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## Education, Research, and Economic Growth

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Economic Theory

# Education, Research, and Economic Growth
**Some Tests for the U.S. and Germany**

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**Abstract**

It is obvious that the German economy exhibits a significant decline in economic growth during the last two decades. Although the German economy has still to overcome the burden of the reunification in 1990 it is shown that this burden might be only one reason of this decline.
In this study we follow the new growth theory and develop and compare indicators for the educational and R&D systems of the U.S. and Germany. In this line, we show that on average the German system can compete with the U.S. one, but a lack of human capital at very high skill levels becomes obvious. This lack, particularly leads to a lower performance of German R&D and could, therefore, possibly explain the decline of the German growth trend.

**JEL - Classification:** O11, O30

**Keywords:** Human Capital, Research and Development, Efficiency of Educational Systems; Sources of Economic Growth

# 1 Introduction

The importance of knowledge and human capital for long run economic growth is known for a long time. For example, Young (1928) has pointed out that the productivity differences between U.S. and U.K. industries at that time might by explained by different levels of inventive activities and better organizational structures of the American industry. The statement of Young (1928) can be regarded as a former description of the importance of human capital and technological change for economic growth. At least, since Lucas (1988) or Romer (1990) the importance of knowledge and human capital has become a subject of recent political and politico-economical discussion.

Taking the role of human capital and innovations as given and comparing the economic development of Germany with that of the U.S. economy during the last two decades, we find a strong decline in the growth trend (80-90: 2.31 %, 91-02: 1.4 %), whereas the U.S. growth trend remained constant at 3.2 %.[1] Of course, one has to point out that the German economy had to overcome the burden of the reunification in 1991, but other reasons, which are pointed out by economists and also various political parties, are deficiencies of the German educational system and the system of inventive activities, particularly research and development activities. At least, since the so-called `PISA - shock'[2] a possible lack of human capital has become obvious. Since then, pronouncements for `elite - universities' or an increase in competition between universities in order to generate higher rates of innovation, etc. are called for in public discussion. Concerning the role of human capital one has to point out that the structure of human capital becomes more and more important to explain the differences in economic growth between the U.S. and Europe and particularly Germany. In recent studies Krueger and Kumar (2004a,b) point out, for example, that too intensive training in specific skills rather than general skills, leads to a lower degree of adoption of new technologies which results in a decrease in growth rates.

The present study examines the efforts and outcomes of the German and U.S. educational and research systems on a macro level. Although it is difficult to compare both countries we derive some insights where the German system might fail and where it is able to compete with the U.S. system. In particular, we show that it is not a general lack of human capital of Germany, however it seems that the structure of Germany's human capital is not `growth - enhancing'.

1 Average growth rates of real GDP. Own calculations with data taken from Sachverständigenrat (2003). See also OECD (2003b) for a detailed survey of the pattern of economic growth across OECD countries.

2 PISA: Programm for International Student Assessment, organized by the OCED in 2000

In our analysis we use time series data rather than cross sectional data which enables us to determine `turning points' since then the one or the or the system turns out to be more efficient. Furthermore, this approach is, from our point of view, in line with the perspective of the new growth theories. That means, that means that we attempt to analyze long term economic development by applying time series data.[3] In order to examine indicators of efficiency or productivity of both systems we follow an attempt where we combine efforts and outcomes of each system.

The remainder of this paper is structured as follows. Section two outlines stylized facts of the U.S. and German educational and R&D - systems. In section three we conduct various tests on a set of indicators which describe aspects of the productivity of educational and research systems. Section 4 concludes.

## 2 Some Stylized Facts

In this section we outline some basic facts of U.S. and German educational and research and development (R&D) efforts. Particularly, we consider relative expenditures per GDP as an input measure which show the country's efforts in education and research. Furthermore, we outline the structure of relative skills relative to employees as an output measure. In particular, the latter indicator enables us to derive indicators of the supply of skills (in terms of `manpower') which determine the `production' and adoption of new knowledge. Figures 1 and 2 below show the relative educational and R&D expenditures per GDP for the U.S. and Germany.

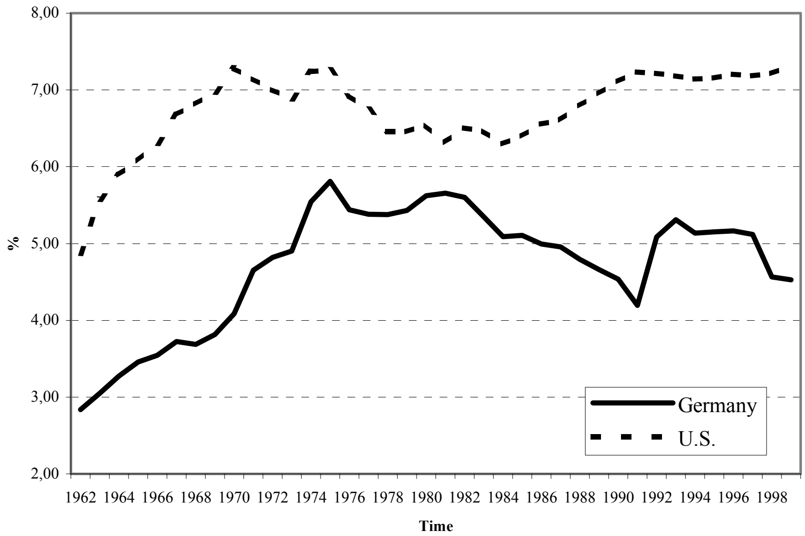


Figure 1: Educational Expenditures / GDP , 1962-1999

[3] See, for example Greiner et al. (2001) for a discussion of the new growth theory from a time series perspective. Furthermore, a detailed

Figure 1 shows total, public and private, educational expenditures per GDP for the U.S. and Germany. Differentiating between public and private educational expenditures one finds, that in 1998 in Germany about 25 % of total expenditures is privately financed compared to 19 % in the U.S.[4] It is obvious from figure 1 that over time the U.S. educational efforts are about 50 % higher than in Germany. In particular, since the beginning of the 1980's we observe a steady decrease for Germany whereas the for the U.S., after a decline during the 1980's, the series remained constant since the end of the 1970's.

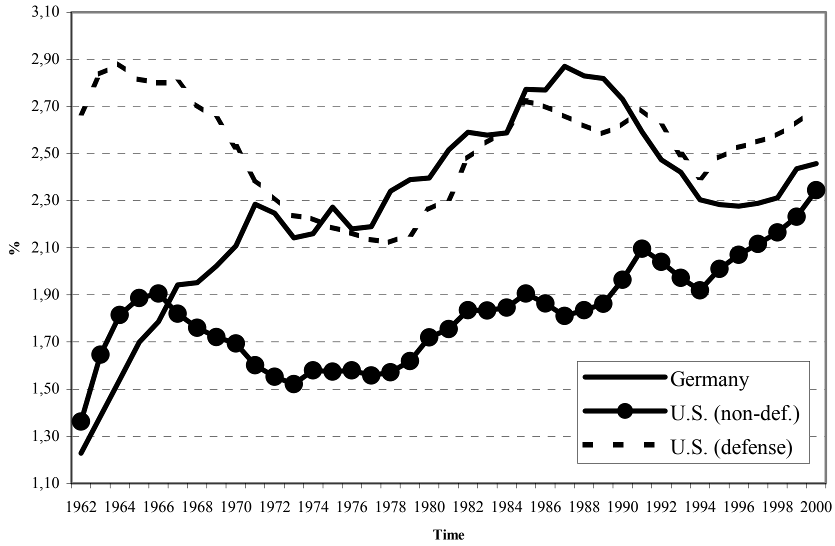


Figure 2 : Total R&D -Expenditures / GDP ,1962-2000

Concerning the total research and development expenditures per GDP (figure 2) we observe that the U.S. efforts fluctuates around 2.5 % if defense related R&D expenditures are included. Differentiating between defense and non-defense related R&D expenditures we observe a steady increase in the latter one from 1.4 % in 1962 to 2.3 % in 2002. For Germany figure 2 reports an increase in relative R&D expenditures until the middle of the 1980's. During that time Germany's relative R&D efforts were higher than the U.S. ones. Since then we observe a significant decline of this number.

The indicators of educational and research efforts presented in figures 1 and 2 show only the input side of educational and research systems. Therefore, we consider further indicators which show relative participants of each system. Figure 3 below presents the number of students at colleges and universities per employees.

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overview of the endogenous growth theory can be found in Aghion and Howitt (1998).

[4] Own calculations based on the Annual Statistical Abstract of the United States 2000 and the Datenreport 2002 published by the Federal Statistical Office Germany.

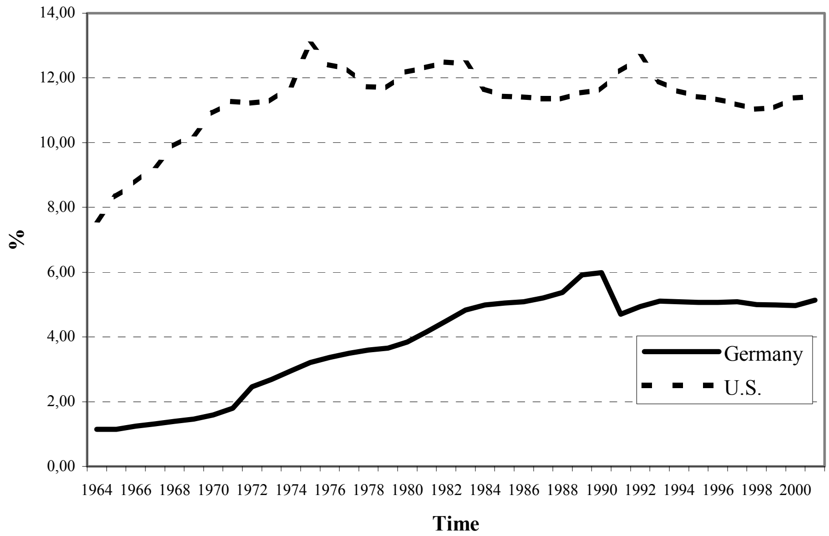


Figure 3: Students at Colleges and Universities per Employees, 1964-2001
*Sources: National Center for Education Statistics (U.S.), Federal Statistical Office (Germany)*

As shown by figure 3 it seems obvious that the relative participation in higher education is much higher in the U.S. than in Germany. However, one has to point out that we compare very different educational systems. In particular, the German post - school education is characterized by apprenticeships, and people participating in the latter system are not covered by the data shown in figure 3. That the attainment in the latter system is very important is shown by the following numbers. For example, in 2000 about 53.5 % of the age cohort 20 to 29 years served an apprenticeship. In comparison, only 6.1 % of this cohort earned a university degree.[5] However, figure 3 shows that the relative number of students has increased significantly between 1960 and 1980 in the U.S. and 1990 in Germany, respectively. Since 1990, the ratio remained relatively constant. These findings hold also, if one considers the educational attainment by various age groups. Considering the cohort of 22-25 years old, one finds that the enrollment in postsecondary education has increased slightly from 17.3 % to 18.5 % in the U.S. and from 15.9 % in 1990 to 18.7 % in 1999 in Germany.[6] Considering the enrollment in tertiary education (table 1 below), only, we obtain for main OECD countries.

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5 Own calculations based on Datenreport 2002, published by the Federal Statistical Office, Germany.

6 See OECD *Education at a Glance*, various issues, OECD, Paris.

Table 1: %-Enrollment in Tertiary Education (age: 25-34 years)

| Country | 1991 | 1996 | 2001 |
|---|---|---|---|
| France | 20 | 26 | 34 |
| Germany | 21 | 20 | 22 |
| U.K. | 19 | 24 | 29 |
| U.S | 30 | 35 | 39 |

*Source: OECD (2003a)*

As can be seen from table 1, the attainment in tertiary education has increased largely for France, U.K. and the U.S.. However, for Germany a constant educational attainment, which is (in 2001) also below the OECD mean (28 %), is reported by OECD (2003a).

In order to obtain comparable indicators of the outcomes of educational systems we focus on tertiary education, only. Referring to Kruger and Kumar (2004b) this approach seems reasonable in the way that education by apprenticeships can be conceived as the acquisition of specific skills, whereas general skills, which drive technological change, are acquired through university education. In particular, we consider the distribution of earned college or university degrees in science and engineering per total degrees. Although a wide range of fields exist (e.g. law, health, ...) , the field of science and engineering is, from our point of view, one of the most important from a growth perspective. One can imagine easily that most innovations, which drive technological progress, is related to the latter field. Table 2 below reports the distribution of earned degrees in science and engineering.[7]

Table 2: Earned Degrees in Science and Engineering, U.S.

| Year | Bachelor[a] | Master | Doctorate | Ph.D. / Master total | per Master S&E[b] |
|---|---|---|---|---|---|
| 1966 | 35.2 | 29.2 | 64.5 | 12.8 | 28.2 |
| 1980 | 32.4 | 21.4 | 57.3 | 10.4 | 27.7 |
| 1990 | 30.5 | 23.9 | 63.4 | 11.1 | 29.4 |
| 2000 | 31.8 | 21.0 | 62.8 | 9.1 | 27.2 |

*Source: National Center for Educational Statistics, U.S. 2002*

[a] Degrees in S&E per total degrees
[b] Doctorate Degrees in S&E per Master Degree in S&E

[7] The definition of science and engineering captures: Engineering, Mathematics, Natural Sciences, Computer Sciences, Social Sciences.

As shown by table 2 in the U.S. about 32 % of bachelor's and about 24 % of master's degrees are earned in the field of science and engineering. However, about two third of doctoral degrees are earned in this field. That the attainment in science and engineering turns out to be very important at the highest educational level is also indicated by the last column of table 2. Only 10 % of all master degrees earn a doctorate degree, whereas this ratio increases to 28 % for the doctoral per master's degrees in science and engineering.

For Germany, table 3 shows there is a large fraction of earned degrees in science and engineering at the `lower' level of tertiary education (comparable to a Bachelor's degree).

Table 3: Earned of Degrees in Science and Engineering, Germany

| Year | Univ.of app.Sc.[a] | University | Doctorate | Ph.D. / Master total | per Master S&E[b] |
|---|---|---|---|---|---|
| 1980 | 89.3 | 59.0 | 40.1 | 26.3 | 17.9 |
| 1990 | 91.2 | 62.8 | 45.9 | 22.7 | 16.6 |
| 2000 | 91.4 | 61.0 | 51.6 | 27.0 | 22.8 |

*Source: Ministry of Science and Education 2000*

[a] Degrees in Science and Engineering earned at Universities of applied Sciences (Fachhochschulen).
[b] Doctorate Degrees in S&E per university degrees in S&E.

As shown by 3 we have to take into account the structure of the German system of tertiary education which is characterized by three kinds of degrees: Degrees earned at Universities of Applied Sciences (comparable to B.A. studies), university degrees (comparable to M.Sc. degrees) and doctoral degrees.

According to table 3, 60 % of total university degrees (diplomas) are earned in S&E. However, the ratio of doctoral degrees in science and engineering has increased from 40.1 % to 51.6 % between 1980 and 2000 in Germany, whereas the U.S. ratio remained constant around 60 %. Furthermore, it is obvious that a higher fraction of university graduates earn a doctoral degree in Germany than in the U.S. (> 20 % to 10 %). However, in Germany only 19% of all graduates in science and engineering earn a Ph.D. in comparison to 28 % in the U.S. (average values calculated from the last columns of tables 2 and 3).

Last but not least, we consider an indicator which shows the employment of scientists and engineers in research and development per employees.[8]

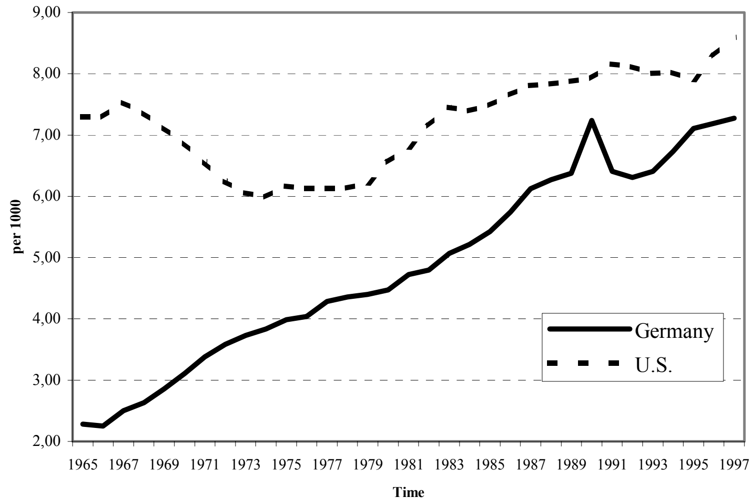


Figure 4: Scientists and Engineers per 1000 Employees, 1965-1997
*Source: OECD Main Technological Indicators (1998)*

In comparison, the U.S. employs more scientists in research and development than Germany. But, the gap between both countries is decreasing over time. This might be due to the fact which is reported in table 3 that about 60 % of German university degrees (without doctorates) are earned in the field of science and engineering.

Drawing a preliminary conclusion of the results reported in this section one has to state, that the efforts in R&D and education are lower in Germany than in the U.S.. On the other hand the educational participation in science and engineering is significantly higher (up to master's degrees) in Germany than in the U.S.. This changes if one considers post - gradual education. Also the number of scientists and engineers engaged in R&D in Germany increases over time compared to a slight increase in the U.S.. However, considering graduate education the situation is rather different.

## 3 Empirical Examination

In this section we try to obtain further insights in the relationship between education and educational efforts and research and development activities which determine technological change.

8 Because of reorganizations of the OECD Main Science and Technology Indicators Database, this index can only be calculated until 1997.

Concerning the workers which studied at college or graduate schools, one possible indicator of the value of higher degree of productivity due to higher education is the so called college or wage premium. That means the premium of the wage which a college graduate earns relative to a high school graduate. Furthermore, it is generally approved, e.g. by Ingram and Neuman (2000), that the returns to education increase with the educational level.[9] Therefore, the application of the college premium as a possible measure of the outcome of tertiary education seems reasonable. Figures 5 and 6 below show the evolution of the wage spread over time for the U.S. and Germany.

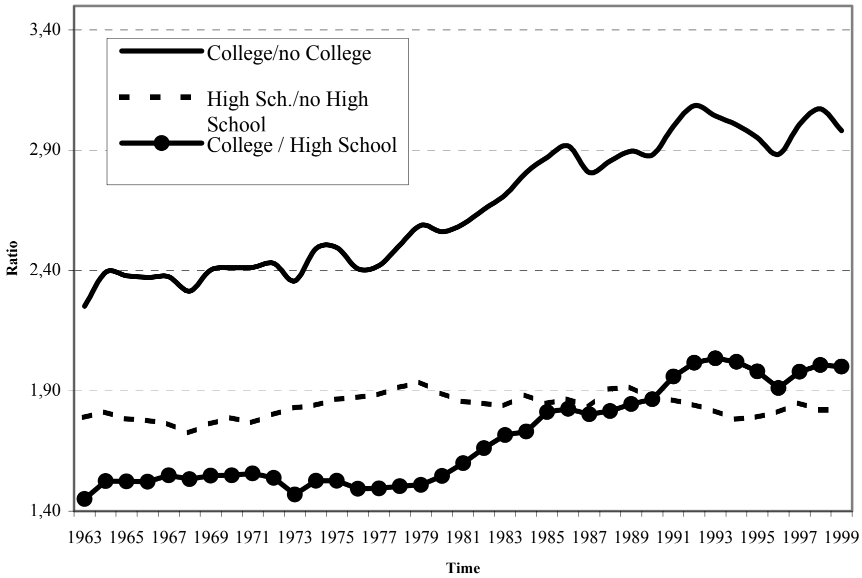


Figure 5: Wage Spread, U.S. 1963-1999
*Source: U.S. Bureau of the Census 2000, and own calculations*

Cf. Jones (1995) for a similar indicator capturing the number of scientists and engineers engaged in R&D.
[9] Ingram and Neuman (2000) show also that the returns to education vary across different types of education. For example, they show that the return of mathematical skills has doubled since the middle of the 1980's whereas the return of manual skills declined.

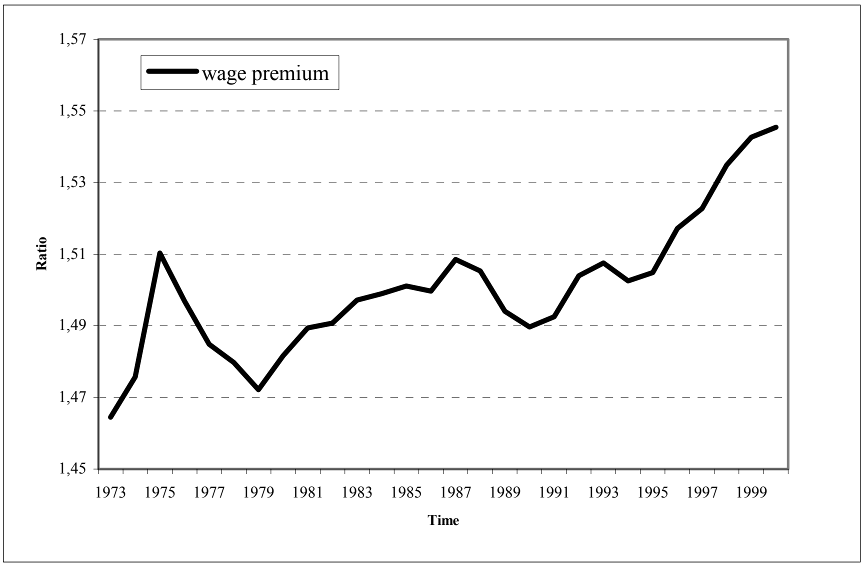


Figure 6: Wage Spread, West-Germany, 1973-2000
*Source: Federal Office of Statistics, Fachserie 16, and own calculations*

As reported by figures 5 and 6 the wage spread increases over time for both countries.[10] Why the wage premium increased over time can be explained largely by the hypothesis of so called skill biased technological change (SBTC).[11] However, concentrating on the relationship between educational efforts and the evolution of wage inequality both, negative and positive relations can be expected. The sign of this relation depends on the relative influence educational efforts have on the respective skill group. Table 4 show the relationship between educational expenditures and as an explanatory variable of the educational wage spread. Furthermore, we analyze a second relation raised by the SBTC - hypothesis that an increase in the number of skilled workers raises the wage premium.

[10] Comparing the results of figure 6 with the German wage inequality reported by the OECD (1993, 1996) one should expect a decline in German wage inequality. But, if the West German manufacturing sector is considered (done here), or, referring to Fitzenberger (1999), the establishment panel is applied one observes
an increase in educational wage inequality for Germany
[11] Recent studies on the hypothesis of skill biased technological change and the returns to education are, for example Greiner et al. (2004), Sianesi and Van Reenen (2003) or Rubart and Semmler (2004).

Table 4: Education and the Wage Spread

| | constant | Educational Exp./ GDP | high skilled/ low skilled workers |
|---|---|---|---|
| | 0.0007 | 0,2821 | |
| | (1.9342) | (2.0573***) | |
| U.S | -0.0005 | | 1.5781 |
| | (-0.3120) | | (15.0035***) |
| | -0.0058 | 0.0432 | 1.5516 |
| | (-0.3805) | (0.7770) | (13.9547***) |
| | 0.0029 | 0.0896 | |
| | (1.5390**) | (2.8878***) | |
| Germany | -0.0027 | | -0.0240 |
| | (-1.1697*) | | (-0.4174) |
| | 0.0035 | 0.0939 | -0.0466 |
| | (1.7617***) | (2.9842***) | (-0.9201) |

t-statistics in parentheses
Significance: ***=95 % ; **=90 % ; *=85 %

The result of this regression analysis is obvious, additional efforts in education lead to an increase in wage inequality in the U.S. as well as in Germany, there, however at a lower extend. Furthermore, we obtain a positive correlation between the growth rate of the wage spread and the relative number of high skilled workers in the U.S.. However, for Germany we obtained a negative relation.[12] An expansion of the regression which includes both, educational expenditures and the relative supply of skilled workers, as explanatory variables lead to similar results. Furthermore, educational wage inequality is determined by a significant trend variable,[13] and furthermore, educational efforts are positively correlated with the growth rate of the wage spread. Concerning the U.S., we observe that the growth rate of the relative supply of skilled workers is significantly related to the wage spread, only.

Besides the relation of wage inequality and educational indicators one has to consider the relation between educational efforts and participation in education. The results of the latter regression is reported in table 5 below.[14]

[12] Note that all regression results reported in table 4 are based on growth rates rather than level variables.
[13] See, for example, Rubart and Semmler (2004) for an evaluation of labor market institutions as factors explaining the trend of wage inequality. Furthermore, a recent discussion of the skill-bias can be found in Card and DiNardo (2002).
[14] Note that, we consider data of the German manufacturing sector, only!

Table 5:Educational Efforts and Supply of Skills

| | constant | Educational Exp./ GDP |
|---|---|---|
| U.S. | 0.0050 | 0.1539 |
| | (2.2623***) | (1.8836***) |
| Germany | 0.0141 | 0.0929 |
| | (1.9133***) | (0.7568) |

t-statistics in parentheses
Significance: ***=95 % ; **=90 % ; *=85 %

For both countries we observe a positive correlation between educational expenditures and the supply of skills. However, the obtained parameter value for the U.S. is twice as high than for Germany, where a non-significant parameter is obtained, too. Interpreting these results one may infer that an additional effort in education does not lead to a higher participation in education in Germany compared to the U.S..

Up to now we had looked are correlations but we did not consider the evolution of a variable over time. Assuming that the wage spread reflects the `market value' of an additional educational degree one can use an indicator of the productivity of an educational system by relating inputs in terms of relative expenditures to output in terms of relative wages or relative skilled workers.

*Indicator I = Wage Spread / (Educational Expenditures / GDP)*

*Indicator II = Relative Number of high skilled workers / (Educ. Exp / GDP)*

The hypothesis which has to be examined is, that a (highly) productive educational system should lead to an increase of this indicator over time. A stationary relation reflects a kind of `constant returns' production of the educational system and a (non-stationary) decreasing pattern of the above defined variables indicates a `low-productivity' system.

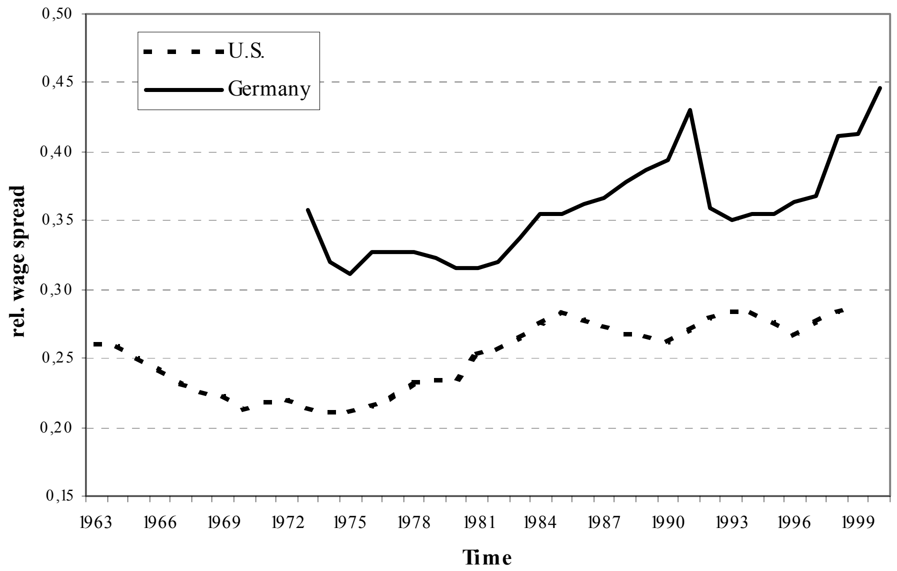


Figure 7: Comparison Wage spread / (Educational Exp./GDP) Germany, U.S.

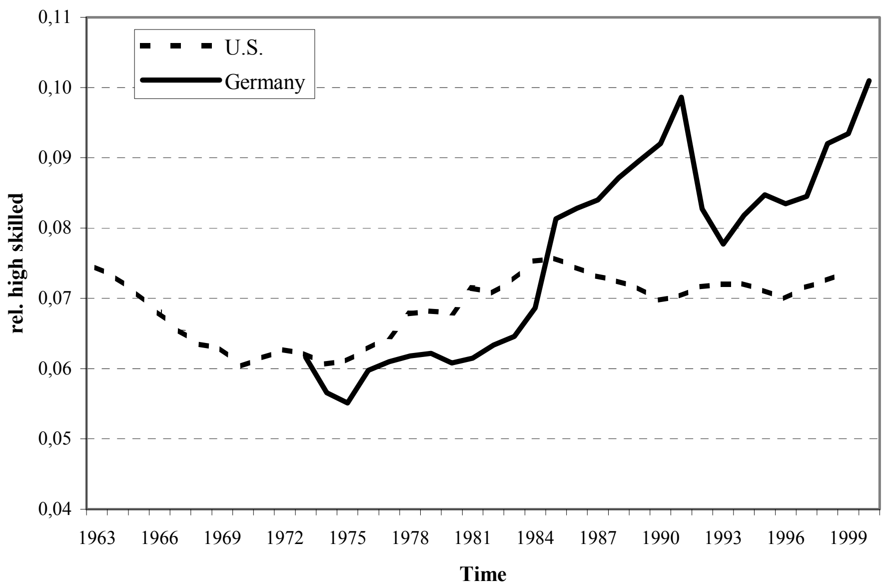


Figure 8: Comparison relative high skilled / (Educational Exp./ GDP) Germany, U.S.

As shown by figures 7 and 8 it is not clear if any series exhibit a stationary or a non-stationary pattern. In particular, one has to attend that the German time series consist of only 28 observations. In order to obtain more profound information on each series, we apply several tests for stationarity. In a first step we apply Dickey Fuller tests (first two columns of tables 6 and 7), augmented Dickey Fuller Test (ADF, columns three and four) and the Phillips-Perron Test (columns five and six).[15]

Table 6: Unit Root Tests, Indicator I

| | U.S. | | | | | Germany | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ADF Test Statistics | PP | $a_0$ | $a_2$ | Γ | ADF Test Statistics | PP | $a_0$ | $a_2$ | γ |
| White Noise | - | - | - | - | 0.0024 | - | - | - | - | 0.0049 |
| | - | - | - | - | (0.4943) | - | - | - | - | (0.4272) |
| R.W. + drift | - | - | 0.0052 | - | -0.0181 | - | - | 0.0584 | - | -0.1594 |
| | - | - | (0.4143) | - | (-0.3637) | - | - | (1.2102) | - | (-1.1693) |
| ADF[a] | 0.3430 | - | | 0.4384 | 0.0015 | 0.8707 | - | - | 0.0101 | -0.0707 |
| | - | - | - | (2.7189)** | (0.3430) | | - | - | (0.8707) | (-0.3655) |
| ADF | - 0.9160 | - | 0.0111 | 0.4674 | -0.0427 | -1.1238 | - | 0.0619 | 0.0428 | -0.1651 |
| | - | - | (0.9547) | (2.8845)*** | (-0.9160) | - | - | (1.1959) | (0.2001) | (-1.1238) |
| PP[b] | - | 0.3065 | - | - | 0.0024 | - | 0.4805 | - | - | 0.0049 |
| | - | - | - | - | (0.4943) | - | - | - | - | (0.4273) |
| PP | - | -0.8171 | 0.0052 | - | -0.01809 | - | -1.2103 | 0.0584 | - | -0.1594 |
| | - | - | (0.4143) | - | (-0.3637) | - | - | (1.2102) | - | (-1.1693) |

*Test Statistics in parenthesis*
*Significance Levels: *** = 1%, ** = 5 %, * = 10 %*
*Adf = Augmented Dickey Fuller Test; PP= Phillips-Perron - Test*

Table 7: Unit Root Tests, Indicator II

| | U.S. | | | | | Germany | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ADF Test Statistics | PP | $a_0$ | $a_2$ | Γ | ADF Test Statistics | PP | $a_0$ | $a_2$ | γ |
| White Noise | - | - | - | - | -0.0006 | - | - | - | - | 0.0191 |
| | - | - | - | - | (-0.1422) | - | - | - | - | (1.3926) |
| R.W. + drift | - | - | 0.0041 | - | -0.0654 | - | - | 0.0033 | - | -0.0267 |
| | - | - | (1.1022) | - | (-1.1101) | - | - | (0.6214) | - | (-0.3557) |
| ADF | 0.0928 | - | - | 0.44465 | 0.0004 | 1.3752 | - | - | 0.00857 | 0.0200 |
| | - | - | - | (2.8821)** | (0.0928) | - | - | - | (0.4146) | (1.3752) |
| ADF | -1.4813 | - | 0.0005 | 0.4797 | -0.0807 | -0.7528 | - | 0.0057 | 0.1249 | -0.0588 |
| | - | - | (1.4917) | (3.1202)*** | (-1.4813) | - | - | (1.0267) | (0.5952) | (-0.7528) |
| PP | - | -1.1422 | - | - | -0.0006 | - | 1.3925 | - | - | 0.01910 |
| | - | - | - | - | (-1.1422) | - | - | - | - | (1.3925) |
| PP | - | -1.1101 | 0.0042 | - | -0.0654 | - | -0.3557 | 0.0033 | - | -0.0267 |
| | - | - | (1.1027) | - | (-1.1101) | - | - | (0.6214) | - | (-0.3557) |

*Test Statistics in parenthesis*
*Significance Levels: *** = 1%, ** = 5 %, * = 10 %*
*Adf = Augmented Dickey Fuller Test; PP= Phillips-Perron – Test*

[15] All tests are computed with EViews. Detailed descriptions of the test procedures can be found in Enders (1995), ch.4 or Hamilton (1994), ch. 17.

As shown by tables 6 and 7, the hypothesis of a unit root, i.e. of non-stationarity **can not** be rejected for both indicators and for both countries, if one considers both variables in levels (as shown by figures 7 and 8. Applying the tests to first differences of each series the unit - root hypothesis is rejected.

Considering the pattern of the series shown by figures 7 and 8 one might expect a structural break in each series. The application of tests on the regression residuals points out that the series are characterized by a structural break in 1982 (U.S.) and in 1986 (Germany), respectively. Therefore, we apply an augmented Phillips - Perron test, which explicitly controls for the existence of a structural break. In particular, we assume that both series can be described by a `jump' to higher level after the break. Assuming this pattern of a break leads to the results shown in table 8.[16]

Table 8: Unit Root Tests - III

| U.S. | | | | Germany | | | |
|---|---|---|---|---|---|---|---|
| *Indicator I* | | | | | | | |
| ADF | $a_0$ | $a_2$ | $\Gamma$ | ADF | $a_0$ | $a_2$ | $\gamma$ |
| -3.2792*** | - | 0.1157 | -0.9706 | -3.1650*** | - | 0.0023 | -0.6859 |
| | | (0.5133) | (-3.2792)*** | | | (-0.0126) | (-3.1650)*** |
| *Indicator II* | | | | | | | |
| -4.2383*** | - | 0.1177 | -1.0228 | -3.6054*** | - | 0.1367 | -1.1113 |
| | | (0.6676) | (-4.2383)*** | | | (-0.0126) | (-3.6054)*** |

*Test statistics in parenthesis*
*Significance Levels: *** = 1 %, ** = 5 %, * = 10 %*

These results suggest to reject the assumption of a unit root, and we may conclude that the educational systems of the U.S. and Germany exhibits patterns of a `constant productivity'. However, considering the levels of the indicators as reported in figures 7 to 8 indicate that the German system is, *on average*, more productive than the U.S. one. In comparison to the stylized facts reported in tables 2 and 3 the results shown in this section are still in line. In particular, if we compare averages the German education system is more productive than the U.S. one. On the other hand, tables 2 and 3 also show that in the upper tail of high skilled people, e.g. Ph.D. students, the U.S. system `produces' more `high potentials' than the German one.

[16] See Enders (1995), Ch. 4, for a detailed discussion of the augmented Phillips-Perron test applied in this section. The break is captured by a dummy variable which describes the higher level of each series after the structural break. Afterwards, a Phillips - Perron - Test is applied to the regression residuals.

However, one might argue that the indicator examined above only reflects private returns to (higher) education rather than social returns. Therefore, we consider the following indicator where we relate the output of researchers to educational expenditures. I.e. we measure

*Indicator III: Patents per Scientist and Engineer / Educational Expenditures per GDP*

In order to ensure that our measure produces a comparable time series we concentrate on total public educational expenditures, only.[17]

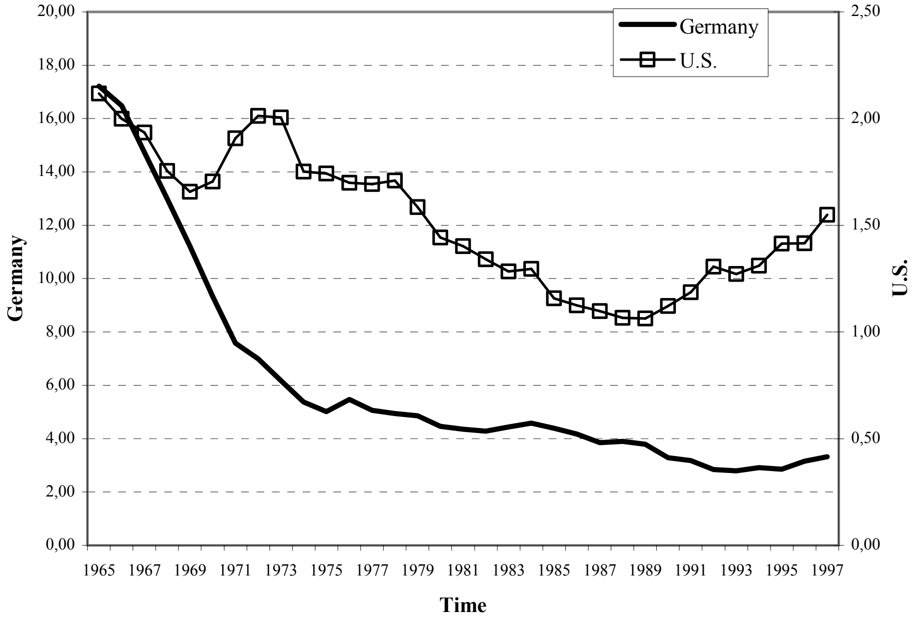


Figure 9: Patents per S&E / (Educational Exp. / GDP) , 1965-1997

Although the level of the German research output (left scale) is still above the U.S. indicator, one observes a strong decline since the middle of the 1960's.[18] In recent time, both series are at similar level. Considering the evolution over time only, both series behave quite similar since the middle of the 1980's. Since then, the U.S. series shows a significant increase whereas the German series remained constant. An explanation of the increasing pattern of the U.S. series might be that the industrial revolution, i.e. the introduction of information technologies, at the

[17] The application of both public and private educational expenditures would lead to a similar shape of the U.S. series.
[18] Applying time series tests on the indicator shown by figure 10 (not reported here), one obtains that the German series is stationary whereas for the U.S. series a Unit root is reported. Furthermore, there are no hints for structural breaks.

end of the 1970's had a higher impact on the `productivity' of researchers in the U.S. than in Germany.[19]

How the indicator above is determined by public educational efforts of each country is analyzed by a simple regression experiment.

Table 9: Educational Efforts and Output of Researchers

| | constant | Educational Exp./ GDP | constant | Educational Exp./ GDP, t-5 |
|---|---|---|---|---|
| U.S. | 0.0110 | 0.1344 | -0.0095 | 0.4884 |
| | (0.9686) | (0.6663) | (-1.1007) | (3.1654***) |
| Germany | 0.2962 | -4.8223 | 0.1339 | -1.7764 |
| | (9.1714***) | (-7.3587***) | (-4.2910***) | (3.1654***) |

*t-statistics in parentheses*
*Significance: ***=95 % ; **=90 % ; *=85 %*

Considering the above regression results we obtain also an important difference between the U.S. and Germany. In particular, we observe a significant negative relation between public educational expenditures and the output of scientists and engineers. However, we observe a positive relation for the U.S. economy. Particularly, if we consider a time lag of five years for educational expenditures the positive parameter becomes highly significant.

Besides the 'returns' of educational systems one has to take a look at the other side of the medal, i.e. the productivity of the research and development system. As known from the growth theory both, human capital and R&D efforts, determine the long run growth rate. In particular, the R&D sector employs, in general, high skilled workers like university graduates in order to develop new innovations. As already shown by figure 4 above, the number of scientists and engineers increases for both countries. The question is, whether the increasing number of scientist generates new knowledge?

Following Griliches (1990) we apply the number of national patent applications as an indicator of innovations and the production of new knowledge. Furthermore, we weight the number of patents with the respective measure of inputs in order to follow our `input - output' - approach, i.e. we assume that the productivity of a country's knowledge production is given by[20]

*Indicator IV: Patents per S&E / (R&D / GDP).*

[19] See, for example, Greenwood and Yorukoglu (1997) or Jorgenson and Stiroh (2000) for a seminal discussion of the IT-revolution as a source of economic growth.

[20] The assumption of patents as an indicator of technological change (innovations) is problematic, but as pointed out by Griliches (1990) patents exhibit all patterns needed for such a measure. Cf. Griliches (1990, p. 1671).

The evolution over time of the above mentioned indicator is presented in figure 9 below:[21]

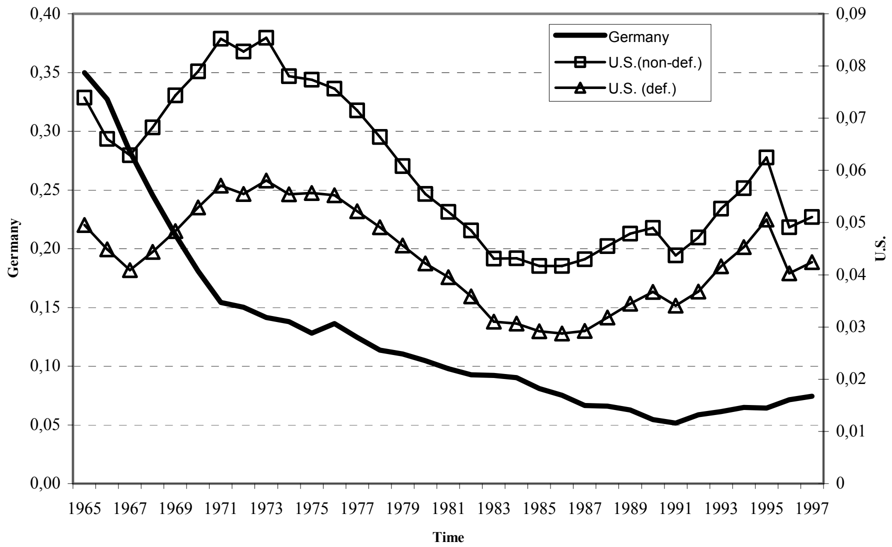


Figure 10: Patents per S&E / (R&D / GDP), 1965-1997

As shown by figure 10 using our measure Germany exhibits a large decline of research productivity compared to the U.S. during the last 40 years.[22] The result of figure 10 is supported by the following regression analysis where we relate our measure of research productivity to relative R&D expenditures.

Table 10: R&D Efforts and Knowledge Production

| | constant | R&D Exp./ GDP |
|---|---|---|
| U.S. (incl. defense) | 0.1486 | -0.0169 |
| | (3.7466***) | (-1.0697) |
| U.S. (excl. defense) | 0.1819 | -0.0419 |
| | (5.5058***) | (-2.2978***) |
| Germany | 1.0669 | -0.3355 |
| | (5.5058***) | (-2.2978***) |

*t-statistics in parentheses*
*Significance: ***=95 % ; **=90 % ; *=85 %*

On the one hand the results reported by figure 9 and table 10 is in line with the assumption of economic growth without scale effects as, for example, pointed out by Jones (1995), Segerstrom (1998), Young (1998), which states that the growth rate of an economy does not depend

[21] For the U.S. we distinguish R&D expenditures including and excluding defense related efforts.
[22] A similar decline is obtained if one considers patents per scientist and engineers.

directly on the number of scientists and engineers and, furthermore, that the research process exhibits decreasing returns to scale. On the other hand, the above results indicate large deficits of the productivity of the German research sector in comparison to the U.S.. For example, as reported by table 10 the efficiency of non-defense related R&D expenditures of the U.S. is 8 times higher than in Germany. However, for both countries the results show a highly significant intercept term which represents a strong relation of R&D efforts and patents.

## 4 Conclusion

Although our measures and indicators only highlight a few aspects of educational and research systems, we could give some evidence why the U.S. economy exhibits higher long run growth: The U.S. universities produce a higher number of doctorates in S&E who are, in addition, more productive than their German counterparts.

Our results indicate that it is not sufficient only to concentrate on general educational levels, e.g. to raise the number of students at colleges and universities. It seems obvious that the distribution of skill groups as well as their educational level, for example college vs. doctorate degrees, might be a more important determinant of technological innovations and economic growth than it is recently discussed.

A further result is, that aggregate measures of productivity and efficiency of educational and research systems are still missing.[23] It goes without saying, the ‘quality’ of research and education does not depend on expenditures only. Educational or intellectual infrastructure, the quality of teachers, class sizes, etc. are further important factors of the return of education or research and development (See, for example, Sianesi and Van Reenen, p.181).

Another point is, that, in particular for Germany, a detailed theoretical and empirical analysis of the productivity of its research and educational system is still missing. In particular, for a detailed analysis of the decline in economic growth of Germany such an analysis is absolutely necessary. Therefore, a detailed analysis of the efficiency of educational and R&D systems with aggregate macroeconomic models will be addressed in future research.

[23] A notable exception in this area is, for example, Lazear (2001).

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