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The Role of Research and Development (R&D) on Gross Domestic Products (GDP) (Case Study USA, China, Japan, Germany and the UK)

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ABSTRACT

Research and Development (R&D) is an activity that is considered to be able to increase the country's productivity. R&D activities can produce the latest technological findings supporting the output production process. This research uses the USA, China, Japan, Germany, and the UK as research objects or case studies with 1996-2018 observation years. These five countries are developed countries and are the top five countries with the highest nominal GDP in the world. The main objective of this study is to examine the role of R&D in economic growth as measured by GDP. The dependent variable in this study is economic growth (GDP). In contrast, the independent variables include the ratio of R&D spending to GDP, the number of patents, the number of workers, the ratio of foreign direct investment to GDP, and total factor productivity. By using the standard effect model, this study confirms that all independent variables simultaneously have a positive and significant effect on economic growth in the five countries that are the research object. As for partially, the ratio of R&D expenditure to GDP and the number of patents does not have a positive and significant effect on economic growth.

Keywords: Economic Growth, FDI, GDP, Patents, R&D

INTRODUCTION

Growth Domestic Product (GDP) is considered the most appropriate instrument to measure the progress of a country. Kumajas, Rarung, and Malau (2022) state that GDP is the reference for a country's development. This GDP calculation is based on the added value added from all businesses owned by the state within a certain period. The measurement of GDP is obtained by adding up all units of goods and services produced by a country. In general, GDP also represents national income and becomes a measuring tool in describing a country's economic growth and welfare. The higher the GDP, the higher the production level, which means that the level of consumption is also increasing. Therefore, a high level of consumption can be assumed that a more prosperous society.

Data released by the World Bank in 2020 shows that the five countries with the largest nominal GDP are the United States, China, Japan, Germany, and the United Kingdom. In 2017 and 2018, the fifth position was occupied by India, but in 2020, the position was replaced by the United Kingdom. This research is limited to ranking the top five GDP and developed countries. India is not included in this research case study.

An important instrument in driving GDP growth is innovation. Innovation is essential in increasing productivity, economic growth, and community welfare (Huda, Adha, & Ashfina, 2020). Technological innovations or updates are obtained through research or development, referred to as Research and Development (R&D) in the future. The authors' findings show that the five countries that are the object of this research have a ratio of R&D spending to GDP that tends to increase from 1996-2018. However, an interesting finding shows that GDP growth in these five countries did not show a consistent upward trend during 1996-2018. This is disproportionate to the consistent increase in R&D sector spending during the year observed.

Economic growth, which GDP generally represents, is one of the issues that economists never stop discussing. Economic growth is an important issue because of its relevance to the country's progress and its people's welfare. According to Solow (1957), technology is the primary driver of economic growth. Solow's theory suggests that capital, labor, and total factor productivity (TFP) are the three factors driving economic growth. Where technological advances strongly influence TFP.

Technological innovation, science, and product innovation are the result of R&D. Technological innovation can increase effectiveness and efficiency in output production by reducing diminishing capital returns (Guloglu & Tekin, 2012). An update or innovation aims to improve something, such as increasing productivity. Increased productivity is a fundamental source of increasing a country's economic capacity. Therefore, R&D is assumed to be something very crucial in order to encourage GDP or GDP growth.

There have been many previous studies exploring the role of R&D on GDP. However, no research was found with a sample of five countries with the largest nominal GDP in the world. So that this research, at the same time, fills the gap in the literature, as the country with the highest GDP ranking, the US, China, Japan, Germany, and the UK, must have a unique formula to maintain that position. R&D activity is considered a key determinant of economic growth in several theories and previous studies. Thus, this statement becomes the basis for the author's motivation to research this topic with case studies of five developed countries and the largest nominal GDP earners in the world.

A study by (Szarowská, 2017) in EU countries shows that government spending on R&D has a positive and significant impact. This indicates that R&D spending is the main driver for economic growth in the sample European countries. In a study conducted by (Gumus & Celikay, 2015) with a sample of 52 countries, it was found that R&D spending has a positive and significant effect in both developing and developed countries in the short and long term. When spending on R&D increases, it will also increase production capacity, technology development, economic growth, labor capacity, and export and import activities.

Furthermore, (Huda et al., 2020) conducted research with case studies of ASEAN countries (Indonesia, Malaysia, Thailand, Singapore & Vietnam) and 4 central Asian countries (China, Japan, South Korea, and India). In addition to producing findings that R&D contributes positively and significantly to GDP growth in these 9 countries, another fact is that investment, FDI, number of patents, total factor productivity, and labor also have a significant effect on GDP growth. These findings are in line with the Solow theory that will be adopted in this study.

Based on this empirical review, this study aims to empirically explore the role of innovation on GDP growth in five developed countries and, simultaneously, become the largest nominal GDP earner in the world with the 1996-2018 observation year. Solow (1957) developed the theory that economic growth is driven by capital, labor, and total factor productivity. The capital (K) can be represented through domestic and foreign direct investments. Meanwhile, the total productivity factor is directly influenced by technological progress, where indicators of technological progress can be represented through the proportion of R&D expenditures and the number of registered patents.

LITERATURE REVIEW

There have been many previous studies on the role of R&D on GDP. However, very few studies have been found with case studies of five developed countries with the largest GDP in the world. Thus, this study is expected to fill the literature gap. Past empirical studies before 2000, conducted by Lichtenberg (1992 in Turedi, 2014), confirmed that R&D positively correlated with productivity growth (GDP). Furthermore, Coe and Helpman (1995) found that R&D expenditure positively affected total factor productivity in the long run. The total factor productivity represents a country's ability to produce output so that it is directly related to GDP.

Studies conducted after 2000, among others, were carried out by (Guloglu & Tekin, 2012), which examined the relationship between R&D, innovation, and economic growth in high-income OECD countries. Using panel data and analysis tools in the form of VAR show a relationship between economic growth and the level of innovation in OECD countries. Where changes in technological progress can accelerate output growth. The findings suggest that accelerating technological change (innovation) is essential.

Using panel data and the observation year 1999-2011, (Huňady & Orviská, 2014) examined European countries (except Estonia) on the impact of R&D spending on innovation performance and economic growth. The fixed effect method (panel data regression) shows that R&D spending positively affects economic growth in 26 European members. In addition, other results show that the flow of foreign funds (FDI) is confirmed to influence economic growth positively. FDI or foreign direct investment represents the technology diffusion or transfer process between countries.

Furthermore, the empirical analysis conducted by (Gumus & Celikay, 2015) in 52 countries (developed and developing countries) with the observation year 1996-2010 shows that R&D spending has a positive and significant relationship to economic growth in all the countries that are the case studies. Using a dynamic panel data model shows that in developing countries, the influence of R&D on economic growth is weak in the short run but firm in the long run. The same result was also confirmed by (Akcali & Sismanoglu, 2015). They studied the impact of R&D in developing and developed countries. The results showed that R&D had a positive and significant effect on economic growth in all the case studies countries. R&D is considered to be an innovation activity that has an essential role in ensuring job growth, sustainable growth, community welfare, and quality of life.

Using 20 European countries as case studies, (Szarowská, 2017) confirms that R&D spending positively and significantly affects economic growth. R&D spending is considered the main driver of economic growth in the case study country over the year analyzed (1995-2015). However, in his research, R&D spending in the private sector has a negative and insignificant effect on several European countries that are case studies. This is because there was a financial crisis in 2008. This means that it is not absolute that significant R&D spending can increase economic growth. This is because there are always extraordinary events beyond predictions that can affect the running of a country's economy.

Through GMM/Generalized Method of Moments, Turedi (2014) examines the causal relationship between R&D spending and the number of patents in 23 OEC countries and confirms that R&D spending and the number of patents have a positive relationship to economic growth. Through the results of this research, a question can be drawn to increase sustainable growth, and it can be done by increasing the allocation of funds for the R&D sector. In addition, to increase the number of patents, it is necessary to increase R&D activities.

The most recent research on the role of R&D on economic growth was conducted by Huda et al. (2020) in 5 ASEAN countries (Singapore, Vietnam, Malaysia, Thailand, and Indonesia) and several Asian countries (China, Japan, South Korea, and India). Several regression models, namely First Difference GMM, GMM System, PLS, FE & RE, confirm that R&D spending positively and significantly affects economic growth in the 9 case study countries. According to this study, an increase in R&D spending by 1% will increase economic growth by 16% in the case study country. This study also confirms that investment, FDI, number of patents, total factor productivity, and number of workers also have a significant influence on economic growth.

RESEARCH METHOD

This study used panel data regression analysis to determine the causal relationship between the dependent and independent variables. The following are some of the estimation models found in panel data regression:
Common Effect Model (CEM) is the simplest method than other methods. One of the unique characteristics of this method or approach is that individual characteristics in this study are ignored, so it is recommended not to adopt this model in panel data research. The estimation of PLS is as follows:

$$Y_{it} = \beta_o + \beta_1 X_{1it} + \beta_2 X_{2it} \quad (1)$$

Fixed Effect Model (FEM), The unique feature of this method is that the differences in intercepts between individuals can be known because each individual tested has its unification characteristics. The FEM method is another term for least squares dummy variables or LSDB. The equation of this model is as follows:

$$Y_{it} = \beta_{oi} + \beta_1 X_{1it} + \beta_2 X_{2it} \quad (2)$$

Random Effect Model (REM), The particular difference between FE and RE methods lies in β_{oi} , where in this case β_{oi} is no longer considered constant as in FE but is considered a random variable with t an average value of β_1. Widarjono (203) defines the REM model as a model used to estimate panel data where disturbance variables may be interrelated over time and between individuals. This model has the form of the equation:

$$Y_{it} = \beta_{oi} + \beta_1 X_{1it} + \beta_2 X_{2it} \quad (3)$$

RESULTS

This section will describe in detail the research variables that were processed using machine learning or STATA software version 17. The purpose of descriptive data analysis is to provide quantitative characteristics of the tested variables. The description in this study includes economic growth (PE) as the dependent variable. The independent variables include the ratio of R&D spending to GDP (GERD), number of patents (PATENT), foreign direct investment (FDI), labor (LABOR), and total factor productivity (TFP).

Table 1 summarizes the output of data processing by STATA. It should be reiterated that the data in this study are panel data with a cross-section of five countries with the highest GDP and are developed countries and time-series 1996-2018. The table above shows that the observations from the entire panel data are 115 observations. Therefore, the output above is the overall output of the panel data or not the individual output of each variable.

Table 1. Data Descriptive Statistical

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
PE (%)	115	3.21	3.50	-5.69	14.23
GERD (%)	115	2.29	0.70	0.56	3.40
PATENT (unit)	115	195,902.9	246,915.4	11,628	1,393,815
FDI (%)	115	2.52	2.42	-0.72	12.76
LABOR	115	2.11	2.80	2.85	7.87
TFP (%)	115	0.92	1.91	-6.24	8.17

Source: Processed Data, 2023

Economic growth, which in this case is represented through GDP, has an average of 3.21% during 1996-2018 in the five case study countries. With a standard deviation of 3.5%, all observations show that the worst economic growth is -5.69%. This happened in Germany in 2009. The negative growth was a response to the 2008 crisis, known as the subprime mortgage crisis. The highest economic growth was 14.23% which occurred in China in 2007.

The ratio of R&D spending to GDP in the case study countries has an average of 2.92% of total nominal GDP and has a standard deviation of 0.70%. The smallest ratio issued to fund R&D occurred in China in 1996, 0.56%. Compared to other case study countries in the same year, Germany has a ratio of 2.1%, the UK 1.5%, Japan 2.69%, and the USA 2.45%. Although many emerging technologies are made in China, China spends relatively tiny research and development funds compared to other countries that are the object of this research. The ratio of R&D spending to GDP, with the highest value, was 3.4% in 2014 in Japan.

This study uses panel data regression which consists of several analytical tools for making hypothetical decisions. The analytical tools include CEM, FEM, and REM, regression models. The method used in determining the best model is the Chow Test, Hausman Test, and LM Test (Lagrange Multiplier). The best model adopted in this study is the regression common effect model.

To find out whether the data being tested is normally distributed or not, it is necessary to do a normality test. The normality test in this study used the Skewness/Kurtosis approach. The criteria for this test are if the probability value is less than 0.05, then the data is not normally distributed. The following is a table of normality test results:

Table 2. Normality Test

Variable	Obs.	Pr (Skewness)	Pr (Kurtosis)	Adj chi2 (2)	Prob > chi2
Shapiro-wilk	115	0.0077	0.0001	17.47	0.0002

Source: Processed Data, 2023

The output table above shows that the data is not normally distributed because the probability value is less than the specified significance level, which is 5% or 0.05. The author suspects that the data are not generally distributed because each country that is the research object has significant data differences. For example, data on the number of workers in China reaches 787 million people, but only about 28-50 million in Germany. This means that the data gap between the cross-sections is very high. It is natural for research that uses several countries as case studies.

The heteroscedasticity test is intended to determine whether the research model has symptoms of heteroscedasticity. Heteroscedasticity means non-uniformity in the variation of the model so that it can cause inconsistent errors. This study uses Cameron & Trivedi's approach to detect the presence or absence of heteroscedasticity problems in the model. The assessment criteria are that the model is free from heteroscedasticity problems if the probability value is more than the 5% significance level. The following is the output of the heteroscedasticity test:

Table 3. Heteroscedasticity Test

Cameron & Trivedi's	Prob.
Chi2 (20)	17.09
Prob. > Chi2	0.6474

Source: Processed Data, 2023

The table above shows that the probability value is more than 5% significance or precisely 0.6474, so the model in this study is free from heteroscedasticity problems.

The multicollinearity test aims to detect whether the tested variables have a perfect relationship in this research model. A research model is considered good if it has a low multicollinearity value. If the multicollinearity value is high, the model cannot partially separate the effect of one independent variable on other independent variables. The VIF (variance inflation factor) approach is used to perform this test. The assessment criteria of the VIF approach are if the mean value of VIF < 10, then the model is free from multicollinearity problems. If the value of 1/VIF is less than 2, the model is free from multicollinearity problems. The following is the output of the multicollinearity test.

The output Table 4 shows that the model in this study is free from multicollinearity problems because the mean value of VIF < 10 or, more precisely, is 2.51.

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Table 4. Multicollinearity Test

Variable	VIF	1/VIF
LABOR	3.82	0.261749
GERD	3.12	0.320171
PATENT	2.15	0.464281
TFP	1.89	0.528319
FDI	1.56	0.641669
Mean VIF	2.51	

Source: Processed Data, 2023

This study uses a common effect panel data regression analysis technique to determine the effect of the number of workers, the ratio of R&D spending to GDP, the number of patents, the ratio of foreign direct investment to GDP, and total productivity factors on economic growth in China, Germany, United Kingdom, Japan, and the USA. In the previous section, the estimation model selection shows that the CEM model is the best model that should be used in this study. The following is the result of panel data regression using the CEM model:

Table 5. Panel Data Regression (*Common Effect*)

Variable	Coef.	Std. Err	t	P > |t|
GERD	−0.21	0.15	-1.41	0.162
PATENT	−1.33	3.65	-3.65	0.000
FDI	0.08	0.03	2.76	0.007
LABOR	5.56	4.29	12.94	0.000
TFP	1.11	0.04	25.21	0.000
Cons	1.52	0.41	3.64	0.000

Source: Processed Data, 2023

Based on the table above, it can be seen that the equation for the panel data regression in this study is:

$$PE = 1.52 - 0.21GERD - 1.33PATENT + 0.08FDI + 5.56LABOR + 1.11\,TFP + e \quad (5)$$

The constant of 1.52 indicates that if all independent variables are zero, then the dependent variable (PE) or Economic Growth will be worth 1.52%. The coefficient of the ratio of R&d expenditure to GDP (GERD) is -0.21%, meaning that every 1% increase in GERD will reduce PE by 0.21%. The coefficient of the number of patents (PATENT) is -1.33, meaning that every 1% increase in the number of patents will reduce PE by 1.33%. The coefficient of the ratio of foreign direct investment to GDP (FDI) is 0.08, meaning that every 1% increase in FDI will increase PE by 0.08%. The coefficient of the number of workers (LABOUR) is 5.56, which means that every 1% increase in the number of workers will increase economic growth by 5.56%. The coefficient of total factor productivity (TFP) is 1.11, which means that every 1% increase in TFP will increase economic growth by 1.11%.

A simultaneous test or F test is a test that aims to detect whether all independent variables affect the independent variable. If the results of the F test show that all independent variables have a significant effect, it means that it can be continued to a partial or independent test. The following is the output of the F Test.

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Table 6. F Test

F calculate	F table	Prob > F	Alpha	Desc.
627.33	2.30	0.0000	0.05	Significant

Source: Processed Data, 2023

The table above provides an interpretation that the calculated F calculate is more significant than the F table (627.33 > 2.30), and the probability value is less than the specified significance level (0.0000 < 0.05), meaning that all independent variables in the model have a positive and significant effect on the dependent variable. In other words, the ratio of R&D spending to GDP, the number of patents, the ratio of foreign direct investment to GDP, the number of workers, and total factor productivity simultaneously have a positive and significant impact on economic growth in China, Germany, United Kingdom, Japan, and the United States in 1996-2018.

Table 7. Uji Koefisien Determinasi

Obs.	F (5, 109)	Prob > F	R-squared	Adj R-squared
115	627.33	0.0000	0.9664	0.9649

Source: Processed Data, 2023

The output of the coefficient of determination test above shows that the coefficient value of R2 is 0.9664 or close to one. All independent variables can explain the dependent variable in the model by 96%, and variables outside the research model explain the remaining 4%. The coefficient value, which is almost close to one, indicates that the regression in this study is of good quality.

The apriori test is intended to compare the coefficients of the regression parameters with existing theories or principles. The assessment criteria for this a priori test is that if the coefficient of the regression parameter is not the same as the predetermined hypothesis, then the variable does not pass the apriori test. The following is the result of a comparison between the regression parameter coefficients and the hypothesis in this study:

The T-test is a partial test that aims to see the influence of the dependent and independent variables. T-test needs to be done after knowing the results of the F test, which shows that all independent variables in the model have a significant effect on the dependent variable. The following is the output of the T-test:

Table 28. T-test

Variable	T table	T calculate	Prob > |t|	Alpha	Desc.
GERD	1.65895	-1.41	0.162	0.05	no significance
PATENT	1.65895	-3.65	0.000	0.05	no significance
FDI	1.65895	2.76	0.007	0.05	Significance
LABOUR	1.65895	12.94	0.000	0.05	Significance
TFP	1.65895	25.21	0.000	0.05	Significance

Source: Processed Data, 2023

Through the output of the T-test above, the variable ratio of R&D expenditure to GDP (GERD) partially has no significant effect on economic growth (PE). As indicated by the T calculate, smaller than the T table (-1.41 < 1.65895) at a significance level of 5%. This also happened to the variable number of patents (PATENT), which had a T calculated smaller than the T table (-3.65 < 1.65895). This means that the number of patents partially has no significant effect on economic growth.

A partial test shows that the ratio of FDI to GDP has a positive and significant effect on PE. This is indicated by T calculate, which is greater than the T table (2.76 > 1.65895), and the probability value is smaller than the specified significance level (0.007 < 0.05). In line with the number of workers who partially have a positive and significant effect on economic growth. Where the value of T calculate is more significant than the T table (12.94 > 1.65895), and the probability value is smaller than the level of significance (0.000 < 0.05). Total factor productivity (TFP) also has a positive & significant effect on economic growth. This is shown by the T calculate, which is more significant than the T table (25.21 > 1.65895), and the probability value is smaller than the significance level (0.0000 < 0.05).

The description of the interaction above is also supported by Turedi's (2014) research, which suggests that the number of patents is an essential indicator of technological innovation. Technological innovation is an important factor for the state to increase the guarantee of labor growth, sustainable economic growth, and citizens' welfare and quality of life (Akcali & Sismanoglu, 2015). Technological innovation is the output of R&D activities, so the input is funds spent on R&D activities which in this study represents the ratio of R&D spending to GDP (GERD). Huňady and Orviská (2014), in their research, stated that countries with high amounts of R&D spending not only have more researchers but also have registered patents (innovation rates) that are high as well..

Foreign direct investment (FDI) is a facilitator for the state in the technology transfer process and capital or capital in R&D activities. According to Liu (2016), foreign direct investment is also a facilitator in labor mobility to help the country increase its productivity. Countries with a large proportion of FDI tend to have high levels of R&D activity. This is because FDI is an instrument of technology diffusion, so the quantity of FDI also affects the level of technological innovation in a country (Huňady & Orviská, 2014). Countries that adopt the latest technology will have faster productivity growth, so economic growth will also grow faster. This statement is supported by the Solow growth model in Inekwe (2014), where technological progress and innovation are the main drivers of economic growth. Adopting the latest technology will also increase the effectiveness and efficiency of output production to increase total factor productivity (TFP) in the long term. The description of the continuity between these variables indicates that R&D is a critical factor in increasing economic growth (PE).

DISCUSSION

The results of this study indicate that the ratio of R&D spending to GDP has no significant effect on economic growth in China, Germany, Japan, the United Kingdom, and the USA. This means that the proportion of R&D funds to GDP does not partially contribute significantly to economic growth. This is also supported by research by Lichtenberg (in Turedi, 2014), who made 74 countries the object of research in the period 1964-1989. The results of his research show that there is no relationship between government spending in the R&D sector on economic growth. Research by Wang and Wu (2015), which makes China the object of research, also shows the same thing, where R&D spending by the Government does not directly affect economic growth.

Research & development (R&D) funds in a country are divided into two: Government R&D expenditures and private R&D expenditures. This research only focuses on Government R&D. US, China, Germany, Japan & UK are countries with giant economies of scale. The five countries delegate all market control to the private sector (free market system). Although China is not a capitalist country, in practice, the market system in China does not have a significant differences from the US, China, Germany, Japan, and the UK. The free market or capitalist system gave rise to many giant private companies such as Google (USA), Amazon (USA), Apple (USA), Alibaba (China), Tencent (China), Softbank (Japan), Adidas (Germany), and KitKat (UK).). The company is a giant private company with large private R&D expenditures to develop its products or services so that it is increasingly in demand by consumers.

Currently, these companies contribute a large proportion of GDP and have a significant influence on economic growth in the country concerned. This description is supported by research by Lichtenberg (in Gumus & Celikay, 2015) that private R&D expenditures have a positive and significant effect on economic growth and are proven to be more effective and efficient than public R&D expenditures. It is also supported by research (Halaskova, Gavurova, & Kocisova, 2020) that of the 28 European countries studied, the majority showed results that R&D spending by the private sector was more effective and efficient than the public. This economic phenomenon certainly supports the findings in this study, especially the relationship between GERD and PE. The ratio of R&D expenditure to GDP by the Government is non-profit (public) oriented, so partially it does not have a significant effect on economic growth.

When compared with several European countries, research by (Silaghi, Alexa, Jude, & Litan, 2014) with case studies of central and western European countries during 1998-2008 also shows that government spending in the R&D sector has no significant effect on economic growth. Then when compared with 30 developing countries with the observation year 2000-2006, research by Samini and Alerasoul (in Gumus & Celikay, 2015) shows that R&D spending has no relationship with economic growth. However, recent research by Banelienė and Melnikas (2020), with case studies of European and Asian countries, shows that R&D spending has a significant effect on economic growth.

The results of this study indicate that the number of patents has no significant effect on economic growth in the US, CHINA, Germany, Japan, and the UK. This finding is also similar to Saini and Jain's (as cited in Turedi, 2014) finding that the number of patents did not have a significant correlation or effect on PE in developed countries such as Singapore, Japan, and some developing countries such as Thailand and Vietnam. According to the author's analysis, the number of patents partially does not affect economic growth because it requires other instruments to affect economic growth positively. An increase in the number of patents will not bring any benefit if it is not supported by foreign direct investment as a facilitator or driver in technology diffusion. For additional information, patents are tangible. That is, patents are tangible assets that have limited monetary value and are usually physical. Thus, this patent is transactable for several monetary values.

The results in this study indicate that the ratio of foreign direct investment to GDP (FDI) has a positive and significant effect on economic growth in the country that is the case study. A 1% increase in FDI will increase economic growth by about 8.74%. Almost all previous studies state the same thing. Foreign direct investment is a constituent component of economic growth (GDP). The higher the foreign direct investment, the higher the contribution to GDP.

Foreign direct investment is also confirmed by Huňady and Orviská (2014) to have a positive and significant influence on economic growth in the European countries that are the case studies. Research by Liu (2016) with case studies of high-income countries (34 countries), upper-middle-income countries (27 countries), and lower-middle-income countries (31 countries) show that FDI has a positive and significant influence on economic growth in the country. This is strong support for the findings in this study.

This study found that labor has a positive and significant effect on economic growth in the country. That is the case study. According to this study, an increase in the quantity of labor by 1% will positively contribute to economic growth of 5.5%. Labor is the primary input in the economic growth model. That is, at a certain point, an increase in the quantity of labor will increase the number of goods and services, thereby increasing national productivity. However, the increase in workers must also be balanced with technological progress. This is because an increase in the number of workers that are not matched by technological advances can cause a diminishing return effect.

The above findings are also supported by the research of Wang and Wu (2015), who made China a case study with the observation year 1997-2013. The results of this study indicate that the workforce has a positive and significant role in economic growth in China. Another study by (Huda et al., 2020) shows that the quantity of labor positively and significantly affects economic growth in Asian and ASEAN countries using five estimation models (PLS, REM, FEM, FDGMM, SYGSMM). Compared with other developing countries, the findings (Inekwe, 2014) show that labor has no significant effect on economic growth in all statistical models used.

A country will benefit from increased labor participation in certain economies of scale. The US, China, Germany, Japan, and the UK have developed countries with the largest economies of scale in the world. That is, the country's technology level is very advanced and up-to-date. Almost in all sectors, such as formal and informal, the country has used advanced technology in the production process. According to the Solow growth model, technological progress can minimize the occurrence of diminishing returns so that an increase in the quantity of labor can increase economic growth.

The human development index in the US, China, Germany, Japan, and the UK, have a very high HDI category, so the quality of human resources in these countries is also high. The increase in workforce participation with good quality human resources will increase the country's productivity, so it will positively impact economic growth.

The results of this study found that the total factor productivity has a positive and significant effect on economic growth in the country. That is the case study. An increase in TFP by 1% will increase economic growth by 1.1%. Simply put, TFP is an indicator of a country's technological innovation level. Countries with high TFP values tend to have a high level of effectiveness and efficiency in producing output. That is, they need less time to produce a certain quantity of output. This is due to the latest technology that helps them in the production process.

The higher the TFP value of a country, it will also increase economic growth. This is because the TFP value represents the level of productivity (output/hours). The higher the productivity level of a country, the more output it produces in a specific time unit. This increase in output will increase the country's economic growth. Research by (Huda et al., 2020) also states that economic growth is influenced by total factor productivity. Furthermore, Liu's research (2016) in 55 developed and developing countries found that TFP positively and significantly impacts GDP (economic growth).

CONCLUSION

Through the description of the research results, it can be concluded the following points: The F test simultaneously shows that all independent variables have a positive and significant effect on economic growth in the US, China, Germany, Japan & UK from 1996-2018. The ratio of R&D spending to GDP had no significant effect on economic growth in the US, China, Germany, Japan, and the UK from 1996-2018. The number of patents had no significant effect on economic growth in the US, China, Germany, Japan, and the UK from 1996-2018. The ratio of FDI to GDP positively and significantly impacted economic growth in the US, China, Germany, Japan, and the UK from 1996-2018. The number of workers positively and significantly impacted economic growth in the US, China, Germany, Japan, and the UK from 1996-2018. Total factor productivity had a positive and significant impact on economic growth in the US, China, Germany, Japan, and the UK from 1996-2018.

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DECLARATION OF CONFLICTING INTERESTS

In this study, we do not have a conflict of interest from any party

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