DID SOCIALISM FAIL TO INNOVATE? A NATURAL EXPERIMENT OF THE TWO ZEISS COMPANIES

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Two Carl Zeiss companies provide a natural experiment for analyzing the effects of socialist versus market systems on innovation. By analyzing patent records from 1950 to 1990, we trace the technological contributions of Zeiss Jena in the German Democratic Republic and Zeiss Oberkochen in the Federal Republic of Germany. We show that Zeiss Jena gradually developed considerable technological competence, but a deficiency of innovative potential within the socialist system led to political pressures on key firms to innovate "by plan." These findings on Zeiss Jena imply that technologically viable firms can fail during the initial period of transition from socialism to capitalism. The diagnosis of a lack of innovation and faulty managerial incentives as the disease that is "cured" by market reforms should be balanced by an understanding of the actual capabilities of socialist firms and the difficulties of radical change mandated by brutal shocks to the macroeconomic system.

THE indisputable hardship associated with the economic and social renewal of the former states of the German Democratic Republic (GDR) poses the question of why the richest country in the Soviet system, absorbed by one of the richest Western capitalist countries, suffered so painfully following the collapse of Communism. Since its beginnings as a science of transition, sociology has debated this global change from what Polanyi (1944) called "redistributive" systems to market systems. The current discussion of the transition from the Soviet economy to a market economy is marked by the debate over the policies required for successful transitions. The neoliberal position, which has prevailed in eastern Germany, argues for the resolute building of capitalism by design and through the rapid reform of "shock therapy"—a set of policies consisting of privatization, macroeconomic stabilization, and elimination of price controls. The creation of a market economy is seen as bringing the novelty of modern private corporate entrepreneurship to noninnovative socialism (Róna-Tas 1994). Influential statements of the benefits of "shock therapy" or "big bang" have been made by Sachs (1994) in reference to Poland, by Kornai (1990) in reference to Hungary, and by Åslund (1995) in reference to Russia. An alternative policy begins when a country is already rebuilding

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organizations and institutions, not *on the ruins* but *with the ruins* of Communism (also see Stark 1992; Walder 1995). In this institutionalist view, transition occurs through the transformation of existing organizations and institutions as they adapt to the changing socioeconomic environment (Fligstein 1997).

These issues hearken back to a prior debate concerning the relative capabilities of socialist and capitalist firms. Are firms under socialism, as Schumpeter (1942) predicted, as capable and innovative as bureaucratic capitalist firms are? Or is the relevant comparison, as Hayek (1988) stated, not between socialist and capitalist firms, but between the abilities of "planned innovation" and the emergent and innovative properties of market competition to generate what he calls an "extended order"?

Our study has two goals. The first is to compare similar firms working in socialist and capitalist systems. By this comparison, we seek to understand firm behavior in different institutional settings and to evaluate empirically the innovative achievement of socialist firms compared with capitalist firms. Based on this comparison, our second goal is to analyze the effects of macrolevel radical changes on organizations and institutions existing during the time of reforms.

To understand firm behavior and capabilities under different institutional settings, we exploit an unusual natural experiment. After World War II, the optical firm, Zeiss, was split into two independent companies—one was located in Oberkochen, West Germany, and the other in Jena, East Germany. By comparing the patent histories of these two companies from 1950 to 1990, we analyze their cumulative technological innovations and their efforts to diversify into new technical fields. These natural conditions create our experimental design—we treat the East German operation in Jena as exposed to 45 years of socialism, while the West German operation in Oberkochen serves effectively as the capitalist control. The historical experiment ends in 1991, when Zeiss Oberkochen acquired parts of Zeiss Jena in the wake of German reunification. The subsequent patent history of the reorganized assets *not* acquired by Zeiss Oberkochen allows us to evaluate the technological capabilities of a socialist firm in the context of a capitalist economy.

The transition from socialism to capitalism places the socialist firm in a quandary regarding how to adapt to new institutional and competitive conditions. An evolutionary perspective, such as that proposed by Murrell (1992), has a natural affinity with Stark's (1996) emphasis on the recombination of existing institutions as innovative and adaptive responses to the collapse of Communism (or what Burawoy [1997] calls "involution" of the economy). In this view, firms in transition countries are in crisis not because of a lack of incentives or the lack of capital, but because of deficiencies in their systemic capability to compete in capitalistic markets. Firms are repositories of knowledge, which means that they operate by a body of routines and organizing principles that are only imperfectly understood and are open to facile manipulation (Kogut and Zander 1992; Nelson and Winter 1982). Firms' resistance to change is not a result of faulty incentives, but rather of their difficulty in reconstituting their ways of doing things. In a period of disequilibrium, the market-price mechanism can eliminate potentially viable firms. In his seminal article on a theory of innovation and evolution, Winter (1964) makes this point by analyzing formally how efficient firms can be disadvantaged under price disequilibria. Gradualist policies allow firms to adapt gradually to the new conditions by an evolutionary transformation, but the initial institutions have persisting effects.

German policy in the East could not strictly follow the principles of shock therapy owing to the particular political considerations entailing German reunification. Firms were privatized fairly quickly, but state subsidies to firms and, more directly, to workers have been substantial. The political policy to convert the East German mark at an overvalued exchange rate, and the subsequent fixing of East German wages relative to West German wages at a level not justified by productivity differences, discouraged investment. As a consequence, transition in East Germany proceeded under the challenging condition of excessively high wages. Because these policies constituted a market "shock," East Germany provides a laboratory in which to address whether socialist firms had developed sufficient capabilities to survive in a radically different macroeconomic climate.

No one doubts that the excessively high wages, given the impoverished capital stock that was inherited from the old regime, made the transition difficult. The interesting question is whether the inference from this observed handicap should be simply that market incentives were inadequate to compensate for the harsh macroeconomic conditions. An evolutionary perspective points not to incentives, but to the difficulty of transition even for the most capable firms of the socialist system. This inertia is a result of the stickiness in adapting capabilities developed under one system to the institutional environment of another system. Studies on returns to human capital in Russia have shown that returns to education did not increase during transition, indicating that individual capital is not always adaptable to new market conditions (Gerber and Hout 1998). The case of Zeiss Jena is particularly instructive for understanding organizational capital because the firm was one of the best and most favored enterprises in the former GDR. The analysis of its record of innovation under socialism and the institutional factors that influenced its evolution opens a window for observing the conditions of radical transition through the interplay of organizations and institutions.

THE NATURAL EXPERIMENT

An experimental design seeks to measure the effects on a dependent variable (or outcome) achieved by varying an experimental condition or treatment. The presence of other potential influences is eliminated in a controlled setting by using a random sample. Outside the laboratory, these controls are applied by measuring their contribution to changes in the dependent variable to isolate the influence of the treatment condition; the samples are often not random. A natural experiment is a design that, while also using non-random samples, is able to isolate the effects of the treatment variable by eliminating the effects of extraneous factors. Cook and Campbell (1976) describe natural, or field, experiments as a powerful methodology capable of yielding results that are high in both internal and external validity. Examples of earlier studies capitalizing on natural experiments are Siegel and Siegel (1957); Notz, Staw, and Cook (1971); Staw, Notz, and Cook (1974); Staw (1974); and Firebaugh and Chen (1995). (An early survey of experimental designs using nonrandom treatment groups is given by Campbell and Stanley [1966].) By employing a matched-pair design, a natural experiment avoids some of the problems of "conjunctural causality" (or multiple causes) inherent in comparative work (Ragin 1987).

The division of the German optics firm Carl Zeiss into two firms at the end of World War II created conditions suited to a natural experimental design. At the end of the war, U.S. forces evacuated the board of management of the Zeiss firm (located in Russian-occupied Jena) and about 100 of its scientists and technicians to West Germany. Shortly before that, the Jena factory had been largely destroyed. Both Zeiss Oberkochen and Zeiss Jena started their operations with basically no physical assets. The machines left in Jena were deported to the Soviet Union as war indemnity during the 1940s.

For our purposes, we identify the patents of the two firms as the experimental outcomes that measure the technological output of the two firms for the period 1950 to 1990. The treatment is the imposition of a socialist planned economy in Zeiss Jena in East Germany, while Zeiss Oberkochen in West Germany is used as the experimental control. The research design thus compares the stock and development of technological skills in the West German and East German firms after World War II until their reunification in 1991.

Zeiss Jena is not a representative GDR firm. It is important, however, to understand the uniqueness and benefits of this experimental design. First, there are few other company pairs that constitute such a natural experiment—Schott, the glass supplier to Jena, is the only other case to our knowledge. The two Zeiss firms are comparable as both companies pursued technological strategies. Zeiss Jena was often mentioned as one of the five stars in the GDR (Henkel 1988). (The other high-performing firms, regarded as internationally competitive by local expertise, were Robotron, Kombinat Chemieanalagebau, Kombinat Polygraph, and Gaskombinat Schwarze Pumpe.) Second, this matched pair removes the common idiosyncratic elements resulting from industry and founding differences. Moreover, the "left censoring" problem in event studies is also minor, since we trace the two firms soon after their division.

The critical element of this natural experiment is the exposure of Zeiss Jena to a socialist environment. Of course, the Federal Republic of Germany (FRG) was not a purely capitalist economy. State-owned firms dominated many important industrial branches, and state equity investments could also be found in important firms in the auto, steel, and banking sectors, among others. The state, often at the provincial level, also provided important subsidies to research and development (R&D) and occasionally promoted particular sectors. Nevertheless, by almost all measures, there were substantial differences in the economic management of the two Germanys. For example, the GDR held tight control over prices for all products, including imported goods; its investment policy was stipulated by a central plan, even if the investment projects were the negotiated outcome between bureaucrats and top managers; it progressively nationalized industry and agriculture, with only a small proportion in private hands; and it did not permit new firm foundings and promoted the grouping of firms into large industrial combines (Kombinate) (Kogut 1983). Because of such differences, it is reasonable to analyze the two Zeiss firms as subject to radically different system effects, which we label socialist and market capitalism.

The Pre–World War II Period

For the first 100 years of its existence, Zeiss was headquartered in Jena. The firm produced and sold microscopes and other optical instruments that were developed in close cooperation with the University of Jena. In the early 1900s, Zeiss competed successfully in international markets and engaged heavily in foreign direct investment (Hagen 1996). Some two-thirds of production was sold in countries outside Germany. During the late 1920s, Zeiss became a conglomerate by acquiring German suppliers and competitors (Schumann 1962). By 1945, the percentage of Zeiss Jena turnover coming from military production had risen to 75 to 80 percent, and some 16 separate R&D laboratories were operating in Jena (Dornseifer 1994).

The West: Zeiss' Operations in Oberkochen

The Oberkochen operation of Carl Zeiss commenced from scratch in 1946 when 85 Zeiss managers, engineers, and designers were deported from Jena by the U.S. occupation forces to Heidenheim in Baden-Württemberg (Carl-Zeiss-Stiftung 1985). The managers were promised that their archives, technical documentation, patent records, as well as their laboratory equipment would accompany them; none of these materials ever reached them, and they later surfaced in the United States. In setting up the new Carl Zeiss enterprise, the managers and engineers, including the whole Board of Directors ("Vorstand"), decided to settle in Oberkochen because of the availability of a suitable empty factory that had produced landing gears for aircraft.[1]

The new location was unfortunate in that the vital contacts with a first-rate university like the University of Jena were impossible to recreate in Oberkochen. However, access to major railway lines and the ample supply of knowledgeable workers ("Facharbeiter") proved to be important for the development of the new enterprise. The large representation of researchers and developers in the "immigrating" group of Zeiss employees led to rapid development of new products, although these were heavily based on work carried out in Jena before the move to Baden-Württemberg. The production of optical instruments in Oberkochen began in 1946. Early products were stereomicroscopes, for which a modular production technology was developed and introduced at an affiliated facility in Göttingen in 1947.

Over time, microscopes for surgeons as well as other medical equipment became important products, together with photographic

[1] Interview with Dr. Pfeiffer, information manager at Zeiss Oberkochen, March 12, 1993.

lenses, eyeglasses, and different types of measuring equipment. R&D and production in the microscope area were soon carried out in parallel in different West German units, an organizational move that led to considerable internal competition. This competition stopped to a certain extent when R&D on microscopes was moved from Göttingen to Oberkochen. Producers of machinery and other related supplies emerged around the Oberkochen factory and were closely linked to the Zeiss group.

In the 1980s, the Zeiss Oberkochen company was represented in all continents and exported 50 percent of production. Zeiss Oberkochen had over 20 overseas production plants and operated workshops, sales subsidiaries, and agents in more than 75 countries. Alliances existed with Swedish, German, American, and Japanese companies. Zeiss in 1990 had 14,453 employees, of which 11,598 were in West Germany. Sales exceeded 2 billion deutsch marks (DM). The West German Zeiss companies in the mid-1980s devoted some 10 percent of their turnover to R&D (Carl-Zeiss-Stiftung 1985). Important product areas were microscopy (light and electron), surgical products (ophthalmic, neurological, brain, and otological microsurgery), surveying and photogrammetry (aerial photography), industrial measurement, opto-electronic modules, and ophthalmic optics (spectacles, lenses, binoculars, and rifle scopes). The West German companies also marketed consulting and engineering services related to large, custom-built instruments for astronomy, planetariums, laser range-finding equipment, thermal imaging, and night vision instruments (Carl-Zeiss-Stiftung 1985).

The East: Rise and Fall of the GDR[2]

Disagreements with the Soviet Union over the reunification of the occupation zones led the United States, Britain, and France to consolidate their zones in 1949 into the FRG (West Germany). Under Soviet auspices, the GDR was officially formed from the Soviet occupation zone in that same year under a Communist government. East Germany became a one-party state with rapidly nationalized industries and collectivized agriculture.

A mass exodus of 3.5 million people between 1945 and 1961 severely damaged the East German economy. Konrad Adenauer, West Germany's chancellor and foreign minister for 15 years starting in 1949, was committed to the reunification of Germany and refused to acknowledge the legal existence of the East German republic. In 1961, the Soviets authorized the building of the Berlin Wall, separating the eastern and western sectors of that city and cutting off the only remaining escape route to West Germany.

The building of the Berlin Wall marked the beginning of an economic revival for East Germany. In the early 1960s and again in 1968, new economic reforms loosened the control of central planning and encouraged investments in technology. Growth in gross domestic product in the 1960s was impressive, but heavy industry and energy production were a priority over the production of consumer goods. The drift toward market socialism was halted in 1970 following severe bottlenecks in production. As a consequence of policies introduced in 1971, the GDR had one of the highest worldwide levels of state ownership and industrial concentration of firms: About 95 percent of industry and agriculture were state-owned or cooperatively held. Increasingly, firms were organized into large holding structures (called *Kombinate*) with the intent of decentralizing some central planning to these intermediate units. Production in the nationalized firms (VEBs) was based on indicators in national economic plans. Short-term annual plans were complemented by medium-term five-year plans and 15-year long-term plans, as well as 30- to 40-year forecasts. Plan directives were given by the party congress (Schneider 1978).

In comparison to developments in the West, these policies did not work (see Maier 1997, chap. 2). Labor productivity declined to about 50 percent of that in West Germany; the high level of work force participation by less costly female workers (84 percent) partly compensated for low overall productivity. Yet, GDR citizens enjoyed the highest standard of living in the Eastern bloc in terms of car density (209 per 1,000 inhabitants), housing standards, and urbanization. In terms

[2] This section is based on Falk (1990), Järtelius (1987), and Tiusanen (1984).

of GDP per capita, the GDR in the postwar years could be compared to Spain, Portugal, Greece, and Ireland. The official statistics, however, hid the vast problems in quality-of-life and strength of infrastructure. Despite falling productivity and investment, the government sought to maintain consumption levels through foreign borrowing. Consequently, in the 1980s disposable income grew faster than national output. Maier (1997:78) cites the chair of ministers, Willi Stoph, as noting ironically during this time that "in terms of distribution, we're champs." By 1990, the shortage of investment goods and the collapse of demand in East Germany seriously impaired the economy.

The Communist state withered away soon after its fortieth birthday. Although opposition forces had been suppressed by a well-developed system of state repression, protests erupted in 1989 (see Opp and Gern 1993). Less than a year later, a single political and economic entity was created from two economies with fundamentally different underlying principles of economic organization and substantially different levels of economic development. With reunification of the two Germanys in the fall of 1990, state-owned property was transferred to the Treuhand, a government agency entrusted with the privatization or liquidation of existing state firms. By 1995, the Treuhand had privatized 13,800 firms, completed its task, and was dissolved.

The East: Zeiss' Operation in Jena

At the end of the war, the Jena operations of Zeiss were for the most part destroyed by Allied air raids. Because of Zeiss' value for industrial and military production, its capital equipment was shipped to the Soviet Union. In the years after the war, most of the scientists (including some from the University of Jena) made their way to a new facility in West Germany. Zeiss Jena inherited no more than empty buildings, patent rights, and the local work force.

The late 1940s and early 1950s were a period of reconstruction in Jena. Already in 1945, Zeiss delivered movie projectors and cameras to the Soviet Union as war indemnities. The reconstruction of the camera industry of Saxony gave a small boost to Zeiss to supply small numbers of photographic lenses that were not exported to the U.S.S.R. Lenses for spectacles were the first products to be sold in the domestic market. Engineers and master craftsmen from smaller firms in the Thuringia area helped Zeiss rebuild factories and machine equipment. In the 10 years following the war, Jena employees reconstructed 53 types of machines for shaping glass and metal, substantially improved and reconstructed 84 other types of machines, and developed and built 74 new types of special machines (BACZ 1955).

Zeiss Jena regained a remarkable competence in optics. Unable to compete in Western markets, partly because of the lack of legal agreement with its Western counterpart, Zeiss Jena became a primary supplier of lens and optical equipment to the Soviet bloc. The technological efforts, under the management of Carl Müller and Rudolph Müller, came to focus on computing machines for the design of photographic lenses. Contacts were established with the Polytechnic University in Dresden, while close contacts with physicists at the University of Jena were maintained through a substantial annual grant. In 1950, the Zeiss works employed almost 13,000 people who were working on fulfilling the established five-year plans. Efforts were made to educate local youth and women for future work in the firm through an apprenticeship system (BACZ 1950).

During the 1950s, VEB Optik Carl Zeiss Jena was determined to remain a technological leader in the field. Zeiss Jena expanded from 10,242 employees to 18,554, of whom 2,300 could be characterized as involved in scientific pursuits (Carl Zeiss Jena 1960). In 1952, VEB Optik Carl Zeiss Jena showed its first electron microscope at the Leipzig Fair.

In the 1960s, GDR politicians under Walter Ulbricht vigorously pursued the idea of specialization in an era of economic reforms. They proposed that Zeiss develop into a pure engineering enterprise. Efforts were made to have other GDR firms (like Optik-Maschinenbau, Rathenow, and Sempuco, Greiz) build standard machines so that Zeiss could concentrate on special machines requiring leading-edge scientific knowledge. Production was to take place in other firms, and Zeiss Jena would increasingly focus on developing scientific instruments. But there were emerging problems. In 1960, an internal report at VEB Carl Zeiss Jena acknowledged quality-control problems in production resulting from the urgent need to invest in important new machinery (BACZ 1960). The insufficient allocation of resources stemmed from supplier firms not fulfilling plan goals and from import restrictions. Problems also emerged in energy supplies and transportation.[3] In 1968, VEB Carl Zeiss Jena was, for all practical purposes, bankrupt. The production facilities were empty, and the firm could not service its debts.

Zeiss Jena's subsequent revival stemmed from the recognition of its potential contribution to the new economic policies of the 1970s. Throughout the 1970s and 1980s, East German officials emphasized the importance of R&D, the link between science and production, and the ongoing rationalization of production. To aid in the rationalization of research and production, the state-owned enterprises (VEB) were gradually integrated into larger production units (*Kombinate*). Zeiss was transformed into a so-called *Stammkombinat* (core enterprise) and was given the status of a Kombinat with integrated control over other state-owned enterprises.

In 1981, the tenth Party Congress gave priority to the use and development of microelectronics, robotics, electronic control of machinery, and computing (Biermann 1988). The growing concern of the socialist bloc countries over the rapid advancement of microelectronic technology in the West led to severe pressures on Zeiss to aid in the development of a modern semiconductor industry. (Optics is a key component in the lithography equipment used in semiconductor production.) Zeiss was reluctant enter into the production of semiconductor equipment. However, Wolfgang Biermann, the managing director of VEB Carl Zeiss Jena from 1976, yielded to political pressures after negotiating for the state to subsidize the project.[4] In 1983, he described the Kombinat's most important task as producing technological equipment for the microelectronics industry and introducing microelectronics into traditional optics. Products for the Soviet space program were also of higher priority than were consumer goods and components for GDR industry (Biermann 1985d).

Biermann played an active role in transforming a stagnating firm into a fast-paced East European technological leader.[5] Small management teams that were knowledgeable of the business were formed, and the Kombinat itself was divided into independent profit centers to increase worker motivation (Biermann 1985a, 1985c). To address the lack of transparency and lack of control, the accounting system was expanded throughout all functions of the Kombinat. To increase coordination with foreign trade organizations, these organizations were partly integrated into Zeiss (Biermann 1985a, 1985d). Attempts were also made to improve the relevance of university education by increasing the focus on application and flexibility in the education of engineers and business students.

The GDR government portrayed Biermann's leadership as a textbook example of progressive socialist management. In the still rigidly planned GDR economy, which had little room for flexibility and experimentation, Biermann enjoyed more latitude than most senior managers because of his closeness to the sources of political power. In Jena, production volume more than doubled from 1976 to 1984 using roughly the same labor force (around 50,000 employees). The export share of production was 60 percent (Biermann 1985e). In certain areas, such as planetariums, the Kombinat led the world in sales. In 1985, the Kombinant VEB Pentacon Dresden was incorporated in VEB Carl Zeiss Jena. The resulting Kombinant employed 58,000 people at 22 locations with a total turnaround of 4 billion East German marks.

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[3] BACZ (1960), and interview with Professor Mühlfriedel, Jena, September 15, 1994.

[4] Interview with Professor Mühlfriedel, Jena. Maier (1997:96ff.) provides a lengthy description of these disastrous policies.

[5] Many apocryphal stories about Biermann circulated in East Germany. One story is that Biermann stood at the entrance to the Zeiss skyscraper office in central Jena with a stopwatch and then ordered the elevators closed after the starting time for the day. Late workers would have to use the stairs. Zeiss also gained prominence because of its sponsorship of one of the most successful soccer teams in Europe.

By the late 1980s, Zeiss Jena had married optics with electronics and had become a major supplier of lithography equipment to Robotron's memory semiconductor facility. Under the leadership of Biermann, the firm tried to catch up with Western and Japanese leaders in semiconductor technology. However, the introduction of electronics into the traditional product lines created major problems when R&D resources were shifted from traditional optics to electronics (Biermann 1985c). The trade embargo on exports of strategically important products imposed by the U.S. government also forced Zeiss to scurry for suppliers and to develop in-house competence in a wide range of technologies (Biermann 1985e).

Still, the technological resources of Zeiss were impressive. If East German R&D statistics are recalculated according to the Frascati Manual (OECD-proposed standard practice for surveys of research and experimental activities), an impressive 4,100 Zeiss Jena employees were engaged in research in 1987. Of these, 47 percent were scientists and engineers, and 28 percent were technicians (SV-Gemeinnützige 1990:53–55). The firm spent 7.7 percent of turnover on R&D, which was among the highest percentages in GDR industry. The importance of Zeiss in East German society is highlighted by the fact that the Kombinat in 1987 employed 4.7 percent of all R&D personnel in the industrial sector.

THE STUDY

Data collection involved both public and archival sources. Initial interviews at Carl Zeiss focused on the historical development of the enterprises in Oberkochen, Baden-Württemberg and Jena, Thuringia. The information was complemented with archival data. Archival research was carried out onsite in the corporate archives of VEB Carl Zeiss Jena. Access to the information on the Zeiss Jena works presented an extraordinary opportunity by which to understand the evolution of organizational and technological capabilities during the period of state socialism.[6]

In addition to interviews and archival records, we collected patent data for the two Zeiss firms. Patents serve as quantitative indicators of the output of research efforts. They also signal the direction of technological efforts. Through frequent contacts with patent authorities, we created a database of patents granted to the West German and East German parts of Zeiss. There are no computerized international patent data for the pre-1973 period. Because we want to study the patenting efforts of both Zeiss firms from the time they resumed production after the war, we manually compiled data on Zeiss Jena's and Zeiss Oberkochen's patenting in their respective home countries. Interviews at Zeiss Oberkochen confirmed that national patent records captured the important technological efforts of the two firms during this early time period. For the period 1950 to 1972, the GDR and FRG historical records of patents were housed and collected at the German Patent Office in Berlin. The change in patent recording practice in the GDR of the 1960s, when patents were no longer assigned to firms but to individual inventors, made it impossible to assign patents to VEB Carl Zeiss Jena for this period. Thus, we could not record Zeiss Jena's patenting for 1960 through 1969 and this period is lost to our study.

For the period 1973 to 1990, computerized data on the international patenting efforts of the two Zeiss firms were available through the European Patent Office in Vienna, Austria. We used the INPADOC database, which is the most comprehensive patent database for the countries covered. It includes the international patent documents of 66 national and regional patent offices. The distribution by country of the first granted patent publication for the two Zeiss firms is shown in Table 1. As expected, both firms first filed the majority of their patents in their respective home countries. Jena's share was 73 percent, while the more internationally active Oberkochen firm's share amounted to 40 percent. Zeiss Jena also patented frequently in France, Great Britain, Japan, and Switzerland, while Zeiss Oberkochen preferred Europe-wide patents,

[6] We are grateful to Frau Hellmuth for her help during the chaotic time when the archives suddenly and unexpectedly moved to another location in Jena.

Table 1. Number of Patents Filed, by Country, for Zeiss Jena and Zeiss Oberkochen, 1973 to 1990

Country	Zeiss Jena	Zeiss Oberkochen
Within Country		
GDR	1,674	—
FRG	—	724
Outside of Country		
Australia	—	16
Austria	—	2
Belgium	—	1
Brazil	—	15
Bulgaria	5	—
Canada	2	3
Denmark	2	8
Finland	5	3
France	162	59
Great Britain	140	266
Hungary	13	—
Italy	2	14
Japan	139	230
Netherlands	—	13
Norway	—	7
Poland	5	—
Portugal	—	2
Soviet Union	31	—
Spain	—	2
Sweden	27	2
Switzerland	54	4
United States	—	36
International		
Europe-wide patents	8	359
World patents	—	26

and also patented in Great Britain, Japan, and France. Our analysis of the patent data relies on a single patent for an innovation; multiple patents were eliminated (i.e., one innovation patented in multiple countries) by checking the records of each filed patent for the original filing.

Our database contains information on applicants, dates, and countries where patents were granted, patent numbers, and priorities. Because the different systems do not use a standard classification code, the patents for the entire 40-year period were also reclassified and analyzed according to the sixth edition of the *International Patent Classification* (World Intellectual Property Organization 1994). Table 2 presents an overview of patent data sources.

With the exception of the 1960s policy change, East German patents followed international patent standards. The GDR authorities, like those in West Germany, granted patents on the basis of novelty, applicability in industry, and technological progress. Successful patent applications had to show an inventive step—it should not be possible to derive the innovation from the known state of the art. In addition to "normal" exclusive patents, the GDR system also granted nonexclusive *Wirtschaftspatente* (in which the right to use the patented invention was shared among the inventor, socialist enterprises, and state organs of the GDR), as well as secret patents. One notable difference from Western patent laws was the rule that an invention was not patentable if it offended the socialist morality. As in the West, patent applications were examined by a Patent Office for form, patentability, novelty, and substance, and subsequently were published if accepted. Comparability with the West was key, since patents in East Germany were critical for international trade. Patents had to hold up in international courts, which became obvious during the legal battles between Zeiss Jena and Zeiss Oberkochen in the 1960s. The quality of East German data is reflected in the GDR's qualification as one of the 16 countries in the European Patent Office database for which both patent documents and legal status data were recorded.[7] It is important to note that we concentrate on the relative patenting in a number of technological areas, not the absolute number of patents.

To determine the overlap or correlation of the patent portfolios of the two Zeiss firms,

[7] For an in-depth account of the patent laws of the GDR, see Manual of Industrial Property (1992). We thank Helena Fernholm of the Swedish Patent Office, Jens Breiding of the German Chamber of Commerce in Stockholm, and Arthur Emtedahl and Petter Rindforth of Enderborg and Partners for their assistance.

Table 2. Data Sources for Patents Filed

	1950s	1960s	1970s	1980s
Zeiss Oberkochen	West German Patent System	West German Patent System	West German Patent System, 1970–1972 European Patent Office, 1972–1979	European Patent Office
Zeiss Jena	East German Patent System	Missing	East German Patent System, 1970–1972 European Patent Office, 1972–1979	European Patent Office

we apply a simple statistic developed by Jaffee (1986). This statistic is defined as:

$$P_{ij} = \frac{F_i' F_j}{\sqrt{F_i'^2 F_j^2}}.$$

where F is a vector consisting of the proportion of patent counts in a given classification. The elements of this vector sum to 1.0. The numerator is the dot product of the Zeiss Oberkochen and Zeiss Jena patent portfolios. The denominator normalizes this statistic by squaring each vector, multiplying the scalar products, and then taking the square root. This statistic varies between 0 and 1, and hence is not the standard correlation. This measure is less sensitive to differences in the length of the vector than is Euclidean distance used for standard correlations.

The patent classifications are similar to three-digit Standard Industrial Classification (SIC) categories. The eight International Patent Classification (IPC) sections can also be further broken down into 150 IPC subsections and 624 IPC classes. (A description of IPC sections is available from the authors on request.) The Jaffee statistic is calculated at the IPC-class level and allows us to determine to what extent the technological efforts of Zeiss Jena coincide with those of Zeiss Oberkochen. Because the correlations do not reveal the extent of differences in the degree of technological diversification, we also calculate Gini coefficients and use more aggregated classifications to weight more heavily the differences in broad technological efforts.

RESULTS

DEVELOPMENT 1950 TO 1990

Patenting in the two Zeiss firms from 1950 to 1990 reveals several remarkable similarities. For the 40-year period, we record 2,355 patents by Carl Zeiss in Oberkochen and 2,393 by VEB Carl Zeiss Jena. The distribution of patents by IPC section is shown graphically in Figures 1 and 2. Both Zeiss firms patented primarily in the IPC section "physics." Both firms also actively patented in electricity, chemistry, and mechanical engineering, while Zeiss Oberkochen was more active in human necessities and Zeiss Jena was more active in performing operations. At a higher level of disaggregation, Zeiss Oberkochen patented in 126 of the theoretically possible 624 classes, while Zeiss Jena displayed a broader technological profile by filing patents in 150 classes. (More details on diversification and a more refined description of technological efforts is available from the authors on request.)

CORRELATION ANALYSIS. The correlation between the overall number of patents of Zeiss Oberkochen and Zeiss Jena in the 207 different IPC classes is .943. As a benchmark by which to evaluate this correlation, it is interesting to note Helfat's (1994:179–180) finding that substantial differences exist among firms' R&D applications in the American petrochemical industry over an eight-year period. The correlation for the two Zeiss firms is thus surprisingly high given that the two firms operated in very different political and economic systems for the entire 40-year period.

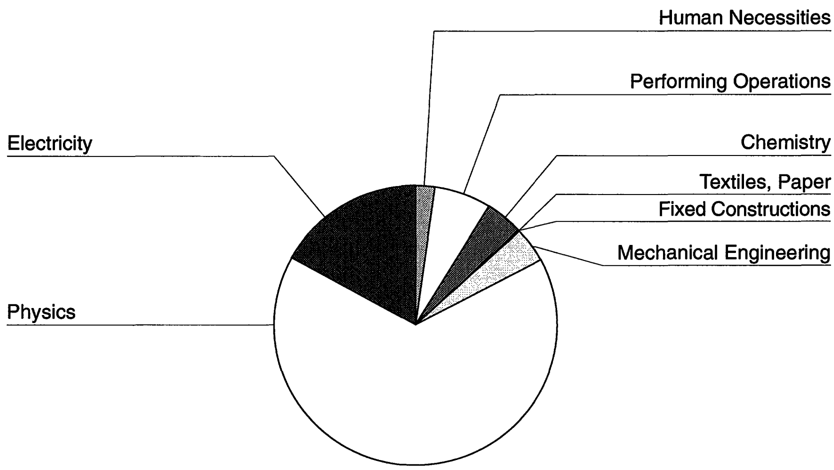

Figure 1. Zeiss Jena Patents Filed, by IPC Section, 1950 to 1990

One possible objection to the quality of the patent data is that the propaganda and industrial struggle between the two Germanys may have distorted their patenting behavior and the treatment of their patents. To verify the quality of the East German data, we compared the technological classes of the patents issued to the GDR and to the FRG in countries outside of Germany, as recorded in the European Patent Office. In these other countries, the patents of both Zeiss companies were submitted to identical standards, without ideological debate. The correlation between patents registered by the two countries in the technology classes is .88. The earlier correlation appears, at worst, only mildly sensitive to distortion due to patenting in the home country, or East German patenting in the FRG.

Because the two Zeiss firms served very different domestic and export markets, the high correlation in their patent registrations indicates that technological "push" is important. It is also possible that the two firms did not lose sight of each other's progress. It is, however, important to remember that even if Zeiss Jena benefited by observing its Western counterpart, it had to retain an important capability to create, absorb, and exploit technological knowledge. Also, the political pressures that Zeiss Jena experienced over the 40-year period were extremely erratic. Consequently, it was by no means consistently focused on keeping up with its Western sister firm. Finally, because we use patents to compare the technological efforts of the two firms, the technologies we compare have all passed severe tests for their novelty

Figure 2. Zeiss Oberkochen Patents Filed, by IPC Section, 1950 to 1990

Table 3. Percentage Distribution of Patents Filed, by IPC Section: Zeiss Jena and Zeiss Oberkochen. 1950s to 1980s

	1950s		1960s		1970s		1980s	
IPC Section	Jena	Oberkochen	Jena	Oberkochen	Jena	Oberkochen	Jena	Oberkochen
Total patents filed	66	313	—	215	224	509	2,051	1,318
Number of IPC classes	20	29		20	52	69	142	90
Human necessities	5	12	—	4	1	11	2	9
Performing Operations, transporting	5	1	—	1	4	2	7	3
Chemistry and metallurgy	0	1	—	0	2	11	5	10
Textiles and paper	0	0	—	0	1	0	0	0
Fixed constructions	0	0	—	0	0	1	0	1
Mechanical engineering, lighting, heating, weapons	5	2	—	1	2	3	5	6
Physics	70	65	—	83	64	62	65	63
Electricity	15	19	—	11	26	10	16	8
Total percent	100	100	100	100	100	100	100	100

and uniqueness, which rules out blind imitation. We analyze the possibility of technological spillover more thoroughly by analyzing patenting in different time periods and examining simple lags in the correlations.

Trajectories of the Two Zeiss Firms

Table 3 shows the distribution of patents by IPC section for both firms from the 1950s to the 1980s. Zeiss Jena's patenting was dominated by efforts in the IPC physics section from 1950 to 1990. From 70 percent of the patents in the 1950s, the share in physics dropped to around 65 percent in the 1970s and 1980s. The share of patents in chemistry and metallurgy grew slowly but steadily over the period, while patents in electricity peaked at 26 percent of total patenting in the 1970s. In the 1980s, electricity patenting as a share was back to 1950s' levels of around 15 percent.

Patenting by Zeiss Oberkochen was also dominated by patents in physics over the four decades, with its share of the total peaking at 83 percent in the 1960s, but then returning to figures around 60 to 65 percent. The share of patents in chemistry and metallurgy increased considerably in the 1970s and remained about 10 percent in the 1980s. Unlike Zeiss Jena's profile, the share of patents in electricity fell from almost 20 percent in the 1950s to 8 percent in the 1980s.

The analysis of patenting by broad IPC sections again reveals surprising similarities between the profiles of the two Zeiss companies operating in different economic systems.[8] Yet, there are two main differences between the companies. First, Oberkochen expanded its patenting in the chemistry and metallurgy sections earlier and faster than did Jena. In the 1970s, Oberkochen's share was five times higher than that for Jena, and it remained at twice Jena's share in the 1980s. Second, Jena increased its share of patents in electricity to 2.6 times times that of Oberkochen in the 1970s, and it remained twice the share of Oberkochen in the 1980s.

[8] Interestingly, a study by Allmendinger and Hackman (1996) reveals that East German orchestras exhibited remarkable stability and continuity with their traditions despite two radical changes in the country's political-economic system—when the socialist regime took power after World War II and in 1990 when the regime fell.

Table 4. Correlation Analysis of Patenting in the Two Zeiss Firms by Decade

Decade	Firm	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1950s	(1) Jena	.94	NA	.85	.77	.81	.88	.84
	(2) Oberkochen	—	NA	.86	.68	.84	.83	.80
1960s	(3) Jena	—	—	NA	NA	NA	NA	NA
	(4) Oberkochen	—	—	—	.70	.92	.91	.90
1970s	(5) Jena	—	—	—	—	.72	.89	.92
	(6) Oberkochen	—	—	—	—	—	.88	.93
1980s	(7) Jena	—	—	—	—	—	—	.93
	(8) Oberkochen	—	—	—	—	—	—	—

Several interesting differences emerge through a finer analysis of the data. In absolute terms, both firms diversified their technology—they patented in more IPC classes. The change in technologies and products over time in both Zeiss firms is striking.

Correlation Analysis. Table 4 shows the correlations between patenting activities in Zeiss Jena and Zeiss Oberkochen for the 1950s, 1960s, 1970s, and 1980s. There is striking similarity in the technological profiles of the two firms in different socioeconomic environments. After 40 years of socialism and a centrally planned economy, the areas of invention for Zeiss Jena and Zeiss Oberkochen still showed a correlation of .93.

The correlation analysis provides a qualification to the "natural" experiment. For the 1970s, the correlation between Oberkochen and Jena is only .72. Given the much higher correlation for the 1980s, why did the two firms deviate for the 1970s? Lagged correlations suggest an answer. The correlation for Oberkochen for the 1970s and 1980s is .89. The correlation between Oberkochen 1980s and Jena 1970s is .92, suggesting that the patenting record of Oberkochen in 1980 is almost as highly correlated with Jena's patenting in the 1970s as it is with its own patent distribution in the 1970s. However, the correlation between Oberkochen in the 1970s and Jena in the 1980s is .88. In other words, to predict Jena's patenting distribution in the 1980s, it would be just as helpful to look at Oberkochen's patents in the 1970s as it would be to look at Jena's own patenting pattern for the same decade.

This statistical result stems directly from the move by Jena away from patenting in electricity in the 1980s. But this result suggests two other possibilities. One is that Jena consciously followed the technological efforts of its West German rival. Of course, even if there are imitative influences, the successful ability to build on the observation of another company's strategy and to generate new patentable knowledge indicates considerable technological capability in Zeiss Jena. The other possibility is that Zeiss Jena in the 1980s enjoyed more freedom in its research efforts, even while the GDR government insisted that the firm deliver optical components for the attempt to build a microelectronic industry.

Diversification Analysis. From 1950 to 1990, Zeiss Oberkochen patented in 126 of the theoretically possible 624 IPC classes, while Zeiss Jena displayed a broader technological profile by filing patents in 150 IPC classes. Jena went from patenting in 20 classes in the 1950s to patenting in 142 in the 1980s; Oberkocken went from 29 classes to 90 classes. To analyze further the patenting profiles of the two Zeiss firms, we calculated Gini coefficients to measure the extent to which the two firms focused their technological efforts.[9] A value of 1 indicates that a firm is patenting in only one class; a value of 0 indicates that the firm distributes its patents equally across all classes. Table 5 shows that the Gini coefficients are consis-

[9] The formula used to measure "inequality" is $G = 1 + 1/n - (2/n^2)Y(y_1 + 2y_2 + 3y_3 + \ldots + ny_n)$, where $y_1, \ldots, y_n$ represent patenting in IPC classes in decreasing order of numbers, Y is the mean number of patents in an IPC class, and n is the number of IPC classes.

Table 5. Gini Coefficients for Patenting: Zeiss Jena and Zeiss Oberkochen, 1950s to 1980s

Decade	Jena	Oberkochen
1950s	.555	.717
1960s	—	.672
1970s	.598	.749
1980s	.754	.782

tently lower for Zeiss Jena than for Zeiss Oberkochen. Only for the 1980s is Jena's coefficient similar to Oberkochen's. Zeiss Jena Director Biermann's policy of focused research during the 1980s is apparently evident in the patent distributions. Because the Gini index measures "inequality," the results indicate that the East German operations had a less focused (more diversified) patenting profile than their West German counterpart until the 1980s.

The simple explanation for this result could be the necessities for Zeiss Jena to do R&D in a number of areas because of problems of purchasing necessary inputs in the marketplace (see Kogut 1983, for a discussion of the increase in in-house production by Kombinate). Jena engineers had to monitor and master a number of technical areas instead of focusing their efforts in certain narrow areas to develop superior competence. Resources (and resulting patents) seem to have been spread more evenly over the technological areas in which Jena was active. In the 1980s, Jena patented in more classes and the Gini index shows that its patenting efforts were less balanced, with "inequality" in patenting approaching Oberkochen's levels.

DISCUSSION

The history of Zeiss Jena's patenting confirms Schumpeter's (1942) principal point that the large socialist firm can successfully innovate. When the overall number of patents of Zeiss Oberkochen and Zeiss Jena in the 207 different IPC classes are compared from 1950 to 1990, the correlation is surprisingly high given that the two firms operated in very different political and economic systems for the entire 40-year period studied. However, the comparison of the two Zeiss companies clarifies an error in Schumpeter's argument that rationalized planning could successfully replicate the industrial research laboratory of the large capitalist enterprise. He assumed too readily that the market socialism of independent firms interacting with a central planner would be free of political interference.

The historical evidence from the archival investigation illuminates the negative effects of political decisions on Jena's research policies, the constraints of having to innovate by plan, and the pressures to supply a wide range of "customers." Zeiss Jena during the 1950s and 1970s displayed a much more diversified patent portfolio than did West German Zeiss. "Forced" diversification was also felt in other sectors of the GDR economy. For example, the Robotron Kombinat produced all electronic components for its products (Axell and Uppenberg 1991). As commonly experienced in all socialist countries, supply shortages were common owing to unplanned shortfalls in already "taut" planned targets (Kornai 1990). In this regard, Schumpeter underestimated the important property of the markets in providing variety and hence a division of labor that allows firms to specialize. In this latter sense, Hayek proved the more important point, namely, that the socialist economic system collectively could not generate the emergent order that spontaneously filters ideas and permits radical innovations.[10]

During the 1980s, the East German government increasingly came under pressure to deliver improvements in living standards while keeping up with the West in production of high technology, often for military use. As a result, pressures on the most dynamic firms increased, and demands were often unrealistic and inconsistent. In Zeiss Jena's case, the outcome is seen in its increased alignment with Oberkochen's patenting profile, its increased specialization as

[10] While we cannot evaluate the innovative record of the GDR, we note that the GDR was popularly known for very few innovations. One of them was a synthetic fiber (Dederon) whose name was a play on the name of the country (see Berliner 1976 for an evaluation of the Soviet system).

revealed by its patenting, and its efforts in the semiconductor area. In speeches to the Friedrich-Schiller-Universität during the mid-1980s (Biermann 1985a, 1985b, 1985c, 1985d, 1985e), Zeiss Jena Director Biermann spoke critically of party officials who interfered in a heavy-handed manner in the firm's activities and still had to be convinced that international competitiveness should be the aim of the Zeiss Kombinat. In 1984, Biermann (1985c) discussed openly the problems of R&D research in comparison with Western firms:

> This does not mean . . . that a scientist is only permitted to imagine what is presented already in the Plan, that he is permitted only to find what he searches. As always, the research process unfolds principally by creative processes, by its own particular laws that largely evade the clutches of planning. (P. 9)

In his speeches, Biermann pointed to motivational problems in research, problems of managing complex projects, lack of contacts with final producers and external buyers, and inflexible export contracts (Biermann 1985b, 1985c).

During the 1980s, patent specialization increased in Zeiss Jena, but management complained about the dual burden of supplying the domestic market while trying to address particular export markets. Politicians put Zeiss Jena under pressure to develop and produce large volumes of goods to satisfy the policy of catching up with Western living standards. In the Western export markets, the complex needs of large buyers required the most advanced technological features, but it was felt in Zeiss Jena that sales of these "spearhead" products were possible only if a full product line was offered in a few focused markets. Thus, Biermann tried to create an understanding that Zeiss should be allowed to focus on providing a full product line in core areas and not be forced to diversify.

Zeiss Jena's situation also differed considerably from Zeiss Oberkochen's because of its mandated role in cooperative programs among socialist countries. In addition to providing the great mass of consumers with certain scarce products, Zeiss Jena was asked to invest in research for military purposes. The military orders, of course, affected technological development, but these orders, when realistic, were directed to Zeiss based on its known capability—Zeiss did not create the market.[11] Partly isolated from Western suppliers and constrained by foreign currency, Zeiss suffered from the failure of the GDR to maintain the pace of the world market. An internal government document noted that when advanced technology is available, the GDR "can hold their own against the very best international achievements . . . . On the other hand, these results are unattainable when this computer technology is only partially available" (Maier 1997:74). Maier (1997:75) indicates that the unit cost of producing a 256-kilobyte memory semiconductor at Zeiss Jena was over 100 times the world price.

Zeiss Jena was indeed the Schumpeterian socialist firm, invested with substantial technological capabilities. But it was hampered by a system of central planning that dissipated innovative resources in accordance with planned targets. By 1987, the head of planning conceded that the state should give autonomy to the most dynamic Kombinate. Biermann's conclusions were more radical. He asked the powerful Economic Minister, Günther Mittag, whether it would not be better to abolish the ministry responsible for science and technology that encouraged "no strategic impulse whatsoever from the Kombinate" (cited in Maier 1997:96). Whatever Mittag's answer, it came too late.

Based on the natural experiment analyzed here, we contend that the best *socialist firms in the high technology sectors did not lack technological capabilities or even lack the managerial capabilities required for market*

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[11] In losing Eastern Europe, Russia lost its best captive defense contractors, among them Carl Zeiss Jena, which supplied the Soviet Union with laser rangefinders, infrared and night-vision equipment, missile-guidance systems, and optics for satellite reconnaissance and space weaponry. Shortly after the unification of Germany, the U.S.S.R. announced its intention to unilaterally halt all new production of mobile SS-24 intercontinental missiles. According to East Germans formerly involved with weapons procurement, the Red Army was no longer able to get the SS-24's key guidance system from Zeiss Jena (Fuhrman 1991).

competition. Zeiss suffered because of the Plan's refusal to permit experimentations in any sector of the economy to fail. This meant that the firm could not rely on the emergence of external innovations. As a consequence, Zeiss was forced, by plan, to try to succeed in areas in which it knew it had already failed.[12] In addition, lacking close contacts with advanced consumers and suppliers in many areas, Zeiss was denied the benefits of what Hayek called the "extended order" that constitutes the market. Instead, the firm had to struggle with inconsistent demands from politicians under increasing pressure to make the socialist system perform in comparison to Western capitalism.

Accepting that firms like Zeiss were hampered by the absence of a division of labor in the market, it is not at all obvious that weak incentives provide an adequate or even necessary explanation for the performance of socialism as a system. In fact, it is hard to imagine Western firms spending as much time creating new incentives, and measuring them, as did managers and bureaucrats in the socialist economies. There is little evidence that managers in the GDR were deficient in their educational and technical training.

It was not that the GDR firms were politicized as the state ministries pursued political goals in opposition to economic efficiency. They were, of course, under political pressures to fulfill the planned targets for innovation. The state ministries had only the Plan to rely on for the critical innovations needed for their microelectronics policies. Yet, in many ways, socialist ministers and managers were not unlike their Western counterparts who also struggled to compete in the fast-moving microelectronics industries.

The difference between socialism and capitalism is that the former could not rely on the extended order to provide the innovations in the case of failure. In the absence of this insurance policy, the socialist firm could not discover its specialization—its specialization and competence were stated in the Plan and there was no redundancy except the constrained and limited access to world markets.

These results resemble Saxenian's (1994) comparison of high technology firms in the regions around Boston and Silicon Valley. She contends that the innovative success of any one firm is contingent on local dynamism in the region. The comparison of patent records of the two Zeiss firms shows a remarkable similarity in the direction of effort, but Zeiss Jena's economic and social environment appears to have been clearly deficient in providing the technological diversity to support its innovative efforts.

ZEISS AND THE TRANSITION PROCESS

The description and comparison of the innovative activities of the two Zeiss firms throw light on the preconditions for the transition from a socialist planned system to a capitalist market economy. Zeiss Jena had been a technological success in the socialist system. Competence was built up technologically, and the firm possessed valuable knowledge related to Eastern markets. Yet, these valuable assets could not be easily adapted to new conditions. Zeiss Jena did not have the systemic resources to compete in the new system. Yet, the reform policies were largely indifferent to the tapering of systemic change to these historical conditions. Rather, massive systemic change was followed by frustration over the slow process of the transformation of individual firms.

The economic conditions of the German reunification agreement created a macroeconomic shock owing to the sudden increase in the real wages of East German workers, despite their lower productivity compared to West Germans. The creation of a currency union and the elimination of all trade barriers between the two former German countries had devastating consequences on East German producers. If ever a country underwent a shock therapy by radical price decontrol, it has been the Eastern states of the reunited Germany.

It must be emphasized that the conditions surrounding reunification dictated the outcome and may not have left politicians with many policy choices. The outcome was a

[12] During a stay in the GDR in 1981, Kogut was asked by an East German student about the quality he felt was most lacking inthe GDR. Upon responding "spontaneity," the student replied, "We are working on it."

pure case of what "shock" means (with the exception of certain subsidies). The economic consequences of these policies—no matter the necessity of their political motivations—have been devastating. According to Owen (1991), two striking features of the monetary union were the surge in exports from West to East Germany and the virtual collapse of East German industrial output. By September 1990, industrial output had fallen to a level 51 percent below its level in the same month of the previous year. The loss of most East European markets began early in 1991 and brought industrial production down to one-third of the pre-currency-unit level where it has stabilized (Roesler 1994). The social impact in East Germany was felt through a reduction in employment from 9.75 million to 6.4 million between 1989 and 1992 (Vogt 1992). Labor productivity, estimated to be half that of West Germany, also decreased between 1989 and 1992. Despite the sell-off and liquidation of East German enterprises, the West German state had to provide massive subsidies. By any account, the costs of reunification have been nothing short of catastrophic.

Even if the fate of Zeiss Jena has been better than that of many other firms of the former GDR, the events following the reunification of Germany *display what may happen to capable firms given very little time to adjust to a radically different socioeconomic environment.* In October 1991, following long negotiations with the Treuhand, two new companies emerged from the former Kombinat VEB Carl Zeiss Jena: Carl Zeiss Jena GmbH and Jenoptik GmbH. The agreement also sealed the merger between Carl Zeiss Jena GmbH and Carl Zeiss Oberkochen, in which the traditional business of optical instruments was to be made competitive. Jenoptik GmbH, containing the remaining business divisions, was named the legal successor to the old Kombinat.

In May 1995, Carl Zeiss Jena GmbH, containing the traditional parts of Zeiss' activities, became a wholly owned subsidiary of Carl Zeiss Oberkochen (Scherzinger 1996). The production of small microscopes (the C-class) was moved from Göttingen in the West to Jena. The production of medical apparatus was also moved from Calmbach in the West to Jena. These transfers of production were in accordance with the obligation by Zeiss Oberkochen to the Treuhand to keep around 3,000 workers out of the original 27,000 employed in Jena. Zeiss Jena was on verge of being wiped out by a neoliberal transition policy.

The non-acquired part of the old VEB Carl Zeiss Jena, Jenoptik, was technologically capable but lacked a brand name, competitive products, and international distribution channels. The markets in the East, once the main sales area of the Kombinat, as well as the profitable military production had ceased to exist. The company, however, had inherited many highly qualified employees with excellent knowledge of laser, outer-space, and semiconductor technology, and the core areas of opto-electronics, systems technology, and precision manufacturing from the former Kombinat (Jenoptik 1998:4). Despite this, the firm in the early 1990s was struggling. Only after massive protests by Jena workers threatened by the loss of their jobs did the local state act. The Treuhand in 1992 took over 80 percent of the assets of the bigger part of the 12 former Zeiss plants, at the time administered by the state of Thuringia under the name "Jenoptik Carl Zeiss Jena." Thuringia financed the repurchase of the remaining 20 percent of the assets in order to save some 6,800 jobs in the new firm, Jenoptik GmbH (Roesler 1994).

The decision to subsidize Jenoptik because of popular pressure proved to be a successful policy. Jenoptik was privatized by a stock market introduction in 1998 in which enthusiastic investors oversubscribed the stock by 26 times. Based on the capabilities of the old Kombinat, the holding integrates more than 100 small firms active in semiconductors, laser optics, impulse physics, industrial measurement technology, automation, and information technology. Jenoptik reached a turnover of over 2 billion DM in 1997, and its two high technology divisions were very profitable. Main technologies include clean-room facilities for chip and pharmaceutical production, robots and software for automation of semiconductor fabrication plants, laser instruments, special optical components, and industrial measuring systems. These areas of technology correspond well to the activities of the old Kombinat Carl Zeiss Jena and were not of

Table 6. Percentage Distribution of Patents Filed, by IPC Section and Subsection: Comparison of Jenoptik, 1991 to 1998 with Zeiss Jena, 1950 to 1990

IPC Section/Subsection	Jenoptik, 1991–1998	Zeiss Jena, 1950–1990
Physics		
Measuring, testing	26	31
Optics	10	21
Photography, cinematography, electrography, holography	5	5
Computing, calculating, counting	5	3
Controlling, regulating	3	1
Instrument details	2	1
Electricity		
Basic electric elements	16	8
Other	2	1
Communication	2	2
Performing Operations		
Conveying, packing, storing, handling thin or filamentary material	10	1
Machine Tools, metal working not otherwise provided for	2	2
Working of plastics, working of substances in a plastic state in general, working of substances not otherwise provided for	1	<1
Human Necessities		
Medical and veterinary science, hygiene	9	3
Mechanical Engineering		
Heating, ranges, ventilating	3	<1
Engineering elements or units, general measures for producing and maintaining effective functioning of machines or installations, thermal insulation in general	2	4
Total percent	98	84

Note: Table reports *most frequent* IPC subsections (out of 150 possible).

interest to Zeiss Oberkochen when they invested at the time of transition.

Today's technologically capable and successful Jenoptik firm would probably have become a victim of neoliberal shock therapy if the therapy had been strictly enforced. A comparison of the patents filed by Jenoptik since its creation with those filed by the old Kombinat between 1950 and 1990 shows an impressive continuity in technological effort. The Jaffee correlation is .7 for patents issued to Jenoptik between 1991 to 1998 and those of its GDR predecessor's for the period 1950 to 1990.

Table 6 provides a breakdown of the patents by main technology areas. The 167 patent applications filed by Jenoptik after the transition fall in 15 IPC subsections (out of 150 possible). Note that 83 percent of Zeiss Jena's patents during 1950–1990 fell in the same 15 classes and that the ranking of patent classes is similar. The remaining 17 percent of Zeiss Jena's patents were dominated by machine tools, measuring instruments for distances, computers and information storage, batteries, electric motors, and pulse technique. Jenoptik dropped these areas of technology in the face of competitive conditions after reunification. The Jaffee correlation of .7 reflects this policy of continuity in technological effort, though in a narrower spectrum of activities. Ironically, Jenoptik has focused many of its patents in the semiconductor and laser areas, capitalizing on the diversification into electronics mandated by GDR central planning in the 1980s. Able to specialize in areas of competence and to source components from a world market, Jenoptik has progressed rapidly in the area that most severely challenged Biermann and his company in the last decade of the GDR.

CONCLUSION

The attitude toward the socialist enterprise in the economics literature of transition is inherently ambivalent, if not contradictory. To a great extent, the presumption is that the socialist enterprise operated far from an efficient frontier of best practice and its vestiges during the period of transition were riddled by political resistance to economic reforms (Åslund 1995; Shleifer and Vishny 1994). Yet, at the same time there is a belief that market reforms are sufficient to weed out inefficient firms and to provide the proper incentives for better enterprises to move to efficient practices. The socialist enterprise is thus the bane of neoliberals, and yet it is the critical institution on which the success of radical reform rests.

The results of the natural experiment we evaluate here provide an institutional view of the causes of the German policy debacle in their efforts to revive the East by understanding institutional conditions in the GDR and their effect on one of the top firms in the system. The initial assessment in 1990 by the Treuhand of the state of East German companies estimated that only 30 percent of the firms were clearly salvageable. Another 50 percent of the firms were thought to be able to stand up to competition, but only after a long phase of thorough restructuring; and 20 percent were thought to face inevitable bankruptcy (Fischer and Schröter 1996). In 1991, 85 percent of the firms in Thuringia were in crisis (Zanger 1991). This situation may yield the misleading implication that East German industry had been under inefficient incentives to develop, in absolute terms, economically viable enterprises. One might as well ask how much of American industry would initially survive a such macro shock—one that not only radically reversed relative prices but also was accompanied by the loss of export markets and the collapse of internal demand.

A more appropriate inquiry for an analysis of the transformation is whether East German industry had the potential for self-renewal under the *newly prevailing conditions*. The analysis of the two Zeiss firms indicates that firms under socialism exploited technological opportunities but within their institutional context. In this regard, they accumulated capabilities to innovate and produce in response to their environmental signals. The pressures of the institutional environment were important in determining the development of technological capabilities of the East German firm.

It is an error to evaluate the competence of the socialist firm entering transition without recognizing that its accumulated capability had considerable value in a system deprived of spontaneous innovation and contacts with important buyers and suppliers. The focus in the transition literature on the inefficiency of socialist firms poses a biased frame by suggesting that poor management and weak managerial incentives impeded technological advancement. The critical starting point for an unbiased assessment of their potential to adapt to capitalist markets is to ask whether these firms developed the requisite innovative capabilities appropriate to the conditions under socialism. Without this assessment, it is easy to fall back on the belief that firms should be forced to "improve" through radical systemic change because they lacked incentives under socialism. In the German case, radical systemic change had liquidated 3,500 of the original 14,000 industrial units (the result of splitting Kombinate among the initial 8,000 units) by 1994. Only about one-third of 333,000 jobs could be saved (Fischer 1996). Firms, including socialist firms, consist of knowledge and organizing routines that encode learned patterns of behavior. Systemic change should bootstrap from an acknowledgment of the value of this knowledge and its relation to the prevailing institutional context.

A primary weakness of the socialist economies was the poverty of the institutions that support the coordination of economic and technological efforts by firms. Competition and specialization, price and contract, and experimentation and innovation form "the market." The imposition of radical macroeconomic change revealed capable firms that were insufficiently specialized in the context of the diversity that constitutes "the market." From the chaos of transition a new extended order may arise built on entrepreneurial firms whose evolution, in turn, develops the extended order. It is this missing link between the accumulated capabilities of socialist firms and the market that transition policies need to restore.

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