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Unable to innovate or just bad circumstances? Comparing the innovation system of a state-led and market-based economy

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Abstract

State socialism failed due to its inner contradictions. Despite huge investments in R&D-intensive industries, the soviet-type economy collapsed in 1989 in Eastern Germany, and the market-based system in the Western part prevailed. We compare the two parallel existing innovation systems in Germany to shed light on the success and failure of the state-led innovation system. Based on newly created indicators from archive data we show in a natural experiment setting that modernization efforts in relation to GDP was much bigger in the socialist as compared to the market economy in the last decades. These achievements, however, could not fully unfold in favor of economic growth due to obstacles related to the setting of research priorities, innovation incentives, and knowledge flow.

Keywords

Comparative economic systems, natural experiment, innovation system, Germany

JEL Classifications

O11, O31, N94

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1. Introduction

Policy makers typically support the generation of new or improved products and technologies with investments in the modernization of the economy to enable technological progress and economic growth (Chaminade et al., 2018). Recent literature argues that there are no major technological breakthroughs and subsequent product innovations in a market economy without underlying large-scale investments of the state (Deleidi and Mazzucato, 2021). In this respect, the state is not reduced to act through regulation and small-scale innovation stimulus. This holds true for the “old economy”, e.g. chemistry, mechanical and electrical engineering, but equally to future digitalization and automation-based economies (European Commission, 2020).

So far, much attention has been put to understand innovation and growth in industrialized market economies, but less or close to nothing on industrialized non-market economies. Soviet-type economies concentrated investments in selected industries to reach the central planning goals, achieve technical progress and leapfrog Western market economies, but the obstacles in their system of innovation impeded economic growth or have contributed to their fall (Glitz and Meyersson, 2020). Some economic studies put the conditions for innovation in a centrally planned economy entirely into question (e.g., Allen, 2001; Slifer, 2006; Steiner, 2010; Berliner, 2019). While the failure of state socialism as such is fully accepted (Kornai, 1995), the effects of huge modernization investments and their relation to economic growth have hardly been analyzed to understand mechanisms of success and failure behind. We challenge the wide-spread assumption that there was no growth-relevant innovation in socialist systems and zoom into the empirical details.

The literature on innovation systems describes the variety of resources that enables the actors to achieve innovation and a competitive advantage (Lundvall, 1992; Chaminade et al., 2018; Rakas and Hain, 2019). Investments play a crucial role to encounter technological backlog and economic growth in the national system of innovation (Alaja and Sorsa, 2021; Ghazinoory et al., 2020; Hipp and Binz, 2020). Nonetheless, the analytical focus is on innovation systems of recent market economies or post-soviet countries (e.g., Chaminade et al., 2018; Cirillo et al., 2019; Radosevic, 2022), and we still know little about the successes and failures of socialist innovation systems. There are considerable parallels in the role of modernization investments between soviet-type and market economies. Due to their long-lasting effects on innovation today (Blind and Grupp, 1999), we need to understand the configuration of their system and the barriers to innovation therein. Moreover, most of the innovation studies focus on R&D investments, neglecting a broader view on investments into the modernization of an economy and their embeddedness in a system of innovation (Zemtsov and Kotsemir, 2019). We define modernization as the investments into the formation of physical capital in economic sectors that are key for technological progress and innovation (i.e. R&D-intensive sectors). This approach seems particularly suitable since innovation systems are heterogenous and their complexity and evolution require a better socio-technical understanding to integrate and coordinate investments (Cirillo et al., 2019). The broad definition allows us to assess the extent of investments and the barriers to the modernization of an economy and thus to operationalize innovation systems to reduce this complexity.

This paper extends the literature on innovation systems to the role of modernization investments and barriers to innovation in an industrialized, state-controlled economy. We include arguments from the innovation economics literature (Moulaert and Sekia, 2003; Wieczorek and Hekkert, 2012; Castellani et al., 2019) and propose a positive relation between modernization investments and the growth of a soviet-type economy. We thus seek to answer the following research question: *How important are modernization investments in the innovation system of a soviet-type economy compared to a market-based economy?*

Second, within this framework we scrutinize obstacles to modernization as structural deficits of an innovation system (Galia and Legros, 2004; Chaminade et al., 2012; De Fuentes et al., 2020). We consider obstacles as part of the constrained institutional arrangement in a system of innovation, especially its centrally set research priorities, the small incentives to invent and the limited knowledge flow. The second research question is: *Which obstacles influence the unfolding of modernization investments in a socialist innovation system?*

We empirically investigate these research questions for the example of the socialist innovation system of the German Democratic Republic (GDR). The GDR was a socialist state with a central planning system after Germany's separation of the Soviet occupation zone from 1949 to 1989. It was characterized by large investments in the modernization of industrial production since the 1970s, but also by high innovation obstacles and a steadily decreasing economic growth till its fall (Ludwig, 2017). We use original primary time series data on GDR's economic growth and its modernization investments from different archival sources such as Stifterverband (1990), Heske (2005a) and Stäglin and Ludwig (2000) that was recalculated according to international standards. We further apply patent-related indicators based on DEPATIS. Comparing these indicators of the GDR to the market economy of the Federal Republic of Germany (FRG) allows us to analyze a case in point in which the formerly unified and after World War II separated regions suit the conditions of a natural experiment (Kogut and Zander, 2000). We provide new empirical evidence on modernization investments and barriers to innovation in a soviet-type economy compared to a market system.

This paper is structured as follows. Section 2 provides an overview on the literatures on innovation systems, investments and obstacles. Section 3 describes the case selection and the generation of data and indicators. Section 4 presents our empirical results on the GDR's economic and innovation system and section 5 illustrates its obstacles to modernization compared to the FRG. Section 6 discusses the findings and provides theoretical implications as well as avenues for further research. Section 7 concludes and offers recommendations for policy makers.

2. Theoretical Framework

2.1. National innovation system, policy and economic growth

The literature on national systems of innovation draws upon a country's actors and institutions to leverage its resources for the generation of innovation and the growth of the economy (Lundvall, 1992). The actors of the system include firms, universities and research labs while institutions exist in form of industrial relations and government policies (Freeman, 1995). They are embedded in a system of structural couplings through which they interact, exchange resources and produce positive externalities for the generation of innovation (Nelson, 1993). The variety of resources relates to tangible resources of production and natural capital as well as intangible resources of intellectual and social capital, of which the latter are less reproducible in other systems (Lundvall et al., 2002). Innovation systems are thus structured by knowledge production and diffusion, financial investments, technological legitimacy and market formation (Binz and Truffer, 2017). They can be considered at the geographical, sectoral or technological level of a market economy (for a recent overview, see Rakas and Hain, 2019). Although originally developed with respect to market economies, the theoretical concept of an innovation system has been used to analyze emerging and transition economies, too (Radosevic, 1998, 1999, 2022; von Tunzelmann et al., 2010; Günther, 2015; Günther et al., 2020). Soviet-type economies followed the same rationale as market economies: technological progress leads to economic growth. They relied on the same actors (firms, universities, research labs), but institutions differed in design and configuration. Thus, they will be paid special attention when applying the innovation system approach to the socialist innovation system.

Innovation systems can involve failures that hinder the development, diffusion and use of knowledge, which legitimates policy to intervene to ensure learning, innovation and economic growth (OECD, 1997). As opposed to market failures, systemic failures require interventions in form of investments, which can be linked to their occurrence in R&D-intensive sectors to achieve an economy's modernization: the industry to make use of knowledge, the infrastructure to diffuse knowledge, and the institutions to create new knowledge through training and education (Edquist, 1997). Without investments, systemic failures would lead to negative externalities for society (Edquist, 1997; Wieczorek and Hekkert, 2012; Chaminade et al., 2018). Investments are thus used to increase knowledge production (Lundvall, 1992), stimulate the physical, financial and knowledge infrastructure (Wieczorek and Hekkert, 2012) and drive private investments (Deleidi and Mazzucato, 2021). They are critical inputs for the creation of innovation and future processes of legitimation or market formation (Binz and Truffer, 2017) and key to solve problems of national competitiveness (Alaja and Sorsa, 2021). Recent innovation system approaches made considerable progress in understanding the role of policy and investments in the context of market economies (e.g., Binz and Truffer, 2017; Chaminade et al., 2018; Hipp and Binz, 2020). Investments in a socialist system of innovation are considered to principally have the same priority, aim and function in the economy (e.g., Kogut and Zander, 2000; Slifer, 2006; Ludwig, 2017).

As main actors of an innovation system, organizations can face problems of absorbing new knowledge, transferring technologies or engaging in interactive learning (Polanyi, 1967). Moreover, they may become locked into particular technologies that build on limited or outdated knowledge that is difficult to replace with new knowledge (Smith, 2000). R&D-intensive industries such as biotechnology, pharmaceuticals or electronics, offer new knowledge to rapidly gear industrial problems and seize emerging technological opportunities (Lundvall, 1992). They attract highly-skilled scientists and engineers that engage in learning, capability development and the generation of new solutions (Arundel et al., 1992). Investments in industries and R&D are core to innovation dynamics (Moulaert and Sekia, 2003). We thus expect that investments in R&D-intensive industries lead to economic growth. However, a pure increase in investments in R&D-intensive industries may be insufficient if firms cannot make use of the R&D-related inputs (Castellani et al., 2019).

Empirical evidence on the relation between investments in R&D-intensive industries and the growth of a soviet-type economy are missing to date. Only indirect evidence on the growth-related effects of investments in R&D-intensive industries in a market economy is provided by O'Mahony and Vecchi (2009) who observe a higher productivity of R&D-intensive industries based on investments in knowledge-generating activities for a sample of five countries from 1988 to 1997. Using the EU Industrial R&D Scoreboard from 2002 to 2010, Montresor and Vezzani (2015) show that the output return of investments into knowledge capital is the largest in high-tech sectors. Using the same panel during the 2004–2012 period, Castellani et al. (2019) found that firms in R&D-intensive industries have a higher capacity to translate R&D into production gains.

In addition to investments in R&D-intensive industries, an economy can be modernized by providing innovation support in form of R&D expenses. R&D expenses are used to incentivize the development of new products and technologies and promote technical progress (David et al., 2000). While we are missing empirical evidence on a soviet-type economy, manifold studies on a market economy found a positive link between the amounts of investments in R&D and the growth potential of firms (e.g., Almus and Czarnitzki, 2003; Bérubé and Mohnen, 2009; Vanino et al., 2019).

Because modernization investments contribute to the use of fundamentally new or improved products and technologies, we predict that they will enhance the growth of a soviet-type economy.

P1. Modernization investments also increase the growth of a soviet-type economy over time.

2.2. System blockades and innovation obstacles

Despite of modernization investments, several obstacles to innovation can arise that impede the generation of innovation and the growth of the economy. The literature on obstacles to innovation identifies different types of obstacles that occur on the level of either the system or a firm in a market economy. In his early work, Lundvall (1992) notes social and institutional changes in the power of users and producers' use and transfer of knowledge in an innovation system. Later, Edquist (1997) refers to obstacles to innovation that arise from institutions that underperform when they lag behind technological changes. Institutional barriers can impede knowledge diffusion via restrictions in intellectual property rights or the commercial use of knowledge or a lack of interactions among organizations. In the context of technology adoption by firms, Baldwin and Lin (2002) identify five obstacles to innovation that are related to costs, institutions, labor, organizations and information. They show that innovative firms in particular engage in a learning process in which different problems of technology adoption occur. In a further study, Galia and Legros (2004) show that economic risk, innovation costs, a lack of financing, organization and skilled personal as well as missing technological information lead to abandoned projects. According to Chaminade et al. (2012), one can group the obstacles to innovation that occur on a systemic level into three main categories: the configuration of research priorities, the small incentives to invent and the limited knowledge flow. The research priorities can be set in regulations, the law and support for firms in the system and represent the importance of R&D and innovation in the economy. They can be restricted to the institutional arrangement in terms of limited knowledge resources, less technical and financial support as well as low openness to innovation. The small incentives to invent relate to the restrictions in the R&D infrastructure and the general conditions to innovate such as the R&D infrastructure in which scientists, engineers, universities and research institutes develop new technologies. The limited knowledge flow refers to the obstacle to the extent of information that could be sourced and knowledge that needs to be exchanged to generate innovation and achieve economic growth (Chaminade et al., 2012).

Empirical evidence on these innovation obstacles in market economies was provided for specific firms, industries and countries. By analyzing Spanish CIS data between 2004 and 2010, García-Quevedo et al. (2018) observe that external constraints affect the failure of innovation projects from their start onward while internal constraints play an additional role during the concept stage. Based on the Ecuadorian Survey of Innovation Activities between 2009 and 2014, De-Oliveira and Rodil-Marzábal (2019) relate the obstacles to innovation to systemic and organizational features particularly perceived by innovative firms. Using survey data in Mexico and Turkey in 2010, De Fuentes et al. (2020) underline that firm characteristics and the institutional context matter as innovation barriers for firms. For soviet-type economies, there is some empirical evidence on particular types of innovation obstacles (e.g., Meske, 1994; Radosevic, 1998; von Tunzelmann et al., 2010), but a comprehensive insight and understanding is missing to date.

We argue that a socialist innovation system's constrained institutional arrangement, that means the centrally set research priorities, the small incentives to invent and the limited knowledge flow negatively influence the relation between modernization investments and economic growth as these obstacles hinder the investments to fully unfold their positive effects. We propose the following:

P2a. The configuration of research priorities in the central plan has a negative impact on the growth of a soviet-type economy over time.

P2b. The small incentives to invent have a negative impact on the growth of a soviet-type economy over time.

P2c. The limited knowledge flow has a negative impact on the growth of a soviet-type economy over time.

Fig. 1 summarizes the propositions on the influence of modernization investments and obstacles in an innovation system on the growth of a soviet-type economy in a conceptual framework.

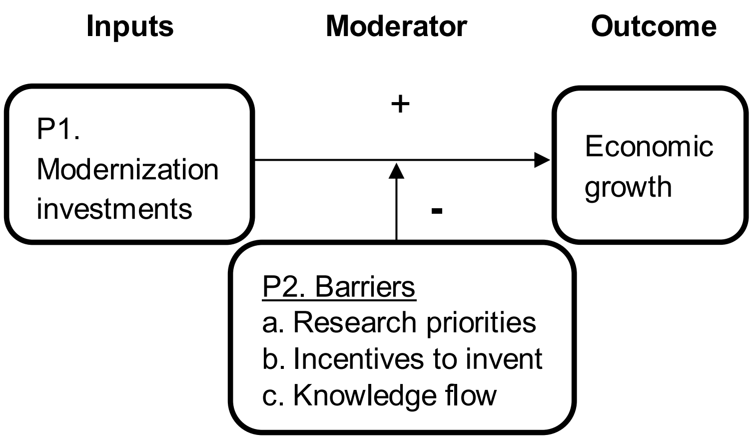

Fig. 1. Conceptual framework on modernization investments, obstacles and economic growth.

3. Case selection, data and methods

3.1. Case selection

We use the case of the GDR because it represents an exemplary soviet-type country to analyze modernization investments and obstacles in an innovation system context. It is internationally known as the showcase model of a soviet-type economy (Lavigne, 1995). The GDR became a socialist state after Germany's separation of the Soviet zone from 1945 until its resolution in 1989. After the initial reconstruction, this soviet-type economy put large investments into R&D-intensive industries in the last decades, but it was also characterized by obstacles to the generation of innovation and decreasing economic growth (Slifer, 2006; Steiner, 2010; Ludwig, 2017). A particular advantage to study GDR's modernization investments and barriers relates to the nature of data on a former, autarchic system that mainly excluded any external influences from e.g. globalized competition or spillovers. The legacies of the GDR recently gained attention by policy makers and scientists 30 years after Germany's unification, which made primary sources available (e.g., Günther et al., 2020; Glitz and Meyersson, 2020). So far, most of the studies on Germany's innovation system focus on the developments after GDR's transformation into a market economy (e.g., Fritsch and Graf, 2011; Eickelpasch, 2015; Cantner et al., 2018).

3.2. Generation of data and indicators

To derive empirical evidence on the modernization investments and obstacles for the case of the GDR, we collected a set of archive data on a yearly basis. We take the entire period from the GDR's foundation in 1949 to its fall in 1989 into account and put a particular focus on the role of modernization from the 1970s onward for reasons of political significance and data availability. After World War II, the GDR initially had to reconstruct its production facilities and the primary focus was on the development of heavy industries within Stalin's model of industrialization (Ludwig, 2017). Only the 1970s became a turning point towards a modern industry policy in which technological progress gained significance. After 1989, the unification treaty between the GDR and FRG allowed for a monetary, economic and social union that firstly guaranteed private property, market-based competition, free pricing mechanism and freedom of work and entrepreneurial decisions (Staatsvertrag, 1990). We take an evolutionary view on modernization investments and the obstacles to innovation during the development of this socialist innovation system.

We collected and prepared archival data from different statistical sources of the GDR. In addition, we use existing recalculated indicators from the literature in order to make a comparative study possible. Our approach requires clarification with respect to data usability and comparability. Krämer and Leciejewski (2021) recently called into question the reliability of GDR statistics due to the tendency of the central planners and high-ranking politicians to publish manipulated material for ideological reasons. However, the planners had to put strict requirements on the compilation and communication of internal, confidential statistics and exercised respective control mechanisms throughout different hierarchical levels to retrieve unfalsified data for the purpose of economic planning (Steiner, 2016). Moreover, operation managers rather tended to deviate from the fulfillment of production plans in order to avoid high future planning goals and the severe sanctions hindered them from manipulating the data (Heske, 2005b; Gesetzblatt der DDR, 1958). We therefore use original primary, harmonized and internationally comparable data to exclude any biases from potential manipulation approaches at the publication stage.

The first group of data relates to GDR's economic performance, its modernization investments and R&D expenses. As main indicator for the economic performance of the GDR, we used data on the gross domestic product (GDP) that was recalculated by Stäglin and Ludwig (2000) and deflated by Heske (2005a) according to international statistical conventions to calculate the compound annual growth rate.[1] We computed the missing values for some years based on an additional estimation procedure. The GDP is a standard economic indicator and used in constant prices of the year 1995 to exclude any biases in the price setting of primary and core products during the adoption of market prices in 1990. We provide a comparison to the growth rate of the GDP in the FRG based on data from Statistisches Bundesamt (2002).[2]

We proxy modernization investments by investments in the capital stock of R&D-intensive industries in an economy. This approach allows us to grasp the modernization of the economy's production in general including replacement and expansion investments to upgrade the production of goods and technologies. We identified nine R&D-intensive industries[3] out of 31 industries based on the international standard classification scheme of Gehrke et al. (2013). Original primary data on the yearly amounts of gross fixed capital investments in the GDR was collected by the national statistical office on basis of ten aggregated industries, of which only three roughly cover

[1] We refrain from using data from Merkel and Wahl (1991), Maddison (1995) or Slifer (2006) because they do not base their analyses on primary statistics, apply a system of indicators that is not harmonized across the different aspects of the national account and their methodological approach is not completely transparent.
[2] Due to the missing exchange rate from GDR Mark to Deutsche Mark a direct comparison to the FRG is not possible. Based on real prices of foreign trade, only Valuta-Mark could be used as an equivalent.
[3] The classification of R&D-intensive industries includes (1) the chemical industry, (2) the production of plastic products, (3) rubber processing, (4) steel and light metal construction as well as railroad equipment, (5) engineering, (6) the production of office machines, (7) automotive manufacturing and repair of motor vehicles, (8) electrical engineering and the repair of appliances as well as (9) medical, precision and optical instruments.

the categorization of R&D-intensive industries. In order to calculate the investments in R&D-intensive industries, we used the investment data of Stäglin and Ludwig (2000) who categorized the original primary data according to the more precise international standard classification scheme. Moreover, the data is in current prices that allows us to provide a better comparison to the extent of investments in the FRG in each year. Again, we computed the missing values for some years based on an additional estimation procedure. We calculated the sum of capital investments in R&D-intensive industries in each year and set it as percent of GDP as well as percent of all industry investments. For comparing the figures to the FRG, we retrieved internal data on the yearly amounts of gross fixed capital investments of the former federal territory from the federal statistical office and applied the same calculations as above.

As another indicator for an economy's modernization, we used the amount of R&D expenses in each year based on data from Stifterverband (1990). Due to the distinct definition and categorization of R&D in the GDR, Stifterverband (1990) recalculated the R&D statistics according to international standards of the OECD (Frasci Manual) and provides harmonized data on the R&D expenses in the GDR for the years from 1981 to 1989. We calculated the arithmetic mean for the missing values of some years and set the amount of R&D expenses as percent of GDP. We compare this figure to the respective indicator of the FRG by using data on the amount of R&D expenses from BMBF (2021) from 1970 to 1989.

The second group of data encompasses GDR's obstacles to modernization. Mostly, evidence on modernization obstacles is based on survey data over a short period of time (e.g., De-Oliveira and Rodil-Marzábal, 2019; De Fuentes et al., 2020). However, long-term survey data on modernization barriers of a former socialist system does not exist, which leads us to focus on archival data sources. The first obstacle refers to the setting of research priorities in the central plan which we operationalize by relating the modernization investments to the sum of all industry investments in the GDR. We compare this figure to the respective indicator of the FRG. The second obstacle to modernization refers to the results from the small incentives to invent that is measured by using data on the number of patent applications per employee from 1950 to 1989. Since 1950, inventions were protected by the Office for Inventions and Patents of the GDR (Amt für Erfindungs- und Patentwesen/AfEP) (DPMA, 2021a). In 1968, one year after its foundation, the GDR became a member of the World Intellectual Property Organization (WIPO), which required the compliance to international standards for the application of patents, i.e. its degree of novelty, the inventive activity and the technical applicability. As a result, GDR's number and quality of patents is comparable to the patents of other countries such as the FRG. In 1990, the AfEP was integrated into the German Patent and Trademark Office, which is the central authority for intellectual property protection in Germany since 1877 (DPMA, 2021b). Its database DEPATIS offers bibliographical and legal event patent data such as the application ID, date, family size, citations and IPC classes. After removing the duplicates, the total number of applications in the GDR counts more than 280,000 patents. We calculated the mean value of the number of applications for each decade to account for the high volatility of patents when used on a yearly basis (Günther et al., 2020). We retrieved employment data from the GDR's national statistical office and equivalent data of the FRG from DEPATIS and the federal statistical office. The third modernization obstacle regarding the limited knowledge flow is measured by the number of co-inventors of the same and different institutions per employee in each year from 1950 to 1989. The number of co-inventors is frequently used as a proxy to measure the extent of knowledge exchange and circulation (e.g., Zaggl, 2017). It is retrieved from the patent data and calculated as mean value of each decade. We relate it to the number of employees in each year and compare this indicator with the respective data of the FRG.

4. The soviet-type economy, its innovation system and modernization investments

The soviet-type economy was based on a central regulation plan that did not allow any private property on production inputs. A communist party governed the system; in the GDR the Socialist Unity Party (SED) targeted at a primacy of production with a focus on the autarkic, large-scale industries of heavy engineering, raw materials and chemicals (Gesetzblatt der DDR, 1958). As other soviet-type economies, the GDR was dominated by commodities (i.e. material goods, fuels, natural resources) to regulated and constant held prices and political strategies based on bargaining and export (Radosevic, 1998). Compared to market economies, the focus was on means of production instead of consumer goods (Ludwig, 2017). To serve the high demand for raw materials in line with regional specialization, the closed economy aligned their production and cooperation agreements with other countries of the Council for Mutual Economic Assistance (Rat für gegenseitige Wirtschaftshilfe/RGW) (Ahrens, 2000).

Fig. 2 depicts the development of the annual growth rate of the GDP as an indicator of the economic performance in the GDR from 1971 to 1989 compared to the FRG. The growth rate of the GDP in the GDR takes 4.1 % in 1971, an average value of 3.3 % over time and decreases to 2.3 % in 1989. It shows an overall downward trend but also some positive outliers that can be explained by the last wave of privatization and the social-political program during the 1970s as well as the export surplus after the balance of payments crisis during the early 1980s. The growth rate of the GDP in the parallel economy of the FRG takes a value of 3.3 % in 1971, an average value of 2.4 % over time and increases to 3.9 % in 1989. The negative outliers can be explained by the oil price crisis at the beginning of the 1970s and 1980s. Despite of its higher value, the growth rate of the GDR decreases to a larger extent compared to the FRG over time, which highlights the increasing backlog of the GDR in terms of economic growth.

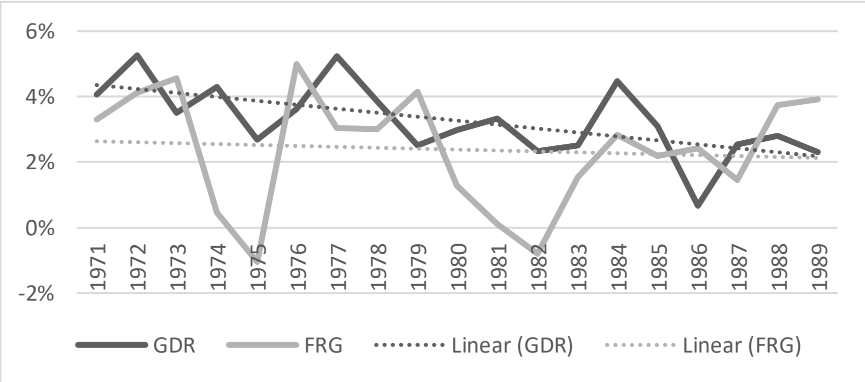

Fig. 2: Compound annual growth rate of the GDP (in %) in the GDR and the FRG.
Data source: GDR: Heske (2005a), for missing values: own calculations; FRG: Statistisches Bundesamt (2002).

The socialist innovation system was characterized by three types of actors: the combinates (in German: "Kombinate") with their industrial research centers, the institutes of the Academy of Sciences, and the higher education facilities. Combinates were large, scale-intensive, vertically and horizontally integrated units of production (Radosevic, 1999; Günther et al., 2010; Ludwig, 2017) and their 38 industrial research centers engaged in applied research to support the implementation of new products and production processes in the GDR (von Tunzelmann et al., 2010). The 60 institutes of the Academy of Sciences were juridically independent academic research institutes that conducted basic research to prepare new technologies for the industry (Mayntz, 1994). The various institutes of higher education comprised universities and technical schools with an exclusive focus on teaching (Chiang, 1990; Meske, 1993, 1994; von Tunzelmann et al., 2010). There is evidence that GDR's number of R&D employees in total and across industry sectors was comparable to the FRG even though more employees worked in the public sector (without universities) than in the industry (Meske, 1993).

Modernization investments played a role in the GDR's innovation system since the 1950s, but its means of scientific-technical progress to leapfrog Western states gained particular importance from the 1970s onwards (Lindig, 1995; Kogut and Zander, 2000; Glitz and Meyersson, 2020). During the 1950s, heavy engineering and raw materials dominated the investment portfolio by about 25% and adding investments in energy and automotive engineering even accounted for 80% of all industry investments (Ludwig, 2017). In 1958, the first chemistry program was agreed, which led to subsequent investments in heavy engineering (ibid.) The economic reforms during the late 1960s enabled increased investments in R&D-intensive sectors such as electrical and apparatus engineering, but the heavy industry and energy production was still the main focus (Kogut and Zander, 2000). With the change of power from Walter Ulbricht to Erich Honecker in 1971, the rationalization of production was key and investments were shifted to housing and consumer goods as well as the chemical, automotive and microelectronics industry (Ludwig, 2017). After the payment crisis in 1982, the latter gained even larger attention as a motor for the "scientific-technical revolution" in the economy of the GDR (ibid.).

Fig. 3 shows the modernization investments, i.e. the investments in the capital stock of R&D-intensive industries, as percent of GDP in the GDR compared to the FRG from 1970 to 1989. They increase from 4.1 % in 1970 to 7.0 % of GDP in 1989 and only the first years of both decades are marked by a short decrease. The modernization investments in the FRG take an initial value of 4.1 % in 1970 that slightly decrease to 2.9 % of GDP in 1989. Except for the first year, they are at all times below the modernization investments as percent of GDP in the GDR, indicating a comparably higher relevance for modernization in the soviet-type economy between 1970 and 1989. The driving forces behind GDR's modernization investments are mechanical engineering, followed by chemistry and electrical engineering.

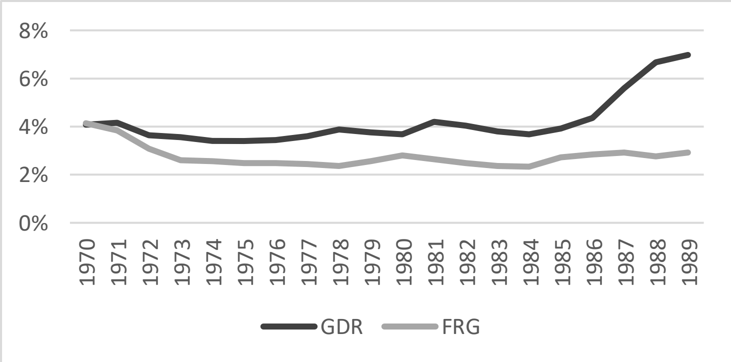

Fig. 3. Investments in the capital stock of R&D-intensive industries in % of GDP in the GDR and the FRG.

Data source: GDR: Stäglin and Ludwig (2000), for missing values: own calculations; FRG: Federal statistical office (Investment statistics provided on demand).

As another indicator of modernization, Fig. 4 illustrates the R&D expenses in percent of GDP in the GDR compared to the FRG from 1970 to 1989. It accounts for 3.2 % in 1981, takes an average value of 3.1 % over time and slightly diminishes to 2.9 % of GDP in 1989. In the FRG, the R&D expenses are 2.1 % in 1970, take an average value of 2.5 % over time and increase to 2.8 % of GDP in 1989. It is below the R&D expenses as percent of GDP in the GDR at all points in time, underlining the higher relevance of modernization in the socialist innovation system. This finding is supported by Legler et al. (1992) who show a higher technological specialization in relation to R&D expenses in the GDR in 1987 compared to the FRG.

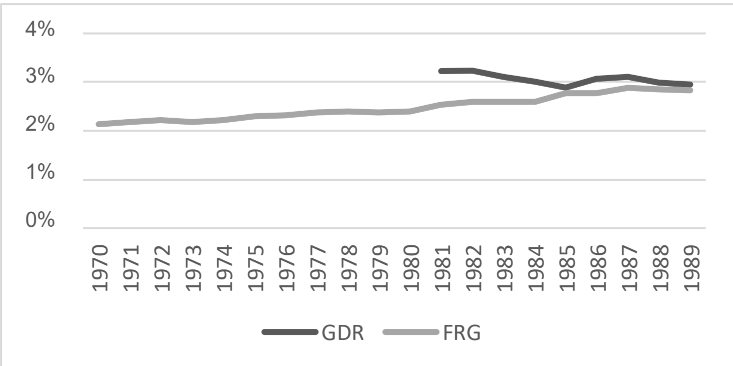

Fig. 4. R&D expenses in % of GDP in the GDR and the FRG.

Data source: GDR: Stifterverband (1990), for missing values: own calculations; FRG: BMBF (2021), for missing values: own calculations.

5. Obstacles to modernization in the socialist innovation system

Despite of the relatively large and increasing investments, GDR's innovation system included severe obstacles to modernization that have contributed to the backlog of the soviet-type economy compared to the parallel market economy of the FRG with regard to its performance (Allen, 2001; Slifer, 2006; Steiner, 2010). In 1989, the final net debt of the GDR was 19.9 billion Valuta-Mark (Deutsche Bundesbank, 1999) and the productivity accounted for only one-third of the FRG (Ludwig, 2017). We use the categorization of Chaminade et al. (2012) to transfer the obstacles to innovation in a market-based system to the case of a soviet-type economy. These obstacles should not be considered as isolated; they rather depend on each other in a system of structural couplings. There is empirical evidence that these obstacles in a socialist innovation system include the selected research priorities, the small incentives to invent and the limited knowledge flow (Meske, 1990; Günther et al., 2010; von Tunzelmann et al., 2010).

Manifold studies argue that the configuration of research priorities in the central plan provided an inadequate basis for capability development, innovation and economic growth (Allen, 2001; Slifer, 2006; Steiner, 2010; Berliner, 2019). At least the failure to comply to the central plan and the loss of economic activities were identified early as the deficits of the system (Gleitze, 1975). The system was based on a linear model of technology push in which knowledge was only transferred from the Academy of Sciences to the industry (Balàzs, 1993; Meske, 1994; Allen, 2001; von Tunzelmann et al., 2010; Günther et al., 2020). Research of the Academy of Sciences was oriented towards central planning goals and only insufficiently separated from production (Radosevic, 1998), suffered a lack of demand (Balàzs, 1993) and often could not get into the application phase (Chiang, 1990). Because of the separation between production and markets, managers were only poorly informed about the international state-of-the-art, which made own technological developments rapidly obsolescent (ibid.). Research projects were only assigned by higher level authorities and not by production or sales units that would allow for the technology's practical use (Allen, 2001). The SED allocated the investments centrally and became aware of recent technological progress only delayed which often made the new goals impossible to include in the five-year-plans in order to keep up with the international pace of development (Augustine, 2020). Technological developments were thus in conflict between the (international) state-of-the-art, the (mostly unrealistically high) central planning goals and the (often dysfunctional) division of labor between the countries of the RGW (Lindig, 1995). Industrial espionage served then as a means to retrieve knowledge on Western technologies (Glitz and Meyersson, 2020). The imitation of Western products (von Tunzelmann et al., 2010) and the overconcentration of investments in selected industries (e.g., microelectronics) reduced the technical progress in the economy as a whole (Ludwig, 2017). Furthermore, the embargo regulations did not allow for a purchase of licenses to produce components, which made the imitations very costly (Dittmann, 2013).

In parallel, other industries had to maintain obsolete and worn-out facilities (Ludwig, 2017). The investment policy of the soviet-type economy has decelerated its growth potential (Vonyó and Klein, 2019; Kukic, 2021). It is the poverty of institutions rather than firm's knowledge that lacked coordinated innovation (Kogut and Zander, 2000).

Fig. 5 illustrates the centrally set research priorities in the GDR that are operationalized by the modernization investments as percent of all industry investments compared to the FRG from 1970 to 1989. They increase from 45.9 % in 1970 to 60.6 % of all industry investments in 1989. The modernization investments in the FRG take an initial value of 65.9 % in 1970 that slightly increase to 68.2 % of all industry investments in 1989. They are at all times above the modernization investments as percent of all industry investments in the GDR, indicating the constrained institutional arrangement in the setting of research priorities in the soviet-type economy. The investments in selected areas caused imbalances in the production structure of the GDR that was characterized by old industries and overemployment until 1989 (Ludwig, 2017). This approach was in contrast to the technology-oriented subsidies for a broad range of industries in the FRG (Legler et al., 1992). Especially the extent of investments in raw material industries such as mineral oil and iron processing is larger in the GDR than in the FRG over time.

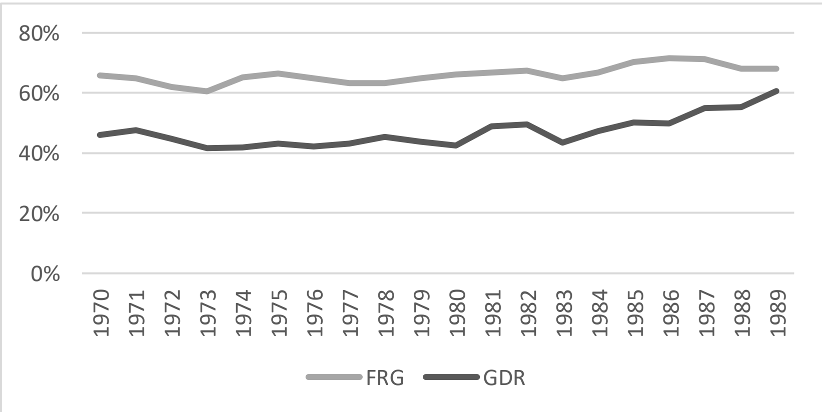

Fig. 5. Investments in the capital stock of R&D-intensive industries in % of all industry investments in the GDR and the FRG.

Data source: GDR: Stäglin and Ludwig (2000), for missing values: own calculations; FRG: Federal statistical office (Investment statistics provided on demand).

The R&D infrastructure of the GDR was characterized by a continued decrease of researchers and graduates that faced smaller incentives to invent as a result of GDR's distinct patent system and its inadequate supply of inputs (Lindig, 1995). The organizations received a financial budget based on their size rather than their projects or the market demands, which reduced the performance competition and demotivated the R&D staff (Chiang, 1990). In addition, managers often employed their R&D personnel in the production unit to avoid a slowdown in the rate of production in order to meet the planning goals (Allen, 2001). R&D employees often had only little time and resources to develop new technologies (Lindig, 1995), why they favored mainly small improvements with low financial costs (Radosevic, 1998). They were further restricted in the implementation of their ideas as a result of the technology-push model (Balàzs, 1993) and had only limited access to equipment, resulting in a lower quality of research (Mayntz, 1994) as well as frequency and impact of patents (Meske, 1994). The lack of innovation incentives and modern production equipment impeded a diffusion of new technologies in the GDR (Günther et al., 2010; von Tunzelmann et al., 2010). R&D in the GDR was production-oriented (Hemmerling, 1986) and patents were treated as 'free goods' (Hanson and Pavitt, 1987). The ministries provided 'soft incentives' to trigger the development of technologies, but the results from the inventive processes could not be appropriated from commercialization (Radosevic, 1998). The system was not able to integrate innovations in different business functions and learning by doing or using was less common in relation to externalized R&D (Radosevic, 1999). Political conformity and the reliance on authority and hierarchy were more important than original ideas in the socialist innovation system (Augustine, 2020). Despite of its comparable number of R&D employees and the portfolio of patent applications to the FRG, the GDR could not catch-up in terms of how many patents were filed per R&D employee (Günther et al., 2020).

Fig. 6 depicts the results from the incentives to invent in terms of the average number of patents per 1,000 employees in the GDR compared to the FRG from the 1950s to the 1980s. It takes an initial value of 0.3 in the 1950s, an average value of 0.9 over time and increases to 1.3 during the 1980s. In the FRG, the average number of patents per 1,000 employees begins with 1.0 in the 1950s, takes an average value of 1.6 over time and increases to 2.1 during the 1980s. Even though both average values increase over the entire observation period, GDR's number of patents per employee is constantly lower than in the FRG, which we relate to the smaller incentives to invent. A similar trend is observed for the number of patents per residents in the GDR over time (Günther et al., 2020).

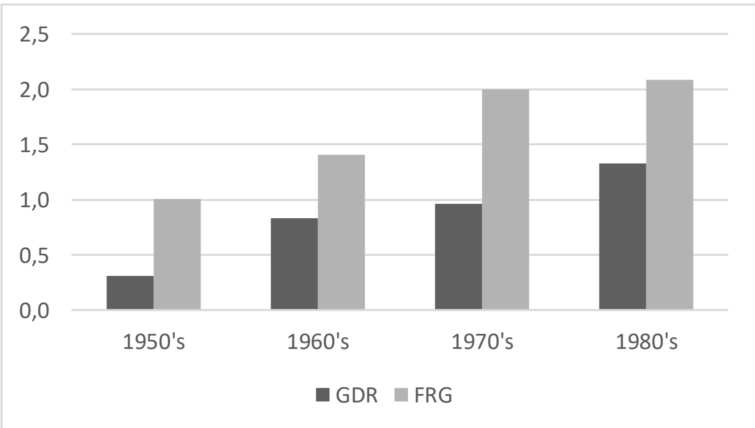

Fig. 6. Average number of patents per 1,000 employees per decade in the GDR and the FRG.

Data source: Number of patents: DEPATIS; Number of employees in the GDR: National statistical office (Statistical yearbooks of 1969-1989); Number of employees in the FRG: Federal statistical office (Statistical yearbook of 2005).

Moreover, the GDR encompassed severe constraints in the knowledge flow. The combinates indeed developed trustful and long-term cooperations with the scientific institutes to share knowledge (Meske, 1994), but they had only limited opportunities to cooperate with other actors (Radosevic, 1998), especially with regard to innovative activities (Radosevic, 1999).[4] These cooperations based on central planning decisions and hindered the industry to receive any feedback from customers or to profit from knowledge spillovers (Günther et al., 2010; von Tunzelmann et al., 2010). While formal cooperations between the actors were often weak, informal networks to exchange materials and spare parts were needed to compensate the shortages and achieve the production plans (Radosevic, 1999).[5] A research regulation in 1986 aimed to increase the knowledge transfer between science and the industry through demanding the Academy of Sciences and universities to achieve 50% of their revenues from contract research, which, however, led to huge capacity deficits in implementing innovations, an increased focus on incremental improvements and a neglect of basic research instead (Meske, 1990; Mayntz, 1994). The compliance with the central plan and the independency from competition led to devastating information deficits in the GDR (Günther et al., 2010).

Fig. 7 illustrates the limited knowledge flow as the average number of co-inventors per 1,000 employees in the GDR compared to the FRG from the 1950s to the 1980s. It takes an initial value of 0.2 in the 1950s, an average value of 1.4 over time and increases to 2.9 during the 1980s. In the FRG, the average number of co-inventors per 1,000 employees starts with 0.3 in the 1950s, takes an average value of 1.7 over time and increases to 3.2 during the 1980s. The graph indicates a continuous increase of GDR's number of co-inventors over time and especially with regard to the 1980s when the compensation for co-inventors grew (Lindig, 1995). However, it remains below the average values of the FRG, which we refer to GDR's limited knowledge flow.

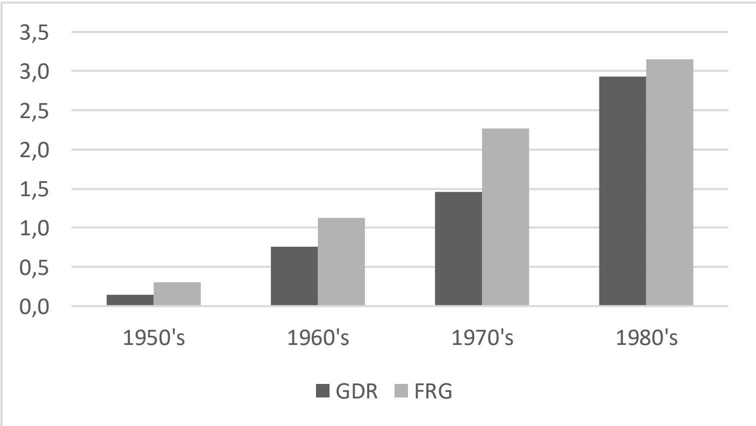

Fig. 7. Average number of co-inventors per 1,000 employees per decade in the GDR and the FRG.

Data source: Number of patents: DEPATIS; Number of employees in the GDR: National statistical office (Statistical yearbooks of 1969-1989); Number of employees in the FRG: Federal statistical office (Statistical yearbook of 2005).

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[4] Some minor cooperations to selected Western suppliers existed to negotiate on technical belongings; however, they were constrained by foreign trade organisations (Sandberg, 1989).

[5] In contrast to civil sectors that relied on informal networks, military sectors could use larger formal networks (Radosevic, 1999) and gained a more prominent role in the soviet-type economy over time because of the arms race with the US (Allen, 2001).

6. Discussion

Our findings have important implications for the literatures on innovation systems, innovation barriers and policy. First, our study shows that GDR's innovation system was characterized by large modernization investments that shaped its evolution and outcome (Proposition P1). Between 1970 and 1989, the modernization investments as percent of GDP as well as the R&D expenses as percent of GDP in this socialist innovation system were above the benchmark of the market economy of the FRG. The driving forces behind GDR's modernization investments were mechanical engineering, chemistry and electrical engineering. This finding is of crucial importance for recent studies that underline the role of investments in an innovation system context (Binz and Truffer, 2017; Chaminade et al., 2018; Hipp and Binz, 2020). We extend the present focus on firm-level investments into R&D or production capabilities (e.g., Ghosal and Nair-Reichert, 2009) to the modernization of an economy and provide new empirical evidence on the evolution of investments in the capital stock of R&D-intensive industries in a socialist system of innovation compared to a market economy.

Future studies could build on our findings by providing statistical evidence on the influence of modernization investments on the development of an economy such as the output growth or productivity of the actors therein. Thereby, the assumptions to our proxy of modernization investments should be scrutinized. As other research in this field, we focus on a single-case study (e.g. Alaja and Sorsa, 2021). Since innovation systems depend on their geographical and political context, one can expect different evolutionary patterns for e.g. market economies, but similar patterns for centrally-organized or highly regulated economies such as China or Russia (Dominguez Lacasa et al., 2019). Cross-comparative studies of different countries would contribute to more generic results on the effects of modernization investments.

Our second contribution concerns the literature on innovation barriers by extending our knowledge on their embeddedness within a socialist system of innovation (Propositions P2a-c). Despite of the increasing modernization investments in the soviet-type economy, a constantly decreasing economic growth is observed that can be partly explained by the structure of its innovation system. Our findings show that several types of modernization barriers exist in the socialist system that influence its structural development. I.e. the modernization investments as percent of all industry investments, the number of patents and the number of co-inventors per employee increased over time but remained at a much lower level in the GDR compared to the FRG. We relate these findings to the obstacles to modernization that include the centrally set research priorities, the small incentives to invent and the limited knowledge flow in a socialist innovation system. We add to recent research on innovation barriers (e.g., De Fuentes et al., 2020) and show that the combination and persistence of these obstacles influence the evolution of an innovation system. We went beyond the use of survey data (e.g., De-Oliveira and Rodil-Marzábal, 2019) and apply a set of comparative economic and innovation-related indicators to a former socialist regime in which long-term survey data on modernization barriers is limited at its best.

Further research could find alternative measures of innovation barriers in a former or resurgent state-led economy and examine their influence in the relation between modernization investments and economic growth. We used several comparative indicators to operationalize the obstacles to modernization but combinate-internal information such as the number and quality of products or materials stocks was impossible to obtain. Despite of our effort to compile a comprehensive set of archival data sources, future studies may access more fine-grained information. The findings could then be linked to recent studies that include various firm-level determinants (e.g., De Fuentes et al., 2020). Especially for the case of a former soviet-type economy, a more complete picture on the determinants of its fall should be gained.

The last contribution relates to the literature on innovation policy. Recent innovation policy approaches use investments as means to solve macro-level societal problems or follow specific missions in an innovation system (Ghazinoory et al., 2020; Deleidi and Mazzucato, 2021). Especially regarding current missions such as digitalization or energy transition, potential risks of excessive unilateral or technology-specific investments as well as the barriers in the underlying innovation system should be considered. Our study focuses on a former soviet-type economy that was characterized by massive investments in the capital stock of R&D-intensive industries, but the persistent obstacles to modernization in its innovation system have impeded their effects and contributed to its demise.

Future studies should anticipate the role of modernization investments to be included in the direction of mission-oriented innovation systems. In parallel, the obstacles embedded in a system of innovation should receive attention since they can change the direction of structural change that is pursued by policy makers. Their role beyond a national framework and within global value chains should be disentangled as well.

7. Conclusion

This study attempted to develop a new framework on the role of modernization investments and obstacles during the evolution of a socialist system of innovation. By combining knowledge on innovation system and barriers literatures, we derived new propositions on the link between modernization investments and economic growth as well as its influence through several obstacles to innovation. Using original primary time series data, we provide empirical evidence on the economic growth, investments and barriers to modernization of the GDR as an exemplary socialist country and link these features to the configuration and limits of its system of innovation.

The results show that GDR's innovation system was characterized by large modernization investments that shaped its structure and evolution. The modernization of this soviet-type economy is related to investments in R&D-intensive industries as well as R&D expenses, whose share of GDP was at all times larger as compared to the parallel market economy of the FRG. The scientific-technical progress was of great importance for the GDR to achieve the production goals and catch-up with Western market economies (e.g., Glitz and Meyersson, 2020). However, the obstacles to modernization affected the evolution of its socialist system of innovation. A comparison to the FRG shows that the GDR was not only marked by a more sharply decreasing rate of economic growth, but also by severe obstacles to innovation that related to the configuration of research priorities, the small incentives to invent and the limited knowledge flow. I.e. the modernization investments as share of all industry investments and the number of patents and co-inventors per employee in the GDR remained largely below the benchmark of the FRG. Based on these findings and recent studies on innovation policy (e.g., Cirillo et al., 2019), we recommend policy makers to reduce the economy's obstacles to modernization with regard to the features of the specific and evolving innovation system.

These findings are important since policies allocated significant amounts of subsidies to R&D-intensive industries without considering the obstacles embedded in the system of innovation. Recent evidence shows that investments in key sectors such as renewable energies could not fully unfold their effects due to the characteristics of the innovation system structure (e.g., Hipp and Binz, 2020). Our study underlines the risks associated with an exclusive focus on investments in R&D-intensive industries by explicating the types of modernization obstacles in a national system of innovation that can lead to an increasing backlog of the economy. Future innovation policies could examine the related structures of the respective system and their potential obstacles to modernization by applying our proposed framework.

References

Ahrens, R., 2000. Gegenseitige Wirtschaftshilfe? Die DDR im RGW: Strukturen und handelspolitische Strategien 1963-1976. Schriften des Hannah-Arendt-Instituts für Totalitarismusforschung 15. Böhlau, Köln.

Alaja, A., Sorsa, V.-P., 2021. The evolution of the national innovation system as programmatic policy idea in Finland. Science and Public Policy 47, 834–843.

Allen, R.C., 2001. The rise and decline of the Soviet economy. Canadian Journal of Economics 34, 859–881.

Almus, M., Czarnitzki, D., 2003. The Effects of Public R&D Subsidies on Firms' Innovation Activities: The Case of Eastern Germany. Journal of Business & Economic Statistics 21, 226–236.

Arundel, A., Lorenz, E., Lundvall, B.-A., Valeyre, A., 1992. How europe's economies learn: A comparison of work organization and innovation node for the ERÙ-15, in: Lundvall, B.-A. (Ed.), National Systems of Innovation. Anthem Press, London, pp. 183–222.

Augustine, D.L., 2020. Management of technological innovation: High tech R&D in the GDR. Business History 1–17.

Balàzs, K., 1993. Lessons from an economy with limited market functions: R&D in Hungary in the 1980s. Research Policy 22, 537–552.

Baldwin, J., Lin, Z., 2002. Impediments to advanced technology adoption for Canadian manufacturers. Research Policy 31, 1–18.

Berliner, J.S., 2019. The Prospects for Technological Progress, in: Bornstein, M. (Ed.), The Soviet Economy: A Book of Readings. Routledge, London.

Bérubé, C., Mohnen, P., 2009. Are firms that receive R&D subsidies more innovative? Canadian Journal of Economics 42, 206–225.

Binz, C., Truffer, B., 2017. Global Innovation Systems—A conceptual framework for innovation dynamics in transnational contexts. Research Policy 46, 1284–1298.

Blind, K., Grupp, H., 1999. Interdependencies between the science and technology infrastructure and innovation activities in German regions: Empirical findings and policy consequences. Research Policy 28, 451–468.

BMBF, 2021. FuE-Ausgaben der Bundesrepublik Deutschland und ihre Finanzierung, Datenportal des Bundesministeriums für Bildung und Forschung. URL https://www.datenportal.bmbf.de/portal/de/Tabelle-1.1.2.html.

Cantner, U., Giebler, A., Günther, J., Kristalova, M., Meder, A., 2018. Innovation cooperation in East and West Germany: a study on the regional and technological impact. International Journal of Computational Economics and Econometrics 8, 242.

Castellani, D., Piva, M., Schubert, T., Vivarelli, M., 2019. R&D and productivity in the US and the EU: Sectoral specificities and differences in the crisis. Technological Forecasting and Social Change 138, 279–291.

Chaminade, C., Intarakumnerd, P., Sapprasert, K., 2012. Measuring systemic problems in National Innovation Systems. An application to Thailand. Research Policy 41, 1476–1488.

Chaminade, C., Lundvall, B.-Å., Haneef, S., 2018. Advanced Introduction to National Innovation Systems. Edward Elgar Publishing, Cheltenham (UK).

Chiang, J.-T., 1990. Management of technology in centrally planned economies. Technology in Society 12, 397–426.

Cirillo, V., Martinelli, A., Nuvolari, A., Tranchero, M., 2019. Only one way to skin a cat? Heterogeneity and equifinality in European national innovation systems. Research Policy 48, 905–922.

David, P.A., Hall, B.H., Toole, A.A., 2000. Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. Research Policy 29, 497–529.

De Fuentes, C., Santiago, F., Temel, S., 2020. Perception of innovation barriers by successful and unsuccessful innovators in emerging economies. Journal of Technology Transfer 45, 1283–1307.

De-Oliveira, F., Rodil-Marzábal, Ó., 2019. Structural characteristics and organizational determinants as obstacles to innovation in small developing countries. Technological Forecasting and Social Change 140, 306–314.

Deleidi, M., Mazzucato, M., 2021. Directed innovation policies and the supermultiplier: An empirical assessment of mission-oriented policies in the US economy. Research Policy 50, 104151.

Deutsche Bundesbank, 1999. Die Zahlungsbilanz der ehemaligen DDR 1975 bis 1989.

Dittmann, F. (2013). Matthias Falter und die frühe Halbleitertechnik in der DDR, in: Forstner, C., Hoffman, D. (Eds.), Physik im Kalten Krieg (pp. 113-123). Springer Spektrum, Wiesbaden.

Dominguez Lacasa, I., Jindra, B., Radosevic, S., Shubbak, M., 2019. Paths of technology upgrading in the BRICS economies. Research Policy 48, 262–280.

DPMA, 2021a. Datenbestand. Deutsches Patent- und Markenamt. URL https://depatisnet.dpma.de/DepatisNet/depatisnet?window=1&space=menu&content=index&action=datenbestand

DPMA, 2021b. Our office. URL https://www.dpma.de/english/our_office/about_us/index.html

Edquist, C. (Ed.), 1997. Systems of innovation: technologies, institutions, and organizations, Science, technology and the international political economy series. Pinter, London.

Eickelpasch, A., 2015. Forschung, Entwicklung und Innovationen in Ostdeutschland: Rückstand strukturell bedingt. DIW-Wochenbericht 82, 907–918.

European Commission, 2020. Science, Research and Innovation Performance of the EU 2020. A fair, green and digital Europe. Publications Office, Brussels.

Freeman, C., 1995. The ‘National System of Innovation’ in historical perspective. Cambridge Journal of Economics.

Fritsch, M., Graf, H., 2011. How sub-national conditions affect regional innovation systems: The case of the two Germanys: Two systems. Papers in Regional Science 90, 331–353.

Galia, F., Legros, D., 2004. Complementarities between obstacles to innovation: Evidence from France. Research Policy 33, 1185–1199.

García-Quevedo, J., Segarra-Blasco, A., Teruel, M., 2018. Financial constraints and the failure of innovation projects. Technological Forecasting and Social Change 127, 127–140.

Gehrke, B., Frietsch, R., Neuhäusler, P., Rammer, C., 2013. Neuabgrenzung forschungsintensiver Industrien und Güter 2012, in: EFI (Ed.), Studien zum deutschen Innovationssystem. Expertenkommission Forschung und Innovation.

Gesetzblatt der DDR, 1958. Zweiter Fünfjahrplan. Deutsche Demokratische Republik.

Ghazinoory, S., Nasri, S., Ameri, F., Montazer, G.A., Shayan, A., 2020. Why do we need ‘Problem-oriented Innovation System (PIS)’ for solving macro-level societal problems? Technological Forecasting and Social Change 150, 119749.

Ghosal, V., Nair-Reichert, U., 2009. Investments in modernization, innovation and gains in productivity: Evidence from firms in the global paper industry. Research Policy 38, 536–547.

Gleitze, B., 1975. Die Produktionswirtschaft der DDR im Wettbewerb mit der westlichen Industriewelt, in: Gleitze, B., Ludz, P.C., Merkel, K., Pleyer, K., Thalheim, K.C. (Eds.), Die DDR Nach 25 Jahren, Wirtschaft Und Gesellschaft in Mitteldeutschland. Duncker und Humblot, Berlin.

Glitz, A., Meyersson, E., 2020. Industrial Espionage and Productivity. American Economic Review 110, 1055–1103.

Günther, J., 2015. Innovation, in: Hölscher, J., Tomann, H. (Eds.), Palgrave Directory of Emerging Markets and Transition Economies. pp. 360–371.

Günther, J., Hipp, A., Ludwig, U., 2020. Universalien der Innovation - Erfindertum und technischer Fortschritt in der DDR und dessen Rolle nach 1990. Universität Bremen, 1–17.

Günther, J., Nulsch, N., Urban-Thielicke, D., Wilde, K., 2010. 20 Jahre nach dem Mauerfall: Transformation und Erneuerung des ostdeutschen Innovationssystems. Institut für Wirtschaftsforschung Halle (IWH). Studien zum deutschen Innovationssystem.

Hanson, P., Pavitt, K., 1987. The Comparative Economics of Research, Development and Innovation in East and West: A Survey. Harwood Academic Publishers, Chur.

Hemmerling, J., 1986. G.D.R. patent information system promotes the creation of modern high technologies as well as of complex innovation processes. World Patent Information 8, 206–209.

Heske, G., 2005a. Bruttoinlandsprodukt, Verbrauch und Erwerbstätigkeit in Ostdeutschland 1970 bis 2000 - Neue Ergebnisse einer volkswirtschaftlichen Gesamtrechnung (VGR No. ZA 8208), Studiennummer. GESIS Datenarchiv, Köln.

Heske, G., 2005b. Meinungsäußerungen, Standpunkte und Einschätzungen zur Statistik und statistischen Ergebnissen aus der DDR. GESIS. URL https://www.gesis.org/fileadmin/upload/forschung/publikationen/zeitschriften/hsr/hstrans17.pdf

Hipp, A., Binz, C., 2020. Firm survival in complex value chains and global innovation systems: Evidence from solar photovoltaics. Research Policy 49, 103876.

Kogut, B., Zander, U., 2000. Did Socialism Fail to Innovate? A Natural Experiment of the Two Zeiss Companies. American Sociological Review 65, 169–190.

Kornai, J., 1995. Das sozialistische System. Die politische Ökonomie des Kommunismus, Schriftenreihe des Bundesinstituts für ostwissenschaftliche und internationale Studien Köln. Nomos Verlagsgesellschaft, Baden-Baden.

Krämer, W., Leciejewski, K., 2021. Statistik im Sozialismus: Amtliche Daten zwischen Realität und Ideologie und ihre Medienrezeption. AStA Wirtschafts- und Sozialstatistisches Archiv 15, 73–91.

Kukic, L., 2021. Technical change and the postwar slowdown in Soviet economic growth. Working Papers in Economic History, 21-10. http://hdl.handle.net/10016/33259

Lavigne, M., 1995. The Economics of Transition. From Socialist Economy to Market Economy. Palgrave Macmillan UK, New York.

Legler, H., Grupp, H., Gehrke, B., Schasse, U., 1992. Innovationspotential und Hochtechnologie: technologische Position Deutschlands im internationalen Wettbewerb. Wirtschaftswissenschaftliche Beiträge 70, Physica-Verlag, Heidelberg.

Lindig, D., 1995. Datenreport: Ausgewählte Rahmenbedingungen erfinderischen Schaffens und soziale Charakteristika der Erfinder in der DDR. BISS-Forschungshefte. Studien und Forschungsberichte aus dem Berliner Institut für Sozialwissenschaftliche Studien Heft 9, 1–42.

Ludwig, U. 2017. Die gesamtwirtschaftliche Entwicklung der SBZ / DDR (1949 bis 1990) – eine Bilanz, in: Heydemann, G., Paqué, K.-H. (Eds.), Planwirtschaft – Privatisierung – Marktwirtschaft. Wirtschaftsordnung und -entwicklung in der SBZ / DDR und den neuen Bundesländern 1945–1994. Vandenhoeck & Ruprecht, Göttingen.

Lundvall, B.A., 1992. National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. Pinter, London.

Lundvall, B.-Å., Johnson, B., Andersen, E.S., Dalum, B., 2002. National systems of production, innovation and competence building. Research Policy 31, 213–231.

Maddison, A., 1995. Monitoring the world economy 1820–1992. Development centre studies. Organisation for Economic Co-operation and Development (OECD), Paris.

Mayntz, R., 1994. Deutsche Forschung im Einigungsprozess. Die Transformation der Akademie der Wissenschaften der DDR 1989 bis 1992. Campus Verlag, Frankfurt/Main.

Merkel, W., Wahl, S., 1991. Das geplünderte Deutschland: die wirtschaftliche Entwicklung im östlichen Teil Deutschlands von 1949 bis 1989, 2. Aufl. ed. IWG, Bonn-Bad Godesberg.

Meske, W., 1994. Restructuring the Parties in Academic—Industry Relations (AIR) in East Germany. Forschungsgruppe Wissenschaftsstatistik, Wissenschaftszentrum Berlin für Sozialforschung: Berlin.

Meske, W., 1993. The restructuring of the East German research system — a provisional appraisal. Science and Public Policy 20, 298–312.

Meske, W., 1990. Wissenschaft der RGW-Länder. 30th ed, Studien und Forschungsberichte. Akademie der Wissenschaften der DDR, Berlin.

Montresor, S., Vezzani, A., 2015. The production function of top R&D investors: Accounting for size and sector heterogeneity with quantile estimations. Research Policy 44, 381–393.

Moulaert, F., Sekia, F., 2003. Territorial Innovation Models: A Critical Survey. Regional Studies 37, 289–302.

Nelson, R., 1993. National innovation systems: A comparative analysis. Oxford University Press, New York.

OECD, 1997. National Innovation Systems. OECD, Paris.

O'Mahony, M., Vecchi, M., 2009. R&D, knowledge spillovers and company productivity performance. Research Policy 38, 35–44.

Polanyi, M., 1967. The tacit dimension. Doubleday, Garden City, N.Y.

Radosevic, S., 2022. Techno-economic transformation in Eastern Europe and the former Soviet Union–A neo-Schumpeterian perspective. Research Policy 51, 104397.

Radosevic, S., 1999. Transformation of science and technology systems into systems of innovation in central and eastern Europe: the emerging patterns and determinants. Structural Change and Economic Dynamics 10, 277–320.

Radosevic, S., 1998. The Transformation of National Systems of Innovation in Eastern Europe: Between Restructuring and Erosion. Industrial and Corporate Change 7, 77–108.

Rakas, M., Hain, D.S., 2019. The state of innovation system research: What happens beneath the surface? Research Policy 48, 103787.

Sandberg, M., 1989. Learning from Capitalists: A Study of Soviet Assimilation of Western Technology. Almqvist & Wiksell, Stockholm.

Slifer, J., 2006. Planning Ahead and Falling Behind: The East German Economy in Comparison with West Germany. Akademie Verlag, Berlin.

Smith, K., 2000. Innovation as a Systemic Phenomenon: Rethinking the Role of Policy. Enterprise and Innovation Management Studies 1, 73–102.

Staatsvertrag, 1990. Vertrag über die Schaffung einer Währungs-, Wirtschafts- und Sozialunion zwischen der Bundesrepublik Deutschland und der Deutschen Demokratischen Republik.

Stäglin, R., Ludwig, U., 2000. Entstehung und Verwendung des Bruttoinlandsprodukts 1970 bis 1989 (DFG-Projekt). Wiesbaden.

Statistisches Bundesamt, 2002. Volkswirtschaftliche Gesamtrechungen, Fachserie 18. DESTATIS, Wiesbaden.

Steiner, A., 2016. Strukturen der Informationsgewinnung und Qualität der Zahlen. Bundeszentrale für politische Bildung. URL https://www.bpb.de/nachschlagen/zahlen-und-fakten/deutschland-in-daten/219859/informationsgewinnung

Steiner, A., 2010. The plans that failed: an economic history of the GDR, 1st ed., Studies in German history. Berghahn Books, New York.

Stifterverband, 1990. Forschung und Entwicklung in der DDR. Daten aus der Wissenschaftsstatistik 1971 bis 1989, in: Materialien zur Wissenschafsstatistik Nr. 6/1990, SV Wissenschaftsstatitik GmbH im Stifterverband für die Deutsche Wissenschaft, Essen.

von Tunzelmann, N., Günther, J., Wilde, K., Jindra, B., 2010. Interactive Dynamic Capabilities and Regenerating the East German Innovation System. Contributions to Political Economy 29, 87–110.

Vanino, E., Roper, S., Becker, B., 2019. Knowledge to money: Assessing the business performance effects of publicly-funded R&D grants. Research Policy 48, 1714-1737.

Vonyó, T., Klein, A., 2019. Why did socialist economies fail? The role of factor inputs reconsidered. The Economic History Review 72, 317-345.

Wieczorek, A.J., Hekkert, M.P., 2012. Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. Science and Public Policy 39, 74–87.

Zaggl, M.A., 2017. Manipulation of explicit reputation in innovation and knowledge exchange communities: The example of referencing in science. Research Policy 46, 970–983.

Zemtsov, S., Kotsemir, M., 2019. An assessment of regional innovation system efficiency in Russia: the application of the DEA approach. Scientometrics 120, 375–404.

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