CHAPTER 3

The Influence of Technical Progress on Economic Growth in the GDR

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1 Introduction

Productivity is driven by technical progress, and technical progress can be achieved by the education, abilities, and qualifications of people, known as human capital (Foster and Rosenzweig 1996). Human capital can be created through schooling, training, and investments, and it contributes to the economy, which absorbs educated labor (Griliches 1997). Many empirical studies observe a positive relationship between human capital, technical progress, and productivity in market-based economies (e.g., Maudos et al. 2003; Henderson and Russell 2005; Teixeira and Fortuna 2010).

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Socialist economies, such as the German Democratic Republic (GDR), the Polish People's Republic, or the Czechoslovak Socialist Republic, were characterized by a high level of education and training of the population (Lavigne 1995). Despite this success, the socialist education system faced a large gap between aspiration and reality, and the political system failed in the end (Kaack 1993). The GDR was known as the wealthiest and most technologically sophisticated nation of the Eastern Bloc (Baker et al. 2007). The amount of its human capital in terms of qualifications and technical progress, especially in comparison to West Germany, should not be underestimated (Günther et al. 2020). Recent studies show that technical progress in the form of patents led to higher productivity of the industry sectors in the GDR (Hipp et al. 2022b). Nonetheless, empirical evidence on the effect of technical progress—based on the contribution of academic and skilled workers—on productivity in socialist economies is scarce. Since the importance of qualifications changed with the shift in the political focus from academics to skilled workers over the course of the GDR era, it is interesting to study the actual effects on the productivity of its economy.

In the present article, we examine the impact of technical progress on productivity based on original primary data from the Statistical Office in the GDR. We measure technical progress based on staff qualifications and distinguish between *academic workers*, which relate to highly qualified personnel who obtained an academic degree at a university or college[1] in the GDR, and *skilled workers*, indicating qualifications obtained through a master's certificate or as a skilled worker. We expect that the higher the qualifications of the staff, the larger the productivity-enhancing effects on the economy.

Using data on the amount of physical capital ("Grundmittel"), investments, immaterial capital ("Bildungsfonds"), and the number of academic, skilled, and other workers in the GDR, we deliver new results from estimating a Cobb-Douglas production function for the observation period from 1960 to 1989. Our results contribute to studies on the relevance of qualifications for the productivity and growth of a socialist economy and its transformation into a market economy.

[1] Even though universities focused on a broad range of sciences, and colleges (Hochschulen) offered a specialization to particular branches, their terms could be used almost interchangeably in the GDR, because of their little difference in prestige and rank (Giles 1978).

The chapter is structured as follows: Section 2 includes a literature overview and the hypotheses development on technical progress, qualifications, and productivity in the GDR. Section 3 describes our empirical strategy regarding the data and methods used. Section 4 shows our descriptive and regression results, and Sect. 5 discusses the findings and concludes.

2 Literature Overview and Hypotheses Development

2.1 *The Political System, Technical Progress, and Economic Growth in the GDR*

Following the devastating World War II, Germany was divided into four occupation zones, with its production potential severely damaged and weakened. Examples were the dismantling by the victorious powers, withdrawal from current production, brain drain of specialists, and high occupation costs. In the aftermath of World War II, the Allied military governments shattered the economy, which had once been fully developed and operated based on labor division. The Potsdam Agreement provided for the restoration of Germany's political and economic unity. However, the conflicting interests of the victorious Western powers and the Soviet Union soon made this a nonissue. As a result, a "rump economy" was left in the Soviet occupation zone (SBZ) (Karlsch 1993, 55f). The former sources of supply of the raw materials essential for an industrial economy—coal, iron, and steel—were located primarily in the Western occupation zones, and the metal manufacturers in the Soviet zone were cut off from them. As a result, there was a tremendous disparity between the primary and processing industries. After the Berlin blockade of 1948/1949, the Cold War between the victorious powers and the establishment of two states in Germany dimmed the prospects for restoring economic unity within a reasonable time frame. Thus, there were two options to address the disparity between the production economies of the SBZ and, accordingly, the GDR: supplementing the rump economy through integration into the international division of labor or building up a separate production sector covering all key sectors. The decision was politically predetermined due to the monopoly on power in the GDR's ruling party, state leadership, and its Soviet advisors[2]: the realization of an industrialization model such as Stalin had prescribed for Russia's backward economy at the end of the 1920s. [3]

Even though the destruction caused by World War II, the dismantling, and the withdrawal of current production had weakened the production potential, there was no evidence of a technically and economically backward economy that first had to catch up with industrialization according to the Soviet model. Because of the lack of mineral resources, some branches of the primary industry were weakly developed, but there was an efficient machine and vehicle construction industry. Nevertheless, the party and state leadership placed the development of its heavy industry at the center of its planning. This was evident not only by the guidelines of the first Five-Year Plans[4] but, above all, by the concentration of investment in primary industries and heavy machinery construction. The path to an autarkic economy was paved, and foreign trade was assigned the role of a service provider: Exports of goods had to generate the foreign exchange needed to pay for imports of raw materials. The state had a monopoly on foreign trade. The GDR's admission to the Council for Mutual Economic Assistance (Comecon) established its integration into an economic system based on the division of labor with countries that, except Czechoslovakia,

[2] On the position of Soviet advisors, see Schneider (2017, 43ff).

[3] Stalin's industrialization model included the development of a large-scale and heavy industry, which was necessary for the transformation of the entire national economy based on modern machine technology, for the victory of socialist economic forms, the technical-economic independence of the country from the capitalist environment, and its readiness for defense (Akademie der Wissenschaften der UdSSR/Institut für Ökonomie, 1959, 419). It overcame Russia's economic backwardness from the tsarist era and was realized with the first two Five-Year Plans from 1928 to 1937. Regardless of the special historical circumstances in Russia, this model was later elevated to a universally valid principle of socialist industrialization (Roesler 1981, 1020ff.).

[4] The first Five-Year Plan, adopted in 1951, p. 7, stated: "Durch den Neu- und Ausbau der Produktionskapazitäten in der Metallurgie, im Schwermaschinenbau und in der chemischen Industrie ist eine weitgehende Unabhängigkeit unserer Volkswirtschaft von dem kapitalistischen Ausland sicherzustellen." The priorities were even clearer in the second Five-Year Plan: "Die vorrangige Entwicklung der Grundstoffindustrie, vor allem der Kohle-, Energie- und Chemieproduktion ist zu sichern," and further, "Der Maschinenbau hat in erster Linie die erforderlichen Ausrüstungen für die Entwicklung der Grundstoffindustrie, insbesondere für Kohle und Energie, zu liefern. Die Produktion von Tagebaugroßgeräten, Ausrüstungen für die Brikettfabriken, Energiemaschinen, Stahlkonstruktionen und anderen wichtigen Schwermaschinenbauerzeugnissen ist dementsprechend zu erhöhen." Gesetzblatt der DDR Teil I, Nr. 5/1958, 42.

were at a lower level of development and primarily needed to catch up in terms of industrialization. The efforts of the highly industrialized countries were thus distracted from their own technical progress.[5]

Thus, in the GDR, considerable labor and capital resources were allocated to the fuel and energy industries, the construction of an iron and steel plant in Eisenhüttenstadt (EKO-Stahl) far from coal deposits and the ore deposit industry, and shipbuilding. In order to avoid bottlenecks in the power supply, coal and energy programs were adopted in 1954 and 1957 to expand the energy supply. This was followed in 1958 by the chemical program. New production capacities for raw lignite, new briquette factories and lignite-based power plants, and the construction of new chemical plants led to the expansion of heavy engineering. Mechanical and electrical engineering were assigned new tasks to manufacture production equipment to mechanize and automate production processes.

The expansion of production possibilities in the heavy industry created a catch-up effect that temporarily spurred economic growth. However, this path hit its limits by the end of the 1950s. The marginal efficiency of capital decreased significantly, and given demographic developments and the migration of thousands of entrepreneurs, engineers, doctors, and scientists to the West, the labor supply diminished. The supply of labor could only be stabilized by the recruitment of new groups of employees, especially women.

For economic growth and increased prosperity, new combinations of production factors and products had to be found with which scarce resources could be used more effectively and productivity increased. In the centrally planned economy, in general, this discovery process did not start in the companies, as the governmental authorities set the priorities and provided the resources. The ruling Socialist Unity Party of Germany (SED) called this "hocheffektive Struktur der Volkswirtschaft" (a highly effective structure of the national economy). To this end, investment was directed primarily into those branches of the national economy considered to be the pacemakers of the scientific and technological revolution. Investments were, in particular, allocated to electrical engineering and electronics, scientific equipment, manufacturing, and branches of mechanical engineering, where "structure-determining" products enabled the

[5] Only a few new-to-the-world technologies were invented in the GDR. For instance, from 1947 to 1957, the engineer Mauersberger developed the so-called stitch-bonding technique, the products of which were marketed under the Malimo trademark.

planning process. Their share in the investment volume was not a trivial item. In 1970, it amounted to 55% in the chemical industry, 60% in electrical/electronic engineering, and 50% in processing machinery and vehicle construction (Staatliche Zentralverwaltung für Statistik 1971, 54). The application of electronic data processing was emphasized and took place primarily in large-scale enterprises, namely for the preparation, planning, and management of production, for the control of technological processes, for the solution of scientific-technical and economic tasks, and for the calculation and balancing of plans (Gesetzblatt der DDR 1967, 66f). There was, however, no loss of focus on the primary industries. On the contrary, the focus of investment was shifted in favor of innovative products and processes. In the energy industry, coal production was not expanded (Riesner 2009, 2). Instead, the construction of a nuclear power plant for energy production was initiated. The use of liquid and gaseous energy sources was pushed ahead. Priority was given to the expansion of the petrochemical industry. In the iron and steel industry, the expansion of the second processing stage continued with the construction of a cold rolling mill at EKO-Stahl in Eisenhüttenstadt.

To support the strategic plans, the central planning system was reformed in the 1960s. Companies were given greater freedom of disposition, and the profit level, henceforth, measured their economic success. Whereas special factors such as the reconstruction effects had determined production growth in the postwar period, technical progress dominated the increase during the reform period (Ludwig 2017). However, the reform failed due to the incompatibility between other components of central planning and the interests of enterprises. There were disruptions in the relationships between suppliers and final producers as well as supply difficulties for the private households. The reform was abandoned at the end of the 1960s, and a central plan was reinstituted to steer the national economy.

In the GDR and other East European countries under the Soviet Union's rule, the accumulation of real capital (expansion of production facilities)[6] was seen as a decisive basis. However, in the Western market economies, Schumpeter's theory shifted the focus on technical progress and innovation, defined as the development of new or improved products

[6] In the socialist countries, money remained as a means of exchange. However, since it could not be converted into capital, it was therefore understood in the analyses of Eastern economies as physical production facilities (buildings and equipment).

or technologies, as a key driver of growth (Schumpeter 1912, 1942). Shortly after, Solow (1956) had developed a neoclassical growth model that measures technical progress in the form of a production function. Because the quantitative expansion of the factor inputs of labor and real capital could explain only part of the production growth, there remained an inexplicable residual to which the effect of technical progress was attributed. There were initial attempts to relate technical progress to investments in education (Denison 1964). However, neoclassical growth models could not explain how technical progress occurs, in contrast to endogenous growth models, initiated in the early 1990s, mainly by the work of Romer as well as Grossman and Helpman (e.g., Romer 1990; Grossman and Helpman 1994). Of central importance in the endogenous growth model are two variables:

- Education: the skills and abilities of individuals. It is a prerequisite for the emergence of new knowledge and the use of this knowledge in the creation of new products and production processes.
- Knowledge: the stock of knowledge created by productive work. It requires the use of scarce resources—especially education.

For market economies, there is ample evidence on the importance of education for achieving technical progress and productivity (e.g., Erken et al. 2018; Wang et al. 2021). However, evidence on the relevance of education and its relation to productivity in a Soviet-type economy is scarce.

2.2 Technical Progress and Qualifications in the GDR

Although the endogenous growth model did not yet exist in the GDR time, the empirical importance of education and qualification for economic growth was already recognized in the 1960s (Ludwig et al. 1972; Maier 1977). From then on, the demand for the intensification of production dominated economic policy.[7] An essential component was the close linking of production with education and science. It was recognized that the economic strength of the country could be increased with the targeted

[7] Conceptually, reference was made to the circular scheme of Karl Marx, who had distinguished between "extensively and intensively extended reproduction" in Volume II of *Das Kapital*.

education of highly qualified professionals. The existence of a highly qualified next generation was a necessary condition for economic growth.

Consequently, human capital in the GDR and staff qualifications could be developed, relying on its education system. Following a collectivist vision, the Marxist-Leninist ideology aimed at reducing inequality among people that comes from the natural hierarchy of status groups (Baker et al. 2007).[8] Therefore, equal chances of education should reduce the social differences in participation in education and increase the technical modernization of the economy (Köhler and Stock 2004; Baker et al. 2007).

Hence, a comprehensive school system up to grade eight (later: tenth) replaced the traditional German three-streamed secondary system of *Gymnasium*, *Realschule*, and *Hauptschule* (Köhler and Stock 2004). After graduation from the *allgemeinbildenden polytechnischen Oberschule* (general secondary school), students could enter the four-year (later: two-year) *erweiterte Oberschule* (upper secondary school), which included more technical and scientific topics. This led to graduation with *Abitur* and higher education. Another option was vocational training (Baker et al. 2007). Concerning higher education, the first university reform targeted the underrepresentation of working-class students to develop a highly trained technical elite and a "socialist intelligentsia" (Axen 1953; Giles 1978). As a result, the enrollment of working-class students increased from 4% in 1946 to 53% in 1958 (Schwertner and Kempke 1967). In addition, the Ministry of Higher and Technical Education introduced *Arbeiter- und Bauernfakultäten* (worker and farmer faculties) as special departments within universities to prepare working-class students for higher education as well as evening and distance courses to educate skilled workers (Baker et al. 2007). In 1951, a second university reform introduced a fixed study period and a set of obligatory courses and requirements for access, such as Russian language, a study of Marxism-Leninism, and membership in the Free German Youth (FDJ) (Giles 1978).

During the 1960s, under the New Economic System of Planning and Governance, academic engineers were regarded as the driving force behind the technical revolution and the leading figure of educational policy, which led to permanent higher education (Köhler and Stock 2004). Ideas about

[8] Apart from reducing material inequality by abolishing private property, the GDR also committed to social and educational equality, which was, however, mostly put back into the economic sphere due to the initial shortage of labor based on denazification and migration to the West after World War II (Wharton 1988).

quotas of working-class students, political records, or courses in the *Arbeiter- and Bauernfakultäten* had been abandoned in favor of academic merit by students from all backgrounds (Baker et al. 2007). Students of low-income families could obtain a monthly basic grant for living; there was no university choice nor a tuition fee, and the study changed from *Grundstudium* (basic study) to *Fachstudium* (subject study) as part of the third university reform (Giles 1978). Because a market for capital or labor was missing, the links between education and jobs needed to be coordinated through state control of job allocation and transfer (Köhler and Stock 2004). By 1961, 81% of all workers were employed in state-regulated enterprises (Baker et al. 2007).

After 1971, as Erich Honecker became the first secretary of the central committee, the SED put the Marxist-Leninist vision of the class struggle between material equality, social security, and the universal socialist-educated person back into focus. The idea was to educate more skilled workers than academics (Köhler and Stock 2004; Baker et al. 2007). Moreover, the SED feared that the highly qualified staff would constitute a breach of the guarantee of employment as academic positions became rare (Köhler and Stock 2004). The threat was seen in the independent, uncontrollable elite with technical expertise and power instead of being committed to socialist values (Giles 1978; Köhler and Stock 2004; Baker et al. 2007). As a result, after a long period of expansion, higher education enrollment rates were reduced in the GDR and also in other socialist states (Reisz and Stock 2006). However, compared to other socialist states, such as Czechoslovakia (10.5%), Romania (9.1%), and Hungary (8.9%), the GDR had already achieved a high percentage of university graduates (39.5%) (Schaefer and Michel 1974, 23). The goal of the period between 1985 and 1989 was to maintain this level and distribution of qualifications (Baker et al. 2007).

Recent empirical studies elaborate on the role of knowledge, education, and technical progress in the GDR. For instance, Günther et al. (2020) show that the importance of education and technical progress based on patents in the GDR should not be underestimated. In this regard, a database with manually cleaned and processed information on 286,478 GDR patents was created (Hipp et al. 2022a). By using newly developed indicators, Hipp et al. (2021) investigate GDR's large investments in the capital stock of R&D-intensive industries, which, however, could not fully unfold their effects on economic growth. This was due to obstacles to innovation (i.e., the central setting of research priorities, limited incentives for innovation, and restricted knowledge flows). In a related study, Hipp et al. (2022b) show the effect of extensive and intensive sources of growth on industrial productivity in the GDR. The authors found a positive impact of technological progress measured by patents on economic growth and the necessity of investments in the industrial sectors. Finally, by focusing on total factor productivity, Hipp et al. (2023) analyze the productivity-related effects of inventorship in the GDR. They show that the creation, accumulation, and diffusion of knowledge contributed to productivity in the industrial sectors despite several misalignments in the system, distorted incentive structures, as well as limited application in the industry. Only in the presence of sufficient local interactive capabilities, international knowledge diffusion did not result in additional productivity gains.

In the next section, we elaborate on the impact of the levels of education and qualifications of staff on technical processes and productivity in the GDR.

2.3 Hypotheses on Qualifications and Productivity of the Economic Sectors in the GDR

2.3.1 Academic Worker

The productivity of economic sectors depends on technological development, and technological development can be supported by the educational qualifications of workers (Sachs 1965). The SED aimed at producing more workers with advanced technical skills—that is, engineers, scientists, and high-level technicians—that develop new production processes, increase productivity, and achieve "technocratic modernization" through an expanded education system (Baker et al. 2007; Ludwig 2017). The production of this "socialist intelligentsia" should drive technical expertise and bring political identification to the ideology of socialism (Axen 1953). University education of engineers and business students became important to apply the new scientific knowledge in the economic sectors (Kogut and Zander 1992). Moreover, education and research in the GDR were closely linked to the industry and local community, which was also supported by the structural reforms (Giles 1978). Other political measures were the chartering of colleges that offered degrees in engineering or the *Arbeiter- and Bauernfakultäten* that were introduced in early years to support the access of children from working-class and peasant families to higher education (Baker et al. 2007).

However, measures to increase the educational levels were based on political decisions rather than concrete requirements, which hindered coordinated long-term development (Giles 1978; Köhler and Stock 2004). For instance, the quota system that limited the university access of students from bourgeois families in favor of working-class students underlined the initial class-based ideology (Giles 1978). Additionally, the incentives to obtain a university degree changed: While the industry paid too much over the standard wage for academic graduates in the early years, their wage was cut in the later years when the academics started to threaten the power of the SED (Baker et al. 2007). Moreover, the working load of academics with too many projects, the restrictions of collaboration in research to the Soviet bloc, and the reluctance toward basic research and toward long-term scientific progress in favor of industry-oriented research have been criticized as having negative consequences for economic productivity (Giles 1978). In general, a balance between education and employment cannot be planned, and individual and social interests do not have to be the same (Korn et al. 1984).

Nonetheless, we argue that the increased access to higher education, the academic qualifications, and large technical expertise positively impacted the application of technical skills to improve the production processes and productivity of the economic sectors in the GDR. We therefore hypothesize:

H1. Academic workers had a positive impact on productivity of the economic sectors in the GDR.

2.3.2 Skilled Worker

The GDR was also a "workers" and "peasant" state. As the technical level of production and the development of higher education increased since the 1970s, the need for skilled workers with vocational training has been argued to grow in a balanced way (Maier 1977). This would solve the "crisis" of having too many academics without appropriate positions (Dore 1976). While the SED adapted the political measures based on the planning goals, there is no evidence of deficient educational or technical training of the workers (Kogut and Zander 1992). Instead, the qualifications of the technical staff increased, more efficient production methods were introduced (Allen 2001), and a balanced relationship between qualifications and positions was achieved at the end of the 1980s (Baker et al. 2007). In addition, particular incentives to increase productivity in the industry—other than academic prestige—determined the generation or improvement of new products or processes; this included the strive after social esteem, the reward system, and the low fees of patenting (Lindig 1995). With the regime's shift to focus on skilled workers, also the wage advantages of this group outweighed the academic positions, which further increased the incentives for vocational training and production work (Baker et al. 2007).

On the other hand, political goals of maintaining the balance between the levels of qualification, through restricted access to higher education or wage advantages for skilled workers, were assessed as more important than free education (Baker et al. 2007). There was almost no public discussion of this restriction but increased dissatisfaction among the workers in lower-qualified positions (Rochlitz and Kasek 1983), which might have impacted their productivity. Moreover, these workers demanded the recognition of their free personality, ideology-free norms and values, and other aspects such as performance differentiation (Kaack 1993). Because the SED could formally reclassify positions, the balance between supply and demand for qualifications contradicted their factual requirements (Köhler and Stock 2004). Moreover, skilled workers were rather occupied with maintaining production and solving short-term shortages than increasing production efficiency (Lindig 1995).

Nonetheless, since it can be argued that skilled workers have a solid technical understanding because they are close to production, and their qualification has been actively supported since the 1970s by the SED, we hypothesize that they contributed to the productivity of the economic sectors in the GDR, too:

H2. Skilled workers had a positive impact on productivity of the economic sectors in the GDR.

3 Empirical Strategy

3.1 Data

To test our hypotheses, we use a set of variables on the national accounts from internal and original primary data of the Statistical Office of the GDR during the observation period from 1960 to 1989. Since published data from socialist states are assumed to be manipulated (Krämer and Leciejewski 2021), but internal statistics had to pass severe controls throughout political hierarchies, which strongly penalized data falsification, one should only focus on internal and original primary data for an empirical investigation of the socialist period (Steiner 2016).

We created a balanced panel of the respective data for the six economic sectors of the GDR (i.e., industry, construction, agriculture and forestry, traffic, post and telecommunications, domestic trade, and other producing sectors[9]). We use economic data such as the measure of a country's economic performance, the input of physical and immaterial capital, and the labor of different qualification levels. Today, the economic performance of a country is calculated by national statistical offices in the form of gross domestic product (GDP) in the national currency. Until the end of the GDR, such official data did not exist because national accounts were based on the material product system (MPS).[10] The MPS is based on a narrower concept of production than the System of National Accounts (SNA), including GDP, and covers only the production, distribution, circulation, and consumption of tangible goods. Services outside of domestic trade, transport and communication, and industrial research and development are excluded. They are not considered value creators but only mere consumers of tangible goods.

The central measure of a country's economic performance in the MPS is national income (net product). It is not directly comparable with the content and size of the GDP, but it represents the result of the more narrowly defined economic cycle in a consistent system of generation, distribution, and use of tangible goods, and served as the basis for economic policy decisions in the GDR. For these reasons, the following analyses of economic growth use the net product in GDR currency as the central indicator of performance measurement in the GDR. Moreover, data on capital input are also available only in GDR currency. Data on labor input at various qualification levels are collected using the GDR's employment statistics.

[9] Other producing sectors include economy-related institutes and their centers for research and development, engineering offices, project- and plant-engineering combinates, and product-related services.

[10] In the meantime, the gross domestic product of the GDR has been reconstructed from official primary statistics (Stäglin and Ludwig 2000). However, the data are only available at current prices in GDR currency and are not of an official nature. There have also been individual attempts to deflate and convert them into DM and Euro (Heske 2005, 2009). However, their results do not cover the interdependence of all stages of the economic cycle, and their economic content is questionable because of different types of price settings.

We operationalize the amount of production output Y by the net product, capital C is the amount of capital assets (called "Grundmittel"), and labor L is measured by the number of employees. We then specify labor by using two indicators for the qualifications of the staff as the number of employees with (1) a university degree or a degree from a college, that is, *Academic workers*, and (2) the number of employees with a master's certificate or a qualification as a skilled worker, that is, *Skilled workers*. As a control variable, we added the number of employees in training or without formal qualification as the variable *Other workers*. Furthermore, we included *Investments* proxied by the amount of investments in the formation of physical capital in the respective economic sector (Ludwig 2017).[11] Finally, we introduced *Education funds* ("Bildungsfonds") as the education expenses materialized in the qualification level of the labor force during the process of preschool education, general education, vocational education, or higher and technical schools (Ludwig et al. 1972). In contrast to current education expenses, it represents a stock figure and a benchmark for the funds of acquired qualification, knowledge, and skills for a longer time period. It was calculated outside of official statistics by the Institute of Economic Sciences at the GDR Academy of Sciences (Wahse and Schaefer 1990) We use the average annual value of education expenses per employee and related it to each sector on basis of the employment structure.

All variables are in constant prices to ensure their comparability over time.

3.2 Method and Empirical Approach

Since our interest lies in the relationship between qualifications and sectoral productivity, we estimate a Cobb-Douglas production function, which can be applied to Soviet-type economies (e.g., Kukić 2018; Glitz and Meyersson 2020). The Cobb-Douglas production function is a mathematical representation of production relating the inputs of physical capital, labor, and other factors to their corresponding output. It is an essential tool for understanding productivity and serves as an indicator of economic growth and efficiency by measuring the output per input unit (Buxton

[11] Investment data according to economic sectors for the 1960s are only available for the price basis of the year 1980. To enable comparability, we recalculated the investment data for the price basis of the year 1985.

1977). This type of production function measures productivity by estimating the marginal product of each input, helping to identify inefficiencies in production and ways to improve it. Furthermore, it is used to estimate returns to scale (Zellner et al. 1966).

Equation (3.1) depicts the standard Cobb-Douglas production function to estimate productivity. It indicates production output (*Υ:* net product) as a function of a scale factor (*A*), labor (*L*), and capital (*K*). Further, β_1 and β_2 are the share of contributions for *L* and *K*. A growth in β_1 and/or β_2 will lead to a growth in output (Buxton 1977). By transforming the variables into logs, we yield Eq. (3.2). Equation (3.3) then specifies the labor input using the subgroups of academic, skilled, and other workers, and it adds the respective inputs of education funds, capital, and investments to the productivity analysis.

The Cobb-Douglas production function is:

$$\boldsymbol{Y} = \boldsymbol{A} \times \boldsymbol{L}^{\beta 1} \times \boldsymbol{K}^{\beta 2} \tag{3.1}$$

Transformed into logs, the equation follows the specification:

$$\ln \textbf{Net product}_{\textbf{it}} = \delta_0 + \beta_1 \ln \textbf{Labor}_{\textbf{it}} + \beta_2 \ln \textbf{Capital}_{\textbf{it}} + \varepsilon_{\textbf{it}} \tag{3.2}$$

By specifying labor input and adding the control variables, we estimate the equation:

$$\begin{aligned} \ln \textbf{Net product}_{\textbf{it}} = \beta_0 &+ \beta_1 \ln \textbf{Academic Workers}_{\textbf{it}} \\ &+ \beta_2 \ln \textbf{Skilled Workers}_{\textbf{it}} + \beta_3 \ln \textbf{Other Workers}_{\textbf{it}} \\ &+ \beta_4 \ln \textbf{Education funds}_{\textbf{it}} + \beta_5 \ln \textbf{Capital}_{\textbf{it}} \\ &+ \beta_6 \ln \textbf{Investments}_{\textbf{it}} + \varepsilon_{\textbf{it}} \end{aligned} \tag{3.3}$$

We tested Eq. (3.3) using the feasible generalized least squares (FGLS) approach, with time and sector fixed effects. FGLS is a statistical technique that is used to estimate the parameters of a linear regression model when the errors are heteroscedastic (unequal variance) or autocorrelated (dependent on previous values) (Härdle and Simar 2012; Mertler et al. 2021). FGLS has many advantages compared to other estimation techniques, as it provides consistent and efficient estimates of the regression parameters (Härdle and Simar 2012). This is important because it allows us to more accurately estimate the effects of the independent variables on the dependent variable and helps avoid bias in the results. However, we also applied a standard ordinary least square (OLS) approach as a robustness test, and the results remain stable. Equally important, we accounted for a potential lack of independence within groups using a mixed methods approach, and the results hold.

4 Results

4.1 Descriptive Statistics and Graphical Trends

Table 3.3 shows the descriptive statistics, and Table 3.4 provides the correlations of our variables.

Figure 3.1 depicts the development of the net product and its input factors for the economic sectors in the GDR during our observation period. The industrial sector was the GDR's most significant contributor to the net product, accounting for around 43% of the total net product in

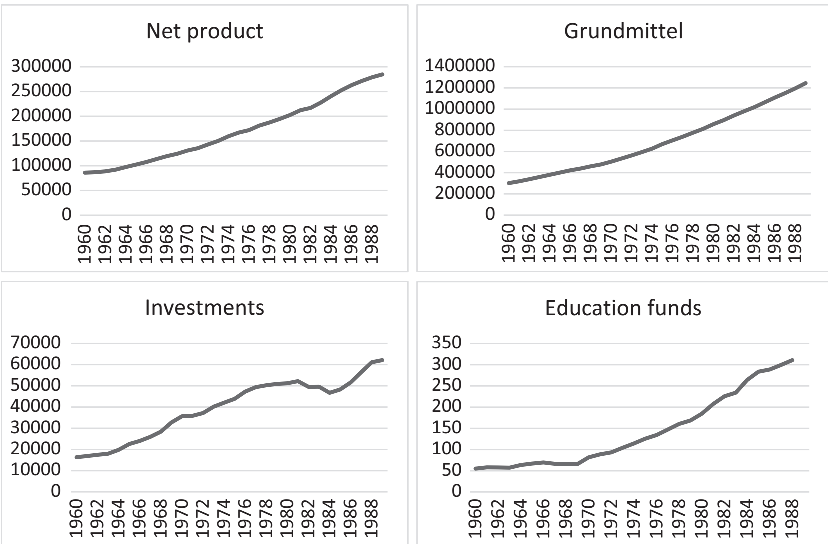

Fig. 3.1 Development of the net product and its input factors (in Mio. GDR currency) of the economic sectors in the GDR over time

1989. Moreover, this sector was a significant driver of economic growth, with consistent growth over the years. The second largest driver was agriculture and forestry, followed by domestic trade, construction, transport/post/telecommunications, and other producing sectors. Except for agriculture and forestry, which experienced a decline at the beginning and at the end of the 1960s, during the mid-1970s, and at the end of the 1980s, all other economic sectors grew continuously.

Regarding the input factors, capital, measured by "Grundmittel," and education funds show a continued increase over time within all economic sectors in the GDR. Investments increased until 1981, then slightly decreased, and only increased again from 1985 onward. While this development is mainly observed for agriculture and forestry as well as construction and domestic trade, a growth of investment over time took place in the industry, transport/post/telecommunications, and other producing sectors.

Figure 3.2 depicts the development of the number of employees of the economic sectors in the GDR over time. The total number of employees decreased until the end of the 1960s, then increased, and decreased again

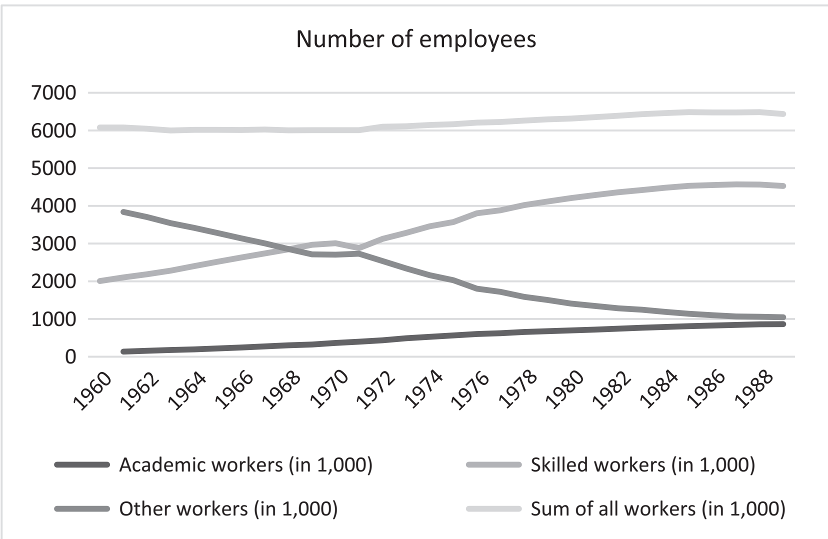

Fig. 3.2 Development of the number of employees of the economic sectors in the GDR over time

from 1986 onward. While the number of academic and skilled workers increased over time, the number of other workers decreased. The number of skilled workers shifted in the 1970s to be the largest contributor to the GDR's economic sectors, especially to the industry sector. Only in *other producing sectors*, the number of academic workers is higher than the number of skilled workers over time.

4.2 Regression Results

Table 3.1 contains the regression results of our model estimations. Models 1–3 include the control variables and one of our variables of interest, that is, the number of academic workers, skilled workers, or other workers. While the number of academic workers and other workers positively and significantly impacts the net product at a 1 to 10 significance level, the

Table 3.1 Relationship between academic and skilled workers and net product

	(1)	*(2)*	*(3)*	*(4)*	*(5)*
VARIABLES	ln_Net product	ln_Net product	ln_Net product	ln_Net product	ln_Net product
ln_Academic workers	0.069*			0.090***	0.035
	(0.035)			(0.028)	(0.034)
ln_Skilled workers		0.009		0.065***	0.036***
		(0.007)		(0.008)	(0.010)
ln_Other workers			0.098***	0.177***	0.145***
			(0.023)	(0.027)	(0.030)
ln_Education funds	0.106***	0.069*	0.081**		0.058
	(0.036)	(0.038)	(0.036)		(0.037)
ln_Capital	0.195***	0.222***	0.183***		0.124***
	(0.040)	(0.035)	(0.038)		(0.038)
ln_Investments	0.049**	0.042*	0.093***		0.066***
	(0.023)	(0.023)	(0.024)		(0.023)
Constant	5.100***	5.411***	5.330***	8.451***	6.186***
	(0.499)	(0.542)	(0.536)	(0.045)	(0.589)
Chi^2	25277.35***	25746.61***	29696.22***	28278.94***	30811.29***
Observations	180	180	180	180	180
Sector and year fixed effects	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

number of skilled workers exerts no influence. The control variables of education funds, capital, and investments positively and significantly impact the net product. Model 4 then introduces all types of workers but without the control variables. Here, the coefficients of academic and other workers remain positive and significant, and the coefficient of skilled workers turns significant. Model 5 finally adds all variables to our baseline model. While the coefficients of skilled and other workers and the control variables of capital and investments remain positive and significant, the coefficients of academic workers and education funds turn insignificant.

Now we turn to our primary focus, which is the role of academic and skilled workers for productivity gains in the economic sectors of the GDR. Academic workers are observed to contribute to the net product in all models except for the last one. The growth in the number of academic workers increases the net product up to 9%. This positively significant effect of academic workers in most model specifications supports our first hypothesis. Regarding skilled workers, the coefficients are positive and significant in all models except for the first model. They contribute up to 6.5% to the net product, which supports our second hypothesis. However, the coefficients of skilled workers are much smaller than the coefficients of academic workers, and they become only significant when academic workers are included in the models. This underlines their smaller contribution to and dependence on academics for productivity gains in the GDR. However, all this subordinated the influence of the capital stock. The transfer of knowledge and innovation, materialized in investments, also seems to support productivity growth.

As a robustness check, we lag the variables by one to three years to test if certain inputs such as qualifications or education funds need time to translate into new or improved products or processes and, then, result in productivity gains. Table 3.2 provides the results of the robustness check for the lag of one year. The coefficient of academic workers remains positive and significant and even increases in size in all models. Growth in the number of academic workers increases the net product even up to 9.1%. However, the coefficient of skilled and other workers turns insignificant in all models, negating a longer-lasting effect on productivity. The effect of the control variable of education funds turns significant and increases in size in all models, contributing to the net product up to 27.6%, which underlines its longer-term influence on productivity gains. The control variables of capital and investments turn insignificant in all models. When testing for the longer time lags of two to three years, the results remain

Table 3.2 Relationship between academic and skilled workers and net product (lagged by one year)

	(1)	*(2)*	*(3)*	*(4)*
VARIABLES	ln_Net product	ln_Net product	ln_Net product	ln_Net product
ln_Academic workers_1	0.080**			0.091**
	(0.032)			(0.038)
ln_Skilled workers_1		-0.006		-0.002
		(0.012)		(0.013)
ln_Other workers_1			0.026	-0.016
			(0.024)	(0.034)
ln_Education funds_1	0.250***	0.248***	0.249***	0.276***
	(0.052)	(0.062)	(0.059)	(0.078)
ln_Capital_1	-0.040	-0.004	-0.028	-0.036
	(0.033)	(0.028)	(0.031)	(0.034)
ln_Investments_1	-0.018	-0.016	-0.012	-0.024
	(0.029)	(0.027)	(0.027)	(0.030)
Constant	8.969***	8.984***	9.056***	9.023***
	(0.236)	(0.230)	(0.224)	(0.256)
Chi^2	23681.42***	28612.17***	29091.97***	23321.06***
Observations	179	179	179	179
Sector and year fixed effects	Yes	Yes	Yes	Yes

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

qualitatively the same. When adding the craftsmen to the industry sector, we observe a longer-lasting positive and significant effect of skilled workers; however, the respective coefficient remains much smaller than the coefficient of academic workers. Omitting the control variables in the first models also leads to similar results.[12]

5 Discussion and Conclusion

This chapter investigates the impact of technical progress—based on the contribution of academic and skilled workers—on economic growth and productivity of the economic sectors in the GDR. First, we provide a literature overview on the development of academic and skilled workers in

[12] Results are available upon request.

the GDR and hypothesize their relation to economic productivity. Then, the hypotheses are tested by using original primary data on the national accounts and employment statistics from the Statistical Office of the GDR on the level of six economic sectors from 1960 to 1989.

In the first decade of its existence, economic growth in the GDR was primarily determined by the expansion of capital stock as a factor of production. The increasing equipment of workplaces with machines and plants made labor, the supply of which increased only slightly, more productive. The increase in labor productivity became the decisive source of economic growth. In addition, capital input per unit of production fell, and so the increasing efficiency of capital supported economic growth. From the 1960s onward, it was hardly possible to draw on these two sources of growth. Labor productivity continued to rise as a result of strong investment in the capital stock, but the efficiency of the capital stock declined. Job expansion and renewal lagged behind in technical terms, and more and more capital was needed to sustain economic growth. Interruptions in this trend occurred only during the years of economic reform and briefly in the mid-1980s.

This analysis assumes homogeneity of factor inputs and does not explicitly investigate how technical progress works. This is remedied by the production function that relates to the quality of factor growth and includes intangible factors, such as knowledge. Our regression results for the years from 1960 onward support the dominant influence of capital input and investments on the quantitative expansion of the use of production factors in the GDR. These effects are, however, only short term, which hints at a low level of innovative strength and the ineffectiveness to use these inputs as catalysts of economic growth in the longer term. The quantity of the factor labor plays a subordinate role since its supply increased only slightly as a result of demographic developments and labor market policy measures. With the differentiation of labor input by qualification levels, we show the importance of two groups, academic and skilled workers, on the growth of net product.

Our first hypothesis postulates a positive relationship between the number of academic workers and the productivity of the economic sectors in the GDR. Our regression results support this relation, which remains largely consistent across the specifications, especially when introducing longer time lags. This shows that academic workers have a (longer-term) productivity-enhancing effect across the entire observation period despite the political shift in the focus from academic to skilled workers during the

1970s. We contribute to the larger debate on how knowledge, capabilities, and qualifications were able to develop in a socialist system and on their effect for technical progress and productivity of the economy (Kogut and Zander 1992; Allen 2001; Berliner 2019). Furthermore, our findings go beyond these studies by focusing on a high level of education and academic qualifications that improved the development and transfer of new technologies applied to production processes, thereby increasing the growth and productivity of the economic sectors in the GDR over longer time periods. Remarkably, this holds even despite the growing disparities between the demand for qualified labor in workplaces and the factual occupation slowdown in the proportionate employment of highly qualified people. Moreover, the efficiency was weakened by institutional obstacles in the system, the Cold War-induced isolation from the world markets, and the West's embargo lists for high technologies. The consequences of these issues consumed immense resources of the GDR, which made it unable to catch up with the international level of development until its end (Marschall 1990).

The second hypothesis posits a positive impact of skilled workers on productivity of the economic sectors in the GDR. Our findings mostly support a productivity-enhancing effect of skilled workers; however, it is much smaller and only short term compared to the effect of academic workers, which underlines the importance of academic workers for boosting economic growth. This finding contributes to the results of research concerning the shift in the focus of the SED from academic qualifications to skilled workers in the GDR (Dore 1976; Maier 1977; Baker et al. 2007). In contrast to the aim of the SED in the 1970s, when the number of academic workers was reduced in favor of more skilled workers, this approach did not, for the most part, improve production efficiency of the economic sectors. This might be explained by the restricted focus of skilled workers on basic research and long-term scientific progress (Giles 1978) or their limited productivity-enhancing tasks (Lindig 1995).

Our analysis provides further interesting findings about the impact of education funds on productivity gains in the GDR. The SED directed all economic activities and allocated respective resources to the various sectors of the economy. High investments were made during the early years in the training and education of workers (Baker et al. 2007). These investments resulted in a long-term efficiency increase by supporting the development of a highly skilled and productive workforce. Moreover, at the beginning of the GDR, many employees were in training or without formal qualification. The respective political measures led to a continued and substantial reduction of this number in favor of skilled and highly qualified workers over time. At the end of the GDR, there was a smaller number of employees without qualification, but a noticeable number of academic and skilled workers that contributed to the transition of the system and the subsequent productivity of the economy. Only the shift in the political focus from academics to skilled workers during the last two decades of the GDR might have caused a long-lasting impact on the structural change of East Germany today (Dietrich 1991).

Future research could analyze the long-term effects of the education funds and qualifications in the GDR for economic growth after its transformation into a market economy. With the end of the GDR, research on education funds was discontinued. This also removed a field of research that could have shed light on the economy's transition to market-based principles in the area of education and skills. As a result, methodological problems also remained unresolved, such as the consideration of changing skills and abilities required from the labor force in the analysis of education funds. So far, the dynamics of the funds resulted from the balance of entries and exits of persons and the changing costs of education and training. However, as production processes evolve, demands on knowledge and skills of the active population changed over the course of a working lifetime. Furthermore, it would be interesting to understand how qualifications facilitated patenting activities in the GDR. Because patents are mostly generated in the industry sector, an in-depth analysis of the related qualifications of the staff will be promising. For this purpose, more data should be collected and prepared from the socialist period to generate new knowledge on the respective relations.

In summary, education had a high priority in the socialist system of the GDR to achieve technical progress and growth of the economy. The SED sought to enhance its productivity and technical modernization with its initial goal of equal educational opportunities for all people in the society, supporting the children of workers, and increasing the number of academics (Köhler and Stock 2004; Baker et al. 2007). However, the retraction of these goals in later decades in favor of ideological and political protection of the regime was not only assessed critically in society (Kaack 1993). It was also a setback for the productivity and growth of the economy. Despite the high level of education and capabilities of the workers, the internal and external obstacles to modernization seemed to be ubiquitous in the system of the GDR, explaining the economic backlog and the final collapse of the regime.

Appendix

Table 3.3 Descriptive statistics

Variables	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
ln_Net product	180	9.694	0.979	7.817	12.125
ln_Academic workers	180	3.873	1.178	0	6.178
ln_Skilled workers	180	5.613	1.896	0	7.717
ln_Other workers	180	5.285	1.342	0	7.379
ln_Education funds	180	15.895	3.136	0	18.897
ln_Capital	180	10.82	1.33	8.339	13.592
ln_Investments	180	7.944	1.317	4.954	10.703

Table 3.4 Correlations of variables

Variables	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
(1) ln_Net product	1.000						
(2) ln_Academic workers	0.687***	1.000					
(3) ln_Skilled workers	0.747***	0.346***	1.000				
(4) ln_Other workers	0.469***	0.533***	0.341***	1.000			
(5) ln_Education funds	0.209***	0.101	0.209***	0.187**	1.000		
(6) ln_Capital	0.842***	0.635***	0.655***	0.388***	0.178**	1.000	
(7) ln_Investments	0.886***	0.625***	0.732***	0.454***	0.210***	0.957***	1.000

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

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