ORIGINAL ARTICLE

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Government expenditures in the support of technological innovations and impact on stock market and real economy: the empirical evidence from the US and Germany

Abstract

Research background: The current changes in the global stock markets are related to the next wave of the industrial revolution "Industry 4.0". It is expected that the Industry 4.0 will lead to an acceleration of the innovation process and growth of volumes of tailor-made products. The stock markets started to react to the upcoming technological changes over the last decade, which are reflected by the changes in the composition of the major stock indices where the technological sector started to grow in importance. But innovations are not only connected with the specialized technological sector, but they are also of direct concern to the whole spectrum of economic entities. Besides the private investments that are usually allocated via the stock market, also the public sector investments play an important role.
Purpose of the article: The aim of this paper is to investigate the relationship between government expenditures on research and development (R&D) and stock markets (and GDP) in the US and in Germany.

Methods: We use the tools of descriptive analysis as well as correlation and regression methods of estimation.

Findings & Value added: Our research confirms that the collection of data on R&D on annual basis for Germany and the US is insufficient for analytical and systemic management purposes. The real effects of investments in the R&D are time lagged. The regression analysis of annual data confirms only the statistical importance of patent applications as well as interest rate and stock index as independent variables in explanation of variability of real economy growth during the 1985–2017 period. Our model did not prove the significance of government expenditures. We can explain it, among others, by the fact that governments do not pay sufficient attention to the challenges yet, which are associated with the Industry 4.0, especially in the US, where the government expenditures in R&D gradually decrease. The governments in both economies try to increase their support, but fiscal sustainability is a limiting factor.

Introduction

Fiscal policy could have a positive impact in supporting real economy as well as stock market development. The government can use direct or indirect instruments of fiscal policy for this purpose. A direct form of fiscal support can be represented by financing different projects by public sources or by public procurement of the goods and services from companies. Stock market appreciates these government purchases because of their enormous financial amount and low risk of buyer insolvency. As an example of such positive direct policy measure realized in various European countries, the scrapping subsidy can be mentioned too. It was introduced not only to support the automotive industry with effects on real economy (stock market included), but also to attain the environmental goals. Similar project has been realized in the US, known as CARS (Car Allowance Rebate System). As an indirect form of fiscal support of technological innovations, the tax allowances for private companies can be used. As a result, in a relatively short time the stock market faced an increase, followed by positive consequences on real economy with some time lags.

The current problem in the form of growing public deficit calls for limiting of government expenditures. Over the last decade private investors by their investments considerably changed the structure of the stock market. The present trends in the global economy call for restructuring of the economy in respect to the Industry 4.0, processes of digitalization and robotization and it makes the pressure to redirect the government expenditures into the R&D. From this point of view, the state can become a serious player as an important investor.

The main goal of this paper is to investigate the relationship between government expenditures in R&D and stock markets indices with impact on the real economy in the US and Germany. Both economies were chosen for the research as USA is the main economic leader in the Americas, similar

to the position of Germany in Europe, especially in the Euro Area. Their economic power, decisions and inventions are crucial not only for regional, but also for the world economic improvement.

Methodologically, we can use as the explanatory variables the indicators which serve as input factors to the support of R&D, for example gross government expenditures in R&D, or the factors which are already the final output of the usage of these sources, so they bring some added value to the economy, for example, the numbers of innovations, patents etc.

Due to the unavailability of data in the area of R&D, we are limited in our analysis. Our data range covers period from 1980 till 2018, we use available annual data from the World Bank and OECD databases. Our scope of dataset includes variables like expenditures in R&D (government and business), patents applications, intellectual property rights receipts, incomes from high technology export as well as macroeconomic indicators like GDP, interest rates (EONIA for Germany, FFR for the US), and financial market indicators like stock indices (DAX for Germany, S&P for the US). Besides the descriptive analysis, we also use approaches of linear correlation and regression analyses.

The paper is structured as follows. In the first part, we bring the brief review of empirical research in this area. The second part is dedicated to the explanation of the methodology of our research. The results of our analysis are presented in the third part. The last two chapters conclude our findings and include some recommendations for policy makers.

Literature review

There is a significant amount of empirical research on the impact of fiscal policy on real economy. A special part of this research pays attention to the relationship between fiscal expenditures and the stock markets. For example, according to Mbanga and Darrat (2016, pp. 987–1002), there are long-term and short-term effects of fiscal policy on American stock markets. However, the long-term impacts are stronger. The error correction models support the existence of robust long-term relationship between fiscal policy and stock returns (but not between the monetary policy and stock returns). They explain the relationship by the fact that the stock market is an important transmission channel for the real economy.

Greenhalgh (2016, pp. 113–138) focuses on the relationship between fiscal policy and stock markets in India, in connection with science, new technologies and innovations. According to this study, the government can

support innovations through direct or indirect stimuli. However, the stimuli affect not only the real economy, but also the fiscal position.

On the other hand, Laird (2020) discusses the long-term problems in the US connected with the government funding of R&D. The author calls for fiscally sustainable R&D system with tangible social benefits. Federal government and universities must rethink their institutional norms, rules, structures and processes that govern the funding of research. Serious reform is expected in this field.

Blanco *et al* (2020) examine the convergence of R&D expenditures in the member countries of European Union for 2004–2015. In 15 countries business expenditures prevail, on the contrary, in 13 economies the main funding instrument is the government financing. According to them, Germany belongs to the group of countries with the highest expenditures in R&D. The convergence of R&D expenditures in EU28 continues due to convergence in the business and higher education sectors and, despite government expenditure, divergence.

Chatziantoniou *et al.* (2013, pp. 754–769) use structural VAR models to measure the impact of fiscal policy shocks on stock markets of Germany, the US and UK. They come to the conclusion that the fiscal and monetary policies must act together, in order to affect the stock markets significantly.

But not only the direct impact of fiscal policy is the subject of investigation. There are very interesting findings about the indirect effects of fiscal policy, for example, through the tax allowances or adjustments to the private sector, which can stimulate investments to R&D and so to contribute to an increase in economic activity. For example, Gomes *et al.* (2013, pp. 531–566) investigate the impacts of fiscal policy on economic activity, wealth distribution and asset prices in the US. They conclude that a higher public debt leads to a higher riskless interest rate and lower equity premiums. On the other hand, an increase in capital income tax rates leads to higher equity premiums.

Xu *et al.* (2019, pp. 110–136) discover that in the case of China, the research and development investments of a company are significantly sensitive to the stock price. It means that the stock price affects the allocation of investments at the corporate level. However, this mechanism can be easily disrupted by government interventions. And Strielkowski *et al.* (2017, pp. 174–185) by comparison of Estonia, India and the United Kingdom add that expenditures on new technologies provoke higher efficiency of economic governance. The governments should be closer to their citizens and try to decrease the level of bureaucracy. This is where new information technologies should be helpful, as they can save money and time in the public administration.

Brown *et al.* (2019, pp. 45–59) provide a slightly different point of view by focusing on the role of stock and credit markets in supporting the technological development in a sample of 38 countries. They find out that the size of the high-tech sector is an important determinant of the GDP growth as well as of the total factor productivity growth. The size of the high-tech sector is highly dependent on the level of the equity market development. A well-developed equity market is positive for the growth of the high-tech sector. On the other hand, the credit market is important for the growth of industries that rely on external financing of their extensive capital needs, but it is not important for the innovation-intense industries.

An interesting study was undertaken by Kim *et al.* (2016). They investigate the consequences of various sources of research and development investments in Korea. They conclude that internal sources are important factors of product innovation for large enterprises as well as for SMEs, however, various government support programs have a significant impact only in the case of SMEs.

The practice shows that a spill-over effect of the research and development expenditures exists. This issue was investigated by Chen *et al.* (2013, pp. 1607–1634) who come to several interesting findings in the US. First of all, the companies that benefit more from the research and development expenditures of other companies tend to experience improved profitability and better long-term stock performance. On the other hand, companies that experience a higher level of outgoing spill-overs (i.e. the other companies are able to benefit from their research and development expenditures significantly), tend to display significantly negative abnormal research and development expenditures.

Findings of Chen *et al.* (2013) are later confirmed by a study of Jiang (2016, pp. 301–318). He concludes that the future operating performance of a US company is positively affected by the research and development expenditures of its peers. Moreover, companies tend to experience positive abnormal returns if their industry peers have high research and development expenditures. Jiang explains this spill-over effect by the fact that in industries with higher research and development expenditures, the sales, employment and operating performance grow faster.

Link *et al.* (2018, pp. 536–546), Canace *et al.* (2018, pp. 265–295), Azoulay *et al.* (2019, pp. 117–152), Ivanova and Cepel (2018, pp. 54–72) also belong to numerous group of authors who pay attention to various aspects of the relations between public and private investments, R&D, economic growth and stock markets They all together, however, conclude that innovations have multiplier effects and create the competitive advantage of

an economy in international comparison, so it is very important to pay special attention to them.

Moreover, some studies claim, that the effects of technological innovations are not still significantly visible on the development of the stock market. For example, Nogare *et al.* (2019, pp. 1–12) investigate the relationship between the Chinese stock market, Chinese technological development and Chinese macroeconomic fundamentals. They conclude that the performance of the Chinese stock market is not affected by the development of the real economy and technological innovations. Also, Zhao (2019, pp. 15–22) calls for higher support of R&D from government side in China. It is especially crucial to understand the benefit from the combination of government procurement and innovation promotional policy on the way to enhance the international strength of the economy.

Research methodology

Our data sample covers annual data from 1980 till 2018. The data from OECD and World Bank databases have been used. In general, statistics in the area of research and development are very poor both with regards to the variability as well as frequency of data. For example, databases of number of government researchers, number of published scientific and technical journal articles or tax allowances are incomplete. For our purposes, we use the available data on gross expenditures in R&D (business and government), patent applications, high technology export, intellectual property (receipts in Balance of Payment statistics) as well as macroeconomic indicator like GDP and stock market indices. All data are analysed in nominal terms as well as in annual % rate of growth, in some cases as % of GDP. As we mentioned in the abstract, we collect data for Germany and United States of America. As we have already stressed, the USA can be considered as the global economic leader, whereas Germany has a leading economic and technological role in Europe, which makes both countries the obvious candidates for the proposed research.

In the first step, we observe the development of macroeconomic indicators, which can be affected by government R&D investments. Our hypothesis is based on the assumption that the stock index serves as an indicator of the future development of GDP.

The second phase of our research is devoted to the assessment of previously mentioned R&D indicators, which are available in databases. Other indicators are available only over the last 10 years with some gaps in the dataset for our selected countries, so our research is rather limited. We con-

duct a deeper analysis of the indicators, which describe the government role in supporting the R&D. So, the second hypothesis is that government can play a very important role in influencing the stock market as well as real economic growth.

The third and the last step of the analysis is our focus of finding and measuring the possible relationships among the variables.

For these purposes, we use a method of descriptive analysis, as well as correlation and regression approaches.

Results

In our expectations, the increase in GDP is connected with the growth of stock indices and in turn, during the period of weaker GDP, the stock indices record some declines. Moreover, the movement in stock indices is ahead of the change in the trajectory of GDP.

Through our analysed period Germany faces four cases of negative annual % rate of GDP growth — in 1982, 1993, 2003 and 2009. The US demonstrates the fall of GDP below 0 % rate of growth in 1980, 1982, 1991, 2008 and 2009. In general, during the whole period Germany shows weaker economic performance of GDP growth in comparison with the US, and the German stock index records a higher volatility as well as deeper declines. However, in both economies on an annual basis, the stock indices in the period of negative economic growth record an improvement in their development. For both economies, the worst period started in 2008, when the latest financial crisis has erupted (Figure 1).

As Figure 2 illustrates, gross expenditures on R&D (GERD) as % of GDP have been gradually increasing from 1996 and their value in Germany is higher in comparison with the US from 2010. In Germany this positive development is connected mainly with the increase of business expenditures on R&D (while the government expenditures stagnate). In the US the business sector has also the better position in financing of R&D, while the government sector financing decreases.

Available data of high technology export (HTE), intellectual property receipts (IPR) and patent applications (P) show us, that the major benefit on an annual basis for both economies comes from high technology export and the lowest from patent applications (in nominal terms by share on GDP in national currency). In the case of high technology export its share in Germany is higher (more than 4-times) despite the fact that its value from 2013 decreases. The share of patent applications on GDP in Germany gradually declines. In 2010 the US became the leader in this indicator with the value

remaining stable during the last 35 years. During our analysed period the share of receipts from intellectual property on GDP is still higher in the US, but from 2012 its value decreases. In Germany, this indicator continuously increases from 2000 (Figure 3).

We investigate also the dynamics of these R&D indicators (Figure 4). In case of high technology export and intellectual property receipts, the dynamic of their growth is stronger in Germany. In the case of patent applications, the annual % rate of growth in whole period is higher in the US, however in 2018 the dynamics is the same in both economies. In both countries the number of researchers increases during the whole analysed period.

After the descriptive analysis, we focus our attention on statistical demonstration of the relationships among the main macroeconomic variables and R&D indicators by correlation and regression analyses. We assume a positive linear relationship among the majority of variables (except relationship with interest rates).

We provide the summary statistics in Table 1. Our data sample for correlation and regression analyses consists of 33 observations for each indicator (yearly data from 1985 till 2017). The majority of variables exhibits the relatively similar value of mean and median, so the data are almost symmetric. The median for the 9 variables (from the set of 14 indicators) is higher than the mean, but to a small extent, so data appear to be a little skewed to the left. Higher standard deviation values against the mean indicate greater spread of the data. Minima and maxima differ widely. But the skewness is, in general, close to zero, as well as kurtosis.

Raw data expressed in domestic currency were not stationary. We use the first difference for interest rates and annual rate of growth for business and government expenditures on R&D and annual % rate of growth of other variables. The results of correlation analysis are shown in Table 2.

As Table 2. illustrates, the correlation analysis documents only weak linear relationships. In comparison, a little bit stronger linear relationship is recorded in the US. The strongest linear correlation is identified between interest rates and GDP, but in the direction opposite to our expectations in both economies. We can explain it by the fact that in the times of higher economic growth there is also possibility to increase the interest rates. Our correlation analysis did not prove our expectations about the same direction in movement of R&D indicators and stock indices (or GDP). Only in the case of the US is there a weak correlation between patent applications as well as intellectual property receipts and GDP.

The last step of our research is to explain the movement of GDP by our indicators of R&D, so we build a regression model. We would like to con-

firm the supporting role of technological innovations on the development of stock indices, as well as economic growth, especially if they are supported by government activities. The stationarity of data is checked by the ADF test.

Simple regression models constructed with stock indices (or GDP) as dependent variables and R&D indicators as explanatory variables did not show significant results, neither economically, nor statistically. We continued by the methodology of backward elimination to find the best fitting model. We started with the usage of all R&D indicators as explanatory variables and step-by-step we eliminated those ones, which were not statistically significant in explanation of variability of dependent variable.

The following multiple regression model brings the best results for both countries (Table 3).

$$
\begin{aligned}
GDP = \ &\beta_0 + \beta_1 \ intellectual \ property \ + \beta_2 stock \ index \\
&+ \ \beta_3 interest \ rate \\
&+ \beta_4 business \ expenditures \ on \ R\&D \\
&+ \beta_5 \ government \ expenditures \ on \ R\&D \\
&+ \beta_6 6 \ patents \ + \ u
\end{aligned} \tag{1}
$$

However, it only confirms the positive impact of patent applications on GDP. Among other indicators, economically and statistically significant were interest rates and in case of the US also S&P index. Our modelling did not prove the significance of the impact of government expenditures on the stock markets or real economy.

Discussion

The US and Germany belong to the main economic and political leaders in the world. They are also very important players on the market with innovations.

Our research confirms the previously mentioned findings of economists. The first of all, the main driver in the support of R&D is a private sector as in the US as in Germany. We can find the same findings in papers of Azoulay *et al.* (2019), Brown *et al.* (2017), Chen *et al.* (2013), Jiang (2016) Ivanova and Cepel (2018) and Blanco *et al.* (2020). The novelty or added value of our approach is in searching relationshi among the stock market

development and GDP growth, while controlling for the effects of techno-logical innovations.

Among the analysed R&D indicators, a high technology export in both economies brings the biggest added value for the growth of GDP. The dom-inant role of this activity confirms also the study of Brown *et al.* (2017), Greenhalgh (2016).

We agree with Brown *et al.* (2017) that the stock market plays an im-portant role in supporting economic growth if there is a more developed market of high-tech sector.

We take into the consideration the findings of Chatziantoniou *et al.* (2013) that the interactions between monetary and fiscal policy are im-portant in explaining stock market developments. Despite the fact, that neither correlation nor regression analysis show strong relationship among interest rates, government expenditures on R&D and stock market indices. Both interest rates — EONIA as well as FFR (and in case of the US index S&P) show significant impact on the economic growth of Germany and the US, respectively.

Our regression analysis confirmed also the findings of Link (2018) about the importance of patents in supporting the economic growth of both economies. On the other hand, in contrary to Mbanga and Darrat (2016), we did not confirm the impact of government expenditures on R&D on the economic growth neither in the US, nor in Germany.

Up to now, the better position in supporting of R&D from government side, in line with our previous results, has been held by Germany. Weaker economic performance in Germany in comparison with the US, however in combination with higher acceleration of government participation in the supporting of technological innovations could bring real benefits to this economy in the long-term. As our analyses confirm, both economies still have the space to improve the role of their governments in promotion and in real support of R&D. More systemic, as well as addressed, approach in the financing of innovations is required. We agree with the previous au-thors, for example Mbanga and Darrat (2016, pp. 987–1002) and Laird (2020) that it is a long-term process. Research and development bear high risk of failure and high costs, so the participation of government support is essential.

Due to unprecedented slump of the global economy in 2020, govern-ments in our analysed economies should be very careful in taking decisions about the adequacy of their exposures in regard to their increasing fiscal indebtedness.

Conclusions

In this article, we have investigated the relationship between the government support of R&D and the development of stock market (GDP as well). We are aware of the limitations of our research.

First of all, it is the weak structure of disposable indicators of R&D as well as the low frequency of statistical data collection (only on annual basis). Data concerning the area of research and development are very often only partial, ungrouped and incomparable. Because of annual character of dataset, we cannot detect possible shocks during the analysed period. Furthermore, we are not able to conduct the analysis of, for example, pre-crisis and post-crisis period, as the number of observations is too small. Our choice to investigate only two economies — Germany and the US was led by the fact that these economies have outsize influence in the world economy (Germany as an economic vehicle in Euro Area) and are the major players in the field of innovations. An analogy can be seen in papers cited in our review of literature, where the economists analysed only a few countries or a very short period.

Our correlation analysis did not confirm our assumptions about the strong positive linear relationships among R&D indicators and economic growth (or stock market indices) in both economies. On the other hand, in the case of the US, there is a small evidence of weak correlation among patent applications and intellectual property receipts and GDP growth. The importance of government expenditures on R&D on the economic growth was not determined in both economies.

Our regression analysis, only on adjusted sample range (from 1985-2017), showed patent applications having economic and statistically significant effect in Germany as well as in the US. Our model has not proven the significance of government expenditures as independent variable in explanation of variability in GDP growth in both economies. On the other hand, monetary policy through the interest rates has economic and statistically important impact on GDP in both economies.

Our actual findings indicate that the extent of government support in the area of R&D could be insufficient. This could also be the possible reason why we failed to confirm our expected hypotheses in our modelling. Namely, there could be a non-linear relationship between government expenditures on R&D and GDP (i.e. the government spending on R&D could start to affect GDP only after passing a certain threshold).

We are convinced that the governments should be more active in searching for new forms, instruments, as well as sources, of reaction to the challenges which occur in globalized world. The necessity of revising R&D

strategies in the US and in Germany is crucial. It can be helpful not only for the future growth of stock indices but also for the real economy. An improvement in data collection is needed too.

In our modelling we have employed R&D indicators, which act as inputs (expenditures) of innovation process as well as outputs (patents applications, intellectual property receipts, high technology export). The next step of our research in regard to the estimated facts will be to build input-output model, to determine intra-sectoral flows and to measure the added value of investments to the R&D on the economy.

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Annex

Table 1. Summary statistics for period 1985–2017

Variable	Mean	Median	St. dev.	Min	Max	Skewness	Ex. kurtosis
IPR_US	9.9861	8.5395	9.1046	-4.474	33.978	0.51930	-0.1261
S&P	9.5536	11.391	16.305	-38.48	34.111	-0.82084	0.7596
FFR	-0.2145	-0.040	1.4919	-4.580	2.4900	-1.0963	1.9117
B_GERD_GDP_US	0.0151	0.0306	0.0618	-0.129	0.1048	-0.71052	-0.2413
G_GERD_GDP_US	-0.0157	-0.026	0.0396	-0.076	0.0775	0.86154	0.0179
P_US	5.0066	6.6951	5.9496	-13.770	15.601	-0.90431	1.2514
GDP_US	2.6541	2.8550	1.5489	-2.5368	4.7532	-1.2978	2.1700
IPR_GE	12.450	10.279	15.366	-13.059	48.893	0.51893	-0.0599
DAX	11.866	12.859	25.438	-43.942	66.427	-0.33837	-0.1644
EONIA	-0.1790	-0.1400	1.0810	-3.1400	2.5800	-0.2310	1.1971
B_GERD_GDP_GE	0.0136	0.0167	0.0669	-0.1779	0.1634	-0.1901	1.0867
G_GERD_GDP_GE	-0.0026	-0.0068	0.0254	-0.0501	0.0723	1.0411	1.7876
P_GE	1.2788	0.6815	3.4086	-4.7831	11.073	0.7318	0.4787
GDP_GE	1.8505	1.9796	1.9917	-5.6189	5.2550	-1.4196	4.3098

Note: IPR denote intellectual property receipts (US – the US, GE - Germany), S&P – stock market index in the US, FFR – federal funds rate (the US), B_GERD_GDP – business gross expenditures on R&D as percentage of GDP (US – the US, GE – Germany), G_GERD_GDP – government gross expenditures on R&D as percentage of GDP (US – the US, GE – Germany), P - patent applications (US – the US, GE – Germany), GDP – gross domestic products (US – the US, GE – Germany), DAX – stock market index in Germany, EONIA – euro overnight index average for Euro Area. All variables are in the form as were used in regression model.

Table 2. Results of correlation for the period 1985–2017

Germany						
	P	IPR	BERD	GERD	EONIA	DAX	GDP
P	1	-0.28	-0.25	-0.35	-0.11	0.25	0.09
IPR		1	0.08	0.01	0.09	-0.44	0.15
BERD			1	0.23	-0.01	0.07	-0.07
GERD				1	-0.34	0.07	-0.36
EONIA					1	-0.08	0.76
DAX						1	-0.12
GDP							1

The USA						
	P	IPR	BERD	GERD	FFR	S&P	GDP
P	1	0.29	-0.21	-0.30	0.25	0.12	0.40
IPR		1	-0.22	-0.003	0.28	-0.02	0.49
BERD			1	-0.29	-0.46	-0.06	-0.10
GERD				1	0.02	-0.06	-0.20
FFR					1	0.31	0.50
S&P						1	0.23
GDP							1

Notes: P denote patent applications, IPR intellectual property receipts, BERD business gross expenditures on R&D, GERD government gross expenditure on R&D, FFR federal funds rate, S&P stock market index in the US, GDP gross domestic products, DAX – stock market index in Germany, EONIA – euro overnight index average for Euro Area. All variables are measured in the same form as in a regression model.

Table 3. Results of regression for period 1985–2017

The US			Germany		
Dependent variable: GDP_US	Regr. coef.	ADF test p-value	Dependent variable: GDP_GE	Regr. coef.	ADF test p-value
const	1.759***		const	1.820***	
IPR_US_p	0.018	0.002	IPR_GE_p	0.015	3.8e-06
S&P_p_1	0.048***	6.6e-05	DAX_p	-0.005	6.1e-06
d_FFR	0.383***	1.3e-05	d_EONIA	1.403***	0.002
d_B_GERD_GDP_US_p_1	1.409	0.0002	d_B_GERD_GDP_GE_p_1	-0.351	0.012
d_G_GERD_GDP_US_p_1	1.558	0.0295	d_G_GERD_GDP_GE_p_1	-1.027	0.0001
P_US_p	0.067***	1.9e-05	P_GE_p	0.127**	0.0308
R^2	0.644		R^2	0.629	
Adj R^2	0.563		Adj R^2	0.544	
F (6,26)	13.361		F (6,26)	8.298	
P-value (F)	7.14e-07		P-value (F)	4.5e-05	
Test statistics	**H0**	**p-value**	**Test statistics**	**H0**	**p-value**
Ramsey's RESET test	specif. is adequate	0.069	Ramsey's RESET test	specif. is adequate	0.065
White's test for heteroskedasticity	heterosc. not present	0.318	White's test for heteroskedasticity	heterosc. not present	0.253
Normality of residual	error distr. normally	0.115	Normality of residual	error distr. normally	0.597
LM test for autocorrelation up to order 1	no autocorr.	0.075	LM test for autocorrelation up to order 1	no autocorr.	0.807

Note: IPR denote intellectual property receipts (US – the US, GE - Germany), S&P – stock market index in the US, FFR – federal funds rate (the US), B_GERD_GDP – business gross expenditures on R&D as percentage of GDP (US – the US, GE – Germany), G_GERD_GDP – government gross expenditures on R&D as percentage of GDP (US – the US, GE – Germany), P - patent applications (US – the US, GE – Germany), GDP – gross domestic products (US – the US, GE – Germany), DAX – stock market index in Germany, EONIA – euro overnight index average for Euro Area. All variables are measured in % as annual rate of growth.
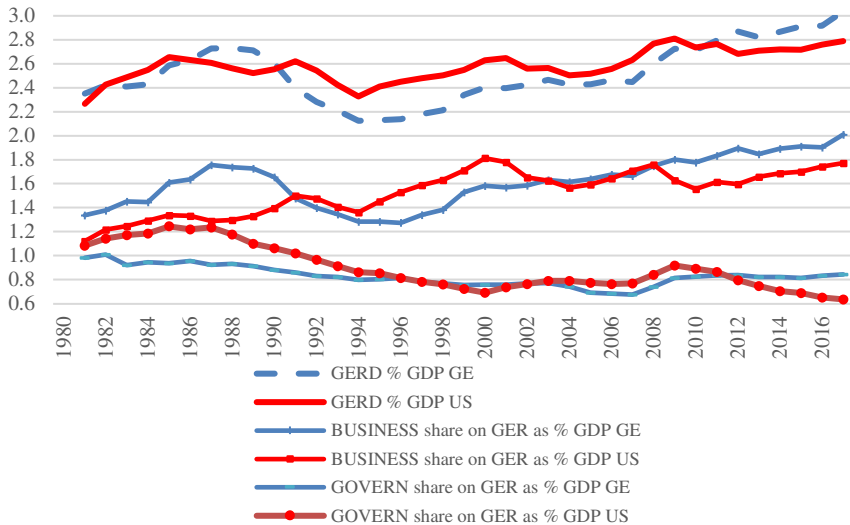* Significance at 10% level. ** Significance at 5% level. *** Significance at 1% level. ADF test: p-value at unit-root null hypothesis: a=1

Figure 1. GDP and stock market indices in Germany and in the US (annual % rate of growth)
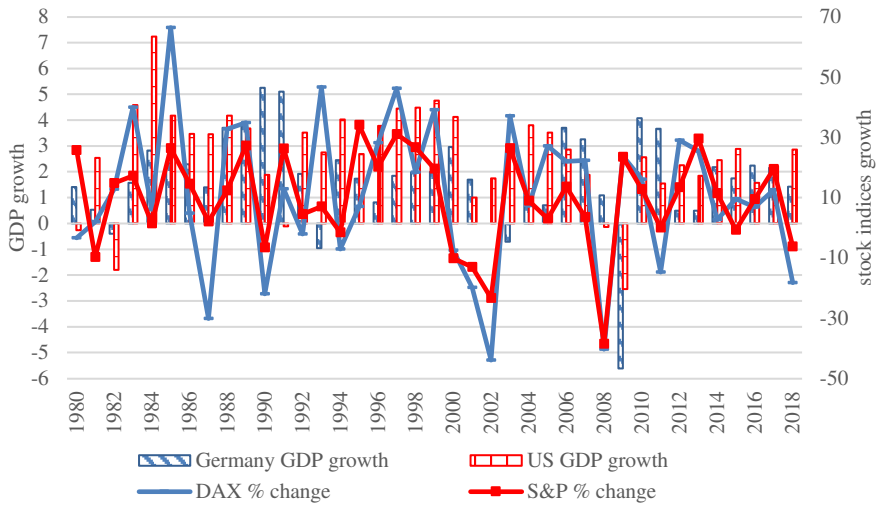
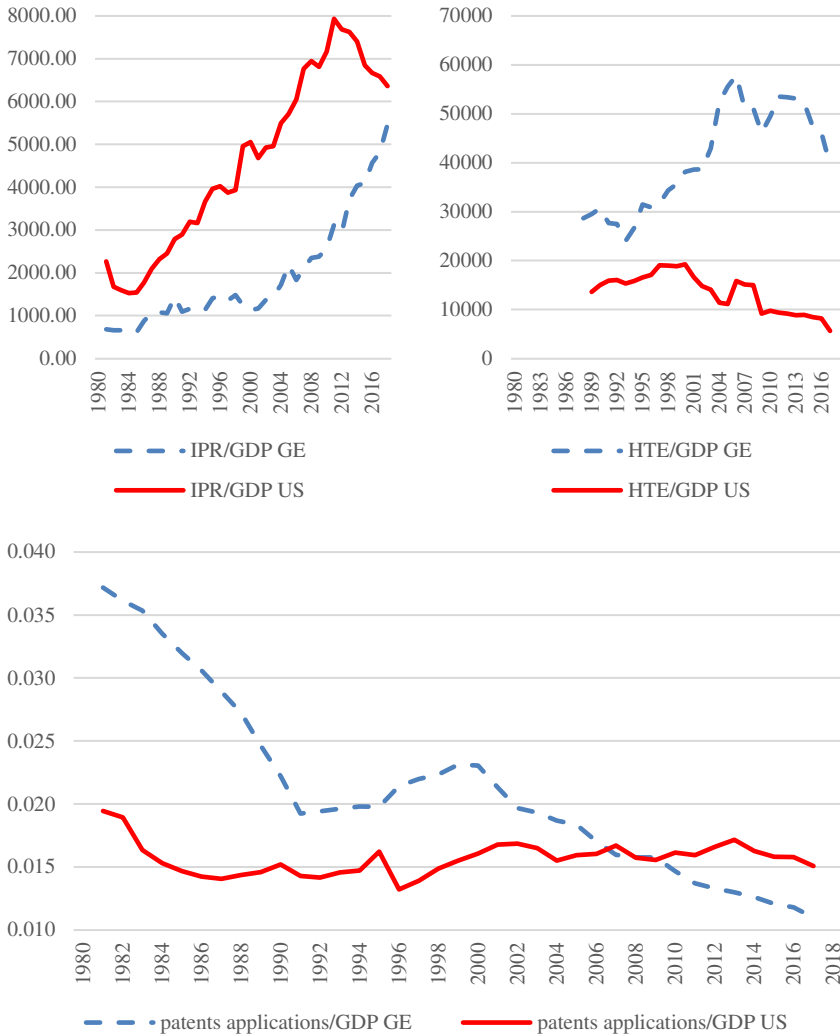Source: own processing based on The World Bank (2019) and OECD (2019) data.

Figure 2. Expenditures on R&D in Germany and in the US (% of GDP)

Note: GERD – gross expenditure on R&D

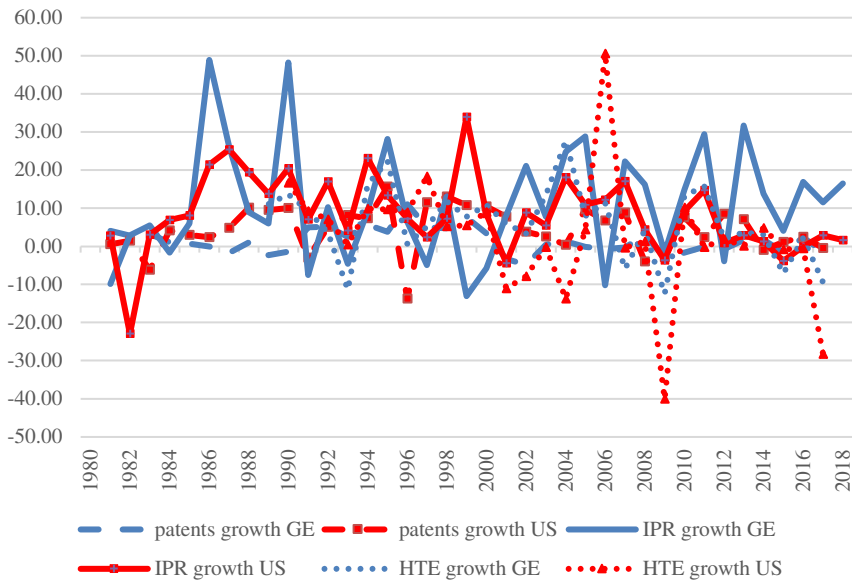Source: own processing based on The World Bank (2019) and OECD (2019) data.

Figure 3. Indicators of R&D in Germany and in the US (% share on GDP)

Note: IPR – intellectual property receipts, HTE – high technology export

Source: own processing based on The World Bank (2019) and OECD (2019) data.

Figure 4. The dynamics of annual growth of R&D indicators in the US and in Germany (in %)

Note: IPR – intellectual property receipts, HTE – high technology export

Source: own processing based on The World Bank (2019) and OECD (2019) data.