The relationship between R&D expenditures and environmental performance in EU countries

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Abstract: Investment in research and development (R&D) can play a key role in improving the environmental performance of EU countries. R&D contributes to a more efficient use of natural resources, which reduces negative environmental impacts. Investment in R&D often leads to innovations that can have a positive impact on sustainable development and on addressing environmental challenges, thereby improving environmental performance. The aim of this paper is to assess the correlation between R&D expenditure and improvements in countries' environmental performance. The paper focuses on EU countries. The analysis also focuses on the structure of R&D expenditure. The study uses changes over a ten-year period. The analysis found that over the period under review, the link between the size of R&D expenditure and environmental performance as measured by the EPI is very low. Significant differences were found between the countries with an initially high EPI (Nordic countries) and the post-communist EU countries.

Keywords: R&D, environmental performance, EU
JEL Classification: E23, G01, F41

1 Introduction

Increasing R&D spending can have a positive effect on economic growth. If we want to assess the impact of these investments, it is necessary to take into account not only the economic effects but also the environmental effects. R&D expenditures can play a key role in improving a country's environmental performance, especially if such investments are targeted at innovations and technological solutions that bring real environmental benefits. The aim of this paper is to assess the relationship between R&D expenditure and improvements in countries' environmental performance.

The importance of investing in R&D to bring about technological change was pointed out by Solow (1957). His study delineated the role of technological change in economic growth showed that technological change is one of the key explanatory factors of economic growth and productivity. The neoclassical production function can be defined in the form Y= F (A;K;L) where A is the level of technology, K is the capital stock and L is the quantity of labour. The cyclical evolution of the economy, and in particular the economic crisis, has an important influence here (Sirucek &Pavelka, 2013) as financial crisis (Sirucek & Setek, 2023). Technological progress occurs through R&D expenditures, which increase over time. Therefore, A represents the current state of endogenously determined technology (Barro, 1999). This relationship was confirmed by the firm study of Wakelin (2001), which found that a positive and significant role of a firm's own R&D expenditures in influencing productivity growth. Prior research has focused on the effects of R&D investment on economic growth, technological progress or competitiveness.

In the last few years, the direction of research into R&D investments has also focused on environmental impacts. This change of perspective is mainly due to the speed of climate change due to global warming. Carrión-Flores & Innes (2010) in their US-focused study, pointed out that environmental innovation is an important driver of toxic emissions reductions and that tighter pollution targets are spurring investment in environmental innovation. This conclusion at the European Union level is confirmed by García-Álvarez and Moreno (2018), who report that eco-innovation is a key theme in the environmental policies of Member States with excellent environmental performance (Sweden, Austria, Denmark, Italy and Germany). On the contrary, according to Beltrán-Esteve and Picazo-Tadeo (2017) study, the Member States that joined the EU in 2004 are far from the environmental technological frontiers of the EU average and therefore a major boost is needed to catch up with the developed EU countries in field of environmental performance.

A corporate study by Alam et al. (2019) found that R&D investments have a significant negative impact on energy consumption and carbon intensity. The analysis found that investment in R&D improves the environmental performance of the firm. At the same time, a study by Verma et al. (2022) points out that while higher R&D investment improves

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environmental performance, it has a negative impact on firms' financial performance. The question is whether R&D investments have a positive or negative effect on environmental performance in the long run. The term "environmental performance" according to Jahn (1998) describes the level of pollution in a country and its changes over time. This term implies that environmental pollution is a process that can improve or worsen.

Bucher (2016) points out that environmental indicators can generally be divided into two types of indicators: end-of-process indicators, otherwise known as lagged indicators, or in-process indicators, also known as leading indicators. Lagged indicators are easy to quantify and understand; they are preferred by the public and regulators. The main advantages of using lagged indicators are that they are usually easy to quantify and understand and the data are often collected for other business purposes. The main disadvantage is that, as the name suggests, they lag or reflect situations where corrective action can only be taken after the fact. This study will use lagged environmental performance indicators of economies. Every country in the world needs to improve its environmental performance, and this requires looking at data on the factors associated with success in achieving environmental sustainability goals. The main indicator showing environmental performance is The Environmental Performance Index (EPI). This indicator (provides a data-driven summary of the state of sustainability around the world. Using 32 performance indicators across 11 issue categories, the EPI ranks 180 countries on environmental health and ecosystem vitality (Wendling et al., 2020). Measuring environmental performance today does not only look at the macro level but also at the level of regions (Dusek, 2019; Redlichová et al. 2019), municipalities or firms (Mura & Hajduová, 2021; Vrchota et al., 2020).

2 Methods

The paper focuses on how changes in R&D spending affect the evolution of countries' environmental performance. Changes in R&D spending are examined in terms of the Government sector and the Business enterprise sector.

The environmental performance of EU countries is assessed through the EPI aggregate indicator, which is a registered trademark of Yale University. The analysis focuses on all EU countries. The study uses changes over a ten-year period. The EPI results for EU countries were obtained from the results database (https://epi.yale.edu/epi-results/2022/component/epi). The data source for R&D expenditure was Eurostat.

The EU countries were divided according to the change in the structure of their economies over 10 years, i.e. the percentage point change by sector, into 3 groups, namely

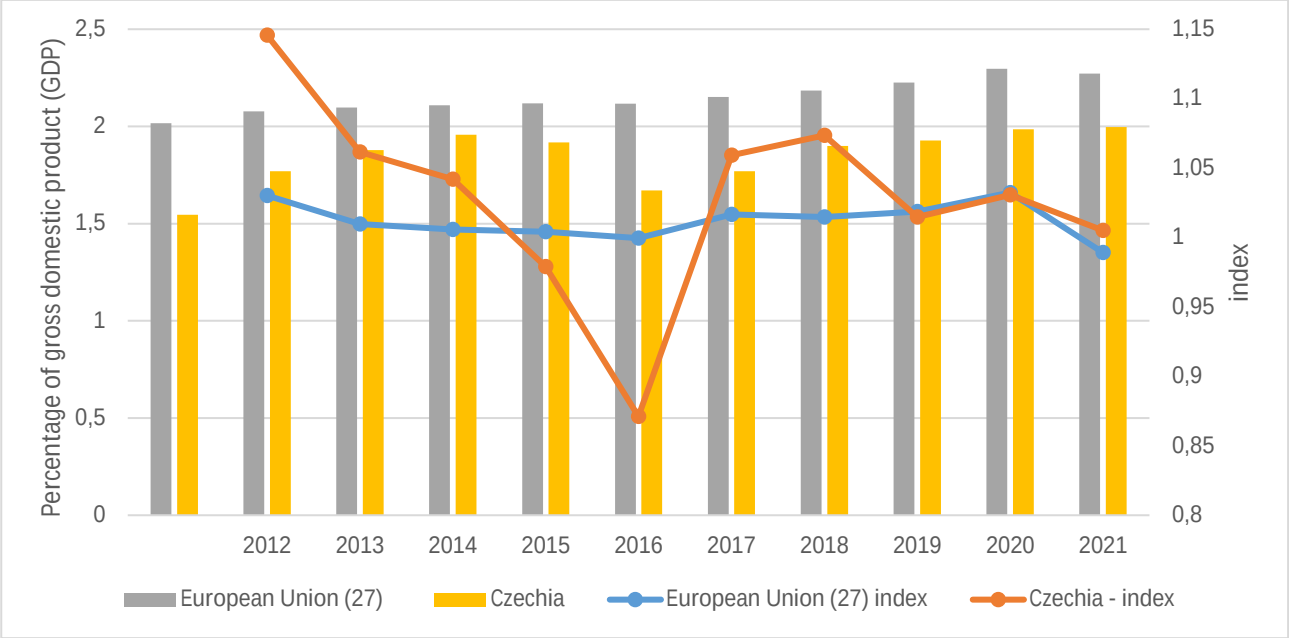
- Negative percentage change (<1),
- a very small change in percentage points (0 - 1),
- positive change in percentage points (>1).

Subsequently, the level and change in the 10-year EPI was assessed for these groups of countries. A correlation matrix (Montgomery & Runger, 2007) was used to test the dependence of each variable.

3 Research results

The first part of the analysis focuses on assessing the importance of R&D expenditure in the EU (27) and in the Czech Republic through the percentage of R&D expenditure in GDP (Figure 1, left y-axis) and the growth rate of R&D expenditure in the EU (27) and in the Czech Republic (Figure 1, right y-axis). Figure 1 shows that the share of R&D expenditure in the Czech Republic does not reach the average level of the EU (27) in any of the years under review. As of 2019, the growth rates of R&D expenditure in the EU (27) and the Czech Republic are almost identical. In the Czech Republic, R&D expenditure has been growing in all years except 2016. In 2016, there was a significant decrease in R&D expenditure in the Czech Republic. This was due to problems with the absorption of R&D expenditure from EU funds.

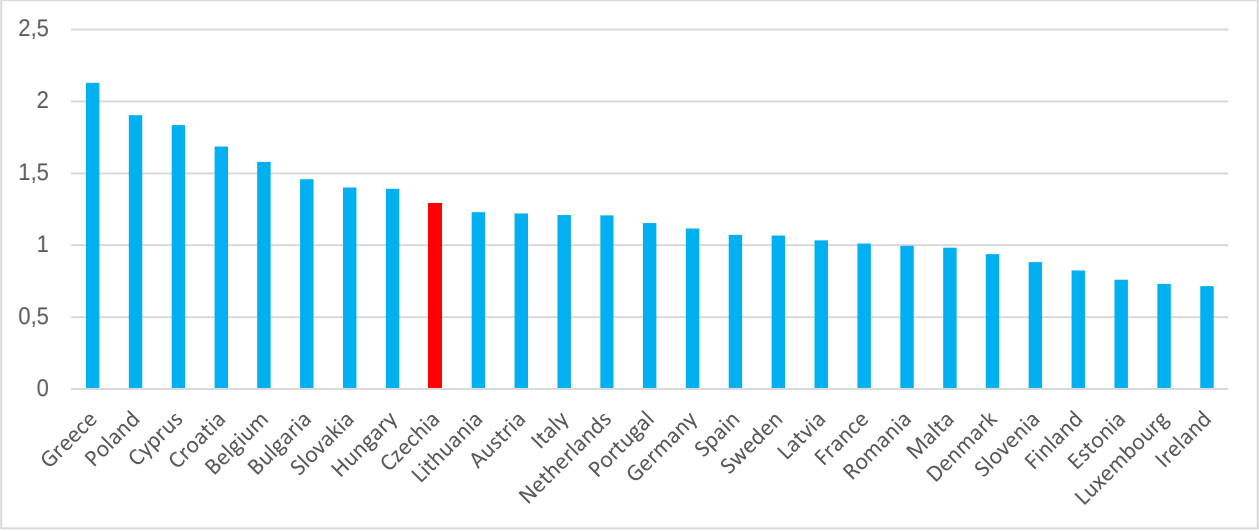
Figure 1 Share of Research and development expenditure (%)



Source: own processing, Eurostat

If we look at the change in R&D expenditure over 10 years (comparing the share of R&D expenditure in GDP in 2021 with 2011), we can see (figure 2) that the largest increase in the share of R&D expenditure is recorded in Greece (2.13 times). In the Czech Republic, there has been a 30% increase over the ten-year period, i.e. a 1.3-fold increase in the share of R&D expenditure in GDP. The R&D expenditure tends to follow the general trend of the business cycle, but is also influenced by sector- and country-specific factors. In sectors that are heavily dependent on technological innovation, the pressure to maintain R&D spending can be higher even in difficult economic times. In sectors that are heavily dependent on technological innovation, the pressure to maintain R&D spending can be higher even in difficult economic times. The different structure of the different EU economies can also be considered as an aspect.

Figure 2 Research and development expenditure – 10 change (index)

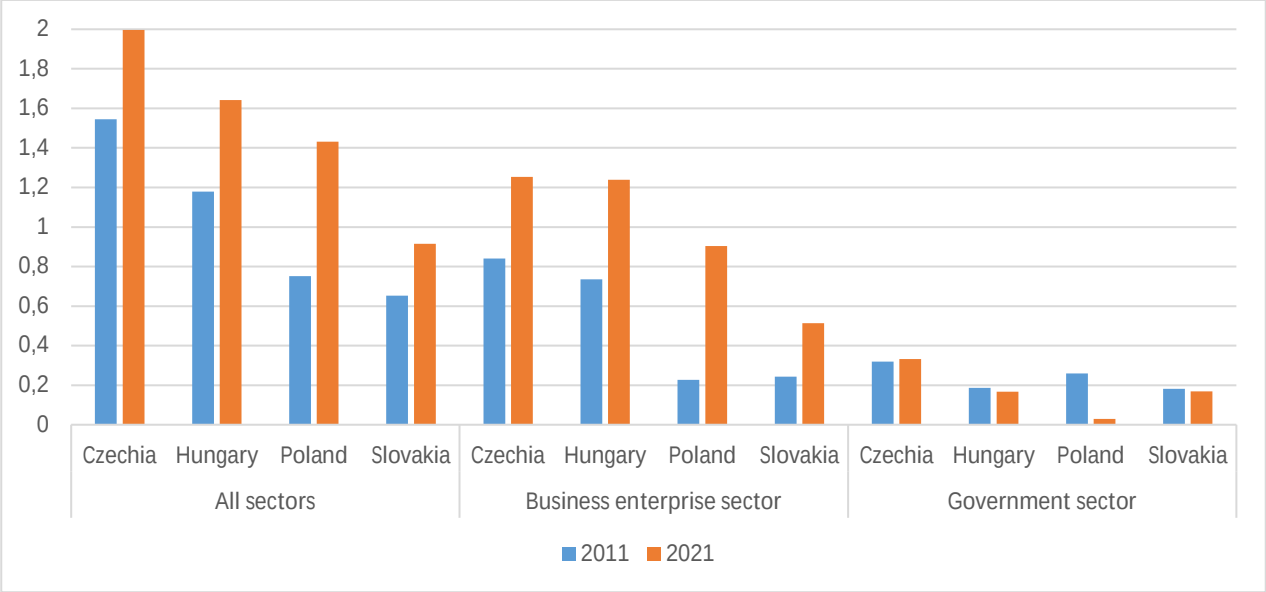


Source: own processing, Eurostat

A more detailed examination focusing only on the Visegrad group (V4) countries reveals (figure 2) that Poland has the highest 10-change in the share of R&D expenditure (0.68 percentage points), followed by Hungary (0.463 percentage points), Czechia and Slovakia. However, the highest share of R&D expenditure in GDP among the V4 countries is achieved by the Czech Republic, followed by Hungary, Poland and Slovakia (figure 3). The 10-change change in R&D expenditure was highest for Poland, which, however, had a low initial level of this indicator. The share of R&D expenditure in GDP provided by the business enterprise sector is highest in the Czech Republic and Hungary. Poland recorded the highest 10-change in this sector (an increase of 0.676 percentage points). The share of R&D expenditure

provided by the Government sector in GDP is again found to be highest in the Czech Republic (about 0.33%), and lowest in Poland (0.029% in 2021), where at the same time there has been a significant decrease in this share over the 10-year period (about 0.231 percentage points).

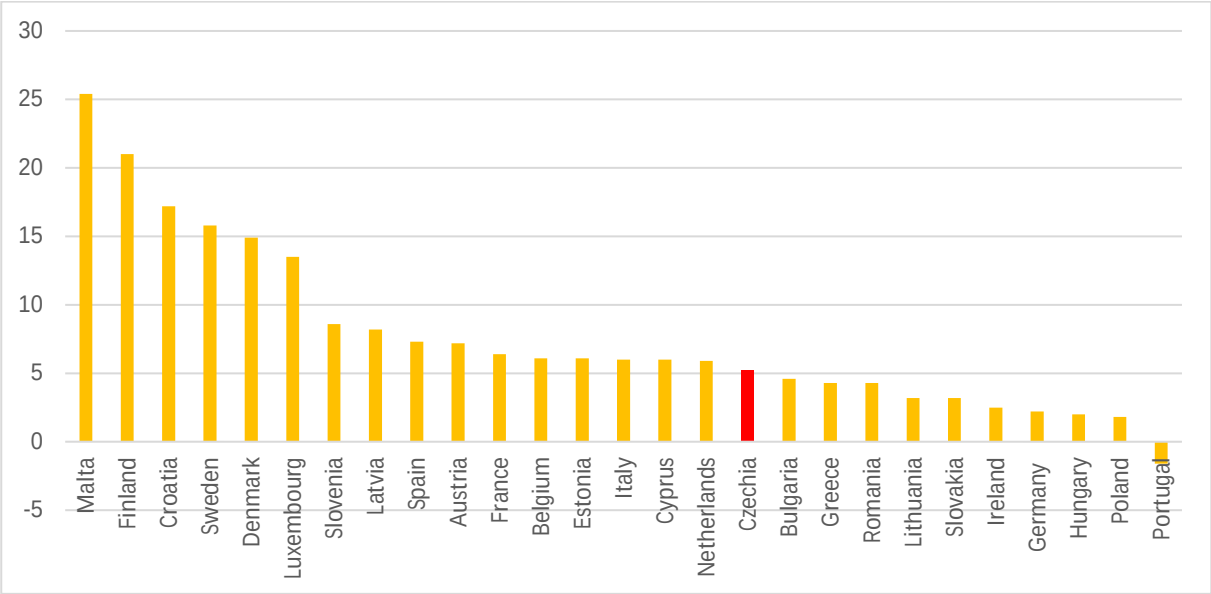
Figure 3 Share of R&D expenditure in GDP in V4 countries in 2011, 2021 (%)



Source: own processing, Eurostat

The next step was to analyse whether the increase in the share of R&D expenditure in GDP is related to the growth of EPI. The authors hypothesised that higher R&D expenditure is related to spending on research on technologies etc. contributing to environmental friendliness and thus leads to an improvement in the EPI. Figure 4 illustrates the 10-change EPI index across EU countries in descending order.

Figure 4 EPI 10 change



Source: own processing, Eurostat

The country of Malta has made the most progress in this area in 10 years, followed by Northern European countries (Finland, Sweden, Denmark) and, surprisingly, Croatia. In the Czech Republic, the EPI increased by 5.2 points. Table 1 focuses on the comparison of the countries with the most significant 10-change (most significant decrease or increase) in the two 10-changes studied. Table 2 offers only the countries with the highest 10-change R&D expenditure per GDP, which also show the lowest 10-change EPI, and conversely the countries with the lowest 10-change R&D expenditure

per GDP and the highest 10-change EPI (antagonistic relationship). The Czech Republic performed at an average level in both observed changes.

Table 1 10-change R&D expenditure to GDP and 10-change EPI (significant changes)

10-change EPI		**10-change Research and development expenditure in GDP (index)**		
Level change	Points	> 1,5	1,5 - 1	<1
high	>10 points			Malta, Finland, Denmark, Slovenia Estonia
medium	10 – 5 points		Czechia, other EU countries	
low	<5 points	Cyprus, Greece, Poland		

Source: own processing, Eurostat

Table 1 then shows that the countries that have seen the highest increase in R&D expenditure as a share of GDP have also shown the lowest progress in EPI. This may be because these states already had a baseline observed level of R&D expenditure to GDP ratio at an above-average level, and so the 10-change is low, but they achieve a significant change in EPI, prioritizing more progress in environmental protection. This inverse proportionality was verified through a correlation matrix (Table 2).

Table 2 10-change R&D expenditure to GDP and 10-change EPI (significant changes)

	p < ,05000 N=25			
	Share R&D on GDP all sector	Share R&D on GDP -Business enterprise sector	Share R&D on GDP -Government sector	EPI - change 10 years
Share R&D on GDP - all sector	1.000000	0.812502	0.281854	-0.208719
Share R&D on GDP - Business enterprise sector	0.812502	1.000000	-0.112435	-0.285819
Share R&D on GDP - Government sector	0.281854	-0.112435	1.000000	0.015334
EPI - change 10 years	-0.208719	-0.285819	0.015334	1.000000

Source: own processing, Eurostat

The assumption of an indirect dependence of the 10-change R&D on GDP on the 10-change EPI was confirmed, but this dependence is very low (this indirect dependence was found for both the 10-change R&D on GDP all sector and the business enterprise sector). To verify this, the number of observations would need to be increased.

4 Conclusions

The study focuses on the link between R&D investment and improving the environmental performance of EU countries. R&D contributes to a more efficient use of natural resources, which reduces negative environmental impacts. Investment in R&D often leads to innovations that can have a positive impact on sustainable development and on addressing environmental challenges, thereby improving environmental performance. The aim of this paper was to assess the correlation between R&D expenditure and improved environmental performance. The study uses changes over a ten-year period. The analysis conducted showed that the states that experienced the highest increase in R&D expenditure as a share of GDP also showed the lowest progress in EPI. This may be because these states already had a baseline observed level of R&D expenditure to GDP ratio at an above average level, and thus the 10-change is low, but they are achieving a significant change in EPI, prioritizing more progress in environmental protection. These countries include in particular Northern European countries such as Sweden (Weiss & Anisimova, 2019). Another analysis focused on the assumption of an indirect dependence of 10-change R&D on GDP on 10-change EPI was confirmed, but this dependence is very low. A study by García-Álvarez and Moreno (2018) recommends that countries with low environmental performance should implement the environmental policies of EU countries with superior environmental performance. Environmental innovation is a key focus of environmental policies in these states. Overall, R&D investments have the potential to play a key role in improving the environmental performance of countries while contributing to sustainable development in various sectors of the national economy. Investments in R&D should not be forgotten as they are investments in the future that can bring many economic, social or environmental benefits.

References

Alam, M. S., Atif, M., Chien-Chi, C., & Soytaş, U. (2019). Does corporate R&D investment affect firm environmental performance? Evidence from G-6 countries. *Energy Economics*, 78, 401–411. DOI 10.1016/j.eneco.2018.11.031.

Barro, R. J. (1999). Notes on growth accounting. *Journal of economic growth*, 4, 119-137.

Beltrán-Esteve, M., & Picazo-Tadeo, A. J. (2017). Assessing environmental performance in the European Union: Eco-innovation versus catching-up. *Energy Policy*, 104, 240–252. DOI 10.1016/j.enpol.2017.01.054.

Bucher, S. (2016). Measuring of Environmental Performance Index in Europe. *Rocznik Ochrona Srodowiska*, 18(1), 46–64.

Carrión-Flores, C. E., & Innes, R. (2010). Environmental innovation and environmental performance. *Journal of Environmental Economics and Management*, 59(1), 27–42. DOI 10.1016/j.jeem.2009.05.003.

Dusek, J. (2019). Autarky indicator as a benchmarking tool for the public sector (on the example inter-municipal cooperation in the South Bohemian Region). In Klimova, V and Zitek, V (Ed.). *International Colloquium On Regional Sciences*, 329–337.

García-Álvarez, M. T., & Moreno, B. (2018). Environmental performance assessment in the EU: A challenge for the sustainability. *Journal of Cleaner Production*, 205, 266–280. DOI 10.1016/j.jclepro.2018.08.284.

Jahn, D.. (1998). None. Policy Sciences, 31(2), 107–131. DOI 10.1023/a:1004385005999.

Mura, L., & Hajduova, Z. (2021). Measuring efficiency by using selected determinants in regional SMEs. *Entrepreneurship and Sustainability issues*, 8(3), 487–503. DOI 10.9770/jesi.2021.8.3(31).

Montgomery, D. C., & Runger, G. C. (2007). Applied statistics and probability for engineers. Hoboken, NJ: Wiley.

Redlichova, R., Chmelikova, G., Blazkova, I., & Tamas, V. (2019). Role of Companies' Size in Socio-Economic Development of Regions in The Czech Republic. Ekonomski Pregled, 70(6), 833–848. DOI 10.32910/ep.70.6.2.

Sirucek, P., & Pavelka, T. (2013). Youth unemployment in the Czech Republic and the impact of economic crisis. in t. Loster & t. Pavelka (eds.), 7th international days of statistics and economics, 1278–1287. Univ Econ, Dept Stat & Probabil; Univ Econ, Dept Microeconom; Univ Econ, Fac Business Econ; Ceska Sporitelna; ESC Rennes Int Sch Business.

Sirucek, P., & Setek, J. (2023). Nositelé Nobelovy ceny za ekonomii pro rok 2022. Politická ekonomie, 71(2), 226-237. DOI 10.18267/j.polek.1383.

Solow, R. M. (1956). A contribution to the theory of economic growth. The quarterly journal of economics, 70(1), 65-94.

Verma, R., Sharma, D., & Priyanka. (2022). Vztah mezi environmentální výkonností, výdaji na výzkum a vývoj a finanční výkonností: Důkazy od indických výrobních firem. Global Business Review , 23 (6), 1316-1335. DOI 10.1177/09721509221129565.

Vrchota, J., Maříková, M., & Řehoř, P. (2020). Teleworking in SMEs before the onset of coronavirus infection in the Czech Republic. *Management: Journal of Contemporary Management Issues*, 25(2), 151-164.

Wakelin, K. (2001). Productivity growth and R&D expenditure in UK manufacturing firms. Research Policy, 30(7), 1079–1090.

Weiss, J. F., & Anisimova, T. (2019). The innovation and performance effects of well-designed environmental regulation: Evidence from Sweden. Industry and Innovation, 26(5), 534–567.

Wendling, Z. A., Emerson, J. W., de Sherbinin, A., Esty, D. C., Hoving, K., Ospina, C., Murray, J., Gunn, L., Ferrato, M., & Schreck, M. (2020). Environmental performance index. New Haven, CT: Yale Center for Environmental Law And Policy. epi. yale. edu.