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CAUSES OF PERSISTENT PRODUCTIVITY DIFFERENCES IN THE WEST GERMAN STATES IN THE PERIOD FROM 1950 TO 1990

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Abstract

Since the Second World War the West German states show persistent differences in their standard of living. The explanation of the incomplete catching-up process within West Germany is of crucial interest. After identifying productivity as the major growth driving force, this paper investigates the main causes of productivity growth on the state level between 1950 and 1990. With the help of growth theories different determinants of productivity growth are identified. These are innovations, secondary and tertiary human capital, structural change, openness and institutions. Finally, the empirical analysis reveals that three of those determinants are able to explain the persistent differences in the regional productivity levels: innovations, tertiary human capital and structural change.

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1 Introduction

Until this day the West German states show persistent differences in the standard of living not only between East and West Germany but also between the North and the South. A closer look at the real GDP level per capita on the federal state level reveals that Berlin possesses only 50 percent of the GDP per capita of Hamburg in 2008.[1] Even if the city-states are excluded because of their special characteristics the remaining states still show disparities. The GDP per capita in Schleswig-Holstein is only 71 percent of the GDP per capita of Hessen. Also the unemployment rate demonstrates that a favorable economic situation prevails over the states in Southern Germany.[2]

So far these persistent differences have not been analyzed in-depth. The question arises since when these disparities have existed and if there has ever been a convergence in the standard of living in the German states. Moreover, I attempt to identify the main causes for the long lasting differences in the productivity levels in this analysis. The investigation period ranges from 1950 to 1990 and the eleven West German states[3] are included in the analysis.

No comparable study exists which analyzes the productivity development of the West German states in detail over a period of 41 years. However, some studies explore related questions for a shorter time period.

Barro and Sala-i-Martin (1991) were the first who analyzed the β- and σ-convergence of US-American and of European regions. For the West German regions they find a moderate convergence pace of 2 percent from 1950 to 1985. This convergence pace would imply a bisection of the gap in the living standard between West and East Germany in 35 years.[4]

In the first part of his study Seitz (1995) answers the question if convergence of output per capita has taken place within the West German regions[5] from 1980 to 1990. In the regression analysis based on a human capital expanded Solow growth model he controls for the industrial structure (proportion of employees in a sector[6]), human capital (employees without apprenticeship, with apprenticeship and employees with graduate degree) and the investment activities (investment share per employee) in the regions. Seitz comes to the conclusion that a significant but slow convergence process takes place between the West German regions.

[1] See table 1 in the appendix.
[2] See table 2 in the appendix.
[3] These are Baden-Württemberg (BW), Bavaria (BA), Berlin (BE), Bremen (HB), Hamburg (HH), Hessen (HE), Lower Saxony (NS), North Rhine-Westphalia (NRW), Rhineland-Palatinate (RP), Saarland (SA) and Schleswig-Holstein (SH).
[4] Barro, Sala-i-Martin (1991), Convergence across States and Regions, in: Brookings Papers on Economic Activity, 1:1991, S. 107-158.
[5] Westdeutsche Kreise and westdeutsche Arbeitsmarktregionen respectively.
[6] Seitz divides the economy in 16 sectors.

Especially, regions with a superior amount of tertiary human capital realize higher growth rates. Furthermore Seitz analyzes three different areas – urban, suburban and rural – separately. Persistent differences exist between urban, suburban and rural areas. Urban and sub-urban areas seem to converge moderately within each type of region. But rural areas are heterogeneous and convergence is much slower within this type than within the other two areas. Hence, rural areas do not form a so-called convergence club.[7] In the second part of his study, Seitz analyzes the interregional assimilation of wages for different degrees of qualification. Convergence of wages of highly qualified labor takes places. The slow convergence pace for the less qualified workers is explained by the higher mobility of highly qualified laborers.

Also Herz and Röger (1995) study the regional β-convergence[8] of the West German regions[9] from 1957 to 1988. They find clear evidence of convergence in the studied regions. In their regression analysis the authors control for human capital (proportion of persons with "Abitur"), the initial level of resource endowment and of technology.[10] The convergence is faster in the period from 1957 to 1970 than in the period from 1970 to 1988.[11]

In contrast, Bohl (1998) criticizes the standard cross section techniques used for the analysis of absolute and conditional β-convergence. Therefore he studies the convergence of the German states on the basis of panel unit-root tests. Bohl concludes that no convergence of real GDP per capita takes place within the West German states form 1960 to 1994. He assumes that the disparities in the output per capita will still persist in the future.[12]

Buscher, Felder and Steiner (1999) study the question whether the economic development of the West German states converged from 1970 to 1996. They could detect neither convergence nor divergence. In general, the poor states stayed poor and the rich states remained rich. The winner in this time period was Hessen that could catch up with the rich states. The loser was North Rhine-Westphalia due to its disadvantageous industrial structure.[13]

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[7] See Seitz, Helmut (1995), Konvergenz: Theoretische Aspekte und empirische Befunde für westdeutsche Regionen; in: Konjunkturpolitik, 41. Jg. Heft 2, pp. 168 – 198.

[8] The different concepts of convergence are explained in section 2 page 5.

[9] 75 Raumordnungsregionen

[10] In order to control for the initial level of technology and resource endowment the authors construct dummies. They divide the regions with regard to their initial real per capita income. Furthermore, they presume that the level of technology and the resource endowment affect initial differences in per capita income. The first dummy comprises 25 regions with low and the second dummy 25 regions with middle real per capita income in 1957.

[11] See Herz, Röger (1995), Economic Growth and Convergence in Germany, in: Weltwirtschaftliches Archiv 131, pp. 132-143.

[12] See Bohl, Martin (1998): Konvergenz westdeutscher Regionen? Neue empirische Ergebnisse auf Basis von Panel-Einheitswurzeltests, in: Konjunkturpolitik, 44. Jg. H. 1, pp. 82 – 99.

[13] Buscher, Felder, Steiner (1999), Regional Convergence and Economic Performance. A Case Study of the West German Laender (Center for European Economic Research (ZEW)).

Kellermann (1998) studies the convergence process of labor productivity and the role of the federal state, especially the fiscal policy, in this process. She discovers σ-convergence[14] of the labor productivity in the West German states form 1950 to 1993. Furthermore, Kellermann analyzes β-convergence of the labor productivity of the business sector in the German states with the help of a Solow model extended by publicly provided inputs and taxation. She detects a slow convergence rate of 2 percent from 1970 to 1993. Her results show that taxation has a negative and publicly provided input a positive impact on the labor productivity growth.[15]

Funke and Strulik (1999) use a panel approach and find conditional convergence, but persistent differences in the regional steady states for the West German states in the period form 1970 to 1994. In their study Hessen is once again the winner in the development process. They remark that the German inter-state tax revenue sharing system ("Länderfinanzausgleich"), which was invented to reduce regional differences, may not work properly.[16]

Jungmittag (2007) shows that differences in total factor productivity explain the persistent differences in growth and levels of the per capita income and the labor productivity in the German states from 1995 to 2001. Furthermore, the growth rates of the total factor productivity are highly correlated with the innovation activities and the technological and economic specialization of the German states. Especially, high technology industrial sectors and knowledge intensive service sectors have a positive influence on productivity growth.[17]

Finally, Döring, Blume and Türck (2008) analyze whether regional economic policy or other long-term factors determine the economic performance of the German states. In a cross-section regression they come to the result that especially long-ranging factors like the geographical position, the settlement structure, social capital or the industrial structure determine the economic performance by 72 percent. Therefore, economic policy has only little influence on the economic performance of the German states. [18]

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[14] The different concepts of convergence are explained in section 2 page 5.

[15] See Kellermann, Kersten (1998): Die interregionale Konvergenz der Arbeitsproduktivität: eine Analyse unter besonderer Berücksichtigung von öffentlichen Inputfaktoren und des Finanzausgleichs (Finanzwissenschaftliche Forschungsarbeit, Bd. 67), Berlin.

[16] See Funke, Michael / Strulik, Holger (1999): Regional Growth in West Germany: convergence or divergence? In: Economic Modelling, 16, pp. 489 – 502.

[17] See Jungmittag, Andre (2007): Innovationen, Beschäftigungsstruktur und Wachstum der totalen Faktorproduktivität. Eine Data Envelopment und Korrelationsanalyse für die deutschen Bundesländer; in: Jahrbuch für Regionalwissenschaft, 27, pp. 143 – 170.

[18] See Döring, Blume, Türck (2008), Ursachen der unterschiedlichen Wirtschaftskraft der deutschen Länder. Gute Politik oder Resultat günstiger Rahmenbedingungen?, Baden-Baden.

All these studies analyze the convergence process of the income level or a productivity measure but none of these studies seriously deals with the question, which factors determine the persistent productivity differences on state level in the long run. Especially, cross-section analyses are less suited to examine long-run dynamics in the development process. The major contribution of the study at hand is that in a first step, it identifies productivity as the main growth driving force. In a second step, I attempt to find the main factors explaining states' different productivity levels in a long panel data analysis.

The remainder of this article is organized as follows: section 2 gives a short theoretical introduction to the so-called catching-up process. In the following section the economic development of the German states is examined. Section 4 identifies productivity as the main driving force of growth. The total factor productivity as a concept of measuring productivity is introduced. Afterwards, the development of the states' productivity levels is analyzed in-depth. Section 6 discusses potential sources of productivity growth. In the fore-last section a regression analysis is run in order to detect the main productivity driving forces. The analysis ends with a conclusion.

2 Theoretical background: Catching-up process

Two main approaches co-exist in economic literature, which treat the phenomena of catching-up. The traditional approach is more descriptive and less theoretical. It claims that some countries can minimize their economic backwardness to the economic leader (USA in the period under observation) by capital accumulation, structural change and technology diffusion. Moses Abramovitz (1986) refined this approach by pointing out that the so-called social capabilities are necessary pre-conditions for the catching-up process. The social capabilities encompass institutions that assure property rights, legal security and an efficient allocation of infrastructure for instance. But the most important part of the social capabilities is a country's possibility to imitate and implement advanced technologies of the economic leader. For this purpose an adequate amount and quality of human capital is necessary.[19]

In contrast, the neoclassical model going back to Solow (1956) is a concept, which makes use of a macroeconomic Cobb-Douglas production function.[20]

$$Y = A \cdot L^{\alpha} \cdot C^{\beta} \qquad (1)$$

[19] See Abramovitz, Moses (1990), The Catch-up Factor in Postwar Economic Growth, pp.2; also Abramovitz, Moses (1986), Catching-up, forging ahead, and falling behind,

[20] See Solow (1957), Technical Change and the Aggregate Production Function.

Equation (1) assumes that a country's economic output Y depends on the two tangible inputs labor (L) and capital (C), and on the productivity level of the economic activities (A). The production elasticities α and β measure the shares in a country's income obtained by the workers and the owner of capital, and therefore add up to one. Two further assumptions have to hold for the neoclassical production function: the law of diminishing returns and perfect competition.

Assuming a neoclassical production function with substitutable factors and falling marginal returns, a stable and unique growth path for every country exists.[21] The neoclassical model explains growth as follows: Countries experience different growth rates because they are situated at different distances to their long-run growth path. In the long run, all states will carry out the equilibrium growth rate, which is the growth rate of technological progress. This mechanism is based on the assumption of the law of diminishing returns. Countries with a lower capital intensity than in the equilibrium realize higher returns of capital. These countries attract capital and therefore realize higher growth rates. Theory assumes that the more capital a country possesses the lower the marginal productivity of capital is and thus are the returns. Finally, per capita growth would end, if no technological progress takes place.

In this regard, the neoclassical theory distinguishes two main concepts of convergence: the concepts of conditional convergence and of absolute convergence. Under the assumption of conditional convergence every country will converge to its own steady state, characterized by country-specific saving rates, population growth, technology and human capital endowment. In contrast, economies that do not differ in these exogenous variables will converge absolutely to the same steady state.

Convergence is measured in two different ways. The so-called β-convergence supposes that the per capita growth rate is negatively correlated with the initial per capita income level. The σ-convergence is defined as the standard deviation of income levels (or growth rates) divided by their mean and shows how the disparities between the income levels of countries change. Because the β-convergence is a necessary but not a sufficient condition for the existence of the σ-convergence, only the σ-convergence will be used in this analysis.[22] Besides, the question weather convergence is taking place at all and not its pace is of special interest.

In the next sections, I will carry these country level concepts over to the West German states.

[21] See Lindlar (1997), Das mißverstandene Wirtschaftswunder, p. 92.

[22] See Quah (1996), Empirics for economic growth and convergence, in: European Economic Review 40, pp.1353-1375.

3 The economic development of the old West German states

Figure 1 shows the economic development of the West German states in the period form 1950 to 1990.[23] During the whole period the city-states Hamburg and Bremen are the economic leaders with respect to the real GDP per capita. This development is due to special circumstances in the city-states. City-states are agglomerations with high economic attractiveness, which experience an employment density above average and a high value creation. No fringe area with low economic outcome exists, which diminishes the overall economic performance of the territorial states. A close connection with the urban hinterland leads to an attraction of labor force form neighboring states. These commuters contribute to the generation of the economic outcome in the city-states but belong to the resident population of the neighboring states. This kind of commuting increases the income per capita in the city-states and decreases it in the neighboring states. Furthermore, the sectoral structure is special in the city-states: the share of agricultural employment is close to zero and the service sector is represented above average.[24]

Figure 2 clarifies that already in 1950 a high dispersion of real GDP per capita exists between the states. Schleswig-Holstein possesses only 39 percent of the real GDP per capita of Hamburg. Lower Saxony (44 percent), Rhineland-Palatinate (46 percent), Bavaria (47 percent) and Berlin with 48 percent have less than half of the income per capita of Hamburg available. At that time Hessen (54 percent), Baden-Württemberg (56 percent) and North Rhine-Westphalia with 65 percent are among the more wealthy states. As already mentioned, the two city-states Hamburg and Bremen have the highest real GDP per capita during the whole period. The third city-state Berlin could not set itself apart from the territorial states. In the course of time North Rhine-Westphalia has lost its good starting position. In contrast, Baden-Württemberg und Hessen could partially catch-up with Hamburg. Over the whole time period Schleswig-Holstein, Lower Saxony and Saarland stick at the last ranges. In 1990 they possess about 58 percent (Schleswig-Holstein and Saarland) and 56 percent (Lower Saxony) of the real GDP per capita of Hamburg.

Figure 3 shows the coefficient of variation (σ-convergence) of the real GDP per capita and demonstrates that especially in 1950 a high dispersion with respect to the income level exists between the German states. Until the 1960s a convergence of the German states takes place.

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[23] All the tables and figures can be find in the appendix.

[24] See Heinemann, André (2005), Die Wirtschaftskraft der Stadtstaaten im Vergleich mit Großstädten (Bremer Diskussionsbeiträge zur Finanzpolitik), p. 3.

Especially after 1970 no further convergence occurs and the disparities persist. In addition to the σ-convergence of all states, the σ-convergence without the city-states is calculated. It displays a similar development, but not surprisingly a higher convergence level is reached. These results question the validity of the catching-up hypothesis because the West German states share most of the social capabilities mentioned by Abramovitz (1986).

4 Main driving force of economic growth

After analyzing the development of the income levels in the West German states I now turn to discuss the main growth driving forces by using the macroeconomic Cobb-Douglas production function (1) described above. By transforming this production function we end up with what Clark (2007) has called the fundamental equation of growth[25]:

$$\frac{Y}{L} = A \cdot \left(\frac{C}{L}\right)^{\beta} = y = A \cdot c^{\beta} \tag{2}$$

$$g_y = g_A - \beta \cdot g_c \tag{3}$$

As a result, long-term economic growth per capita g_y depends only on two factors, on the increases of the productivity level g_A and on the capital accumulation per capita g_c. Equation (3) also demonstrates that a one percent growth of the productivity level (A) leads to a one percent increase in the output per worker whereas a one percent growth of capital per worker increases the output per worker only by β percent with $\beta<1$. Clark (2007) claims that, in the industrialized part of the world, the accumulation of real capital (C) explains just about one quarter of the long-term growth of output per worker. Therefore, three quarters of long-run economic growth has been caused by the permanent growth of the productivity level (A).[26]

While the development of output, labor, and capital can be estimated by using historical data, the productivity level (A) is not directly observable and can be calculated in different ways. One way is to determine the productivity level as the ratio between the output per worker and the capital endowment per worker to the power of its production elasticity. The result of this calculation is called total factor productivity (TFP).[27]

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[25] See Clark, G. (2007). *A farewell to alms: a brief history of the world*, pp. 197-199. The production elasticity β measures the share in a region's income obtained by the owners of capital.

[26] See Clark, G. (2007). *A farewell to alms: a brief history of the world*, p. 200.

[27] Another way is to estimate the productivity level with the help of the so-called Malmquist-Index. See Caves, Christensen, Diewert (1982), The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity, Econometrica 50(6), pp.1393-1414. See Cantner, Krüger, Hanusch (2007), Produktivitäts- und Effizienzanalyse: der nicht-parametrische Ansatz, pp. 247. See Färe et all. (1994), p. 71. See Krüger (2000), Produktivität und Wachstum im internationalen Vergleich, pp. 95.

$$TFP = \frac{y}{c^{\beta}} \qquad (4)$$

5 The development of the regional productivity levels

As the main growth driving force of the regional development the productivity levels of the West German states will be analyzed in detail. Figure 4 and 5 show that Hamburg is the productivity leader during the whole period under observation. Especially, Figure 5 demonstrates a structural break in the development of the productivity measured with the help of TFP. Until the mid 1960s, a general convergence of the productivity levels in the states takes place. Since then disparities persist or increase again. In 1950, Rhineland-Palatinate has the lowest TFP level with only 44 percent of Hamburg's productivity level. Bremen and North Rhine-Westphalia possess above average productivity levels until the end of the 1960s. Bavaria, Rhineland-Palatinate, Saarland and Schleswig-Holstein have the lowest productivity levels in the whole period.

Figure 6 shows σ-convergence of the states' productivity levels. Strong convergence takes place until the mid 1960s. Afterwards, only an alleviated convergence occurs until the end of the 1970s. In the 1980s even a divergence of the productivity levels takes place.[28] What can explain these persistent disparities in the productivity levels of the West German states?

6 The main sources of productivity growth

After identifying the development of the productivity levels as the main driving force of growth, the question arises which factors have determined the changes of productivity levels in the West German states. In order to respond to this question, Edward Denison (1967) gives a first hint. He analyzed the post-war growth performance of the West European countries. He also pointed out that productivity growth was the major growth-driving factor. He assumed intuitively five major sources for productivity growth. These are:

1. Improvement of knowledge
2. Reallocation of resources (structural change)
3. Growth friendly governments and coalition

[28] The calculation of the Malmquist-Index leads to similar results as the total factor productivity analysis. Both productivity measures are highly correlated with a correlation coefficient of 0.97. Therefore the traditional total factor productivity can be seen as a robust result.

4. Economies of scale
5. Efficiency gains

According to Denison the improvement of knowledge, the allocation of resources and the economies of scale had the greatest impact on the German post-war development. In the analysis at hand these factors should also be taken into account.[29]

Furthermore, since the 1980s a huge literature on the causes of economic growth has emerged.[30] But a self-contained theory on productivity development does not exist. The only way to find the potential sources of productivity development is to extract these factors that are seen as the source of productivity growth from existing growth theories.

<u>Innovation and knowledge</u>

A first strand of literature treats innovations as a highly important factor for explaining productivity growth.[31] To find adequate measures for innovation it is useful to divide the typical innovation process into the three successive stages of invention, innovation and diffusion.[32] In the invention phase an inventor tries to find a new product or production method. The outcome will be kept secret or patented. In the following innovation phase, the pioneer attempts to build up an economic market for its technological invention. If the invention is successful, competing firms will try to imitate or refine the successful innovation in the diffusion phase.[33]

Table 3 lists commonly used empirical indicators for the inputs and outputs of the three stages of the innovation process. None of these indicators is perfect. That is why the choice of a special indicator depends on both the availability of data and the focus of the innovation analysis. Output indicators are generally preferred to input indicators because the relationship of innovation input and output is not constant.[34] However, the output indicators also have their disadvantages. A well-known fact is that the propensity to patent varies across industries. Some industries try to appropriate the returns of their inventions primarily by keeping them secret while others, like the chemical industries, prefer patenting instead. Because of industries' different propensities to patent it might be misleading to interpret a

[29] See Denison (1967), Why Growth Rates Differ?, pp.7-11 and 307-309.
[30] See for example Aghion, Durlauf (eds.) (2005), Handbook of economic growth.
[31] See for example Romer (1990); Aghion /Howitt (1992); Grossman/ Helpman (1991).
[32] This innovation process is, of course, not linear but characterized by interdependencies between the different phases.
[33] See Streb, Waidlein (2011), Knowledge and Space in Economic History: the Example of Innovations in the German Empire 1877-1914; in: Glückler, Meusburger (eds.), Knowledge and Economy, Heidelberg, pp.4.
[34] For example, R&D productivity, which is defined as the ratio between R&D output and R&D expenditures, differs significantly over time, between industrial sectors, and between individual firms.

particular industry's comparatively high number of patents automatically as a sign for its alleged above-average innovativeness. Furthermore, pure patent counts allocate the same weight to every patent, no matter whether it has a high or a low economic value for the patentee or the society. Using the number of patents as an indicator for new technological knowledge suitable to foster productivity growth therefore might lead to a measurement error. Lists of important innovations compiled by scholars of the history of technology frequently show a selection bias because these experts often prefer basic innovations and product innovation to incremental innovations and process innovations. Productivity growth as a measure for innovations is also inaccurate. As is shown in this analysis, productivity growth is driven by more than solely innovation. That is why the observable productivity growth overestimates the influence of innovations.[35]

The most suitable regional indicator available for the innovation activity is the number of granted patents. That is why in order to measure the innovativeness of the German states, a sample of granted patents in the West German states was drawn. The internet database of the German Patent and Trademark Office (depatisnet) contains among other things all granted patents for the period form 1950 to 1990. Every patent contains information about the application date and the location of the applicant. The sample comprises all granted patents that are published in the calendar weeks 38 and 44 of every year from 1950 to 2005. The period between application and publication (granting) can last for over 10 years in some cases. In order to construct the patent stock I use the application date of these patents granted between 1950 and 2005, which application date was between 1950 and 1990. The calendar weeks were randomly chosen under the precondition that no major holydays (like Christmas, Easter or summer holidays) are in these selected calendar weeks.[36] Afterwards the location of the applicant (the city) was extracted manually and allocated to the corresponding West German states. Finally, the states' patent stocks (PS_i) are calculated with the help of the perpetual inventory method from the time series of the number of patent applications.[37]

$$PS_{i,t} = (1-\delta)\cdot PS_{i,t-1} + PA_{i,t}, \qquad (5)$$

[35]See Spoerer, Baten, Streb, (2007), Wissenschaftlicher Standort, Quellen und Potentiale der Innovationsgeschichte, In R. Walter (Ed.), Innovationsgeschichte, pp. 39-59. Also Streb, Waidlein, Knowledge and Space in Economic History: the Example of Innovations in the German Empire 1877-1914; forthcoming in: Glückler, Meusburger (eds.), Knowledge and Economy, Heidelberg.

[36] The sample contains 8483 patents.

[37] See Labuske, Kirsten / Jochen Streb (2008), Technological Creativity and Cheap Labour? Explaining the Growing International Competitiveness of German Mechanical Engineering before World War I, in: German Economic Review 9 (1), pp. 65-86. They also use patent stocks to measure innovativeness.

where $PA_{i,t}$ is the number of patent applications in state i and period t and δ is the annual rate of depreciation of the potential knowledge stock, which I set to 0.15, following Czarnitzki.[38] Finally, the patent stock of every state is set in relation to its population.

$$ps_{i,t} = \frac{PS_{i,t}}{population_{i,t}} \qquad (6)$$

The patent stock per capita of every German state is shown in figure 7. Berlin possesses the highest patent stock due to the fact that highly innovative firms like Siemens are located there.[39] Berlin should be seen as a special case. In general, the states' patent stocks increase until the mid 1950s. Afterwards the patent stocks decrease until 1970 and increase once again till the mid 1980. During the whole period, the states Saarland, Schleswig-Holstein, Lower Saxony and Bremen have the lowest patent stocks. In contrast, Baden-Württemberg, Bavaria and Hessen possess the highest patent stocks apart from Berlin. Especially Baden-Württemberg has reached the leading position in patenting activity since 1975.
Figure 8 illustrates that a slight positive relationship between the patent stock per capita and the productivity level exists.

An additional input measure for innovativeness is the share of public expenditure for R&D in relation to 1000 DM GDP. For this variable data are only available for 1964, 1966 and from 1968 to 1990. As Figure 9 demonstrates Berlin has the highest share of public expenditure for R&D during the whole time period. Saarland also shows a high share. The lowest shares of public expenditures are realized in Bremen and Rhineland-Palatinate. Apart from Berlin the shares of expenditure for R&D do not increase considerably during the period under consideration. Figure 10 shows a positive relationship between the productivity level and the share of public expenses for R&D in the West German states.

Human capital

Closely related to innovations is the positive influence of human capital on the productivity development.[40] Human capital encompasses the individual manpower, which is created by education. In this spirit, all economically usable knowledge, skills and behavior of an individual, which raise the productivity and finally the income, mirror human capital.[41] Furthermore, human capital is a necessary precondition to create innovation through research

[38] See Czarnitzki, Dirk (2002), Research and Development: Financial Constraints and the Role of Public Funding for Small and Medium-sized Enterprises, pp.12.
[39] See Degner, Streb (2010), Foreign Patenting in Germany, 1877-1932 (FIZD Discussion Papers, 21-2010). They already stated that few highly innovative firms are able to determine the innovativeness of a region.
[40] See for example Mankiw, Romer, Weil (1992), Lucas (1988).
[41] See Dichtl, Issing (1994), Vahlens Großes Wirtschaftslexikon, p.99.

and development. As Aghion (2008) demonstrated, also the composition of human capital influences the imitation and innovation activities. Thus, primary and secondary education are particularly important for the imitation of advanced technologies. Tertiary education is suited for the invention of new technologies.[42] I will get back to this in the empirical analysis.

Human capital cannot be measured directly. Instead, different proxies for human capital and the quality of the educational system exist. Often used measures of human capital are literacy rates, enrolment rates, dropout rates, pupil-teacher ratios, average years of schooling in the population or test scores.[43] Another method is the cost-based approach, in which the investment costs for child rearing and education are used as a measure for human capital. In contrast, the income-based approach measures the human capital stock by summing up the discounted future income flows of the working population. A modified version of this approach is the income based index method, where index values are calculated instead of monetary measures.[44]

Unfortunately, the common measures for human capital are not available due to non-existent data on state-level in the period under observation. However, two measures for tertiary human capital are available for the whole period. These are the number of students and the number of potential students (high school graduates).

The number of students as a measure for tertiary human capital is imprecise because city-states like Berlin and Hamburg, which are big university towns, cannot keep most of their former students in their local labor market. Besides, the number of students comprises all students and not only the first-year students or graduates, for which reason the calculation of a human capital stock is much more complicated.

In contrast, the number of potential students indicates the amount of potential tertiary human capital. With regard to the problem of temporary migration, some high school graduates may leave their home state and some of them may come back for good. Unfortunately, no study exists that examines the mobility of graduates in the German states before 1984.[45] Today, approximately 70 percent of the university graduates of West Germany work in their home

[42] See Aghion (2008), Higher Education and Innovation; in: Perspektiven der Wirtschaftspolitik, Special Issue 9, pp. 28-45. Or Acemoglu, Aghion, Zilibotti (2002), Distance to Frontier, Selection, and Economic Growth, NBER Working Paper No 9066.

[43] See for an overview Le, Gibson, Oxley (2005), Measures of human capital: A Review of Literature. New Zealand Treasury Working Papers 05/10.

[44] Following Jeong (2002) a version of this measure is available on German state level since 1960. It will not be shown in the following regression tables due to its statistically insignificant influence.

[45] See Busch (2007), When have all the graduates gone? Internal Cross-state migration of graduates in Germany 1984-2004, SOEPpapers No. 26.

states, where they acquired their diploma ("Abitur") before. In addition, the states also gain graduates from other states. In general, the mobility has most likely been much lower in the period under observation.[46]

In addition to the potential future tertiary human capital the number of high school graduates also mirrors the already existing tertiary human in the German states, because education is highly dependent on the social background of an individual in Germany. Hence, young persons visit a secondary school ("Gymnasium") and start their studies at the university more frequently when at least one parent is a graduate.[47]

With the help of the number of potential students a stock of potential tertiary human capital is constructed. Once again, use is made of the perpetual inventory method. I assume a 5 percent depreciation rate for the human capital stock.[48] The stock is set in relation to the population of the state.[49]

Figure 11 presents the development of the stock of potential tertiary human capital per capita in the German states. The human capital stock increases in all states. Until 1973 Berlin and Bremen possess the highest stock of potential tertiary human capital per capita. Afterwards Hamburg, Bremen but also North Rhine-Westphalia and Hessen have relatively high human capital stocks. In the last two decades Bavaria has the lowest stock of potential tertiary human capital and, as we have already seen, also a relatively low productivity level. Figure 12 reveals a positive linear relationship between the productivity level and the stock of potential tertiary human capital per capita.

In order to measure secondary human capital the number of "Berufsschüler" is used to calculate a stock of potential secondary human capital as well with the perpetual inventory method. The stock is set in relation to the population of the state. Figure 13 shows that Bremen has the highest and Berlin (especially since 1966) the lowest stock of potential secondary human capital per capita. The human capital stock augments in all states. Figure 14 shows a positive relationship between the stock of potential secondary human capital and the productivity development.

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[46] See Fabian / Minks (2008), Muss i denn zum Städele hinaus?, in: HIS-Magazin, 3, pp. 4-5. For the mobility of first-year students see Kultusministerkonferenz (2007), Die Mobilität der Studienanfänger und Studierenden in Deutschland von 1980 bis 2005 (Dokumentation Nr. 183), p. 19*. Table 5 in the appendix shows the states' shares of immobile first-year students in the 1980s in more detail.

[47] See Schimpl-Neimanns (2000), Soziale Herkunft und Bildungsbeteiligung, Empirische Analysen zu herkunftsspezifischen Bildungsungleichheiten zwischen 1950 und 1989, in: Kölner Zeitschrift für Soziologie und Sozialpsychologie, Jg. 52, Heft 4, pp. 636-669

[48] See Grundlach, Erich (1999), The impact of human capital on economic development: problems and perspectives; in: Tan, Loong-Hoe, Human capital formation as an engine of growth, p. 19.

[49] For Saarland data is only available since 1957. The values from 1950 to 1956 are estimated.

Structural change

Structural change may also be a possible source for productivity growth as Denison already mentioned. Especially the decline of the agricultural labor force is expected to have a positive impact on the productivity growth, because the productivity level in the agricultural sector is much lower than in the industrial or service sector.[50] That is why the share of workers in agriculture as a percentage of the labor force is used to measure the impact of the structural change on the productivity development.[51] Figure 15 reveals a sharp decline of the share of agricultural employment in most West German states. In 1950 Rhineland-Palatinate, Bavaria and Lower Saxony have the highest shares of agricultural employment. North Rhine-Westphalia and Saarland have the lowest shares of employment in the agricultural sector apart from the city-states.

Figure 16 reveals the suspected negative relationship between the productivity development and the share of agricultural employment. One should have in mind that this structural change measured via the shift of agricultural employment to the other sectors has little meaning in the city-states. All values of log share of agricultural employment that are below zero are measured in the city-states and should not be interpreted.

Openness

The endogenous growth theories fancy the idea that economic openness has a positive effect on the economic development of a country.[52] Trade can affect the economic development in different ways. By importing technologically advanced products countries get the chance to imitate these technologies.[53] Furthermore, a higher international competition leads to a selection process where only the fittest firms in the different states survive. Moreover, a larger market can enable economies of scale.[54]

In order to measure the openness of the West German states the share of exports in GDP is included to the analysis. A better measure would be the share of imports and exports in GDP but imports at the federal state level are only available since 1970.

Figure 17 illustrates strong fluctuations of the export shares during the period under observation.[55] In the first decade North Rhine-Westphalia has the highest export share. Afterwards Saarland possesses a much higher export quota. In the last few years under

[50] Table 4 in the appendix demonstrates the different labor productivity levels of the three sectors on state level.
[51] Data for the agricultural employment is missing for the years 1951-1956. These missing values are estimated via a linear interpolation.
[52] See for examble Rivera-Batiz, Romer (1991), Economic integration and endogenous growth, Quarterly journal of economics, Vol. 106, p. 531-555. Lucas (1993), Making a Miracle, Econometrica, Vol. 61, p. 251-272.
[53] See Lindlar (1997), Das mißverstandene Wirtschaftswunder, Tübingen, p. 326.
[54] See Denison (1967), Why Growth Rates Differ?, pp 225-255.
[55] Data for Saarland is only available since 1959.

consideration Bremen can overtake Saarland. In contrast, Schleswig-Holstein, Berlin and also Hamburg have the lowest export shares. The case of Hamburg might surprise, but the harbor of Hamburg predominantly serves as a port of transit. From here goods are exported that are not produced within Hamburg. That is the reason why Hamburg's export share is relatively low.

Figure 18 reveals a positive relationship between the development of the export share and the productivity level.

<u>Institutions</u>

The Nobel laureate Douglass North (1990) stated in his seminal work: *"The factors we have listed (innovation, economies of scale, education, capital accumulation etc.) are not causes of growth, they <u>are</u> growth. [...] Growth will simply not occur unless the existing organization is efficient."*[56]

Thus, institutions are of vital importance for the economic development of a country, because they decrease transaction costs by reducing uncertainty during an exchange of two market players.[57] Institutions encompass formal and informal rules. Rules that are formally written down (like a legal text) are termed formal institutions. In contrast, human life is also influenced and restricted by norms and habits, which are the so-called informal institutions.[58]

For the most part formal institutions are the same in the West German states. [59] Informal institutions are in fact highly stable over time and change only very slowly, but they may differ between the West German states.

In order to get an idea of these informal institutions that exist in the West German states the fraction of CDU/CSU-voters is taken into consideration. Among other things, this variable reflects the voters' long-run preferences, which are driven by their age, gender, profession, religious denomination, value orientation and attitude. With regard to CDU/CSU-voters they are older on average (above 45), predominantly Catholics, rarely unionist and with respect to their employment relationship they are often executives, executive staff or self-employed.[60] Especially the last two criteria indicate that the CDU/CSU-voters tend to be more growth-orientated and therefore growth friendly than SPD-voters, which might have a tendency to be more redistributive orientated.

[56] North; Thomas (1993), The Rise of the Western World, A new Economic History, p. 2.
[57] See Sydow, Jörg (1992), Strategische Netzwerke, p. 130.
[58] See North, Douglass (1990), Institutions, Institutional Change and Economic Performance, p. 3.
[59] See Ritter, Ernst-Hasso (1999), Zur Entwicklung der Landespolitik, in: Ellwein, Holtmann (Eds.), 50 Jahre Bundesrepublik Deutschland, p. 346.
[60] See Andersen, Uwe/Wichard Woyke (Ed.) (2003): Handwörterbuch des politischen Systems der Bundesrepublik Deutschland.

Figure 19 shows the development of the share of CDU/CSU-voters in the West German states. In general, the shares increase till the end of the 1970s. In the 1980s the proportion of CDU/CSU-voters tends to decrease. The states Bavaria, Baden-Württemberg and Rhineland-Palatinate posses the highest proportions of CDU/CSU-voters. Bremen has the lowest share over the whole period. Figure 20 demonstrates a positive relationship between the proportion of CDU/CSU-voters and the productivity level of the German states.

7 Regression analysis

In the previous section different potential sources for productivity growth have been identified. To determine the influence of these sources of productivity growth on the different productivity levels of the West German states use is made of regression analysis. The regression analysis contains the eleven West German states over a time period of 41 years from 1950 to 1990, which is a long panel or a so-called time-series-cross-section (TSCS).

7.1 Methodology

Following the suggestions of Beck and Katz (1996, 2004, 2006) a model for panel corrected standard errors is applied that controls for both panel heteroskedasticity and contemporaneous correlation across panels.[61] Dynamics are modeled via adding a lagged dependent variable (LDV)[62] or an AR1 error estimation. In both models a lagged dependent variable is included. In the LDV model the variable shows up in the regression table, in the AR 1 error model it does not. The difference between these two models is, that in a LDV model the observed and unobserved variables have impacts that diminish exponentially, and in the AR1 error model the measured variables have just an immediate influence, but the unobserved variables still die off exponentially.[63]

Furthermore, the lagged dependent variable will dominate the regression results. In this regard, Katz and Beck advise: "[….] those who estimate LDV models must remember not to

[61] Statistical tests support the presence of groupwise heteroskedasticity and contemporaneous correlation in the data. See for a theoretical discussion Beck, Katz (1995), What to do (and not to do) with Time-Series Cross-Section Data, in: American Political Science Review, Vol. 89, No. 3, pp. 634-647.

[62] Possible remaining serial correlation of the errors was checked with a Lagrange multiplier test. The null hypothesis that the errors are serially independent cannot be rejected.

[63] See Beck, Katz (2004), Dynamics, p. 17.

interpret the ϕ [*regression*] coefficient […] causally, that is, not to conclude that a unit change in last year's *y* causes (whatever that means) a ϕ unit change in current *y*."[64]

In addition, Plümper, Troeger, Manow (2005) warn that the addition of the lagged dependent variable (and /or time dummies) leaves little variance for the explanatory variables. The lagged dependent variable reflects not only time persistency of the dependent variable but also the dynamics of all independent variables. The coefficient of the lagged dependent variable may be biased upwards, whereas the coefficients of the independent variables may be biased downward, when the dependent variable shows a general time trend and only one (or some) of the independent variables have a permanent effect. This happens because the lagged dependent variable assumes the same persistent effect for all independent variables.[65]

Since literature gives no clear advise both types of models are run in this analysis.

When using a LDV model all estimated β coefficients have to be interpreted as short-run coefficients. The long-run coefficient $\tilde{\beta}_k$ can easily be calculated from the estimated coefficients as follows:

$$\tilde{\beta}_k = \frac{\beta_k}{1-\phi}, \textit{ for all } k = [1; K] \tag{7}$$

where ϕ refers to the estimated coefficient of the lagged dependent variable and β_k to the estimated coefficient.[66]

Thus the productivity level is modeled as a function of the lagged productivity level, the patent stock per capita, the share of agricultural employment, the stock of potential tertiary human capital per capita, the stock of potential secondary human capital per capita, the export share, the share of CDU/CSU-voters, a control variable for the cyclical trend, unit effects, the time variable year, which controls for the trend in the dependent variable and year dummies for all T-1 years, which control for exogenous shocks that are common to all states. For these variables data is available for the whole period under consideration. In a second step the explanatory variable share of public R&D expenditure (lagged by one year) is included, for which data only exists since 1962.

The logarithm is taken of all variables, thus the reported results are elasticities. The Hausman test rejects the use of a random effects model. Therefore a fixed effects model should be used. But including fixed effects for all N-1 units might encounter a problem because these fixed

[64] Beck, Katz (2004), Dynamics, p.18.

[65] See Plümper, Troeger, Manow (2005), Panel data analysis in comparative politics: Linking method to theory, pp.334-343.

[66] See IMF (2003), World Economic Outlook, chapter IV: Unemployment and Labor Market Institutions: Why Reforms Pay Off?, p. 148.

effects take much of the variation between the units. This is because fixed effects remove stable variables from the analysis and hinder slowly moving variables to show their inter-unit impact. If one suspects level effects of an independent variable on the dependent variable fixed effects should not be included, because they entirely take up differences in the level of exogenous variables. In contrast, the possibility of an omitted variable bias still remains if the fixed effects are not included but the data show that they are needed. [67]

To solve this problem unit fixed effects are added in four different ways. In the first specification no fixed effects are added, in the second specification a dummy for Berlin is inserted, which controls for the special position of this city-state among the German states. In a third specification fixed effects for the three city-states Berlin, Bremen and Hamburg are added. And finally unit effects for all N-1 states are included in the analysis.

7.2 Endogeneity

Another serious problem is the violation of the assumption of strict exogeneity that is the errors are correlated with one or more dependent variables. Already North's quotation from above gives a first hint to the existence of this problem in the analysis of economic development. Here the question arises if innovations, structural change, openness and institutions not only explain the productivity level, but the productivity level in turn influences these explanatory variables considerably. Endogeneity has serious consequences for the estimation results, because it produces biased and inconsistent parameter estimates in an OLS regression. Different approaches exist to solve this problem by using a proxy that does not suffer from the same endogeneity problem. A very common approach is to lag the suspected endogenous variable by one or more time periods. In this spirit, the productivity level might influence the contemporary innovativeness but it has no influence on past innovations. Therefore this first approach is applied, in which all potentially endogenous variables (patent stock per capita, share of agricultural employment, and the export share)[68] are lagged by one year in order to overcome the problem of endogeneity.[69]

This approach is admittedly simple to implement. But no possibility exists to test how severe the endogeneity problem is and weather the solution is satisfactory. A more sophisticated way to deal with endogeneity is to employ instrumental variables regression. In this approach one

[67] See Beck, Katz (2004), Time Series Cross-Section Issues: Dynamics, pp. 5.
[68] Lagging all explanatory variables by one year leads to no different results.
[69] See Baccaro, Lucio / Diego Rei (2005), Institutional determinants of unemployment in OECD countries: A time series cross-section analysis (1960-98), International Institut for Labour Studies Discussion Paper DP/160/2005. And IMF (2003), World Economic Outlook, chapter IV: Unemployment and Labor Market Institutions: Why Reforms Pay Off?, p. 148 footnote 35.

has to find an exogenous variable that is strongly correlated with the suspected endogenous variable, but uncorrelated with the error term. This procedure has the advantage that statistical tests for the appropriateness of the instruments and for the scope of the endogeneity are available. Unfortunately, no genuinely exogenous instrument is available in the context of the underlying research project. The productivity level might influence every economic variable by some means or other. An example is the structural change, which is measured with the share of agricultural employment. This variable can be instrumented with the help of the population density. Both variables are highly correlated (-0.9). But also the population density is most likely influenced by the productivity development of a region. More productive regions attract more people than less productive regions.

Furthermore, the availability of data is severely limited. In a cross-section analysis it is much easier to find a suitable instrument because constant variables can also serve as a proxy. In contrast, in a time series cross section the instrument has to follow the same variations as the suspected endogenous variable over time.

However, I attempted to overcome these problems by constructing instrumental variables. Thus, the first-year value (here: t=1950) of the original variable is multiplied with the years (1950, 1951,…., 1990). In this way, the proxy variables for the patent stock per capita, agricultural employment and the export share are generated that are highly correlated with the potential endogenous variable and definitively uncorrelated with the error term. All other variables do not directly run the risk of endogeneity.

A first attempt, in which I used the already implemented STATA command for instrumental variable regression (xtivreg2), did unfortunately not lead to any significant results.

Therefore, I applied first and second stage regression to the model of panel corrected standard errors with an AR1 error estimation. In doing so I am able to control for contemporaneous correlation and groupwise heteroskedasticity, which are crucial problems in time-series cross-section data, as already mentioned above. Besides, three different fixed effect specifications were estimated: no fixed effects, a dummy for Berlin and dummies for the city-states. The inclusion of unit effects for all N-1 states did not lead to significant results in the first stage regression. Therefore, fixed effects for all states are excluded from the instrumental variable analysis. The model is again applied to the two time periods from 1950 to 1990 and from 1962 to 1990.

A first stage F-test was run in order to show weather the instruments are weak or not. The outcome of the F-statistics was that the instrument for the export share is weak in the model specification with no fixed effects in the period from 1950 to 1990 and in all specifications in the shorter period from 1962 to 1990. Therefore only two specifications (with unit effects for Berlin and all city-states, respectively) were estimated for the whole time period (i.e. the share of public expenditure was also excluded). Afterwards the standard errors of the second stage regression had to be corrected manually. Finally, this approach proved unsuccessful, because no significant results were left over. Hence, regression results only for the first approach with lagged endogenous variables will be reported in the next section.

7.3 Regression results

With regard to the endogeneity problem, table 7 and 8 report the results of the lagged explanatory variable approach. In addition, table 7 reports the regression results for the explanatory variables, which are available for the whole time period. Columns 1.1-1.4 display results for the LDV model with the four different unit effect specifications. The same specifications are estimated in columns 1.5 – 1.8 with the AR1 error model. In table 8 the same is done with the additional explanatory variable the share of public expenses for R&D, which reduces the period under observation from 1962 to 1990.

In table 7 the distinction between the LDV model and the AR1 error model makes a difference. As expected the explanatory variables have a higher impact on the dependent variable in the AR1 error model than in the LDV model. The unit effect specifications also have a bearing on the regression results.

The lagged dependent variable, not surprisingly, has a positive and highly significant impact on the productivity level, but does not help to detect the causes of productivity growth.

The main explanatory variable is the patent stock per capita, which has a positive and highly significant influence on the productivity level. Especially, the long run effect of the patent stock per capita increases up to 0.22 percent when fixed effects for all states are included.

The share of agricultural employment has a surprisingly positive impact in the third LDV model specification. In contrast, in the first three specifications of the AR 1 error model the share of agricultural employment satisfies the expected negative impact on the productivity level. A one percent decrease in the share of agricultural employment leads to an increase from 0.018 to 0.063 percent in the productivity level depending on the specification. But the change of sign puts the truly underlying influence of the structural change on the productivity level into question.

As expected, the stock of potential tertiary human capital per capita has a positive and significant influence. The long run effect is highest in the first LDV model (about 0.41

percent). The variable loses its significant influence when fixed effects are added. The reason might be that the stock of potential tertiary human capital per capita changes slowly so that the fixed effects capture all the inter-unit variation as already suspected above.

Furthermore, the stock of potential secondary human capital per capita has a positive impact in the first LDV model. But in the AR1 error model it has a significant and negative bearing on the productivity level. A one percent decrease of the stock of potential secondary human capital per capita leads to an increase of the productivity level from 0.111 to 0.234 percent. Even if the change of sign puts the impact of this variable into question, the results in the AR1 error model support Aghion's theory that for the innovation process tertiary human capital is needed instead of secondary human capital. Secondary human capital is especially necessary in the imitation process. But the development of the German states might be too advanced in order to catch-up via imitation. In this regard, innovation with the help of tertiary human capital is the only way to catch-up with the productivity leaders of Germany's economy.

The export share has a positive impact in the third and fourth LDV model. In the long run an increase in the export share by one percent leads to an increase of the productivity level from 0.07 to 0.15 percent.

Finally, the share of CDU/CSU-voters has a positive influence in the LDV model, but a negative impact in the AR1 error model. For a start, the true impact of this variable remains uncertain.

In table 8 regression results are reported for the additional explanatory variable share of public expenditure for R&D in the time period from 1962 to 1990. Once again the lagged dependent variable has a positive and highly significant impact on the productivity level.

The patent stock per capita can also maintain its positive and significant influence in both model specifications. The variable only loses its significance when fixed effects for all N-1 states are added. The reason might be that in the period from 1962 onwards the patent stock per capita in the states does not fluctuate sufficiently. As a consequence of this, the fixed effect dummies absorb the inter-unit variation of the patent stock per capita.

The share of agricultural employment has a negative and significant impact in all specifications of the AR1 error model. This result emphasizes the negative impact already seen before in table 7.

Once more, the stock of potential tertiary human capital per capita has a positive and significant influence. Also in this case the stock of potential tertiary human capital per capita loses its influence when fixed effects are included in the LDV model.

The stock of potential secondary human capital, the export share and the share of CDU/CSU-voters cannot be considered as robust due to changes of sign.

The additional explanatory variable, that is the share of public R&D expenditures, has a positive impact in the first two LDV models and a negative impact in the AR 1 error models with fixed effects for the city-states and for all N-1 states, respectively. For this variable the true impact on the productivity level is uncertain.

8 Conclusion

This paper investigates the main causes of productivity development in the West German states during the time period form 1950 to 1990.

With the help of growth theories different sources of productivity growth were detected. These are innovations, secondary and tertiary human capital, structural change, openness and institutions. In a regression analysis the relationship between these different sources of productivity growth and the productivity development was analyzed.

The regression analysis has shown that three main independent variables are able to explain the development of the productivity level. These are the patent stock per capita, the share of agricultural employment and the stock of potential tertiary human capital per capita.

The patent stock per capita is a measure for the existing knowledge stock in the German states. An increase in the knowledge stock leads to an increase of the productivity level. Apart from Berlin that can be seen as an exception Baden-Württemberg, Bavaria and Hessen exhibit the highest patent stocks per capita and therefore the highest innovational power. This analysis once again proves that innovation and knowledge play a decisive role in the economic growth process. But one has to bear in mind, that only few highly innovative firms – especially in electrical engineering and chemical industry – generate most part of the granted patents. Therefore the question arises if the patent stock mirrors the knowledge stock of a region or state in an adequate way. It may underestimate the knowledge stock especially in regions where small firms and branches with a low propensity to patent dominate the economic structure.

Moreover a decrease in the agricultural employment share also increases the productivity level. After World War II states like Rhineland-Palatinate, Bavaria, Lower Saxony, Baden-Württemberg, Schleswig-Holstein and Hessen possessed the highest potential productivity gain due to structural change. This temporal potential did not last forever. Since the 1970s the productivity gains from a reduction of the agricultural sector have decreased more and more.[70] Furthermore, the increase of the potential tertiary human capital stock per capita raises the productivity level. Admittedly, the measure for tertiary human capital is very imprecise. It is disputable if a high number of high school graduates does ensure high quality of tertiary human capital. In this regard the states should strive for quality, not quantity.

The study clarifies that innovations and tertiary human capital are of vital importance for the development of the productivity and a potential convergence process in the West German states especially after the structural change became less influential. Since the 1970s, innovation activities of some West German states have been too small to boost their productivity level.

These results are in accord with the conclusion Paqué (2009) presented recently. He assess that the persistent labor productivity differences between the East and the West of Germany have to be explained by a lag of the industrial innovative activity in the East German economy.[71]

In this regard, the German inter-state tax revenue sharing system ("Länderfinanzausgleich"), which was invented in 1950 to equalize the financial power of all German states, does only make sense if the allocated funds are invested in productivity driving sources like innovation and human capital. Otherwise this system will never come to a prosperous end as reality already demonstrates. Meanwhile only three donor states (Baden-Württemberg, Bavaria and Hessen) face thirteen economically weak states that receive their payments in the horizontal financial equalization in 2010. This system, which has been in force for 60 years, seems not to be crowned with success.

[70] See Lindlar (1997), Das mißverstandene Wirtschaftswunder, pp. 320-324.
[71] See Paqué, Karl-Heinz (2009), Die Bilanz: eine wirtschaftliche Analyse der deutschen Einheit.

Appendix

Table 1.: GDP per capita in Euro in 2008

Ranking	Federal state	GDP per capita	Hamburg = 100
1	Hamburg	50.640	100
2	Bremen	41.918	83
3	Hessen	36.382	72
4	Bayern	35.530	70
5	Baden-Württemberg	33.876	67
6	Saarland	30.168	60
7	Nordrhein-Westfalen	30.113	59
8	Niedersachsen	26.902	53
9	Rheinland-Pfalz	26.623	53
10	Schleswig-Holstein	25.945	51
11	Berlin	25.554	50

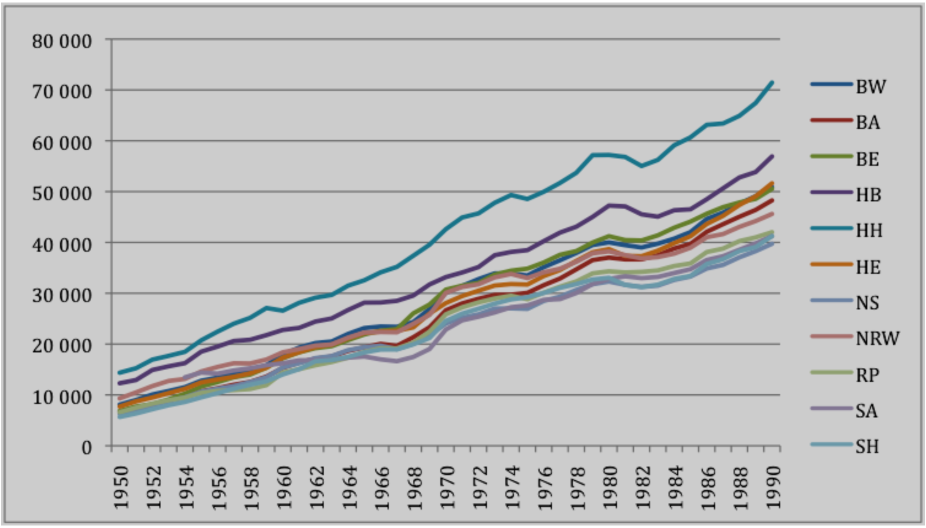
Source: Own calculations based on VGR der Länder:
http://www.vgrdl.de/Arbeitskreis_VGR/tbls/tab01.asp#tab07

Table 2.: Unemployed and unemployment rate 2008

Federal state	Unemployed	Unemployment rate in percent
Baden-Württemberg	229.129	4,1
Bayern	276.638	4,2
Berlin	233.737	13,9
Bremen	36.837	11,4
Hamburg	72.958	8,1
Hessen	204.417	6,6
Lower Saxony	304.363	7,7
North Rhine-Westphalia	759.564	8,5
Rhineland-Palatinate	116.260	5,6
Saarland	37.005	7,3
Schleswig-Holstein	107.509	7,6
Germany	3.267.943	7,8

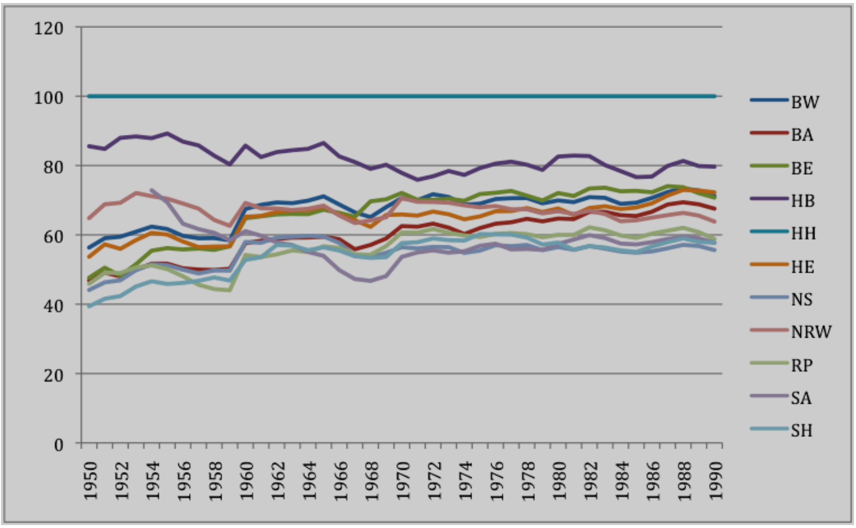
Source: Bundesagentur für Arbeit (BA); http://www.statistik-portal.de/Statistik-Portal/de_jb02_jahrtab13.asp

Figure 1: Real GDP per capita (1950-1990)



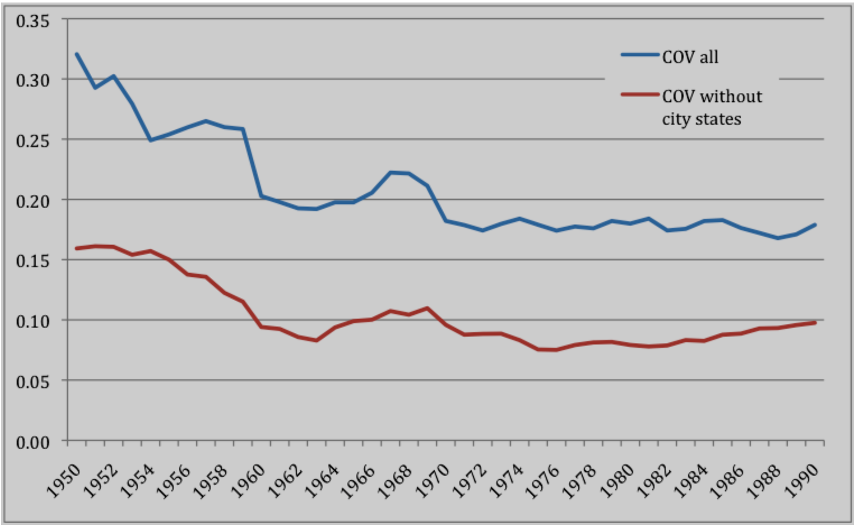
Source: Own calculation based on Statistisches Bundesamt (various volumes), Bevölkerungsstruktur und Wirtschaftskraft der Bundesländer; Statistisches Bundesamt (various volumes), Statistisches Jahrbuch; Statistisches Landesamt Berlin (1958), Statistisches Jahrbuch Berlin; Statistisches Amt des Saarlandes (various volumes), Statistisches Handbuch für das Saarland.

Figure 2: Real GDP per capita (HH=100)



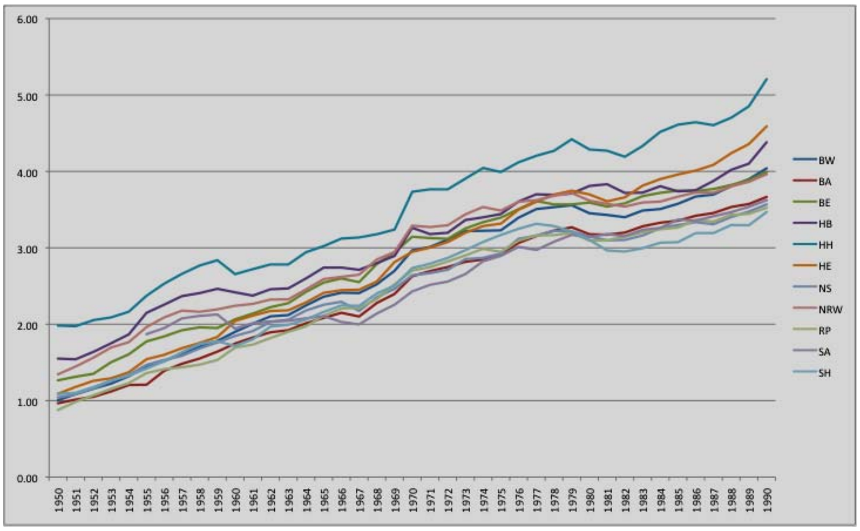
Source: Own calculation based on Statistisches Bundesamt (various volumes), Bevölkerungsstruktur und Wirtschaftskraft der Bundesländer; Statistisches Bundesamt (various volumes), Statistisches Jahrbuch; Statistisches Landesamt Berlin (1958), Statistisches Jahrbuch Berlin; Statistisches Amt des Saarlandes (various volumes), Statistisches Handbuch für das Saarland.

Figure 3: Coefficient of variation of the real GDP per capita



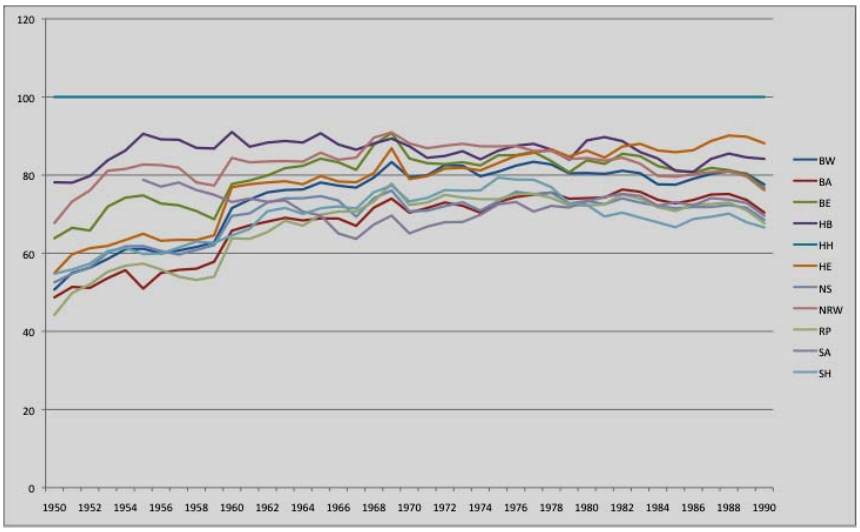
Source: Own calculation based on Statistisches Bundesamt (various volumes), Bevölkerungsstruktur und Wirtschaftskraft der Bundesländer; Statistisches Bundesamt (various volumes), Statistisches Jahrbuch; Statistisches Landesamt Berlin (1958), Statistisches Jahrbuch Berlin; Statistisches Amt des Saarlandes (various volumes), Statistisches Handbuch für das Saarland.

Figure 4: Development of TFP in the West German states



Source: Own calculations based on Arbeitskreis Volkswirtschaftliche Gesamtrechnung der Länder (various volumes), Entstehung, Verteilung und Verwendung des Sozialprodukts in den Ländern der Bundesrepublik Deutschland; Allmendinger, Jutta (ed.) (2005), IAB, Handbuch Arbeitsmarkt.

Figure 5: Development of TFP (HH=100)



Source: Own calculations based on Arbeitskreis Volkswirtschaftliche Gesamtrechnung der Länder (various volumes), Entstehung, Verteilung und Verwendung des Sozialprodukts in den Ländern der Bundesrepublik Deutschland; Allmendinger, Jutta (ed.) (2005), IAB, Handbuch Arbeitsmarkt.

Figure 6: Coefficient of variation of TFP in the West German states

Source: Own calculations based on Arbeitskreis Volkswirtschaftliche Gesamtrechnung der Länder (various volumes), Entstehung, Verteilung und Verwendung des Sozialprodukts in den Ländern der Bundesrepublik Deutschland; Allmendinger, Jutta (ed.) (2005), IAB, Handbuch Arbeitsmarkt.

Table 3.: Indicators for innovation activities

Phase	Input indicator	Output indicator
Invention	• R&D expenditures by private firms • R&D expenditures by the government • R&D expenditures by public research organisations	• Patents • Scientific publications
Innovation		• Long-lived patents • Lists of innovations compiled by experts
Diffusion		• Productivity

Source: Spoerer, Baten, Streb (2007). Wissenschaftlicher Standort, Quellen und Potentiale der Innovationsgeschichte, in R. Walter (Ed.), Innovationsgeschichte (pp. 39-59). Stuttgart.

Table 4.: Labor productivity in the three sectors

	Labor productivity in primary sector				Labor productivity in secondary sector				Labor productivity in tertiary sector			
	1960	1970	1980	1990	1960	1970	1980	1990	1960	1970	1980	1990
BW	11,223	15,128	20,128	37,582	30,311	47,742	60,087	70,111	32,547	52,374	62,637	73,052
BA	12,050	11,792	10,907	16,602	27,445	43,307	48,734	59,310	29,519	47,352	63,975	75,214
BE	24,856	31,955	40,312	45,800	29,748	47,491	62,303	70,585	26,496	43,892	64,486	68,452
HB	114,718	12,782	40,091	40,000	43,007	65,774	95,398	108,109	36,428	61,693	73,923	63,914
HH	37,329	28,479	34,951	23,750	39,223	66,928	80,785	94,128	41,027	72,791	93,625	89,883
HE	13,122	16,608	14,182	31,625	31,799	45,083	54,112	67,003	36,341	57,507	78,361	92,784
NS	17,162	22,241	33,442	47,166	31,092	44,387	51,110	57,854	28,734	43,830	54,140	66,641
NRW	14,959	26,189	29,889	29,645	35,087	50,872	58,855	68,276	31,888	54,679	66,863	70,184
RP	10,959	15,772	19,204	29,538	28,348	49,741	51,931	62,293	29,553	43,960	54,834	71,780
SA	15,933	20,003	16,962	47,000	36,605	39,445	55,124	69,377	32,487	49,528	65,567	63,181
SH	24,397	35,733	34,002	39,760	24,963	42,738	46,906	60,869	25,339	44,905	52,033	66,716

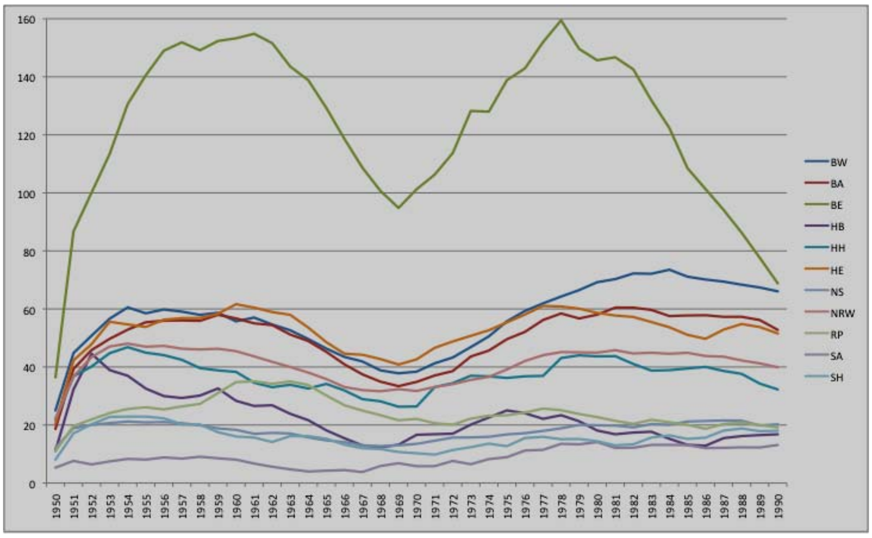
Source: Own calculations based on Arbeitskreis Volkswirtschaftliche Gesamtrechnung der Länder (various volumes), Entstehung, Verteilung und Verwendung des Sozialprodukts in den Ländern der Bundesrepublik Deutschland

Table 5.: Share of immobile first-year students

	1980	1984	1986	1988	1990
Baden-Württemberg	82.1	78.4	75.2	72.2	73.4
Bayern	90.3	90.0	88.9	88.4	88.7
Berlin	92.9	93.9	94.3	93.6	91.8
Bremen	43.3	40.6	50.1	51.6	57.1
Hamburg	82.2	76.0	72.0	67.3	67.3
Hessen	67.7	69.5	68.9	68.7	70.1
Niedersachsen	62.6	59.3	60.5	58.5	61.0
NRW	83.7	82.7	82.3	82.3	83.1
Rheinland-Pfalz	45.4	48.5	47.2	47.0	48.7
Saarland	57.9	58.2	56.9	56.0	58.4
Schleswig-Holstein	53.3	50.2	48.0	49.9	52.3
BRD	76.6	75.3	74.4	73.4	-

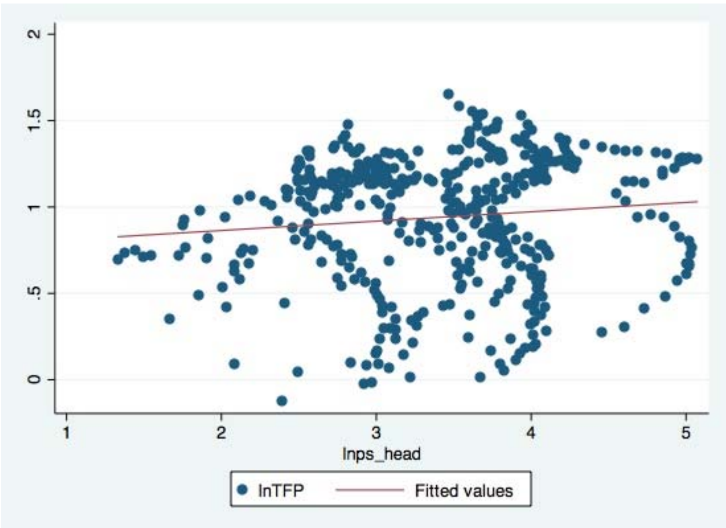
Source: Kultusministerkonferenz (2007), Die Mobilität der Studienanfänger und Studierenden in Deutschland von 1980 bis 2005

Figure 7: Patent stock per capita



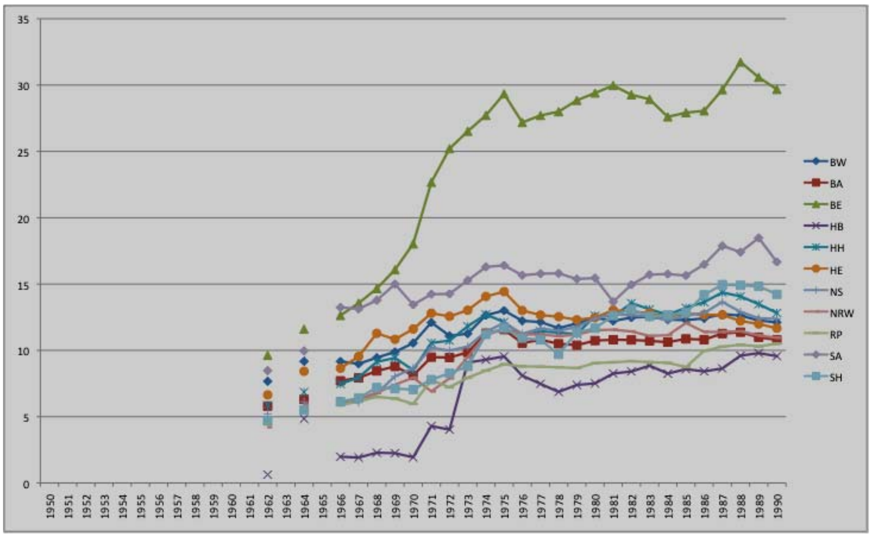
Source: Own calculation based on the database of the German Patent and Trademark Office, www.depatisnet.de

Figure 8: Relationship between patent stock per capita and productivity



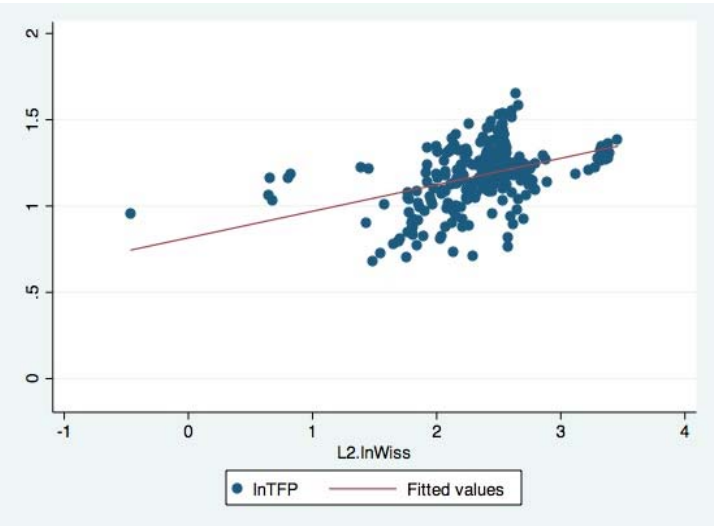
Source: Own calculations

Figure 9: Share of public expenses for R&D (per 1000 DM GDP)



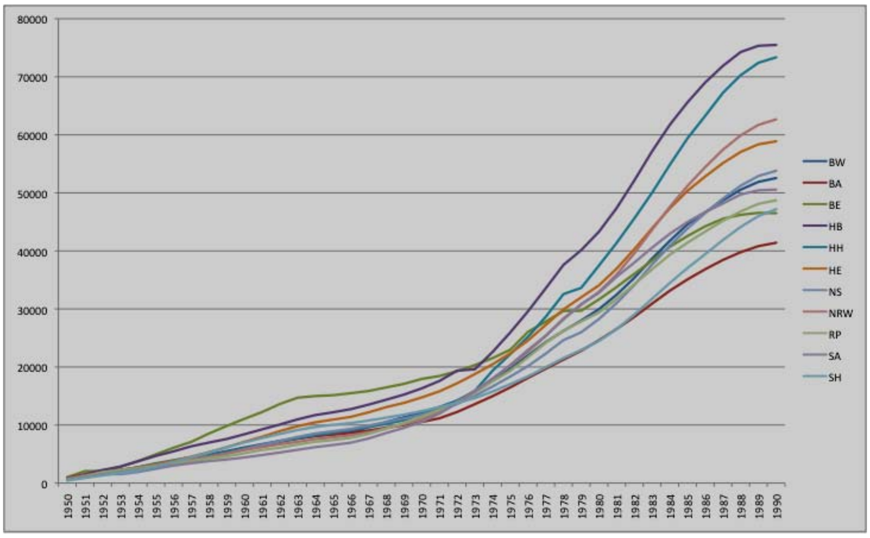
Source: Own calculation based on Bundesministerium für Bildung und Forschung (various volumes), Bundesbericht Forschung, Statistisches Bundesamt (various volumes), Bevölkerungsstruktur und Wirtschaftskraft der Bundesländer; Statistisches Landesamt Berlin (1958), Statistisches Jahrbuch Berlin; Statistisches Amt des Saarlandes (various volumes), Statistisches Handbuch für das Saarland.

Figure 10: Relationship between public expenses for R&D and productivity



Source: Own calculation.

Figure 11: Stock of potential tertiary human capital per capita



Source: Own calculation based on Statistisches Bundesamt (various volumes), Allgemeinbildende Schulen, Statistisches Material; Bevölkerung nach Alter und Familienstand; Statistisches Bundesamt (various volumes), Bevölkerungsstruktur und Wirtschaftskraft der Bundesländer.

Figure 12: Relation between stock of potential tertiary human capital per capita and productivity

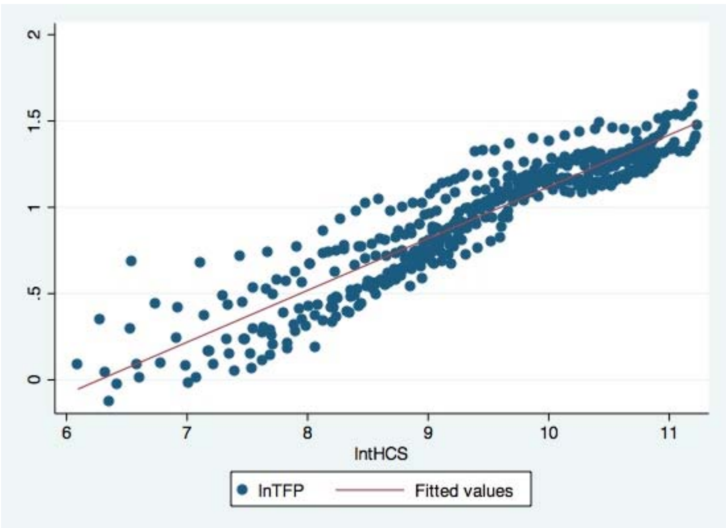
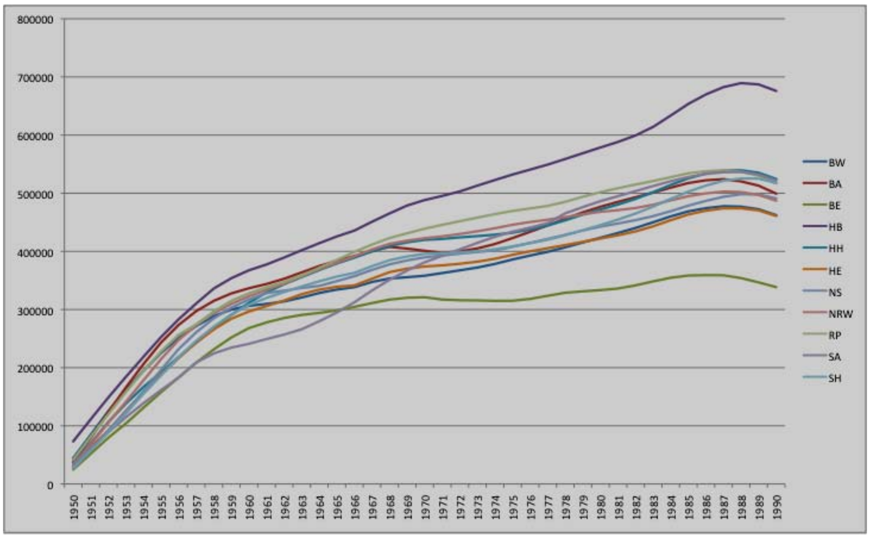
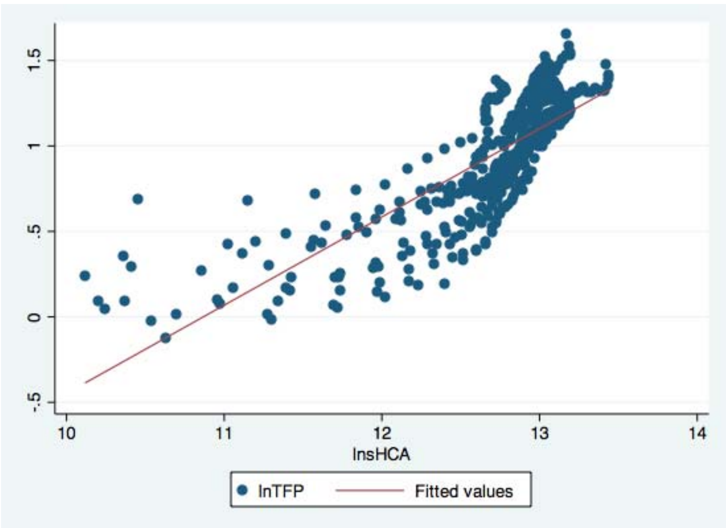


Figure 13: Stock of potential secondary human capital per capita



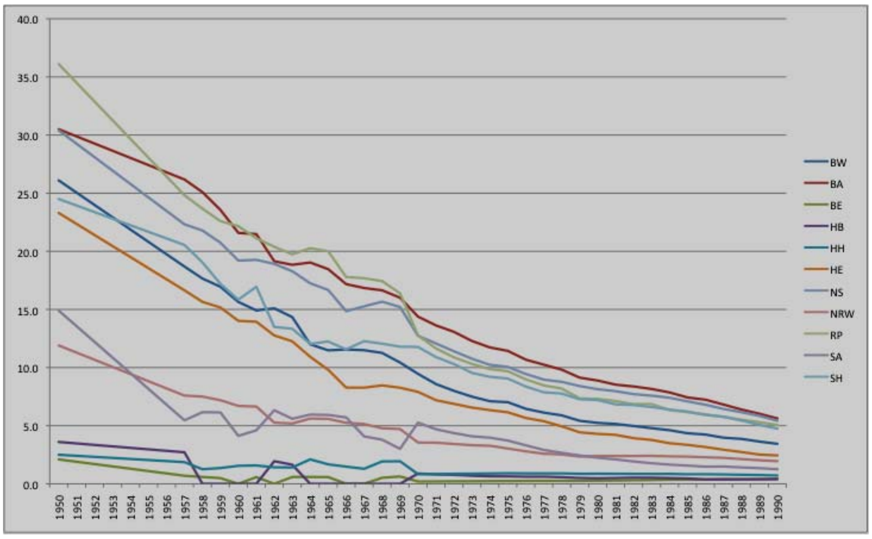
Source: Own calculation based on Lundgreen, Peter (2008), Berufliche Schulen und Hochschulen in der Bundesrepublik Deutschland (Datenhandbuch zur Deutschen Bildungsgeschichte, 8), Tab. 2.1 CD-Rom, Schüler an Berufsschulen 1949-2001; Statistisches Bundesamt (various volumes), Bevölkerungsstruktur und Wirtschaftskraft der Bundesländer.

Figure 14: Relation between stock of potential secondary human capital per capita and productivity



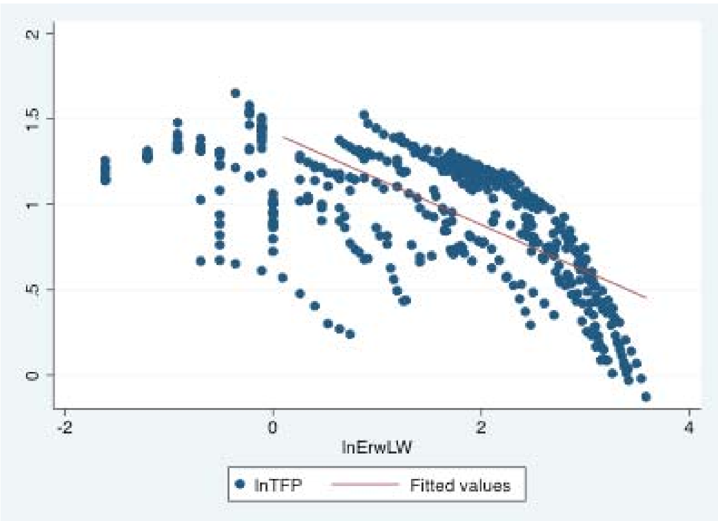
Source: Own calculations.

Figure 15: Share of agricultural employment (in percent)



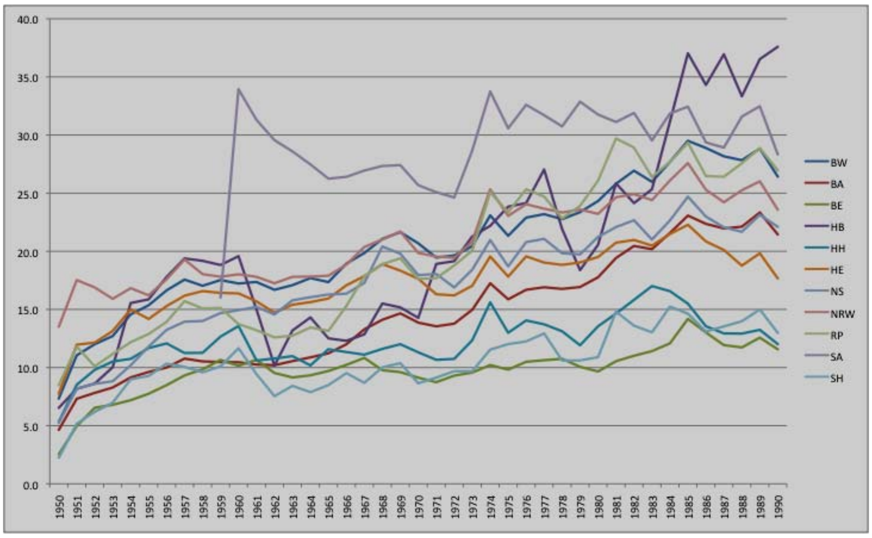
Source: Own calculations based on Statistisches Bundesamt (various volumes), Bevölkerungsstruktur und Wirtschaftskraft der Bundesländer, Kommission der Europäischen Gemeinschaft (1969), Regionale Entwicklung der landwirtschaftlichen Erwerbsbevölkerung, II. BR Deutschland, p 42.

Figure 16: Relationship between share of agricultural employment and productivity



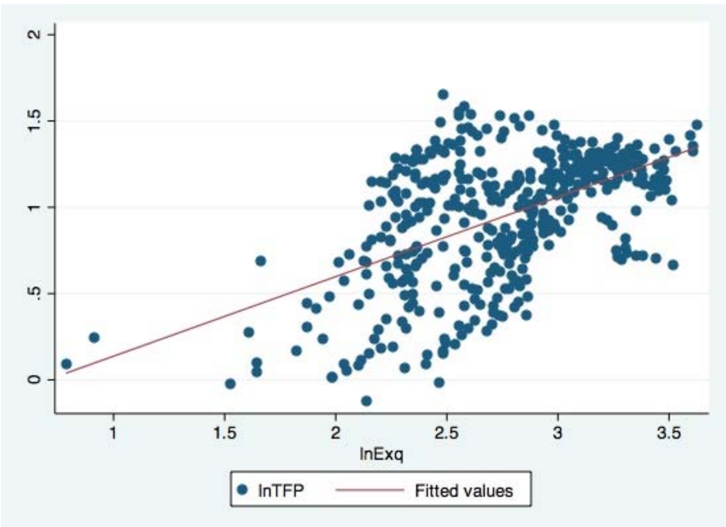
Source: Own calculation.

Figure 17: Export share in percent



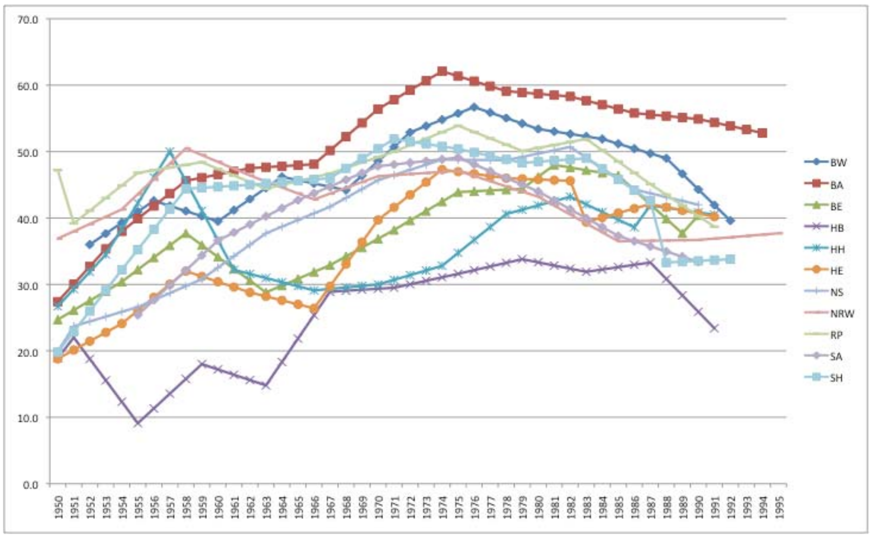
Source: Own calculations based on Statistisches Bundesamt (various volumes), Bevölkerungsstruktur und Wirtschaftskraft der Bundesländer.

Figure 18: Relationship between export share and productivity



Source: Own calculations.

Figure 19: Proportion of CDU/CSU-voters



Source: Own calculation based on Statistisches Bundesamt (various volumes), Bevölkerungsstruktur und Wirtschaftskraft der Bundesländer. Proportions of CDU/CSU-voter are linear interpolated during a legislative period.

Figure 20: Relationship between proportion of CDU/CSU-voters and productivity

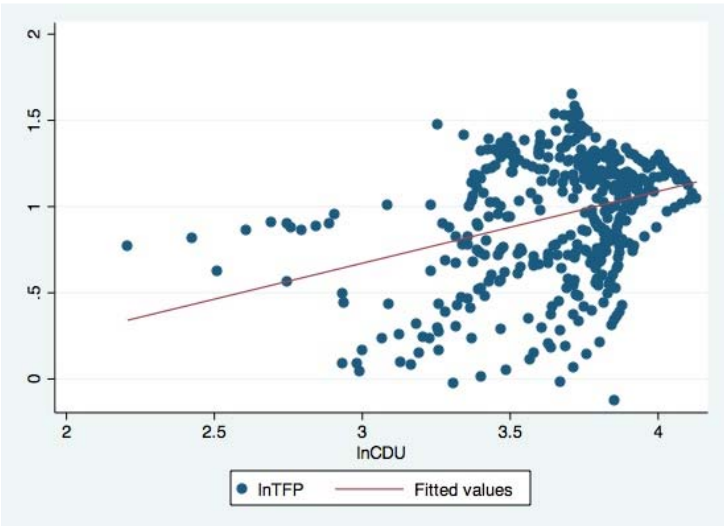


Table 6.: Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Log (TFP)	451	0.942	0.367	-0.128	1.651
Log (patent stock per capita)	451	3.440	0.748	1.334	5.072
Log (share agric. employment)	451	1.519	1.283	-1.609	3.586
Log (stock of pot. tertiary HC per capita)	451	9.409	1.133	6.098	11.232
Log (stock of pot. secondary HC per capita)	451	12.692	0.574	10.121	13.444
Log (export share)	442	2.762	0.430	0.788	3.627
Log (share of CDU/CSU-voter)	444	3.654	0.311	2.208	4.129
Log (share of public expenses R&D)	297	2.370	0.464	-0.462	3.457
Log (cyclical trend)	447	11.562	0.112	11.118	12.109

Table 7.: Determinants of total factor productivity (1950-1990)

Explanatory variables	(1.1)	(1.2)	(1.3)	(1.4)	(1.5)	(1.6)	(1.7)	(1.8)
	LDV				AR1			
TFP (t-1)	0.955	0.928	0.910	0.858				
	(0.0125)	(0.0178)	(0.0193)	(0.0233)				
Patent stock per capita	0.006	0.009	0.009	0.032	0.016	0.042	0.039	0.033
	(0.0023)	(0.0023)	(0.0022)	(0.0068)	(0.0113)	(0.0104)	(0.0089)	(0.0139)
Share agric. employment	0.002	-0.003	0.0009	0.014	-0.033	-0.063	-0.018	-0.002
	(0.0015)	(0.0030)	(0.0031)	(0.0044)	(0.0068)	(0.0075)	(0.0068)	(0.0074)
Stock pot. tertiary HC	0.018	0.022	0.025	0.011	0.080	0.110	0.070	0.021
	(0.0072)	(0.0072)	(0.0072)	(0.0086)	(0.0264)	(0.0282)	(0.0237)	(0.0239)
Stock pot. secondary HC	0.016	-0.005	-0.005	-0.007	-0.012	-0.111	-0.234	-0.190
	(0.0085)	(0.0112)	(0.0135)	(0.0194)	(0.0514)	(0.0517)	(0.0532)	(0.0531)
Export share	0.002	-0.0008	0.007	0.021	-0.004	-0.017	0.018	0.010
	(0.0032)	(0.0035)	(0.0039)	(0.0073)	(0.0129)	(0.0132)	(0.0123)	(0.0131)
Share public expenses R&D								
Share CDU/CSU-voters	-0.001	0.002	-0.002	0.012	-0.050	-0.044	-0.008	0.019
	(0.0049)	(0.0052)	(0.0057)	(0.0064)	(0.0215)	(0.0204)	(0.0203)	(0.0207)
Cyclical trend	-0.006	-0.004	0.002	0.010	0.097	0.088	0.103	0.095
	(0.0099)	(0.0103)	(0.0106)	(0.0099)	(0.0192)	(0.0194)	(0.0225)	(0.0201)
Year	-0.001	-0.0002	0.0001	0.003	-0.0002	0.0004	0.001	0.001
	(0.0008)	(0.0010)	(0.0010)	(0.0011)	(0.0003)	(0.0003)	(0.0004)	(0.0003)
BW				-0.040				0.015
				(0.0117)				(0.0274)
BA				-0.048				-0.059
				(0.0101)				(0.0262)
BE		-0.025	-0.009	-0.005		-0.225	-0.069	0.024
		(0.0105)	(0.0098)	(0.0192)		(0.0362)	(0.0306)	(0.0427)
HB			0.006	0.045			0.206	0.271
			(0.0073)	(0.0133)			(0.0383)	(0.0347)
HH			0.021	0.048			0.317	0.366
			(0.0057)	(0.0133)			(0.0342)	(0.0295)
HE				-0.022				0.072
				(0.0113)				(0.0319)
NS				-0.015				-0.009
				(0.0059)				(0.0192)
NRW				-0.010				0.145
				(0.0103)				(0.0267)
RP				-0.029				-0.032
				(0.00799				(0.0238)
SA				0.008				0.013
				(0.0100)				(0.0307)
SH								
Constant	2.546	0.267	-0.345	-5.335	-	-	-	-
	(1.4615)	(1.7726)	(1.796)	(2.0811)				
R-squared	0.9970	0.9970	0.9971	0.9973	0.5394	0.6970	0.7778	0.8906
Observations	430	430	430	430	430	430	430	430
	Long-run effects							
Patent stock / capita	0.13	0.12	0.10	0.22				
Share agric. employment				0.10				
Stock pot. tertiary HC	0.41	0.31	0.27					
Stock pot. secondary HC	0.36							
Export share			0.07	0.15				
Share public expenses R&D								
Share CDU/CSU-voters				0.09				

Notes: All models linear regression with panel-corrected standard errors (PCSE). Standard errors in parenthesis.
Patent stock per capita, share of agricultural employment and export share are lagged by one year.
*, **, *** denotes significance on 10, 5 and 1 percent level.
All models include T-1 time dummies.

Table 8.: Determinants of total factor productivity (1962-1990)

Explanatory variables	(2.1)	(2.2)	(2.3)	(2.4)	(2.5)	(2.6)	(2.7)	(2.8)
	LDV				AR1			
TFP (t-1)	0.979	0.944	0.916	0.827				
	(0.0174)	(0.0215)	(0.0290)	(0.0414)				
Patent stock per capita	0.003	0.006	0.007	0.009	0.026	0.052	0.053	0.004
	(0.0017)	(0.0020)	(0.0022)	(0.0081)	(0.0096)	(0.0090)	(0.0059)	(0.0153)
Share agric. employment	0.003	-0.003	-0.003	0.004	-0.040	-0.067	-0.041	-0.015
	(0.0015)	(0.0026)	(0.0031)	(0.0044)	(0.0083)	(0.0098)	(0.0080)	(0.0084)
Stock pot. tertiary HC	0.018	0.021	0.024	0.001	-0.013	0.051	0.078	-0.018
	(0.0107)	(0.0106)	(0.0108)	(0.0126)	(0.0499)	(0.0436)	(0.0286)	(0.0237)
Stock pot. seondary HC	0.036	0.015	0.005	0.070	0.158	-0.134	-0.216	0.070
	(0.0144)	(0.0152)	(0.0167)	(0.0339)	(0.0590)	(0.0706)	(0.0532)	(0.0716)
Export share	-0.001	-0.005	-0.002	-0.008	-0.015	-0.034	0.021	0.001
	(0.0033)	(0.0038)	(0.0040)	(0.0114)	(0.0165)	(0.0150)	(0.0126)	(0.0190)
Share publ. expenses R&D	0.009	0.009	0.005	-0.005	-0.009	-0.004	-0.034	-0.042
	0.0050)	(0.0048)	(0.0061)	(0.0083)	(0.0138)	(0.0129)	(0.0133)	(0.0134)
Share CDU/CSU-voters	0.006	0.008	0.006	0.027	-0.105	-0.080	-0.038	0.023
	(0.0103)	(0.0103)	(0.0105)	(0.0113)	(0.0390)	(0.0357)	(0.0288)	(0.0259)
Cyclical trend	-0.002	0.002	0.007	0.012	0.103	0.096	0.010	0.094
	(0.0079)	(0.0084)	(0.0091)	(0.009)	(0.0220)	(0.0230)	(0.0276)	(0.0194)
Year	-0.001	0.0001	0.001	0.004	-0.001	0.001	0.001	-0.0003
	(0.0009)	(0.0009)	(0.0010)	(0.0013)	(0.0005)	(0.0005)	(0.0004)	(0.0004)
BW				0.016				0.094
				(0.0191)				(0.0324)
BA				-0.014				-0.018
				(0.0129)				(0.0252)
BE		-0.023	-0.021	0.043		-0.257	-0.145	0.147
		(0.0104)	(0.0103)	(0.0305)		(0.0455)	(0.0300)	(0.0536)
HB			0.002	0.036			0.048	0.122
			(0.0083)	(0.0151)			(0.0335)	(0.0313)
HH			0.011	0.061			0.202	0.304
			(0.0065)	(0.0172)			(0.0241)	(0.0254)
HE				0.034				0.151
				(0.0181)				(0.0316)
NS				0.004				0.011
				(0.0086)				(0.0164)
NRW				0.024				0.125
				(0.0148)				(0.0263)
RP				-0.005				-0.020
				(0.0103)				(0.0197)
SA				0.020				-0.008
				(0.012)				(0.0254)
SH								
Constant	0.537	-0.634	-1.728	-8.843	-	-	-	-
	(1.5752)	(1.5919)	(1.6960)	(2.4776)				
R-squared	0.9941	0.9942	0.9942	0.9947	0.9431	0.9494	0.9622	0.9678
Observations	286	286	286	286	286	286	286	286
	Long-run effects							
Patent stock / capita	0.14	0.10	0.08					
Stock pot. tertiary HC	0.85	0.37	0.29					
Stock pot. secondary HC	1.67			0.41				
Share public expenses R&D	0.43	0.15						
Share CDU/CSU-voters				0.15				

Notes: All models linear regression with panel-corrected standard errors (PCSE). Standard errors in parenthesis.
Patent stock per capita, share of agricultural employment and export share are lagged by one year.
Black characters denote significance on 10 percent level or better.
All models include T-1 time dummies.

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