by imports. Japanese producers grabbed 43 percent of the import market for CNC lathes that year. What was worse, the West Germans appeared to have completely missed the significance of CNC technology. Very few companies in the industry even manufactured the technology. In 1980, the Japanese produced 22,000 CNC machines while German producers made only 4800 (Handelsblatt, 1986; SHfdM, 1987, 1985). By 1984, however, the picture had completely changed. The percentage of domestic demand for CNC equipment supplied by imports fell from 73 percent to 30 percent. Moreover, in that year, West German machine tool builders produced 10,600 CNC machines. This was 34 percent of the total value of turnover in the industry and more than the combined total of American, British, and French machine tool producers measured in terms of units. By 1986, 53 percent of the value of output in metalcutting machines was accounted for by CNC. Machine tool producers in West Germany have exported more CNC machines than were imported every year since 1981.

This relatively rapid turnaround was possible because of the availability of technological know-how in the public space created by the framework of order in the industry. In the early 1980s when it appeared that the West Germans had been overtaken by technological change in the industry, all of the institutions and actors involved in the industrial order focused their attention on CNC technology and the problem of microelectronic applications on machine tools. The VDW and the machinery producers' association (VDMA) worked with the Federal Ministry of Research and Technology (BMFT), together with other associations, to develop a special subsidy program that allowed small and medium-sized firms to discount all research and application expenses related to CNC technology on their machines (Ziegler, 1989). Innumerable joint "pre-

competitive research" projects were conducted at the major technical universities. The regional government of Baden-Württemberg launched a significant program to extend the consulting services provided by regional research institutes to small and medium-sized companies without increasing the cost of those services.

The machinery producers association and the metalworkers union (IG Metall) each advocated the need for a qualification offensive in vocational education and advocated cooperation in the construction of a curriculum that would educate German skilled workers in computer programming. Interfirm cooperation was also a central aspect of the industry's adjustment strength. By reducing their fixed costs, and relying on the specialized know-how of outside suppliers, firms were able to integrate the new technology and bring products to market faster with less cost and greater flexibility. Typically, machine tool producers cultivated a core circle of suppliers with which they could work very intimately and provide them with know-how. Important suppliers to the machine tool industry, such as Siemens, which supplied the industry with the computer numerical controllers that they placed on their machines, worked individually with companies to help them adapt CNC technology to their special machine tool products. In most cases, the transfer of know-how goes in both directions: Machine tool firms provide their suppliers with mechanical engineering know-how, often by collaborating on production engineering of single parts and subassemblies, in exchange for the specialists' expertise in electronics, plastics, or hydraulics, among other areas.

This list of factors could be easily extended. No single factor alone can be isolated as "most significant" in facilitating the industry's successful adjustment. Rather, successful adaptation in the industry in many ways was produced by the logic of order in the industry itself.

Conclusion: Industrial Order and Industrial Adjustment

The comparative historical experience of machine tool producers in the United States and Germany over the course of the twentieth century is a good case for developing the notion of industrial order. Given different political and economic starting points, producers of machine tools created very different framework rules for the way they practiced their trade. In each case, producers shared common beliefs about what industry was and how it legitimately related to the rest of society. Moreover, the different frameworks of industrial order in the two countries created a repertoire of governance mechanisms that shaped the character of adjustment in the industry throughout the twentieth century. Thus, even though the German and American machine tool industries faced the same technological challenges in the middle of the twentieth century, because they were different forms of industrial order they responded (successfully) in radically different ways. The framework of order in the United States made strategies of adjustment, which resulted in concentration and vertical integration, appear obvious and inevitable to American firms. In Germany, under the same technological pressures in their product markets, not only were such strategies not inevitable, they were not pursued.

A similar logic was at work during the 1980s, only this time without mutual success. All comparative evidence, in Germany as well as Japan (e.g., Friedman, 1988), suggests that an industry that practices according to rules that exclude cooperation, that foment mistrust and hostility among producers by resorting to contests of strength on the market to resolve disputes, and that delegitimate the potential contributions to production that players in society outside the boundaries of the firm can make will not be able to survive in the current international environment. And, yet, it was precisely according to such rules of practice that the American machine tool industry attempted to cope with the transformation of world markets in the 1980s.

Many ironies abound in the case of the U.S. machine tool industry. It has for most of the twentieth century been conventional among students of industry in the United States to think of the machine tool industry as the great exception inside an industrial economy. Unlike other industries, machine tool producers were not mass producers; they relied disproportionately on skilled workers; they were flexible. A straight kind of market logic has always been employed to explain the distinctiveness of the industry: Because their market was for a single purpose—often unique machine that let their users efficiently mass-produce—machine tool producers were forever blocked from implementing mass-production techniques themselves. Following this logic, many at the beginning of the 1980s believed that if any U.S. sector were to have the inner resources to compete in a turbulent world market that seemed to favor flexibility, it would be the machine tool industry. This kind of thinking made the total collapse of the industry that much more shocking—and, perhaps, the success of others that much more suspicious.

But, if we put the folk understanding of the industry aside, the comparison with Germany makes it easier to see what kind of an industry the U.S. machine tool industry actually was. That is, only in an industrial economy in which the rules of industrial practice are defined as they have been in the United States is the machine tool industry reasonably considered a craft-production industry. In comparison to the radically decentralized craft production that exists within the framework of order in the German industry, U.S. toolmakers don't look like a craft-production-based industry at all. Indeed, the story of the development of the American industry has much more similarity with the organizational forms prevalent in other American industries than it does with the foreign competitors it confronts in its own sectoral markets.

This point casts the entire question of adjustment in the current U.S. industry into a very particular light. The challenge that the industry faces is not simply a technological one. Nor is it rightly characterized, as has been done, as a problem of unfair competition on the part of major competitors (see the excellent discussion of the Houdaille Industries case in Holland, 1989:171–222).

Rather, the challenge to the United States posed by German and Japanese competitors is to the way in which producers in America have traditionally defined the rules of the game in industry and to the way that they have understood the proper relationship between industry and society. The Germans and Japanese are not playing *unfairly* by engaging in cooperative research and pro-

duction or by utilizing the resources of extra-firm institutions and governments—they are playing according to different rules. The relationship between industry and society exists within a different framework of order, and they view the relationship between industry and society differently. If the U.S. industry, or what is left of it, is going to compete in world markets as they are currently defined, manufacturers are going to have to rethink who they are and what the proper boundaries between industrial practice and the rest of society should or can legitimately be. Finally, for the achievement of this task, the Germans exist less as a model that can be directly transferred, than as an example of possibilities that the Americans, because of the way their indigenous understanding of industrial order shapes their capacity to recognize available strategies, are unable to see.

Notes

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1. According to Stephen Holmes (1988:227): "Constitutions [are] binding in a possibility-engendering way." Russell Hardin (1989:115) similarly remarks: "The point of a constitution is to tie our hands in certain ways in order to discipline them to more productive use."

2. "Like it or not," writes Ackerman about the way that the Constitution has shaped the character and possibilities for political self-reflection in the United States, "it is these symbols and structures, not any of my own devising, that set the terms of my own efforts at political communication with my fellow citizens" (Ackerman, 1988:156).

3. Eighty-one percent of the top 100 firms were located in these regions in 1908 (see Herrigel, 1990:202, n. 112).

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CHAPTER 6

The Chemical Industry:

A Study in Internationalization

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WE SHALL argue in this chapter that the chemical industry is a highly internationalized industry, one in which the integration of world markets has led to a considerable degree of convergence in regimes of governance. Even so, there are still important national differences that may bear on the competitive performance of the chemical industry in different countries. These differences do not always lead in an expected direction. For example, although Japan is a major player in the world chemical industry, it is not a dominant, or even a leading producer, as is the case with industries such as consumer electronics. We also caution against forging too many generalizations regarding the chemical industry, an industry with many distinctive features. The chemical industry should also not be seen as a model for future developments in other industries, but rather one whose particular pattern of development and distinctive characteristics have produced various interrelationships among firms, markets, interest associations, and governments that have a number of special features.

Before proceeding to a discussion of the extent of internatonalization in the chemical industry, some preliminary remarks have to be made about the definition of the industry, and the institutions with which it comes into contact. An important distinction may be made between how industrial sectors are defined in schemes of classification because of the need to find a location for every product group (an important consideration in categorization), and how sectors actually see themselves. It must be stressed that many subsectors classified as being part of the chemical industry either resent being so classified (notably cosmetics and toiletries) or regard themselves largely as *users* of basic chemical products with very different sets of interests from their suppliers of raw materials. Hence, our analysis focuses on ISIC 351 (basic industrial chemicals) rather than ISIC 352 (consumer products such as paints, pharmaceuticals, soaps and detergents, etc.). In terms of value-added, ISIC 351 and ISIC 352 are of similar size in the developed world. It should also be noted that the space available to us here does not pemit any discussion of the distinctive problems