Did Socialism Fail To Innovate?

A Natural Experiment of the Two Zeiss Companies

by

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Abstract

The case of Carl Zeiss Jena provides a natural experiment to analyze the effects of the socialist system on innovation against a backdrop of technological activities of a ”twin” firm in a capitalist market economy. By an analysis of patent records from 1950 to 1990, we trace the technological efforts of Zeiss Jena in the German Democratic Republic (GDR) and Zeiss Oberkochen in the Federal Republic of Germany (FRG). The analysis shows that Zeiss Jena gradually developed considerable technological competence, but the deficiency of the innovative potential of the socialist system led to political pressures on key firms to innovate by plan. The findings on the innovative capability of Zeiss Jena carry the important implication that technologically viable firms can fail in the initial period of transition. The emphasis on lack of innovation and faulty managerial incentives as the disease that is cured by market reforms needs to be better balanced by an understanding of the competence of the socialist firm and the difficulty of radical change under conditions of brutal shocks to the macro-economic system.

The indisputable hardship of the economic and social renewal of the former states of the German Democratic Republic poses the perplexing question why the richest country in the Soviet system, absorbed by one of the richest capitalist countries, suffered so painfully following the collapse of communism. Since its beginnings as a science of transition, sociology has debated exactly this transition from what Polanyi (1944) called ”redistributive” systems to market mechanism and the general shift from hierarchies to markets. The current discussion of the transition from the Soviet to market economies is marked by the debate over the policies required for successful transition. The neoliberal position, which has largely prevailed in eastern Germany, argues for resolute building of capitalism by design and through rapid reform of ”shock therapy”.[1] An alternative policy, as stated by Stark (1996), begins where a country already is, by rebuilding organizations and institutions not *on the ruins* but *with the ruins* of communism.[2] In this institutionalist view, transition is the transformation of existing organizations and institutions through their efforts to adapt to the changing socioeconomic environment (Fligstein, 1997).

These issues hearken back to an older 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? Or is the relevant comparison, as Hayek (1988) articulated it, not between socialist and capitalist firms, but between planned innovation and the emergent and innovative properties of market competition to generate what he calls an ”extended order”?

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[1] Shock therapy is 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 non-innovative socialism (see e.g. Róna-Tas, 1994). For eloquent statements of the benefits of ”shock therapy” or ”big bang” see Sachs (1994) in reference to Poland, Kornai (1990) on Hungary, and Åslund (1995) on Russia.

[2] See also Stark (1992) and Walder (1995).

We establish two aims in this study. The first is to analyze similar firms working under a socialist and a capitalist system, *i.e.* to understand firm behavior under different institutional settings and to evaluate empirically the innovative potential of socialist firms and the socialist system. Based on this understanding, our second aim is to discuss macro-level changes of radical reform and their intersection with the existing organizations and institutions in place at the time of reforms.

In order to understand firm behavior and capabilities under different institutional settings, we exploit an unusual quasi-natural experiment to analyze the development of innovative capabilities under different institutional regimes.[3] The optical firm, Zeiss, was split into two independent companies after World War II, one located in Oberkochen, West Germany, the other in Jena, East Germany. By a comparison of their patent histories from 1950 to 1990, this paper analyzes the cumulative technological innovations of the two companies and their efforts to diversify into new technical fields. These conditions create the experimental design that we exploit by treating the East German operation in Jena as exposed to 45 years of socialism; the West German operations in Oberkochen serve effectively as the control. The historical experiment ends by Zeiss Oberkochen acquiring parts of Zeiss Jena in the wake of German reunification. By looking at the subsequent patent history of the remaining (and reorganized) part, the reunification events allow considerable insight into evaluating the technological capabilities of a socialist firm in the context of a capitalist economy.

The results of comparing patent histories indicate a high correlation in the technological achievements of the firms under both systems. Using a measure developed by Jaffee (1986) for technological relatedness, we analyze the degree of overlap in the technological output of the two

[3] We qualify the natural experiment as "quasi", because the two firms were not in isolation from each other. We discuss the possible contamination of their mutual awareness in the history below.

Zeiss companies. Despite significant technological diversification - especially by Zeiss Jena, their patent activities remained highly correlated throughout the post-war period.

The transition from socialism to capitalism poses to the socialist firm the quandary of how to adapt its capabilities to new institutional and competitive conditions. An evolutionary perspective, such as proposed by Murrell (1992), has a natural affinity with Stark's 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 due to a lack of incentives or the lack of capital, but to deficiencies in their cumulative capability to compete in capitalistic markets. Firms are repositories of knowledge, by which it is meant that they operate by a body of routines and organizing principles that are only imperfectly understood and open to facile manipulation.[4] The resistance of firms to change is not due to faulty incentives, but rather to the difficulty of firms to reconstitute their ways of doing things. In a period of disequilibrium, the market price mechanism can serve to eliminate potentially viable firms.[5] Gradualist policies provide the opportunity for firms to adapt to the new conditions by an evolutionary transformation, but the initial institutions have persisting effects.

German policy in the East could not follow the principles of shock therapy by the rulebook due to the particular political considerations entailing German reunification. Firms were privatized fairly quickly, but state subsidies to firms and, more directly, workers have been substantial. The political policy to convert the eastern mark at an overvalued exchange rate, and the subsequent fixing of East-German wages relative to the West-German wages at a level not justified by productivity differences, discouraged investment. As a consequence, transition in East Germany

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[4] See Nelson and Winter (1982).

[5] See the seminal article by Winter (1964) that lays out formally the analysis by how efficient firms may be evolutionarily disadvantaged under price disequilibria.

proceeded under the challenging condition of transformation under excessively high wages. Because these policies constituted a market ”shock," East Germany provides an extreme laboratory to address the issue 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 more difficult. The interesting question is whether the inference from this observed hardship should be simply that market incentives were inadequate to compensate for the harsh macroeconomic conditions. Another possibility is that transition is difficult even for the most capable firms of the socialist system due to the stickiness in adapting capabilities developed under one system to the institutional environment of another. From studies on returns to human capital in Russia, we know that returns to education did not increase in transition, indicating that individual capital is not always adaptable to the new market conditions (Gerber and Hout, 1998). The case of Zeiss Jena is particularly instructive in the regard of understanding organizational capital, because it constituted 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 on understanding the conditions of radical transition that is attentive to the interplay of organizations and institutions.

I. THE NATURAL EXPERIMENT

An experimental design seeks to measure the effects on a dependent variable (or outcome) under study by varying an experimental condition, i.e. treatment. The presence of other potential influences is eliminated in a controlled setting using a random sample. Outside the laboratory, these controls are applied by measuring their contribution to changes in the dependent variable in order to isolate the influence of the treatment condition; the samples are often not random. A natural experiment is a design that, though also using non-random samples, is able to isolate the effects of the treatment variable by eliminating the effects of extraneous factors.[6]

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, US forces evacuated the board of management of the Zeiss firm (located in Russian-occupied Germany) and about 100 scientists and technicians of the Carl Zeiss firm (Jena) to West Germany. Shortly before that, the Jena factory had been largely destroyed. Both Zeiss Oberkochen and Zeiss Jena started their operations basically without 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 of 1950 to 1990. The treatment is the imposition of a socialist planned economy in the East; Zeiss Oberkochen is used as the experimental control. The research design thus involves the comparison of the stock and development of technological skills in German firms divided in West German and East German entities 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 the experimental design. First, there are few other pairs that constitute this natural experiment, with the glass supplier to Jena, Schott, being the only other case to our knowledge. The two firms are very comparable since both companies pursued technological strategies. Zeiss Jena was often mentioned as on of the five stars in the GDR (Henkel, 1988).[7] Second, the merits of the matched pair are to remove the common idiosyncratic elements due to

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[6]Cook and Campbell (1974) describe natural 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, and Staw, 1974.

[7] Other high-performing firms, regarded as internationally competitive by local expertise, were Robotron, Kombinat

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 itself was not a purely capitalist economy. Many important industrial branches were dominated by state-owned firms, 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 R&D and occasionally promoted particular sectors. However, the issue is not to what extent was West Germany a market economy, or whether Zeiss Oberkochen would have behaved differently if it were located in another capitalist setting. History did not run these experiments. By almost all measures, there were substantial differences in the economic management of the two Germanys. For example, East Germany had tight control over price determination 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; it did not permit new firm foundings and promoted, to the contrary, the grouping of firms into large industrial combines (Kombinate) (see Kogut, 1983). Because of these differences, it is reasonable to analyze the two Zeiss firms as subject to radically different system effects, which we will label socialist and market capitalism.

Historical Background: *The Pre-World-War II Period*[8]

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

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Chemieanalagebau, Kombinat Polygraph, and Gaskombinat Schwarze Pumpe.

the University of Jena. In the early 1900s, Zeiss competed successfully in international markets and engaged heavily in foreign direct investment (Hagen, 1996). Some 2/3 of production was sold in countries outside Germany. During the late 1920s, Zeiss was turned into a conglomerate by the acquisition of German suppliers and competitors (Schumann, 1962). By 1945 the percentage of Zeiss Jena turnover coming from military production had risen to 75-80 percent, and some 16 separate R&D laboratories were operating in Jena.[9]

The West: Zeiss' Operations in Oberkochen

The Oberkochen operation of Carl Zeiss commenced from scratch in 1946 by some 85 Zeiss-managers, engineers, and designers deported from Jena by the US 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, but none of this material ever reached them and later surfaced in the USA. In setting up the new Carl Zeiss enterprise, the managers and engineers, among which the whole Board of Directors ("Vorstand") were represented, decided to settle in Oberkochen on the basis of a suitable empty factory having produced landing gear for aircraft.[10]

The new location was of course unfortunate in that the vital contacts with a first-rate university, like the University of Jena, were impossible to recreate in the Oberkochen area. However, the 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, even if these were heavily based on work carried out in Jena before the move to Baden-Württemberg. The production of optical instruments in Oberkochen

[9] For Zeiss' leading role in the development of the industrial R&D laboratory, see Dornseifer (1994).

began in 1946.[11] Early products in the West were stereomicroscopes, where a modular production technology was developed and introduced at an affiliated facility in Göttingen already in 1947.

Over time, microscopes for surgeons well as other medical equipment became important products, together with photographic lenses, eyeglasses, and different types of measuring equipment. Research and development (R&D) and production in the microscope area were soon carried out in parallel in different German units, which led to a considerable degree of internal competition. This stopped to a certain extent when R&D on microscopes were moved from Göttingen to Oberkochen. A number of producers of machinery and other related supplies emerged in the surroundings of the Oberkochen factory and were to a large extent closely linked to the Zeiss group.

In the 1980s, the Zeiss company was represented in all continents and exported 50% of production. Zeiss 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 in Germany. Sales exceeded DEM 2 billion.[12] The West-German Zeiss companies in the mid-1980s devoted some 10% of their turnover to R&D (Carl-Zeiss-Stiftung, 1985). Important product areas were microscopy (light & electron), surgical products for ophthalmic, neuro-, brain-, and ear-microsurgery, surveying and photogrammetry (aerial photography), industrial measurement, opto-electronic modules, and ophthalmic optics (spectacles, lenses, binoculars, and riflescopes). The companies also marketed consulting and engineering services related to large, custom-built

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[10] Interview with Dr. Pfeiffer, information manager at Zeiss Oberkochen.

[11] Schott carried out the first successful glass molding in Zwiesel and built a new laboratory in Landshut. The new Schott works in Mainz went into operation in 1952/53 (Carl-Zeiss-Stiftung, 1985).

[12] The figures for the entire Carl-Zeiss-Stiftung are 31,845 employees and a turnover of DEM 4.4 billion.

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[13]

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 with 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 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. GDP growth levels in the 1960s were impressive, but heavy industry and energy production were a priority over 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 levels of state ownership and industrial concentration of firms. About 95% of industry and agriculture were state-owned or cooperatively held. Increasingly, firms were organized into large holding structures, called Kombinate, with the intent to decentralize some central planning to these intermediate units. The nationalized firms (VEBs) produced on the basis of indicators in national economic plans. Short-term annual plans were complemented with 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.[14]

In comparison to developments in the West, these policies did not work.[15] Labor productivity declined to about 50% of that in West Germany; the high level of female participation (84%) partly compensated for the lower productivity. Still, 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 level. In terms of GDP per capita, the GDR could be compared to Spain, Portugal, Greece, and Ireland. However, the official statistics hid the vast problems in quality and weak infrastructure. Despite falling productivity and investment, the government sought to maintain consumption levels by foreign borrowing; disposable income grew faster than national output in the 1980s.[16] By 1990, the shortages in investment goods and the collapse of demand in the East seriously impaired the economy. The Communist state withered away soon after its 40th birthday[17], and in less than a year a single political and economic entity was fused from two economies with fundamentally different underlying principles of economic organization and substantially different level 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

[13] This section is based on Falk (1990), Järtelius (1987), and Tiusanen (1984).
[14] Schneider, 1978.

[15] See Maier (1997, chapter 2) for an overview.

[16] Maier (1997: 78) cites the chair of ministers, Will Stopf, as noting ironically during this time that ”in terms of distribution, we’re champs”.

[17] Although opposition forces were suppressed by a well-developed system of state repression, protests erupted in 1989. The regimes breakdown began on October 9, 1989 when about 70,000 people demonstrated on Leipzig’s Karl Marx Platz to demand reforms, even though government forces would probably use violent means to end the demonstration (Opp and Gern, 1993).

privatization or liquidation of the existing 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 during allied air raids. The future of the company was in jeopardy also due to its significant role in military production. Most of the capital equipment vanished, and in the years after the end of the war most of the scientists (including some from the University of Jena) made their way to a new facility in the West. Zeiss-Jena inherited no more than empty buildings, patent rights, and the local work force.

The late 1940s and early 1950s were period of reconstruction in Jena. Already in 1945, movie projectors and cameras were delivered to the Soviet Union as war indemnities. The reconstruction of the camera industry of Saxony gave a small boost to Zeiss to supply small number of photographic lenses that were not exported to the USSR. 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, heavily improved and reconstructed 84 types of machines, developed and built 74 brand new types of special machines (BACZ, 1955).[18]

Zeiss-Jena regained a remarkable competence in optics. Unable to compete in western markets partly due to the lack of legal agreement reached 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 and Rudolph Müller, came to focus on computing machines for the design of photographic lenses. Contacts were established with the Polytechnic University in

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[18] In addition, 116 apparatuses were reconstructed, 109 improved and reconstructed, and 185 newly developed and built.

Dresden, while the close contacts with the physicists at the University of Jena were maintained through a substantial annual grant. In 1950, the Zeiss works employed almost 13,000 people, busy working on fulfilling the by now established 5-year plans. Efforts were made to educate local youth and women for future work in the firm through an apprenticeship system (BACZ, 1950).[19]

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, whereof 2,300 could be characterized as involved in scientific pursuit.[20] In 1952, VEB Optik Carl Zeiss Jena showed their first electron microscope at the Leipzig Fair.

In the 1960s, GDR politicians under Walter Ulbricht vigorously pursued the idea of specialization under the auspices of the wave of economic reforms. They proposed that Zeiss should develop into a pure engineering enterprise. Efforts were made to have other GDR firms (like Optik-Maschinenbau, Rathenow, and Sempuco, Greiz) build standard machines, in order for Zeiss to be able to concentrate on special machines requiring leading-edge scientific knowledge. Production was to take place in other firms, and Zeiss-Jena increasingly focused on developing scientific instruments. But there were growing problems. In 1960, an internal report at VEB Carl Zeiss Jena acknowledged quality problems in production due to the urgent need to invest in important new machinery (BACZ, 1960). The insufficient allocation of resources was driven by supplier firms not fulfilling plan goals and by import restrictions. Problems also emerged in terms of energy supplies and transportation.[21] 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.

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[19] BACZ (1950).

[20] From Zehn Jahre DDR- Zehn Jahre neues Leben im Zeiss-Werk Jena (Carl Zeiss Jena,1960).

[21] BACZ (1960), and interview with Professor Mühlfriedel, Jena.

Zeiss Jena’s revival stemmed from the recognition of its potential contribution to the new economic policies of the 1970s. Throughout the 1970s and 80s, East German officials emphasized the importance of R&D and the link between science and production and ongoing rationalization of production. To aid in the rationalization of research and production, the state-owned enterprises (VEB) were gradually placed integrated into larger production units, called ”Kombinate”. Zeiss was transformed into a so-called ”Stammkombinat," insofar that it was given the status of a Kombinat with integrated control over other state-owned enterprises.

In 1981, the tenth Party Congress decided to give 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 micro-electronic technology in the West led to severe pressures for 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 to make this entry into semiconductor equipment production. 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 financial costs. [22] In 1983, he described the Kombinat’s most important task as producing technological special equipment for the microelectronics industry and the introduction of microelectronics in traditional optics. Products for the Soviet space program were also of higher priority than consumer goods and components for GDR industry (Biermann, 1983).

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

Biermann played an active role in the efforts to transform a stagnating firm into a fast-paced East European technological leader.[23] Small management teams that were knowledgeable of the business were formed; the Kombinat itself was divisionalized into independent profit centers to increase worker motivation (Biermann, 1984a, 1985a). To address the problems of lack of transparency and lack of control, the accounting system was expanded throughout all functions of the Kombinat. To increase coordination with the foreign trade organizations, these were partly integrated into Zeiss (Biermann 1983, 1985a). Attempts were also made to improve the relevance of the university education by increasing the focus on application and flexibility during 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 with 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 1976-1984 using roughly the same labor force (around 50,000 employees[24]). The export share of production was 60% (Biermann, 1985b). In certain areas like Planetariums, the Kombinat was world leading in sales. By the late 1980s, Zeiss-Jena had married optics with electronics, and became 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

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[23] Many apocryphal stories of 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 due to its sponsorship of one of the most successful soccer teams in Europe.

electronics (Biermann, 1984a). The trade embargo on exports of strategically important products imposed by the US Government also forced Zeiss to scurry for suppliers and to develop in-house competence in a wide range of technologies (Biermann, 1985b).

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% were scientists and engineers, and 28% were technicians (SV-Wissenschaftsstatistik, 1990: 53-55). The firm spent 7.7% 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% of all R&D personnel in the industrial sector.

The Study

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[24] In 1985, the Kombinat VEB Pentacon Dresden was incorporated in VEB Carl Zeiss Jena. The merger resulted in a Kombinat employing 58,000 people at 22 locations with a total turnaround of 4 billion East-German Marks.

The 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 on-site 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.[25]

In addition to the interviews and archival records, patent data for the two Zeiss firms was collected. Patents serve as quantitative indicators of the output of research efforts. They are also act as signposts of the direction of technological effort. Therefore, frequent contacts with German patent authorities were used to create a database of patents granted to the Western and Eastern parts of Zeiss.

For the period 1973-1990, computerized data on the international patenting efforts of the two Zeiss firms, in addition to the West- and East German patents, was available through the European Patent Office. The country distribution of patenting for the two firms is shown in Appendix A. As expected, both firms filed the majority of their patents in the respective home countries. Jena's share was 73%, while the more internationally active Oberkochen's amounted to 40%. Zeiss Jena also patented frequently in France, Great Britain, Japan, and Switzerland, while Oberkochen preferred European Patents, and patenting in Great Britain, Japan, and France. Our analysis of the patent data relied upon a single patent for an innovation and eliminated multiple patents (i.e. a given innovation patented in multiple countries) by checking the records of each filed patent for the original filing.

Since we want to study the patenting efforts of both Zeiss firms from the time they got started again after the war, and no computerized international patent data was available for the pre-

1973 period, 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, both the GDR and FRG historical records of patents were housed and collected at the German Patent Office in Berlin.[26] The change in patent recording practice in the GDR of the 1960s, where patents were assigned no longer to firms but individual inventors, made it impossible to assign patents to VEB Carl Zeiss Jena for this period.

Otherwise, East German patents were, as in the West, granted on the basis of novelty, applicability in industry, and technological progress. In addition, they had to be based on an inventive step, i.e. it should not be possible to derive it obviously from the known state of the art. In addition to "normal" exclusive patents, the GDR system also granted non-exclusive "Wirtschaftspatente" (where the right to use the patented invention was shared between the inventor, socialist enterprises, and state organs of the GDR), as well as secret patents. A notable difference from Western patent laws, was the rule that an invention was unpatentable if it offended the socialist morality. As in the West, patent applications were examined by a Patent Office as to form, patentability, novelty, and substance and subsequently published if accepted.[27]The resulting database contains information on applicants, date and countries where patents were granted, patent numbers, and priorities. Since the different systems do not use a standard classification code, the patents for the entire 40-year period were also reclassified and analyzed within the frame of the sixth edition of the International Patent

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[25] We are grateful to Frau Hellmuth for her help during the chaotic time when a sudden and unplanned move of the archives to another location in Jena took place.

[26] Special thanks to Frau Benke at the Deutsches Patentamt, Berlin for help locating the material.

[27] For an in-depth account of the Patent laws of the GDR, see Manual of Industrial Property, 1992. We would like to thank Helena Fernholm of the Swedish Patent Office, Arthur Emtedahl, and Petter Rindforth of Enderborg & Partners for assistance.

Classification (World Intellectual Property Organization, 1994) by the World Intellectual Property Organization.[28]

To determine the overlap or correlation of the patent portfolios of the two Zeiss firms, we apply a simple statistic developed by Jaffee (1986). This statistic is defined as:

$$P_{ij} = \frac{F_i^{'} F_j}{[F_i^{'2} F_j^{2}]^{.5}}$$

F is a vector of the proportion of patent counts in a given classification. The elements of this vector sum to 1. 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.[29]

The patent classifications are similar to 3 digit SIC categories. The eight IPC sections can also be further broken down into 150 IPC subsections and 624 IPC classes.[30] 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. Since the correlations do not reveal the extent of differences in the degree of technological diversification, we calculate Gini coefficients as

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[28] We would like to thank the personnel at the Swedish Patent Office for help regarding the concordance lists used to translate patents from different systems.

[29] For an illustration, consider two vectors: Fi and Fj. The elements sum to one, so each kth element is a fraction formed by the number of patents in that class over all patents of firm i,j. The numerator is Fi'Fj, or a scalar (or dot) product. Let's let Fi= [.4 .3 .3] and Fj = [.2 .3 .5] (column vectors). Then, Fi'Fj is 1x1, or .08 + .09 + .15 = .32. To normalize, we want to take the square root of the product of the squared vectors, i.e. Fi'Fi = .16 + .09 + .09 = .34, Fj'Fj = .04 + .09 + .25 = .38. Then the product of these two numbers is: .34x.38=.1292. The square root is .3594. Now dividing numerator by denominator, we have .32/.3594 = .89.

[30] For a description of IPC sections, subsections, and classes, see Appendix A.

well as use more aggregated classifications in order to weight more heavily differences in broad technological efforts. The results are presented below.

Descriptive Result

Development 1950-1989

The study of the two Zeiss firms in terms of patenting during 1950-1990 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 in IPC Sections can be seen graphically in Figures 1 and 2 (see Appendix B for an explanation of what kinds of patents fall under which section).

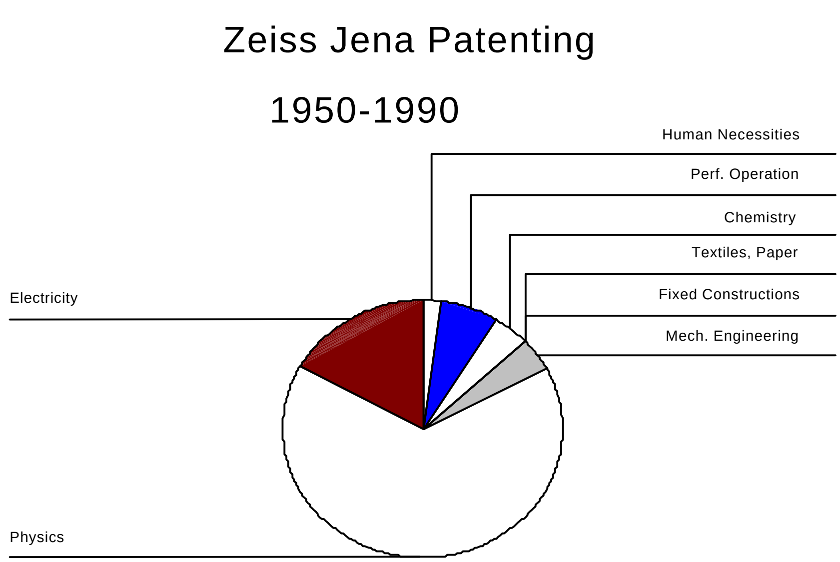

Figure 1

Zeiss Oberkochen Patenting

1950-1990

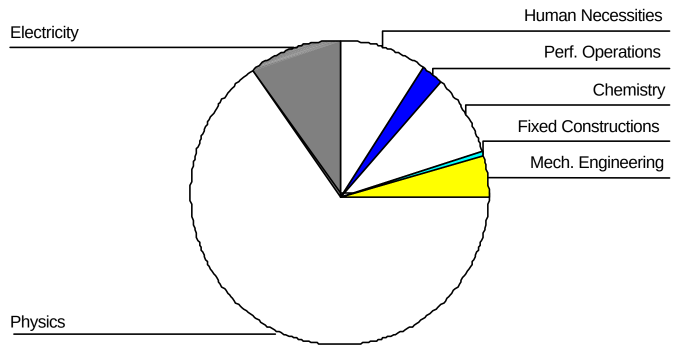

Figure 2

The Zeiss firms patented dominantly in physics IPC section. Both firms have also been actively patenting in electricity, chemistry, and mechanical engineering, while Oberkochen has been more active in human necessities and Jena in performing operations.

Insight into diversification and more refined description of technological efforts can be gained by looking at a lower 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. On a simple count basis, Zeiss Jena is more diversified.

It is especially important to look more carefully at the two most important IPC sections of physics and chemistry. Within the section physics, both firms patented most heavily in optical elements, systems, or apparatus (Oberkochen: 723 patents, Jena: 498), followed by measuring instruments linear (Oberkochen: 210, Jena: 225). Oberkochen also figured prominently in investigation of materials (108), photographic apparatuses (107), instruments for measuring distance, levels, or bearings (90), and spectacles (53), while Jena patented heavily in instruments for measuring distance, levels, or bearings (169), and investigation of materials (127). Within the chemistry section, Jena shows a fairly even distribution between patents in IPC-classes with coating, adhesives, glass composition and crystal growth, while glass composition and glass manufacture heavily dominate Oberkochen's patenting.

The effects of the policy in the GDR to move Zeiss Jena toward semiconductor production is reflected in the electricity patent activity. In the electricity section, electric discharge tubes, and secondarily devices using stimulated emission dominate Oberkochen's patenting. Jena is prominent in devices using stimulated emission, electric discharge tubes, pulse technique, and semiconductor devices. In other words, Jena and Oberkochen built similar the patenting histories of Oberkochen Zeiss in the electricity area, except for the diversification of Jena into semiconductor technologies.[31]

The correlation between the overall number of patents of Zeiss Oberkochen and Zeiss Jena in the 207 different IPC-classes is 0.943. 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.

Since the two Zeiss firms served very different domestic and export markets, the correlation indicates that technological ”push” is quite important. There is also the possibility that the two firms did not lose sight of each other's progress. It is, however, important to remember that even if Zeiss Jena should have benefited by observation of its western counterpart, it would have had to retain an important capability to create, absorb, and exploit technological knowledge. Also, the political pressures Zeiss Jena experienced over the 40-year period were extremely erratic, and by no means consistently focused on keeping up with its Western sister firm. Finally, since we use patents to compare the technological efforts of the two firms, the technologies we compare have all passed severe tests of their novelty and uniqueness, which too a large extent rules out the possibility of imitation. In the following, we analyze the possibility of technology spillover more thoroughly by analyzing patenting in different time periods and simple lags in the correlations.

The Trajectories of the Two Zeiss Firms

As can be seen from Table 1 below, Zeiss Jena's patenting has been dominated by efforts in the IPC-section *physics* throughout the period 1950-1990.[32] From accounting for 70% of the patents in the 1950s, the share dropped to around 65% in the 1970s and 1980s. The share of patents in *chemistry and metallurgy* has been growing slowly but steadily over the period, while patents in *electricity* peaked at 26% of total patenting in the 1970s. In the 1980s, electricity patenting as a share was back to 1950s' levels of around 15%.

Zeiss Oberkochen's patenting classified according to broad IPC-sections can also be seen in Table 1. Oberkochen was dominated by patenting in *physics* over the four decades, with the share of the total peaking at 83% in the 1960s, but then returning to figures around 60-65%. The share of patents in *chemistry and metallurgy* increased considerably in the 1970s and remained at the 10% level in the 1980s. Unlike Zeiss Jena's profile, the share of patents in *electricity* fell from almost 20% in the 1950s to 8% in the 1980s.

Table1: Technological Trajectory in Jena and Oberkochen

	Jena 1950s	Ober-kochen 1950s	**Jena 1960s**	Ober-kochen 1960s	**Jena 1970s**	Ober-kochen 1970s	**Jena 1980s**	Ober-kochen 1980s
Total number of patents / Number of IPC classes	**66 / 20**	313 / 29	**N.A.**	215 / 20	**224 / 52**	509 / 69	**2051 / 142**	1318 / 90
Human necessities (% of total)	**5%**	12%	**N.A.**	4%	**1%**	11%	**2%**	9%
Performing Operations, Transporting (% of total)	**5%**	1%	**N.A.**	1%	**4%**	2%	**7%**	3%
Chemistry and Metallurgy (% of total)	**0%**	1%	**N.A.**	0%	**2%**	11%	**5%**	10%

[31] Interviews with a Corning executive indicated that Zeiss Oberkochen did manufacture lenses used in semiconductor production, but other manufacturers assembled the equipment. Firms such as Nikon produce both lenses and equipment for semiconductors.

[32] For the content of different IPC-sections, see Appendix B.

Textiles and Paper (% of total)	**0%**	0%	**N.A.**	0%	**1%**	0%	**0%**	0%
Fixed Constructions (% of total)	**0%**	0%	**N.A.**	0%	**0%**	1%	**0%**	1%
Mechanical engineering, Lighting, Heating, Weapons (% of total)	**5%**	2%	**N.A.**	1%	**2%**	3%	**5%**	6%
Physics (% of total)	**70%**	65%	**N.A.**	83%	**64%**	62%	**65%**	63%
Electricity (% of total)	**15%**	19%	**N.A.**	11%	**26%**	10%	**16%**	8%

The analysis of patenting in broad IPC-sections once again reveals surprising similarities between the profiles of the two Zeiss companies, operating in different economic systems.[33] In sum, Zeiss Jena during the 1950s, 1970s, and 1980s concentrated its patenting efforts to *optics and measuring instruments* of different kinds. Similarly, Oberkochen has throughout the period 1950-1990 also focused on developing technology in *the optics and glass related areas,* with *medical diagnosis* being another important area of research and patenting. Two main differences between the companies can however be found. First, Oberkochen expanded its patenting in the chemistry and metallurgy sector earlier and faster than Jena. In the 1970s, Oberkochen's share was five times higher than that of Jena and it remained at twice Jena's share in the 1980s. Secondly, Jena increased its share of patents in electricity to be almost three times that of Oberkochen in the 1970s and kept it at twice the share of Oberkochen in the 1980s.

If the patent data are further broken down into IPC-classes, a number of interesting observations can be made. In absolute terms, both firms diversified their technology base as indicated by patenting in more and more IPC-classes. Jena went from 20 classes in the 1950s to 142 in the 1980s. Oberkochen went from 29 to 90. The change in technologies and products over time in both Zeiss firms is striking. For a more detailed description of the evolution of patenting profiles in the two companies, see Appendix C.

Correlation analysis

Table 2 shows the correlations between patenting activities in Zeiss Jena and Zeiss Oberkochen for the 1950s, 1960s, 1970s, and the 1980s. The overall impression of the correlation analysis is the striking similarity of technological profiles between two firms sharing the same history but then getting exposed to different socioeconomic environments. After 40 years of socialism and a centrally planned economy, Zeiss Jena's areas of invention still showed a correlation of 0.93 with Zeiss Oberkochen's patenting.

[33] 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 2: Correlation Analysis of Patenting in the Two Zeiss Firms by Decade

	1.	2.	3.	4.	5.	6.	7.	8.
1. Jena 1950s	-	0.94	N.A.	0.85	0.77	0.81	0.88	0.84
2. Oberkochen 1950s		-	N.A.	0.86	0.68	0.84	0.83	0.80
3. Jena 1960s			-	N.A.	N.A.	N.A.	N.A.	N.A.
4. Oberkochen 1960s				-	0.70	0.92	0.91	0.90
5. Jena 1970s					-	0.72	0.89	0.92
6. Oberkochen 1970s						-	0.88	0.93
7. Jena 1980s							-	0.93
8. Oberkochen 1980s								-

The correlational 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, this statistic poses a question why did the two firms deviate for just the 1970s. The lagged correlation suggests an answer. It is useful to look at four lagged correlations of Oberkochen and Jena for the years 1970 and 1980. Note first that the correlation for Oberkochen for 1970 and 1980 is .93, whereas Jena has a correlation with itself for those years of .89. The correlation of Oberkochen 1980 and Jena 1970 is .92. This last correlation suggests that the patenting record of Oberkochen in 1980 is almost as correlated with Jena in 1970 as it is with its own patent distribution in 1970. However, the correlation between Oberkochen 1970 and Jena 1980 is .88. In other words, if one wanted to predict Jena's patenting distribution in 1980, it would be just as helpful to look at Oberkochen's patents in 1970 as it would to look at Jena's own patenting pattern for the same year.

This statistical result stems directly from the move by Jena away from electrical patenting in the 1980s. But more importantly, it suggests two other possibilities. One is that Jena consciously followed the technological efforts of its West German rival. Of course, it is critical to note that even if there are imitative influences in the data, the successful ability to build upon 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 micro-electronic industry. We turn to this evidence below in assessing the archival literature.

Diversification analysis

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.[34] A value of 1 indicates that a firm is patenting in only one field; a value of 0 indicates that the firm distributes its patents equally across all classes. As Table 3 shows, the Gini-coefficients are consistently lower for Jena than for Oberkochen. Only for the 1980s, Jena's coefficient value is similar to Oberkochen's; The Zeiss Jena Director Biermann's policy of focused research during the 1980s is apparently evident in the patent distributions. Since the Gini-index measures "inequality," the results indicate that the East German operations have shown a less focused patenting profile than the Western 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 due to problems of purchasing necessary inputs in the market place.[35] Jena engineers had to monitor and master a number of technical areas instead of focusing their efforts in

[34] The formula used to measure "inequality" is $G=1+1/n - 2/n^2Y(y_1+2y_2+3y_3+\ldots+ny_n)$, 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.

certain narrow areas to develop superior competence. Resources (and resulting patents) seem to have been spread more evenly over the technological area where Jena was active. In the 1980s, Jena patented in more classes and the Gini-index shows that the patenting efforts were less balanced, with ”inequality” in patenting going up almost to Oberkochen levels.

Table 3: Gini-coefficients for patenting in Zeiss Jena and Zeiss Oberkochen

	Gini-coefficient Jena	Gini-coefficient Oberkochen
1950s	0.555	0.717
1960s	N.A.	0.672
1970s	0.598	0.749
1980s	0.754	0.782

II. DISCUSSION

The history of Zeiss Jena’s patenting certainly confirms Schumpeter’s (1942) principal point that the large socialist firm can successfully innovate. If the overall number of patents of Zeiss Oberkochen and Zeiss Jena in the 207 different IPC-classes are compared, the correlation must be regarded as surprisingly high given that the two firms operated in very different political and economic systems for the entire 40-year period. However, the comparison of the two Zeiss companies clarifies clearly 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 the belief that the market socialism of independent firms interacting with a central planner would be free of political interference.

[35] See Kogut, 1983, for a discussion of the increase in-house production by Kombinats.

The historical evidence from the archival investigation points to 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 very different "customers". Zeiss Jena during the 1950, and 1970s displayed a much more diversified patent portfolio than the 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 under the same roof.[36]. As commonly experienced in all socialist countries, supply shortages were common due 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 and grows ideas into radical innovations.[37]

During the 1980s, the East German government came increasingly under pressure to deliver improvements in living standards and at the same time keep up with the West in terms of the production of high technology often for military use. As a result, the pressures on the most dynamic firms increased, and demands were often unrealistic and inconsistent. In Zeiss Jena's case the outcome is seen in the increased alignment with Oberkochen's patenting profile, the increased specialization revealed by its patenting, and the efforts in the semi-conductor area. In speeches to the Friedrich-Schiller-Universität during the mid-1980s (Biermann, 1983, 1984a&b, 1985a&b), the Zeiss Jena Director Biermann spoke critically of party officials who interfered heavy-handedly in the firm's activities and had still to be convinced that international competitiveness should be the

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[36] Axell and Uppenberg, 1991.

aim of the Zeiss Kombinat. Two speeches in 1984 are especially significant (Biermann, 1984a&b). Biermann discussed openly the problems of R&D research in comparison with western firms:

> This does not mean … that a scientist is not 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 (Biermann, 1984a: 9).[38]

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.

During the 1980s, patent specialization increased in Jena, but Zeiss management complained about the dual burden of supplying the domestic market and at the same time trying to focus on 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 especially large buyers required the most advanced technological features, but it was felt in Zeiss Jena that the sales of these "spearhead" products were only possible 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 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 did, of course, have an effect on technological development, but these

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[37] It is beyond our efforts to evaluate the innovative record of the GDR. However, it can be noted that the GDR was popularly known for very few innovations, one of them being a synthetic fiber (Dederon) that was a play on the name of the country. See Berliner, 1976, for an evaluation of the Soviet system.

[38] "Das heisst aber nicht….dass einem Wissenschaftler nur noch das einfallen darf, was im der Plan vorgibt, dass er nur noch das finden darf, was er sucht. Nach wie vor vollzieht sich der Forschungsprozess, schöpferische Prozesse überhaupt, nach gewissen eigenen Gesetzen, die sich dem Zugriff der Planung zum Teil entziehen."

orders, when realistic, were directed to Zeiss based on its known capability; Zeiss did not create the market.[39] 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.”[40]

Zeiss Jena was indeed the Schumpeterian socialist firm, invested with substantial technological capabilities but 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 (Eigenwirtschaftung) 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 altogether to abolish the ministry responsible for science and technology which encouraged ”no strategic impulse whatsoever from the Kombinate.”[41] Whatever Mittag’s answer, it came too late.

An understanding of the technological strength and weakness of the socialist system informs an analysis of public policies. Based on the natural experiment analyzed in this paper, it is our contention that the best *socialist firms in the high technology sectors did not lack technological capabilities, nor even clearly the managerial capabilities required for market competition*. Zeiss

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[39] 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 USSR 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).

[40] Cited in Maier, 1997: 74. Figures from Maier (p. 75) indicate that the unit cost of producing 256-kilobit memory semiconductor was over a 100 times the world price.

[41] Cited in Maier (1997: 96).

suffered because of the inadmissibility of the plan to permit experimentations in any sector of the economy to fail.[42] By this, it is meant that the firm could not rely upon 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. In addition, lacking close contacts with advanced consumers and suppliers in many areas, Zeiss was bereaved of 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 such as Zeiss were impeded by the absence of the 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 insofar that they lacked economic incentives, or that the state ministries pursued political goals in opposition to economic efficiency. They were under political pressures to fulfill the planned targets for innovation. The state ministries had only the Plan upon which to rely for the critical innovations needed for the microelectronics policies. In many ways, socialist ministers and managers were not unlike their western counterparts who also have struggled to compete in the fast-moving microelectronics industries.

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[42] One of the authors to the paper was asked by a young East German in 1981 during a stay in the GDR what was the quality he felt was most lacking in the GDR. Upon responding ”spontaneity,” the student replied, ”We are working on it.”

The difference between socialism and capitalism is that the former could not rely upon 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; there was no redundancy except the constrained and limited access to world markets.

III. ZEISS AND THE TRANSITION PROCESS

The description and comparison of the innovative activities of the two Zeiss firms throws light on the preconditions for the transition from a socialist planned system to a capitalist market economy. The economic conditions of the German reunification agreement created a macro-economic shock due 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 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 did not leave politicians with much policy choices. The outcome was a pure case of what a 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 western to eastern Germany and the virtual collapse of eastern German industrial output. Industrial output had by September 1990 fallen to a level 51% below its level in the same month of the previous year. The loss of most East European markets only started in the beginning of 1991 and brought industrial production down to 1/3 of the pre currency-unit level where it has stabilized (Roesler, 1994). The social impact in Eastern Germany was felt through employment reduction from 9.75 million to 6.4 million between 1989 and 1992 (Vogt, 1992). Labor productivity, estimated to be half as high as that of western Germany, also decreased between 1989 and 1992. Despite the sell-off and liquidation of East German enterprises, the West German State has 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, where 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, was turned into 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 about to be wiped out by neo-liberal 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 large numbers of 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.[43] Despite this, the firm in the early 1990s was struggling for its life. Only after massive protests by Jena workers threatened by the loss of their jobs, the Treuhand in 1992 took over 80% 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% of the assets in order to save some 6,800 jobs in the new firm Jenoptik GmbH (Roesler, 1994).

The decision to subsidize Jenoptik due to popular pressure has nevertheless been a successful policy. Jenoptik was privatized by stock market introduction in 1998 when enthusiastic investors over subscribed 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 two billion DEM 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 fab automation, 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 interesting to Zeiss Oberkochen when they invested at the time of transition. The antecedent of today’s technologically capable and successful Jenoptik firm would most probably have become a victim of neo-liberal shock therapy if it had been strictly enforced.

A comparison of the patents filed by Jenoptik since its creation to those filed by the old Kombinat’s patenting between 1950 and 1990 shows an impressive continuity in technological effort. The Jaffee

[43] Jenoptik (1998), p. 4.

correlation between Jenoptik's patents recorded at the fine-grained IPC-class level 1991-1998 and its GDR predecessor's patents 1950-1990 is 0.70.

Appendix D provides a breakdown of the patents by the main technology areas. The 167 patent applications filed by Jenoptik after the transition fall in 15 IPC subsections (out of 150 possible). It is worth noting that 83 percent of Zeiss Jena's patenting 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 patenting 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 (cited above) 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 upon 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.

IV. 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 remaining vestiges during the period of transition were riddled by political resistance to economic reforms (See Åslund, 1995; Shleifer and Vishny, 1994). Yet, at the same time, the belief is that market reforms are sufficient to weed out inefficient firms and to provide the proper incentives for better enterprises to move to efficient practices by the force of market incentives. The socialist enterprise is thus the bane of neoliberals, and yet oddly it is the critical institution upon which the success of radical reform rests.

The results of the quasi-natural experiment provide an institutional window on the causes of the German policy debacle in their efforts to revive the East by understanding the 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 gave the estimate that only 30 % of the firms were clearly salvageable.[44] This estimate gives 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 macro shock that not only radically reversed relative prices, but also was accompanied by the loss of export markets and the collapse of internal demand.[45]

A more appropriate inquiry for an analysis of the transformation is whether the 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 in reference to 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 an important factor 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

[44] Another 50% of the firms were believed to be able to reach the aim of standing up to competition after a long phase of thorough restructuring, and 20% were believed to face inevitable bankruptcy (Fischer and Schröter, 1996). In 1991, 85 % of the firms in Thuringia were in a crisis (Zanger, 1991).

[45] By 1994, 3,500 of the originally 14,000 industrial units (the result of splitting Kombinate among the initial 8,000 units) had been liquidated. Nearly one third of 333,000 jobs could be saved (Fischer, 1996).

transition literature on the inefficiency of socialist firms frames the question wrongly. The critical issue in analyzing their potential to adapt to capitalist markets is whether these firms developed the requisite innovative capabilities under socialism.

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 are the substance labeled the market. The imposition of radical macro-economic change revealed capable firms that were insufficiently specialized in the context of the diversity that constitutes the market. From the chaos of transition may arise a new extended order built on entrepreneurial firms whose evolution is simultaneously linked to the development of an 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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Note: BACZ: Betriebsarchiv Carl Zeiss (Jena)

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Appendix A:
Zeiss Jena and Zeiss Oberkochen: Patenting by Country 1973-1990

Country	Zeiss Jena	Zeiss Oberkochen
AT		2
AU		16
BE		1
BG	5	
BR		15
CA	2	3
CH	54	4
DD	1674	
DE		724
DK	2	8
EP	8	59
ES		2
FI	5	3
FR	162	59
GB	140	266
HU	13	
IT	2	14
JP	139	230
NL		13
NO		7
PL	5	
PT		2
SE	27	2
SU	31	
US		36
WO		26

Legend: AT=Austria, AU=Australia, BE=Belgium, BG=Bulgaria, BR=Brazil, CA=Canada, CH=Switzerland, DD=GDR, DE=FRG, DK=Denmark, EP=European Patent, ES=Spain, FI=Finland, FR=France, GB=Great Britain, HU=Hungary, IT=Italy, JP=Japan, NL=Netherlands, NO=Norway, PL=Poland, PT=Portugal, SE=Sweden, SU=Soviet Union, US=USA, WO=World Patent.

Appendix B:
Extracts from International Patent Classification
(only IPC classes where either of the Zeiss companies has ten or more patents)

HUMAN NECESSITIES[1]

Health; Amusement

Medical or veterinary science; hygiene:[3]

- Diagnosis; surgery; identification
- Filters implantable into blood vessels; prostheses; orthopaedic, nursing or contraceptic devices; fomentation; treatment or protection of eyes or ears; bandages, dressings or absorbent pads; first-aid kits

PERFORMING OPERATIONS; TRANSPORTING

Shaping

Machine tools; metal working not otherwise provided for:

- Soldering or unsoldering; welding; cladding or plating by soldering or welding; cutting by applying heat locally, e.g. flame cutting; working by laser beam
- Details, components, or accessories for machine tools, e.g. arrangements for copying or controlling; machine tools in general, characterised by the construction of particular details or components; combinations or associations of metal-working machines, not directed to a particular result

Grinding; polishing:

- Machines, devices, or processes for grinding or polishing; dressing or conditioning of abrading surfaces; feeding of grinding, polishing, or lapping agents

Hand tools; portable power-driven tools; handles for hand implements; workshop equipment; manipulators:

- Manipulators; chambers provided with manipulation devices

CHEMISTRY; METALLURGY

Chemistry

Glass, mineral or slag wool:

- Manufacture, shaping, or supplementary processes
- Chemical composition of glasses, glazes, or vitreous enamels; surface treatment of glass; surface treatment of fibres or filaments from glass, minerals or slags; joining glass to glass or other materials

Organic macromolecular compounds; their preparation or chemical working-up; compositions based thereon:

- Macromolecular compounds obtained otherwise than by reactions only involving carbon-to-carbon unsaturated bonds

Dyes; paints; polishes; natural resins; adhesives; miscellaneous compositions; miscellaneous applications of materials:

- Adhesives; adhesive processes in general; adhesive processes not provided for elsewhere; use of materials as adhesives

Metallurgy

Coating metallic material[4]:

- Coating metallic material, surface treatment with metallic material by diffusion into the surface, by chemical conversion or substitution…(see footnote 4).

Crystal Growth:

- Single crystal growth: unidirectional solidification of eutectic material or unidirectional demixing of eutectic material…(see footnote 4)

FIXED CONSTRUCTION

Building

Doors, windows, shutters, or roller blinds, in general; ladders:

- Fixed or movable closures for openings in buildings, vehicles, fences, or like enclosures, in general, e.g., doors, windows, blinds, gates

MECHANICAL ENGINEERING; LIGHTING; HEATING; WEAPONS; BLASTING

Engineering in general

Engineering elements or units; general measures for producing and maintaining effective functioning of machines or installations; thermal insulation in general:

- Shafts; flexible shafts; elements of crankshaft mechanisms; rotary bodies other than gearing elements; bearings
- Springs; shock-absorbers; means for dampening vibrations
- Gearing
- Valves; taps; cocks; actuating-floats; devises for venting or aerating

Lighting and Heating

Heating, ranges and ventilating:

- Other domestic stoves or ranges; details of domestic stoves or rangers, of general applications

Weapons; Blasting

Weapons:

- Weapon sights; aiming

PHYSICS

Instruments

Measuring; Testing:

- Measuring length, thickness, or similar linear dimensions; measuring angles; measuring areas; measuring irregularities of surfaces and contours
- Measuring distances, levels, or bearings, for surveying or navigation; gyroscopic instruments, photogrammetry
- Measuring not specially adapted for a specific variable; arrangements for measuring two or more variables not covered by a single other subclass; tariff metering apparatus
- Measurement of intensity, velocity, spectral content, polarisation, phase or pulse characteristics of infra-red, visible or ultra-violet light; colorimetry; radiation pyrometry
- Measuring temperature; measuring quantity of heat; thermally-sensitive elements not otherwise provided for
- Testing static or dynamic balance of machines or structures; testing structures or apparatus not otherwise provided for
- Investigating or analysing materials by determining their chemical and physical properties
- Measuring linear or angular speed, acceleration, deceleration, or shock; indicating presence, absence, or direction, of movement
- Measuring electric variables; measuring magnetic variables
- Radio direction-finding; radio-navigation; determining distance or velocity by use of radio waves; locating or presence-detecting by use of reflection or reradiation of radio waves; analogous arrangements of other waves

Optics:

- Optical elements, systems, or apparatus
- Spectacles; sunglasses or goggles insofar as they have the same features as spectacles
- Devices or arrangements, the optical operation of which is modified by changing the optical properties of the devices…(see footnote 4)

Photography; cinematography; analogous techniques using waves other than optical waves; electrography; holography:

- Apparatus or arrangements for taking photographs or for projecting or viewing them; apparatus or arrangements employing analogous techniques using other than optical waves; accessories therefor
- Photomechanical production of textured or patterned surfaces, e.g., for printing, for processing of semi-conductor devices; materials therefor; originals therefor; apparatus specially adapter therefor

Controlling; regulating:

- Control or regulating systems in general; functional elements of such systems; monitoring or testing arrangements for such systems or elements
- Systems for controlling or regulating non-electric variables
- Systems for regulating electric or magnetic variables

Computing; calculating; counting:

- Electric digital data processing
- Recognition of data; presentation of data; record carriers; handling record carriers

Educating; cryptography; display; advertising; seals:

- Educational or demonstration appliances; appliances for teaching, or communicating with, the blind, deaf or mute; models; planetaria, globes; maps; diagrams

Information storage:

- Information storage based on relative movement between record carrier and transducer

Instrument details:

- Details of instruments, or comparable details of other apparatus, not otherwise provided for

Nuclenoics

Nuclear physics; nuclear engineering:

- Techniques for handling practices or electromagnetic radiation not otherwise provided for; irradiation devices; gamma or X-ray microscopes

ELECTRICITY

Basic electric elements:

- Electronic discharge tubes or discharge lamps
- Semiconductor devices; electric solid state devices not otherwise provided for
- Line connectors; current collectors
- Devices using stimulated emission

Generation, conversion, or distribution of electric power:

- Dynamo-electric machines
- Apparatus for conversion between ac and ac, between ac and dc, or between dc and dc, and for use with mains or similar power supply systems; conversion of dc or ac input power into surge output power, control or regulation thereof
- Control or regulation of electric motors, generators, or dynamo-electric converters; controlling transformers, reactors or choke coils

Basic electronic circuitry:

- Pulse technique

Electronic communication technique:

- Pictorial communication, e.g., television

Electric techniques not otherwise provided for:

- Electric heating; electric lighting not otherwise provided for
- Printed components circuits; casings or constructional details of electric apparatus; manufacture of assemblages of electrical

[1]IPC sections, [2]Sub-sections, [3]IPC-classes, [4] see International Patent Classification (1994) for further details

Appendix C:
Rough Patent Profiles for the Two Zeiss Companies

	Zeiss Jena	Zeiss Oberkochen
1950s	50% of patenting in: - Optical elements, systems, and apparatuses (24%) - Measuring distance, levels, or bearings[46] - Electric discharge tubes Company sources (Carl Zeiss Jena, 1960 and Schumann, 1962) claim that new research activities in the 1950s were ultra-sound, vacuum, and semi-conductor technology, photo-elements, optical measuring instruments, photocells, cameras (also X-ray cameras), computers, and electric motors. Research also continued in the areas of astronomic equipment, and microscopes (light and electron). The challenge of the time was the combination of fine-mechanics, optics, and electronics.	80% of patenting in: - Optical elements, systems, and apparatuses (30%) - Electric discharge tubes - Measuring distance, levels, or bearings - Medical diagnosis[47] - Photographic apparatuses Important new products in the 1950s were photo-microscopes with automatic exposure units, lenses for satellite observation cameras and aerial surveys, and sintered glass-to-metal seals for electronics and nuclear technology (Carl-Zeiss-Stiftung, 1985).
1960s	NA	- Optics (49% of patenting) - Medical diagnosis - Composition, surface treatment, and joining of glass - Photographic apparatuses New products during the 1960s were electron microscope with automatic exposure, photographic lenses for space flights, and a scanning microscope photometer for cell research (Carl-Zeiss-Stiftung, 1985).

[46] Zeiss Jena delivered measuring instruments to the chemical, petrochemical, pharmaceutical, and the paint industries (Schumann, 1962).

[47] Zeiss Oberkochen launched its first microscope for microsurgery in 1953. Since the breakthrough with surgical microscopes in the 1950s, laser technology, instruments for cancer detection, and ophthalmics instruments have been delivered from Oberkochen as therapeutic and recording instruments for surgeons and medical technicians (Carl-Zeiss-Stiftung, 1985).

Appendix C (con´t):
Rough Patent Profiles for the Two Zeiss Companies

	Zeiss Jena	Zeiss Oberkochen
1970s	- Optics (16% of patenting) - Linear measuring instruments (12% of patenting) - Measuring instruments for distance, levels, or bearings - Devices using stimulated emission - Investigation of materials	- Optics (30% of patenting) - Medical diagnosis - Composition, surface treatment, and joining of glass - Photographic apparatuses Products introduced in the 1970s included photo lenses with virtually perfect color correction, electro-optical tachometers, the UMM 500 universal measuring machine with three-dimensional object scanning, improved microscopes, lightweight spectacle lenses, and an electron microscope for extra-vacuum photography (Carl-Zeiss-Stiftung, 1985).
1980s	- Optics (22% of patenting) - Linear measuring instruments (9% of patenting) - Investigation of materials - Efforts in the computer and semiconductor areas	- Optics (30% of patenting)[48] - Linear measuring instruments (13% of patenting) - Investigation of materials - Medical diagnosis - Composition, surface treatment, and joining of glass

[48] The laser scan microscope launched in 1982 and the new electron microscopes with energy filter were important innovations. Oberkochen lenses in the mid-1980s also permitted printing in the sub-micron range of one megabyte of information and more on a single computer chip.

Appendix D:
Patents filed by Jenoptik 1991-1998 and VEB Carl Zeiss' patenting 1950-1990
Most frequent IPC subsections (out of 150 possible)

IPC subsection	**Percentage of Jenoptik's patent filings 1991-1998**	**Percentage of Zeiss Jena's patenting 1950-1990**
Physics: Measuring; Testing	**26%**	**31%**
Electricity: Basic Electric Elements	**16%**	**8%**
Physics: Optics	**10%**	**21%**
Performing Operations: Conveying; Packing; Storing; Handling thin or filamentary material	**10%**	**1%**
Human Necessities: Medical and Veterinary Science; Hygiene	**9%**	**3%**
Physics: Photography, Cinematography, Electrography, Holography	**5%**	**5%**
Physics: Computing, Calculating, Counting	**5%**	**3%**
Mechanical Engineering: Heating; Ranges; Ventilating	**3%**	**<1%**
Physics: Controlling, Regulating	**3%**	**1%**
Performing Operations: Machine Tools; Metal working not otherwise provided for	**2%**	**2%**
Mechanical Engineering: Engineering elements or units; General measures for producing and maintaining effective functioning of machines or installations; Thermal insulation in general	**2%**	**4%**
Physics: Instrument Details	**2%**	**1%**
Electricity: Other	**2%**	**1%**
Electricity: Communication	**2%**	**2%**
Performing Operations: Working of plastics; Working of substances in a plastic state, in general; Working of substances not otherwise provided for	**1%**	**<1%**
Total	**100%**	**83%**