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Industry impact on GDP growth in developed countries under R&D investment conditions

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ABSTRACT

The impact of industry on GDP growth is widely discussed in light of the industrial revolution that arose as the first wave of innovations and has since been a common subject of theoretical and empirical research papers. However, the issue of R&D investment, industrial structure and the impact on GDP growth is still under discussion and requires much deeper investigation under conditions of globalization. The results of this paper supported the hypotheses that growth of the industry share in gross value added has a higher impact on GDP growth in well-developed industrialized countries with high GDP per capita than in industrialized countries whose GDP per capita is at a lower level under business-financed R&D investment conditions. In addition, the multiplier effect of business-financed R&D investment and its impact on economic growth depend on the economic development level of a given industrialized country. The proposed hypotheses suggest that policy makers of less-developed countries should pay more attention to enhancing the quality of industry by introducing appropriate incentives rather than to increasing the share of industry in GDP, with a particular focus on the best practices of well-developed industrialized countries.

Introduction

The impact of industry on GDP growth is widely discussed in light of the industrial revolution that arose in the mid-18th century as the first wave of innovation. Crafts and Mills (2017) provided a time-series analysis of annual estimates of real GDP and industrial output covering 1270-1913, the period before and after the first innovation wave. Their main findings were as follows: on average, the growth trend was 0.2% per year over the 500 years from 1270 to 1770; following the industrial revolution, the growth in real GDP per capita peaked at approximately 1.25% per year in the mid-nineteenth century.

Among the conclusions of Solow (1957) based on the application of a crude production function to American data over the period 1909-1949 were that gross output per working hour doubled over the period, with 87.5% of the increase attributable to technical change and the remaining 12.5% to increased use of capital.

Schumpeter's (1934) theories and the concept of "creative destruction" introduced the disruption of existing economic activity by innovations as a possibility for creating new ways of producing goods or services or entirely new industries (OECD/Eurostat. (2018). The strategic stimulus to economic development in Schumpeter's (1934) analysis is innovation, defined as the commercial or industrial application of something new: a new product, process, or method of production; a new market or source of supply; and a new form of commercial, business, or financial organization. The innovational process incessantly revolutionizes the economic structure from within, incessantly destroying the old one and incessantly creating a new one (Schumpeter, 1934).

Based on Schumpeter's (1934) work, the Oslo Manual (2005) defined four types of innovations that encompass a wide range of changes in firms' activities: product innovations, process innovations, organizational innovations and marketing innovations. These efforts were furthered in the 2018 Oslo Manual (OECD/Eurostat. (2018), and innovation was defined as a new or improved product or process that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).

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The impacts of innovations on firm performance range from effects on sales and market share to changes in productivity and efficiency. Important impacts at the industry and national levels are changes in international competitiveness and in total factor productivity, knowledge spillovers from firm-level innovations, and an increase in the amount of knowledge flowing through networks.

According to the Oslo Manual (2018), many factors could have an impact on boosting innovations in the business sector, including *internal factors,* such as general resources of the firm, management capabilities, workforce skills and human resources management, and technological capabilities; and *external factors,* such as knowledge flows, including the diffusion of innovations and the collection of data on knowledge flows, the location of business activities, markets and environment for business innovation, public policy in the forms of regulations and government support programs, public infrastructure, the macroeconomic policy environment, and the social and natural environment for innovation.

The revived interest in industrial policy comes at the time of a new technological transformation and accompanies the arrival of radical and disruptive technologies associated with the applications of artificial intelligence, automation and machine learning. Industry 4.0 and the so-called "Fourth Industrial Revolution" embody technologies such as advanced robotics, increased automation, digitalization and data exchange in manufacturing technologies supported by artificial intelligence, cyber-physical systems, platform economy innovations and cloud computing (Bailey, 2019).

Comparable and representative data for 2015 on the deployment of industrial robot technologies show that Korea and Japan lead in terms of robot intensity (i.e., the industrial stock of robots over manufacturing value added). The robot intensity in these economies is approximately three times that in the average OECD country (OECD, 2017).

Innovative effort is on the rise as a share of economic activity. Investment in knowledge has grown more rapidly than investment in machinery and equipment since the mid-1990s in most OECD countries (OECD, 2007).

There is no doubt that innovation is fundamental to economic development and growth. Innovation enables not only firms but also industries and even countries to compete with each other (Slaper & Justis, 2010). Innovation is the engine of economic growth: innovation and its diffusion within and across national boundaries rather than the accumulation of capital explain the economic growth rates of countries (Sainsbury, 2020).

The novelty of this study is its examination of the link between industry and GDP growth in developed countries under business R&D investment conditions, including the price of capital. Previous research and the majority of existing models investigated the relation between GDP growth and industry without keeping in mind R&D investment conditions, as will be shown in the section "Theoretical Approach and Empirical Evidence" of this paper.

The purpose of this study is to analyze the impact of industry and business R&D investment on GDP growth in OECD countries. Seeking to examine the hypothesis on the relation of industry and GDP growth in developed countries under business R&D investment conditions, data for 36 OECD countries were used, and regression analysis was applied. The structure of this article is as follows: the theoretical approach and empirical evidence clarify the direction for the empirical study and model development, which is a proven novelty of this study in comparison to existing empirical evidence. The empirical background part analyzes OECD countries' statistical data with a special focus on industry, its structure and country segmentation by GDP per capita. The part regarding the methodology, model and data describes the developed model for testing the proposed hypotheses, and the results part provides the modeling outcomes. The conclusion and discussion section summarizes the major insights of this study and highlights the implications for policy makers.

Theoretical Approach and Empirical Evidence

The links between technology and the economy were at the very heart of the Industrial Revolution, and the successful conversion of many inventions into profitable innovations in numerous small but growing firms made possible the acceleration of productivity growth in the leading sectors; this was not a linear process any more than it is in the present (Freeman, 2019).

Fagerberg & Verspagen (2020), by following Freeman's analytical framework on long-run economic development as a succession of technological regimes with quite different properties, stressed that at the core of each regime is a constellation of radical innovations, the diffusion of which generates many new applications and, for a while, strong economic growth.

The relationship between innovation and economic change is conceptualized as a two-way link. On the one hand, the former is indeed a major driver of economic performance; on the other hand, specific economic and business conditions can explain the way particular innovations emerge, for example, when exports and profits shape industries' ability to introduce product innovations (Pianta, 2017).

The results for manufacturing alone are somewhat different. Although R&D maintains a strong influence on innovative sales, technology adoption loses its significance; manufacturing industries have been characterized by widespread processes of restructuring, and technology adoption from external sources (particularly regarding new machinery) has mainly had the effect of reducing labor use, rather than increasing innovative sales (Bogliacino & Pianta, 2012).

Denoncourt (2020), with reference to Rahman et al. (2017), noted that society has changed, with the decline of traditional manufacturing and simple supply chains and their frequent replacement with digital and intellectual property (IP)-reliant business models operating in the intangible (virtual or weightless) economy. Firms with new digital technologies create new markets and value networks that impact established markets, firms, products and alliances.

Artificial intelligence (AI) radically shortens the time needed to discover new industrial materials, sometimes from years to days (Chen, 2017). Currently, the greatest AI commercial potential for advanced manufacturing is expected to exist in supply chains, logistics and process optimization (Chui et al., 2018). In addition to having direct uses in production, AI used in logistics enables real-time fleet management while significantly reducing fuel consumption and other costs (OECD, 2018).

Ulku (2007) provided an empirical analysis of the relationship between R&D intensity, rate of innovation and growth rate of output in four manufacturing sectors, namely, chemicals, drugs and medicine, electrical and electronics, and machinery and transport, in 17 OECD countries over the period 1981-1997. Her findings suggest that knowledge stock is the main determinant of innovation in all four manufacturing sectors and that R&D intensity increases the rate of innovation in the chemicals, electrical and electronics, and drugs and medicine sectors. In addition, the rate of innovation has a positive effect on the growth rate of output in all sectors.

Coccia (2009) analyzed the relationship between productivity growth and R&D investment. The econometric analysis showed that gross domestic expenditure on R&D (GERD), as a percentage of GDP, is an important driver of productivity growth. The optimization showed that the long-run magnitude of GERD between 2.3% and 2.5% maximizes productivity growth. He stated that countries should focus their targets on R&D investment in the amount of approximately 2.3-2.5% of GDP in the long run. However, this problem is still under discussion and requires much deeper investigation through the examination of other indicators, including GDP per capita. The data collected for this study could not clearly prove or reject Coccia's hypothesis or indicate whether there is an optimum level of R&D investment, based on the relation between business R&D expenditure and GDP per capita.

Frick et al. (2019) argued that the differences in R&D intensity observed among subsectors of the manufacturing sector are primarily a result of differing returns to innovation and differing innovation behaviors. According to Guellec et al. (2001), R&D is important for productivity and economic growth. Business R&D has high spillover effects; it enhances the ability of the business sector to absorb technology coming from abroad or from government and university research. The social return on business R&D is then higher than its private return, which is a possible justification for government support of business R&D.

Using the innovation index and its component indexes as a measure of the innovative environment prevailing in US states, Cheung (2014) found that the more innovative a state is, the higher its per capita real GDP and per capita personal income are. Higher per capita personal income is associated with both the availability of human capital for innovative activities and the presence of the economic dynamics that facilitate those activities.

Using data on top R&D spenders in the US and the EU from 2004 until 2012, Castellani et al. (2016) investigated the sources of the US/EU productivity gap. They found robust evidence that US firms have a higher capacity to translate R&D into productivity gains (especially in high-tech industries), and this contributes to explaining the higher productivity of US firms. Conversely, EU firms are more likely to achieve productivity gains through capital-embodied technological change, at least in medium- and low-tech sectors.

Sainsbury (2020) pointed out that the growth of high value-added per capita industries is the key to economic development, and the creation of competitive advantage and production efficiency by innovation is the way firms create high value-added per capita. Governments need to draw up policies that support industry in four main areas: firm financing and governance, regional policy, the national system of education and training, and the national system of innovation.

Guimón & Paunov (2019) pointed out that three factors are particularly important for evaluating a country's policy mix: 1) the characteristics of the business sector, 2) the characteristics of higher education institutions and public research institutes and of their research, and 3) macroeconomic conditions.

Appelt et al. (2019), based on the OECD R&D Tax Incentives Database for 36 OECD countries and partner economies, found that over the past two decades, many countries have increased the availability, simplicity of use and generosity of R&D tax incentives.

Empirical Background

Seeking to investigate industry directions that have a high impact on economic growth, this analysis is based on the data of OECD countries. In the first step, an overview of all 36 OECD countries was made considering two criteria – manufacturing share in gross value added and GDP per capita.

In the second step, we analyzed the data in more detail and found that 17 OECD countries could be called industrialized countries with high GDP per capita. The largest selection of countries – 13 countries whose GDP per capita is higher than $40,000 and whose manufacturing share in gross value added is 10-19.9% – included Austria, Belgium, Canada, Denmark, Finland, France, Iceland, Italy, Netherlands, New Zealand, Sweden, the United Kingdom, and the United States. For further analysis, four countries from other segments were included: Germany and Japan, where manufacturing share in gross value added exceeds 20% and whose GDP per capita higher than $40,000; Switzerland, where manufacturing share is in between 10-19.9% and GDP per capita is above $60,000; and Ireland, whose manufacturing share in gross value added exceeds 30% and whose GDP per capita is above $60,000 (see Table 1).

Furthermore, the industry structure in 16 selected countries by the top three industries was analyzed in more detail. Differences in terms of population were accounted for, and population figures were additionally included in this step of analysis. Eurostat data for the year 2017 were used for European Union countries (Germany, Sweden and United Kingdom data for 2016) and Iceland; and 2016 data were used for Switzerland. In addition, national statistical offices data were used for 2017 for the US, Japan, New Zealand, and Canada (Bureau of Economic Analysis 2019; Statistics of Japan (2019); Stats NZ (2019); & Statistics Canada (2019), respectively). Population data for 2018 were extracted from the World Bank (2019) database. Ireland was excluded from this step of the analysis due to the unavailability of detailed

Table 1
OECD countries by GDP per capita in relation to manufacturing share in gross added value, 2017

GDP/Capita	Manufacturing Share in Gross Added Value			
	Less than 10%	10-19.9%	20-29.9%	30% and More
Less than $20,000		Mexico		
$20,000-$39,999		Greece, Poland, Portugal, Spain, Turkey, Chile, Estonia, Israel, Latvia, Lithuania	Czech Republic, Hungary, Slovakia, Slovenia	Korea
$40,000-$59,999	Australia	Austria, Belgium, Canada, Denmark, Finland, France, Iceland, Italy, Netherlands, New Zealand, Sweden, United Kingdom, United States	Germany, Japan	
$60,000 and More	Luxembourg, Norway	Switzerland		Ireland

Source: Prepared by author, based on OECD data (OECD 2019b, 2029d). Data on manufacturing share in gross value added for Iceland and New Zealand for 2016 and for Canada for 2015.

data on the manufacturing structure (Eurostat, 2019b).

After data analysis, it was found that most of the selected countries had the manufacture of food products, beverages and tobacco products as one of the top 3 industries (13 of 16 countries; of which 5 small countries had a population under 10 million). This suggests that high-income countries should pay attention to the food industry and seek to develop a sustainable food supply with appropriate quality standards for their populations. The second most common top industry is machinery and equipment manufacturing: more than half of the selected countries (10 of 16), both small and large developed countries, have this industry as one of the top 3 manufacturing sectors. Basic metal and fabricated metal product manufacturing is in third place: 8 of the 16 selected countries have developed this industry, and the importance of this industry likewise does not depend on a country's size in terms of population.

Motor vehicles, trailers, semitrailers and other transport equipment manufacturing and chemicals and chemical product manufacturing are industry priorities in large countries with a population above 10 million. This could be explained by historical aspects based on the first wave of innovations and the owned natural resources that allowed the development of the transport equipment manufacturing sector in Canada, France, Sweden, the United Kingdom, Germany and Japan, even though the extraction of metal ores is currently shrinking in many of these countries (Materials Flow Analysis Portal, 2019). The priority of chemical product manufacturing in Belgium, the Netherlands and United States could be explained by the same historical reason – owned natural resources and inventions. Although this industry is not found only in large countries, there is a great difference in population between the US and Belgium and the Netherlands.

Basic pharmaceutical product and pharmaceutical preparation manufacturing and computer, electronic and optical product manufacturing are the top 3 priority industries in the selected countries, both small and large countries.

In addition, this research step showed that small, well-developed industrialized countries have used their natural resources for boosting economic growth, and this is one of their top 3 manufacturing directions: for example, Finland has used wood as its own natural resource for developing wood, paper, printing and reproduction manufacturing, and New Zealand has developed petroleum and coal product manufacturing. However, industries based purely on countries' own natural resources cannot be considered a trend for all selected OECD industrialized countries and were excluded from further analysis in this study.

As the first-stage outcome of the data analysis, seven major manufacturing directions could be observed: 1) food products, beverages and tobacco products; 2) machinery and equipment; 3) basic metals and fabricated metal products; 4) motor vehicles, trailers, semitrailers and other transport equipment; 5) chemicals and chemical products; 6) basic pharmaceutical products and pharmaceutical preparations; and 7) computer, electronic and optical products, which could create high value added in the industrial sector, as proven by their development as top directions in OECD industrialized countries whose GDP per capita is higher than $40,000. In addition, it should be noted that only two of the seven directions – motor vehicles, trailers, semitrailers and other transport equipment manufacturing and chemicals and chemical products manufacturing – belong to the top 3 industries of large countries, whose population is above 10 million.

Eurostat (2019a) classified only two of the seven highlighted manufacturing sectors as high-technology sectors: manufacture of basic pharmaceutical products and pharmaceutical preparations and manufacture of computer, electronic and optical products. According to technological intensity, three of the seven manufacturing industries are considered medium-high technology: manufacture of chemicals and chemical products, manufacture of machinery and equipment, and manufacture of motor vehicles, trailers and semitrailers, and other transport equipment. Basic metal and fabricated metal product manufacturing is classified as a medium-low-technology industry, and food product, beverage and tobacco product manufacturing is classified as a low-technology industry. A similar classification is provided by the OECD (2011).

Innovation in low- and medium-technology industries (LMTs) often receives less attention than innovation in high-technology industries. However, innovation in LMTs can have a substantial impact on economic growth, owing to the weight of these sectors in the economy (OECD/Eurostat, 2005).

Method

Regression analysis was used for modeling based on the following equation:

$$\frac{GDP}{capita} = c + \frac{BER\&D}{GDP} + \frac{IND}{GAV} + LTIR + \varepsilon \quad (1)$$

Here, *BER&D/GDP* refers to the business-financed gross domestic expenditure on R&D as a percentage of GDP, *IND/GAV* denotes the share of industry as a percentage of gross value added, and *LTIR* denotes the long-term interest rate.

This study uses OECD data from 36 countries (see Appendix). The model hypotheses (HP) are as follows:

HP1. Growth in the share of industry has a higher impact on GDP growth in well-developed industrialized countries whose GDP per capita is higher than $40,000 than in industrialized countries where GDP per capita is at a lower level under business-financed R&D investment conditions.

HP2. The multiplier effect of business-financed R&D investment and its impact on economic growth depend on the industrialized country's economic development level.

Results

The panel least squares method was applied for the estimations. Annual data for 36 OECD countries over the period 2014-2017 were used for modeling. Three countries were excluded due to lack of data on the long-term interest rate (Estonia, Turkey) and on business-financed gross domestic expenditure on R&D (Australia). Modeling was performed using the Eviews10 program.

The estimation results prove the hypothesis that the growth of industry share in gross value added has a higher impact on GDP growth in well-developed industrialized countries whose GDP per capita is higher than $40,000 than in industrialized countries whose GDP per capita is at a lower level under business-financed R&D investment conditions.

For the baseline estimation, data were used for 33 OECD countries, excluding 3 OECD countries due to the lack of data for Australia on business sector R&D expenditure and for Estonia and Turkey on the long-term interest rate. The estimation covers the period 2014-2017 and includes 105 (total panel unbalanced) observations. The panel least squares method with white cross-section standard errors and covariance and fixed cross-sectional variables (dummy variables) was used for the baseline estimation as shown in Equation (2).

$$\frac{GDP}{capita} = 13507.80 + 8568.59\frac{BER\&D}{GDP} + 1175.38\frac{IND}{GAV} - 1314.23LTIR + \varepsilon$$

R-squared (R^2) = 0.9910; adjusted R-squared ($\bar{R}^2$) = 0.9864; D-W = 1.7953.

The estimation shows a positive impact of R&D investment by business sector on GDP per capita, where one additional percentage point of R&D investment growth raises GDP per capita by $8,569. In addition, an additional percentage point of industry share growth in gross added value raises GDP per capita by $1,175. A one percentage point increase in the long-term interest rate has a negative impact, leading GDP per capita to drop by $1,314 (see Equation (2) and Table 2).

In the second modeling step, the same estimation was made for 17 industrial OECD countries whose industry share in gross value added is above 10% and whose GDP per capita is above $40,000, namely, Austria, Belgium, Canada, Denmark, Finland, France, Iceland, Italy, Netherlands, New Zealand, Sweden, the United Kingdom, the United States, Germany, Japan, Switzerland and Ireland (see Table 1). The data covers the same period, 2014-2017, and includes 49 (total panel unbalanced) observations. The panel least squares method with white cross-section standard errors and covariance and fixed cross-section variables (dummy variables) was used for this estimation.

$$\frac{GDP}{capita} = 11334.92 + 13223.27\frac{BER\&D}{GDP} + 1251.10\frac{IND}{GAV} - 1912.08LTIR + \varepsilon \quad (3)$$

R-squared (R^2) = 0.9763; adjusted R-squared ($\bar{R}^2$) = 0.9608; D-W = 1.7410.

The second estimation results show the same relations as the baseline estimation: positive relationships between GDP per capita and business sector R&D investment, as well as between GDP per capita and industry share in gross value added, and a negative relation with the long-term interest rate.

However, in the second estimation, the impact of business-financed R&D investment is 1.54 times higher than that in the estimation for all selected 33 OECD countries. Additionally, industry share growth in gross value added has a higher impact on GDP per capita growth but only of 6.4% in comparison to the baseline estimation results. The long-term interest rate in this case is 1.45 times more vulnerable than the estimation output for all 33 selected OECD countries (see Equation (3) and Table 3).

Table 2
Review regression estimation: All selected OECD countries

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
C	13507.80	1961.109	6.887837	0.0000
BER&D/GDP	8568.587	1745.701	4.908393	0.0000
IND/GAV	1175.383	38.29223	30.69509	0.0000
LTIR	-1314.225	435.3570	-3.018730	0.0036

Effects Specification

Cross-Section Fixed (Dummy Variables)			
R-squared	0.990959	Mean dependent var	40001.53
Adjusted *R*-squared	0.986373	*SD* dependent var	13418.09
SE of regression	1566.331	Akaike info criterion	17.81672
Sum squared residuals	1.69E+08	Schwarz criterion	18.72665
Log likelihood	-899.3778	Hannan-Quinn crit.	18.18544
F-statistic	216.0902	Durbin-Watson stat	1.795279
Prob(*F*-statistic)	0.000000		

Table 3
Review regression estimation: 17 selected OECD industrialized countries with high GDP per capita

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
C	11334.92	4172.468	2.716598	0.0110
BER&D/GDP	13223.27	2977.429	4.441171	0.0001
IND/GAV	1251.104	59.92816	20.87673	0.0000
LTIR	-1912.082	163.0936	-11.72383	0.0000

Effects Specification

Cross-Section Fixed (Dummy Variables)			
R-squared	0.976320	Mean dependent var	48442.13
Adjusted *R*-squared	0.960805	*SD* dependent var	8102.611
SE of regression	1604.129	Akaike info criterion	17.89035
Sum squared residuals	74623633	Schwarz criterion	18.66252
Log likelihood	-418.3136	Hannan-Quinn crit.	18.18331
F-statistic	62.92906	Durbin-Watson stat	1.741032
Prob(*F*-statistic)	0.000000		

The third estimation was made for the 14 selected OECD industrialized countries whose GDP per capita was below $40,000 and whose industry share in gross value added was higher than 10%: Mexico, Greece, Poland, Portugal, Spain, Chile, Israel, Latvia, Lithuania, Czech Republic, Hungary, Slovakia, Slovenia and Korea (see Table 1). Turkey and Estonia were excluded from the estimation due to lack of data on the long-term interest rate. The data cover the same period, 2014-2017, and include 52 (total panel unbalanced) observations. The panel least squares method with fixed cross-section variables (dummy variables) was used for the estimation.

This estimation shows that the industry share in gross value added is irrelevant in modeling the impact on GDP per capita by Equation (1) ($p = 0.93$).

After elimination of the industry indicator from the equation, the estimation shows the same positive relation between GDP per capita and R&D investment by business sector and a negative relation to the long-term interest rate, as in the two previous estimations. The level of GDP per capita at which a one percentage point increase in business-financed R&D investment could enhance GDP per capita growth by $7,647 is more than twice as high ($27,511) as the level in the baseline and second estimations: for comparison, in the baseline estimation for all selected OECD countries, the GDP per capita starting point is $13,508, while in the second estimation for industrialized countries with high GDP per capita, it is $11,335. In addition, the impact of R&D investment by the business sector is lower (in the baseline estimation, it is equal to $8,569, and in the second estimation, it is equal to $13,223) (see equations (2), (3) and (4)). This supports the hypothesis that the multiplier effect of business-financed R&D investment and its impact on economic growth depend on the economic development level of a given industrialized country.

$$\frac{GDP}{capita} = 27510.85 + 7647.12\frac{BER\&D}{GDP} - 1213.18LTIR + \varepsilon \quad (4)$$

R-squared (R^2) = 0.9536; adjusted R-squared ($\bar{R}^2$) = 0.9343; D-W = 1.5301.

In the third estimation, growth of the long-term interest rate has a negative impact on economic growth, although it has a lower negative impact than it does in the baseline ($1,314) and second ($1,912) estimations: a one percentage point higher interest rate will shrink GDP per capita by $1,213 (see Equations (2), (3) and (4)).

The estimations support the hypotheses that growth in the industry share in gross value added has a higher impact on GDP growth in well-developed industrialized countries where GDP per capita is higher (in this case, more than $40,000) than in industrialized countries whose GDP per capita is at a lower level under business-financed R&D investment conditions. In addition, the multiplier effect of business-financed R&D investment and its impact on economic growth depend on the economic development level of the industrialized country.

Table 4
Review regression estimation: industrial OECD countries with low GDP per capita

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
C	27510.85	2429.926	11.32168	0.0000
BER&D/GDP	7647.120	3064.581	2.495323	0.0173
LTIR	-1213.175	271.2666	-4.472262	0.0001
		Effects Specification		
Cross-Section Fixed (Dummy Variables)				
R-squared	0.953621	Mean dependent var		29684.26
Adjusted *R*-squared	0.934296	*SD* dependent var		5217.581
SE of regression	1337.408	Akaike info criterion		17.48251
Sum squared residuals	64391738	Schwarz criterion		18.08290
Log likelihood	-438.5454	Hannan-Quinn crit.		17.71269
F-statistic	49.34753	Durbin-Watson stat		1.530123
Prob(F-statistic)	0.000000			

Therefore, policy makers of less-developed countries should pay more attention to the rising quality of industry by introducing appropriate incentives, for example, R&D tax incentives, than to the share of industry in GDP, with a particular focus on the best practices of well-developed industrialized countries. Moreover, industrial companies should focus on increasing their efficiency by implementing the best practices of well-developed countries' industrial companies.

Discussion and Conclusion

The problem regarding the optimum level of R&D investment is still under discussion and requires much deeper investigation to examine its relation not only to productivity but also to other indicators, including GDP per capita. The data collected for this research could not clearly prove or deny the Coccia (2009) hypothesis or indicate whether there is an optimum level of R&D investment in the long run.

This study highlighted that seven major manufacturing directions can create high value added in the industrial sector, as proven by their development as top industries in industrialized OECD countries whose GDP per capita is higher than $40,000. Although only two of the seven manufacturing sectors belong to the high-technology sector, three are medium-high-technology industries, one is classified as a medium-low-technology industry, and one is classified as a low-technology industry. However, innovation in low- and medium-technology industries can have a substantial impact on economic growth, owing to the weight of these sectors in the economy.

The modeling and estimations supported the hypotheses that growth of the industry share in gross value added has a higher impact on GDP growth in well-developed industrialized countries whose GDP per capita is high (in this case, more than $40,000) than in industrialized countries whose GDP per capita is at a lower level under business-financed R&D investment conditions. In addition, the multiplier effect of business-financed R&D investment and its impact on economic growth depend on the economic development level of a given industrialized country.

Policy makers in less-developed industrialized countries should pay more attention to increasing the quality of industry by introducing appropriate incentives than to enhancing the industry share in GDP, with a particular focus on the best practices of well-developed industrialized countries.

The research limitations are the limited scope of the variables used, which could have an impact on the relation between industry and GDP growth in developed countries under business R&D investment conditions. Another limitation concerns the lack of investigation of the industrial structures of OECD industrialized countries with a lower GDP per capita. However, the estimations show that even if the manufacturing structures of countries with lower GDP per capita fully or partially reflect the manufacturing structures of well-developed industrial OECD economies, their industries do not have the same impact on economic growth. Therefore, OECD industrialized countries with lower GDP should make efforts to improve their manufacturing sectors by enhancing their quality, changing their supply chains, focusing on high added value activities and transferring the other activities to less-developed countries.

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Appendix

Data used for modeling

Country	Year	GDP per capita ($, current PPPs)	Share of industry (% of gross value added)	Business-financed GERD (% of GDP)	Long term interest rate (%)
Australia	2014	47639	6.74	n/d	3.66
	2015	47351	6.55	n/d	2.71
	2016	50263	6.21	n/d	2.34
	2017	51994	6.20	n/d	2.64
Austria	2014	48814	18.56	1.47	1.49
	2015	49954	18.72	1.52	0.75
	2016	51637	18.74	1.66	0.38
	2017	53895	18.65	1.70	0.58
Belgium	2014	44720	14.05	n/d	1.71
	2015	45739	14.24	1.44	0.84
	2016	47366	14.10	n/d	0.48
	2017	49526	14.38	1.72	0.72
Canada	2014	45628	10.45	0.78	2.23
	2015	44671	11.08	0.74	1.52
	2016	45109	n/d	0.71	1.25
	2017	46810	n/d	0.65	1.78
Chile	2014	22688	12.38	0.12	4.74
	2015	22593	12.77	0.12	4.48
	2016	22788	12.00	0.13	4.41
	2017	24181	11.48	0.11	4.24
Czech Republic	2014	32265	26.76	0.71	1.58
	2015	33701	26.81	0.67	0.58
	2016	35234	26.84	0.66	0.43
	2017	38037	26.81	0.70	0.98
Denmark	2014	47905	13.67	n/d	1.33
	2015	49071	14.29	1.81	0.69
	2016	50685	14.98	n/d	0.32
	2017	54337	14.41	1.78	0.48
Estonia	2014	28937	16.15	0.53	n/d
	2015	29260	16.01	0.60	n/d
	2016	30895	16.02	0.60	n/d
	2017	33493	15.65	0.56	n/d
Finland	2014	41463	16.90	1.70	1.45
	2015	42213	17.12	1.58	0.72
	2016	43730	17.03	1.56	0.37
	2017	46349	17.70	1.60	0.55

France	2014	40144	11.47	1.24	1.67
	2015	40841	11.66	1.23	0.84
	2016	42067	11.51	1.23	0.47
	2017	44125	11.22	n/d	0.81
Germany	2014	47190	22.73	1.89	1.16
	2015	47979	22.97	1.91	0.50
	2016	49921	23.40	1.90	0.09
	2017	52574	23.36	2.01	0.32
Greece	2014	26839	9.51	0.25	6.93
	2015	26902	9.80	0.30	9.67
	2016	27274	10.53	0.40	8.36
	2017	28580	10.81	0.51	5.98
Hungary	2014	25518	23.15	0.65	4.81
	2015	26356	24.41	0.68	3.43
	2016	26852	23.49	0.68	3.14
	2017	28799	23.16	0.71	2.96
Iceland	2014	45713	12.28	0.70	3.20
	2015	48857	11.61	0.79	2.66
	2016	52340	10.67	0.80	2.78
	2017	55330	n/d	0.77	2.22
Ireland	2014	51126	21.75	0.79	2.26
	2015	69147	37.16	0.58	1.11
	2016	70616	35.41	0.57	0.69
	2017	77679	33.93	n/d	0.79
Italy	2014	36071	15.48	0.63	2.89
	2015	36836	16.02	0.67	1.71
	2016	39045	16.44	0.71	1.49
	2017	40981	16.61	n/d	2.11
Israel	2014	34228	14.23	1.46	2.89
	2015	35450	14.53	1.41	2.07
	2016	37475	13.99	1.61	1.88
	2017	38882	13.76	n/d	1.91
Japan	2014	39183	19.88	2.63	0.52
	2015	40406	20.93	2.56	0.35
	2016	41138	20.79	2.46	-0.07
	2017	41985	20.84	2.51	0.05
Korea	2014	33587	30.15	3.23	3.19
	2015	35761	29.76	3.14	2.31
	2016	37143	29.49	3.19	1.75
	2017	38839	30.41	3.47	2.28

Latvia	2014	23802	12.35	0.19	2.51
	2015	24726	11.97	0.13	0.96
	2016	25843	11.87	0.10	0.53
	2017	28378	12.23	0.12	0.83
Lithuania	2014	28174	19.19	0.34	2.79
	2015	28910	19.27	0.30	1.38
	2016	30300	18.77	0.33	0.90
	2017	33325	19.12	0.32	0.31
Luxembourg	2014	100934	4.44	n/d	1.34
	2015	102817	5.19	0.60	0.36
	2016	104702	5.91	n/d	-0.18
	2017	107525	5.43	n/d	0.50
Mexico	2014	18168	16.87	0.10	6.01
	2015	18438	18.29	0.10	5.93
	2016	18969	18.20	0.10	6.19
	2017	19655	18.25	n/d	7.25
Netherlands	2014	49233	11.50	1.01	1.45
	2015	50302	12.01	0.97	0.69
	2016	51340	12.11	1.04	0.29
	2017	54504	12.33	n/d	0.52
New Zealand	2014	37061	12.09	n/d	4.30
	2015	37158	12.36	0.54	3.42
	2016	38784	10.95	n/d	2.76
	2017	40121	n/d	0.63	2.99
Norway	2014	65896	7.61	n/d	2.52
	2015	60357	7.72	0.85	1.57
	2016	57728	7.42	0.88	1.33
	2017	62012	7.22	0.90	1.64
Poland	2014	25298	18.91	0.37	3.52
	2015	26529	19.86	0.39	2.70
	2016	27406	20.44	0.51	3.04
	2017	29583	19.28	n/d	3.42
Portugal	2014	28747	13.49	0.54	3.75
	2015	29685	13.94	0.53	2.42
	2016	31042	14.14	0.57	3.17
	2017	32554	14.40	0.62	3.05
Slovakia	2014	28928	21.70	0.28	2.07
	2015	29700	22.23	0.29	0.89
	2016	30896	22.27	0.36	0.54
	2017	32376	22.54	0.43	0.92

Slovenia	2014	30847	22.87	1.62	3.27
	2015	31649	23.08	1.52	1.71
	2016	33191	23.32	1.39	1.15
	2017	36163	23.72	n/d	0.96
Spain	2014	33728	13.73	0.57	2.72
	2015	35054	13.72	0.56	1.74
	2016	36743	13.83	0.55	1.39
	2017	39087	14.16	0.58	1.56
Sweden	2014	46573	16.50	n/d	1.72
	2015	48437	15.46	1.87	0.72
	2016	49084	15.11	n/d	0.52
	2017	51405	15.36	2.06	0.66
Switzerland	2014	61902	18.99	n/d	0.69
	2015	63939	18.54	2.14	-0.07
	2016	64324	18.67	n/d	-0.36
	2017	66396	18.87	2.26	-0.07
Turkey	2014	23983	18.99	0.39	n/d
	2015	25728	18.96	0.39	n/d
	2016	26330	18.83	0.44	n/d
	2017	28190	19.85	0.48	n/d
United Kingdom	2014	40878	9.97	0.80	2.57
	2015	42055	10.12	0.82	1.90
	2016	42943	10.02	0.87	1.31
	2017	44909	10.07	n/d	1.24
United States	2014	54952	12.08	1.69	2.54
	2015	56718	12.05	1.70	2.14
	2016	57822	11.53	1.74	1.84
	2017	59879	11.56	1.77	2.33

Source: Prepared by author, based on OECD data (OECD 2019a, 2019b, 2019c, 2019d).