Economic Growth and Investment in R&D: Contemporary Challenges for the European Union
Rūta Banelienė and Borisas Melnikas

ABSTRACT

This paper presents new approaches to investigating economic growth and innovation activity as well as analyzing investment in R&D needs and efficiency in the context of contemporary challenges for European integration. Our research modeled the impact of R&D investment on GDP growth under broad conditions of globalization. In addition to capital and labor factors, we took into account factors that influence climate change, keeping in mind their relation to economic activity. Additionally, we paid particular attention to other factors driving sustainable economic growth, such as consumption of scarce resources as well as inequality and poverty. Herein, we proposed new modeling conceptions for evaluating the impact of R&D investment on economic growth. The suggested method was adapted to analyze the case of development processes in the European Union. Our research confirmed the hypothesis that R&D expenditure has a positive impact on economic growth, and the impact is much higher in well-developed EU economies under conditions of sustainable economic development and globalization. The research was based on the case of the European Union economies. The panel least squares method was applied for the modeling and estimations.

KEY WORDS: economic growth, R&D investment, European Union, sustainable development.

JEL Classification: A10, E17, F01, F39, O39.

Vilnius Gediminas Technical University, Lithuania

1. Introduction

Economic growth processes and their acceleration are widely perceived to be essential in solving current social and economic problems and improving the quality of social and economic life in the context of the contemporary challenges of globalization and European integration. Therefore, priority should be given to problems, needs and opportunities in activating economic growth.

Innovation and innovation stimulation, as well as related economic policy decisions, are a very wide and complex area of practice and scientific study. This area could be considered particularly difficult: in the real world, innovation research has to constantly respond to new and increasingly complex challenges arising from globalization and growth in international competition, and existing early-stage scientific knowledge is becoming inadequate for rapidly changing needs.

One of the most complicated and essential issues requiring both serious scientific research and knowledge, as well as informed economic policy decisions, is the role of R&D investment and its impact on economic growth. Answering this question requires the ability to measure the impact of R&D investment on economic growth properly, purposefully and comprehensively.
The answer determines the ability to select in a well-grounded way the most viable and highest-priority directions for innovation activity and, at the same time, develop and implement effective economic policy decisions.

These objectives could be furthered by comprehensive modeling of various investments in R&D processes and alternatives, including the specific contexts of different countries and regions.

In turn, relevant instruments must be developed and used with an eye toward understanding and solving a double-faceted scientific and practical problem: (a) R&D investment needs and the impact of R&D on economic growth are not properly taken into account in either current innovation stimulation practices and activity or economic policy development and implementation, and (b) R&D investment modeling often does not adequately reflect the specificities of the situation in different countries and regions.

Obviously, this problem is important in both scientific and practical terms, especially under the contemporary conditions of social and economic development in the European Union. There are many specific challenges that are especially relevant in achieving priority goals in social development, enhancing economic growth and R&D investment efficiency, and increasing competitiveness in the EU.

This problem could be analyzed and solved in two directions by (a) analyzing and prioritizing innovation activity and investment in R&D processes, taking into account the contemporary challenges for social and economic development and technological progress in the EU and (b), analyzing and improving the assessment and modeling of the impact of R&D investment on economic growth, especially under the current development conditions in the European Union.

This paper presents a theoretical investigation and the results of empirical research in these directions in more detail.

2. Theoretical Approach and Empirical Background

Research on economic growth processes and scientific and technological progress, enhancement, and acceleration covers a wide range of topics and issues (Spetzler et al., 2016). This research has become essential—especially under the current conditions of globalization, European integration and development of knowledge-based societies and knowledge economies—and should focus on the following:

— orientation towards solving the progress problems that are most important for contemporary societal development (Boldrin & Canova, 2001; Calori et al., 1999; Chortareas & Pelagidis, 2004; Currie, 2000; Drews et al., 2018; Garrett & Mitchell, 2001; Grace & Butler, 2005; Hayo & Seifert, 2003; Huseman & Godman, 1999; Krugman & Obstfeld, 1997; Leydesdorff, 2004; Melnikas, 2002, 2011, 2013; Melnikas & Reichelt, 2004; Perraton, 2001; Rosenzweig, 2001; Steinmueller, 2002; Tomaselli et al., 2019);

— development of conditions, assumptions, and effective tools, measures, and applications to purposefully enhance social and economic prosperity, scientific and technological progress, and economic growth (Alexiou et al., 2018; Armstrong, 2006; Carlaw & Lipsey, 2003; David & Foray, 2002; Ein-Dor et al., 2004; Feng & Ji, 2018; Hummels et al., 2001).

The following particularly significant social and economic problems could be defined in contemporary society, especially the EU:

— limited supply and efficient use of raw materials and energy resources. These problems are particularly relevant in the EU and the European Economic Area in general because the European economy is heavily dependent on natural raw material and energy imports.

At the EU level, the following 20 raw materials (European Commission, 2014) were listed as critical for the EU because the risk of supply shortages and the resulting impacts on the economy is higher than for most other raw materials: antimony, beryllium, borates, chromium, cobalt, coking coal, fluor spar, gallium, germanium, indium, magnesite, magnesium, natural graphite, niobium, phosphate rock, platinum group metals, heavy and light rare earth elements, silicon, and wolfram (for which China is the most influential country in terms of global supply).

Additionally, the EU is highly dependent on imports of energy products. According to Eurostat (2019a), the EU-28’s dependency on energy imports increased from slightly more than 44% of gross available energy in 1990 to 52.9% in 2007 and then to 55.1% by 2017. Since 2004, the EU-28’s net imports of energy...
have been greater than its primary production; in other words, more than half of its gross available energy was supplied by net imports. The situation is much more critical in the cases of oil and petroleum products, where the dependency rate was 86.7% in 2017, and natural gas, where the dependency rate was 74.3%. According to Eurostat (2019b), crude oil is the largest imported energy product (70% of total EU energy imports in the first half of 2018), ahead of natural gas in the gaseous state (19%). Russia and Norway are the largest suppliers of petroleum and natural gas to the EU: In 2018 Russia provided 27.9% and 41.5% by net mass of all EU petroleum and natural gas imports, respectively, and Norway 10.9% and 32.7%.

— Problems of social, economic, and ecological development sustainability, including economic growth and focusing adequately on the needs for social stability and high quality of life throughout the process of economic development. These problems are particularly relevant in the context of growing social and economic disparities in the world, including contemporary European society.

According to the Eurostat report (2016a) on achieving targets set in the Europe 2020 strategy, almost every fourth person in the EU remained at risk of poverty or social exclusion in 2014. Therefore, the challenge of fighting poverty is still on the EU policy agenda. The situation is better in the field of environmental protection, where EU achievements are significant. In 2014, EU greenhouse gas emissions were down by 23.0% compared to 1990 levels. The EU is thus expected to exceed its Europe 2020 target of reducing greenhouse gas (GHG) emissions by 20% by 2020. However, the average global surface temperature continues to rise, with 2015 being the warmest year on record, and climate change is still a global, not regional, problem.

— New competition and competitiveness problems arising in the context of contemporary globalization and economic internationalization. Particularly significant are the problems caused by excessive differences in productivity, purchasing power and economic and business conditions in different regions and countries, including in different regions and countries of the European Union. According to Eurostat (2019c; 2019d), in 2018, labor productivity per working hour in the EU varied from 46.2% of the EU-28 average in Bulgaria to 177.3% in Ireland; compensation of employees per hour worked varied from €5.5 in Bulgaria to € 46.6 in Luxemburg.

— A rising gap between expectations and opportunities to realize them in many areas of social and economic life. They create preconditions for conflicts and unsustainable development in many areas of social and economic life, in various economic and business sectors and in many regions and countries.

It is obvious that the solutions to these problems should be based on innovations and scientific and technological tools, measures and capabilities oriented towards:

— finding and implementing various alternatives for efficient use of scarce raw materials and energy resources (Voudouris et al., 2015);

— implementing sustainability goals, in particular achieving sustainable social, economic and ecological development (Bond et al., 2001; Drews et al., 2018; Kim & Shin, 2002; Liu et al., 2019; Olsen & Osmundsen, 2003; Ott & Soretz, 2018; Ouyang et al., 2019);

— achieving a high level of competitiveness in all areas of economic activity, as well as implementing various ambitious quality, prosperity and social comfort standards (Hofbauer, 2003; Hunt, 2000; Melnikas & Reichelt, 2004);

— reducing social and economic disparities and eliminating the preconditions for various kinds of conflict and exclusion (De Dominicis, 2014; Dell’Anno & Amendola, 2015; Caraballo et al., 2017; Ghose, 2004; Goeransson & Soederberg, 2005).

These needs and aspirations to solve the social, economic and other problems described underline the priority of developing conditions and assumptions and preparing effective tools and measures for use in purposeful social and economic development, economic growth and scientific and technological progress. These priorities reflect the prospects for R&D activities, scientific and technological progress, and research in social and economic development and economic growth in general (Melnikas, 2011, 2014).

The basic concept is to assess the impact of R&D investment on economic growth, which could allow rational identification of R&D investment needs and priorities. An investment in the identification of R&D priorities could be defined as the first crucial phase in the multilevel processes of initiation and enhancement of economic growth and social and economic develop-
ment–oriented innovations.

These circumstances illustrate the necessity of the impact of R&D investment on economic growth assessment and modeling, taking into account contemporary conditions.

This impact, as well as the main estimation results based on modeling the impact for European Union economies, is presented in this paper in more detail.

3. Methodology: Model and Data

The model is based on the theoretical approach described in the previous section and focuses on economic growth, which could be driven by:

1. The indicators set in the Europe 2020 strategy, which are in line with five major directions for enhancing EU competitiveness: employment, R&D investment, climate/energy targets, education, and fighting poverty; and
2. Indicators covering the broader innovation and economic growth context: intellectual property rights protection, material consumption, and inequality.

The major idea was to develop a model for evaluating R&D investment impact on economic growth in the European Union by using indicators that reflect contemporary challenges for the European Union under sustainable economic development and globalization conditions.

Therefore, indicators are divided into four separate fields: capital indicators, labor and labor force quality indicators, intellectual property protection indicators, and sustainability indicators, which are based on the idea of sustainable societal and environmental development, including management of scarce resources.

For modeling, we used annual Eurostat data for the EU-28 countries for the period 2007–2016 (Eurostat 2016b). In the field of capital indicators, we used Eurostat data on R&D investment, including separate data on business investment. These indicators are in line with the directions of the Europe 2020 strategy. Additionally, Eurostat data used in the category of labor and labor force quality included the employment rate, early leavers from education and training, and tertiary educational attainment, which related to targets set in Europe 2020 strategy as well; other indicators, such as persons with tertiary education and/or employed in science and technology, and persons employed in science and technology, are closely related to enhancing innovation.

With the intention of better reflecting the real innovation environment, we also used other Eurostat data on patent applications to the European Patent Office (EPO) and sustainability indicators on climate and energy, inequality, and poverty, which also reflect the directions of the Europe 2020 strategy. Additionally, as mentioned in the Theoretical Approach section, where we discussed scarce materials and effective consumption, we used the domestic material consumption indicator provided by Eurostat for modeling. In addition, we used a few indicators calculated by the World Bank (GINI index) and NASA (annual European temperature deviation) (see Figure 1). All data were expressed per capita or as share of the total to estimate the impact of the independent variables on GDP per capita.

Hypothesis: R&D expenditure has a positive impact on economic growth, and its impact is higher in well-developed economies under conditions of sustainable economic development and globalization.

Our target is to make a broader estimation focusing on the innovation environment and impact on GDP growth by using a wider spectrum of data on sustainable economic growth.

The major equation of our model uses R&D investment as the major indicator whose impact on GDP is estimated. Our model uses early leavers from education and training (ELET) as a labor force quality indicator. As independent environmental variables, the model includes domestic material consumption (DMC) per capita in tons and greenhouse gas emissions (GHGE) per capita. Finally, one of two poverty indicators is used for modeling in separate equations: mean equivalized net income (MENI) in euros is used as the independent variable in the main equation; in another equation, the inability to face unexpected financial expenses (IFUFE) is the independent variable used. Other indicators, provided in Table 1, are also used for the modeling process but extracted from the equations due to their insignificance or better representation of other indicators in the same field.
Table 1. Variables description.

| Variable   | Description                                                                 |
|------------|----------------------------------------------------------------------------|
| GDP/capita | Gross domestic product at market prices in euros per capita                |
| R&D/capita | Total intramural R&D expenditure in euros per inhabitant                  |
| R&DB/capita | R&D expenditure of business enterprise sector in euros per inhabitant      |
| ER     | Employment rate, age group 20–64                                           |
| ELET    | Early leavers from education and training, % of the population aged 18–24   |
| TEA     | Tertiary educational attainment, % of the population aged 30–34             |
| PTEEST  | Persons with tertiary education and/or employed in science and technology, % of total employment |
| PEST    | Persons employed in science and technology, % of total employment           |
| PA      | Patent applications to the European Patent Office (EPO) per million inhabitants |
### Table 1. Variables description (Continued).

| Variable | Description |
|----------|-------------|
| PA       | Patent applications to the European Patent Office (EPO) per million inhabitants |
| DMC/capita | Domestic material consumption per capita in tons |
| GHGE/capita | Greenhouse gas emissions per capita in units of CO2 equivalents |
| RE       | Share of renewable energy in gross final energy consumption |
| AETD     | Annual European temperature deviation (GIStEMP; from NASA Goddard Institute for Space Studies) |
| GINI     | GINI index |
| IFUFE    | Inability to face unexpected financial expenses, % of persons in the total population who are in the state of enforced inability to face unexpected financial expenses. |
| MENI     | Mean equivalized net income, in euros per person in household |

### Table 2. Review regression estimation: case of low GDP.

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|----------|-------------|------------|-------------|-------|
| C        | 13075.31    | 1279.887   | 10.21599    | .0000 |
| R&D/capita | 6.561917   | 1.097982   | 5.976341    | .0000 |
| ELET     | -115.2338   | 22.56934   | -5.105766   | .0000 |
| DMC/capita | 274.2973   | 21.97771   | 12.48071    | .0000 |
| GHGE/capita | -429.8853 | 83.15100   | -5.169935   | .0000 |
| MENI     | 0.661375    | 0.059637   | 11.09007    | .0000 |
The main equation of our model, reflecting the estimation conditions for lower GDP per capita, is:

\[
\frac{GDP}{capita} = c + \frac{R&D}{capita} + ELET + \frac{DMC}{capita} + \frac{GHGE}{capita} + MENI + \epsilon 
\tag{1}
\]

The second equation, reflecting the estimation conditions for higher GDP per capita, is:

\[
\frac{GDP}{capita} = c + \frac{R&D}{capita} + ELET + \frac{DMC}{capita} + \frac{GHGE}{capita} + IFUFE + \epsilon 
\tag{2}
\]

where GDP/capita is gross domestic product at market prices per capita in euros; R&D/capita is total intramural R&D expenditure in euros per inhabitant; ELET is the labor force quality indicator of early leavers from education and training (% of the population aged 18-24); and the three sustainable economic growth indicators for material consumption, climate and energy, and poverty are, respectively, DMC/capita (domestic material consumption per capita in tons), GHGE/capita (greenhouse gas emissions per capita), and MENI (mean equivalized net income in euros). In the estimation in equation 2, MENI is replaced by the poverty indicator IFUFE (inability to face unexpected financial expenses).
4. Results
The panel least squares method with cross-section weights and fixed cross-section variables (dummy variables) was used for the estimations. We used annual data from the period 2007–2016 for 28 European Union countries with 280 observations. Modeling was done using the Eviews10 program.

The modeling results prove our hypothesis that R&D expenditure has a strong positive impact on GDP growth and a higher impact in well-developed economies under conditions of sustainable economic development and globalization.

When the GDP per capita starting point is 13,075 euros, every euro per capita invested in R&D will increase GDP per capita by 6.6 euros (see equation 3 and the modeling results provided in Table 2).

\[
\frac{GDP}{capita} = 13075.31 + 6.5619 \frac{R&D}{capita} - 115.2338 ELET + 274.2973 \frac{DNC}{capita} - 429.8853 \frac{GHGE}{capita} + 0.6614 MENT + \epsilon
\]  

(3)

R-squared (R²) = 0.9964; adjusted R-squared (R²) = 0.9959; D-W = 1.2543.

In addition, the modeling results show a positive impact of labor force quality growth by decreasing the level of early leavers from education and training. The sustainability indicators have a positive impact on economic growth, as the domestic material consumption per capita is in line with the logic that to produce higher gross added value, which is part of GDP and has an impact on GDP growth, more materials could be needed. The other indicator that is important for modeling is greenhouse gas emissions per capita, which has a positive impact on GDP growth by shrinking the value of GDP per capita growth due to strict EU rules on environmental protection. The last sustainability indicator in the equation reflects sustainable development of society and has a positive impact on GDP growth by reducing the share of people who are unable to face unexpected financial expenses (see equation 4 and the modeling results provided in Table 3).

Our modeling proved the hypothesis that the multiplication effect of R&D expenditure on economic growth is higher in well-developed economies under conditions of sustainable economic development and globalization and has half the impact on GDP growth in EU economies where the GDP level is near 13 thousand euro per capita in comparison to economies whose GDP starting point is twice as high. In other words, each euro per capita invested in R&D in Bulgaria, Romania, Croatia, Poland, Hungary and Latvia, where GDP per capita is below 13 thousand euros (see Appendix A) will have a high impact on GDP growth (one euro per capita invested in R&D will increase GDP per capita by 6.6 euros), but this will be half the impact of R&D investment in well-developed EU economies where GDP per capita reaches 26,000 euros, such as Italy and France.

5. Conclusions and Discussion
The developed concept of assessing and modeling the impact of R&D investment on economic growth could be successfully used in various analyses of the situation
Table 3. Review regression estimation: case of higher GDP.

| Variable      | Coefficient | Std. Error | t-Statistic | Prob.  |
|---------------|-------------|------------|-------------|--------|
| C             | 26468.35    | 2138.056   | 12.37964    | .0000  |
| R&D/capita    | 13.08776    | 1.590171   | 8.230414    | .0000  |
| ELET          | -165.1856   | 24.79300   | -6.662588   | .0000  |
| DMC/capita    | 294.5110    | 25.15382   | 11.70840    | .0000  |
| GHGE/capita   | -757.6589   | 106.0518   | -7.144235   | .0000  |
| IFUFE         | -68.93342   | 13.31886   | -5.175624   | .0000  |

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

| R-squared     | 0.995929    | Mean dependent var | 42773.59  |
| Adjusted R-squared | 0.995402    | Standard deviation dependent var | 26589.12  |
| Standard error of regression | 1616.601    | Sum squared resid | 6.46E+08  |
| F-statistic   | 1888.294    | Durbin-Watson stat | 1.133436  |
| p(F-statistic)| 0.000000    |                      |          |

Unweighted Statistics

| R-squared     | 0.988499    | Mean dependent var | 25367.14  |
| Sum squared resid | 8.85E+08    | Durbin-Watson stat | 0.653776  |
of the European Union economy. This concept would make it possible to identify in detail and justify innovation activities and R&D investment priorities in accordance with the needs of economic growth and sustainable social, environmental and economic development.

Our modeling under conditions of sustainable economic development and globalization proved the hypothesis that the multiplication effect of R&D expenditure on economic growth is higher in well-developed economies and has half as much impact on GDP growth in EU economies where the GDP level is low (near 13 thousand euros per capita). In other words, each euro per capita invested in R&D in Bulgaria, Romania, Croatia, Poland, Hungary and Latvia (where GDP per capita is below 13 thousand euros) will have a high impact on GDP growth (one euro per capita invested in R&D will increase GDP per capita by 6.6 euros), but this will be half the impact of investment in R&D in well-developed economies where GDP per capita reaches 26 thousand euros, such as Italy and France.

Further research and comprehensive analysis of the processes of R&D investment and an integrated analysis of the processes of economic growth in the European Union are considered important preconditions for solving contemporary problems, enhancing social and economic development, and advancing science and technology.

References
Alexiou, C., Vogiazas, S., & Nellis, J. G. (2018). Reassessing the relationship between the financial sector and economic growth: Dynamic panel evidence. *International Journal of Finance & Economics*, 23(2), 155–173. https://doi.org/10.1002/ijfe.1609

Armstrong, M. (2006). *A handbook of human resource management practice*. Kogan Page Ltd.

Boldrin, M. & Canova, F. (2001). Inequality and convergence in Europe’s regions: reconsidering European regional policies. *Economic Policy*, 16(32), 206–253.

Bond, E. W., Syropoulos, C., & Winters, L. A. (2001). Deepening of regional integration and multilateral trade agreements. *Journal of International Economics*, 53(2), 335–361. https://doi.org/10.1016/S0022-1996(00)00064-7

Buede, D.M. & Miller, W.D. (2016). *The engineering design of systems: Models and methods*. John Wiley and Sons, Inc.

Burns, P. (2016). *Entrepreneurship and small business: start-up, growth and maturity*. Palgrave Macmillan.

Calori, R., Atamer, T., & Nunes, P. (2000). *The dynamics of international competition: from practice to theory*. Sage Publications.

Caraballo, M.A., Dabus, C., & Delbianco, F. (2017). Income inequality and economic growth revisited. *Journal of International Development*, 29, 1025–1029. https://doi.org/10.1002/jid.3300

Carlaw, K.I. & Lipsey, R.G. (2003). Productivity, technology and economic growth: What is the relationship? *Journal of Economic Surveys*, 17(3), 457–495. https://doi.org/10.1111/1467-6419.00201

Chortareas, G. E. & Pelagidis, T. (2004). Trade flows: a facet of regionalism or globalisation? *Cambridge Journal of Economics*, 28(2), 253–271. https://doi.org/10.1093/cje/28.2.253

European Commission. (2014). The review of the list of critical raw materials for the EU and the implementation of the raw materials initiative. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014DC0297

Currie, W. (2000). *The global information society*. John Wiley & Sons.

David, P. A. & Foray, D. (2002). An introduction to the economy of the knowledge society. *International Social Science Journal*, 54(171), 9–23. https://doi.org/10.1111/1468-2451.00355

De Dominicis, L. (2014). Inequality and growth in European regions: Towards a place-based approach. *Spatial economic analysis*, 9(2), 120–141. https://doi.org/10.1080/17421772.2014.891157

Dell’Anno, R. & Amendola, A. (2015). Social exclusion and economic growth: An empirical investigation in European economies. *The Review of Income and Wealth*, 61(2), 274-301. https://doi.org/10.1111/roiw.12096

Drews, S., Antal, M., & Van den Bergh, J. C. J. M. (2018). Challenges in assessing public opinion on economic growth versus environment: considering European and US data. *Ecological Economics*, 146, 265–272. https://doi.org/10.1016/j.ecolecon.2017.11.006

Ein-Dor, P., Myers, M., & Raman, K.S. (2004). IT
industry and the knowledge economy: A four country study. *Journal of Global Information Management, 12*(4), 23–49. https://doi.org/10.4018/jgim.2004100102

European Commission. (2010). Europe 2020 A strategy for smart, sustainable and inclusive growth. Retrieved from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF

Eurostat. (2016a). Smarter, greener, more inclusive? Indicators to support the Europe 2020 strategy. Luxembourg: *Publications Office of the European Union.*

Eurostat (2016b). Data: GDP per capita, intramural R&D expenditure per capita, intramural R&D expenditure per capita in business enterprise sector, employment rate, early leavers from education and training, tertiary educational attainment, persons with tertiary education and/or employed in science and technology, persons employed in science and technology, patent applications to the EPO, domestic material consumption per capita, greenhouse gas emissions per capita, share of renewable energy in gross final energy consumption, inability to face unexpected financial expenses, and mean equivalized net income; annual European temperature deviation (GISTEMP; from NASA Goddard Institute for Space Studies). Retrieved January 31, 2019, from http://ec.europa.eu/eurostat/data/

Eurostat. (2019a). Energy production and imports data. Retrieved from: https://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_production_and_imports

Eurostat. (2019b). EU imports of energy products - recent developments. Retrieved from: https://ec.europa.eu/eurostat/statistics-explained/index.php/EU_imports_of_energy_products_-_recent_developments

Eurostat. (2019c). Labour productivity and unit labour costs. Retrieved from https://ec.europa.eu/eurostat/web/products-datasets/product?code=nama_10_lp_ulc

Eurostat. (2019d). Labour productivity per person employed and hour worked. Retrieved from https://ec.europa.eu/eurostat/databrowser/view/tesem160/default/table?lang=en

Farnsworth, K. (2005). Promoting business-centred welfare: International and European business perspectives on social policy. *Journal of European social policy, 15*(1), 65–80. https://doi.org/10.1177/0958928705049163

Feng, F. & Ji, X. (2018). An empirical study on economic growth driving forces in onshore area. *Journal of coastal research*, Special Issue, 83(sp1), 204–211. https://doi.org/10.2112/SI83-032.1

Garrett, G. & Mitchell, D. (2001). Globalization, government spending and taxation in the OECD. *European Journal of Political Research, 39*(2), 145–177. https://doi.org/10.1111/1475-6765.00573

Ghose, A. K. (2004). Global inequality and international trade. *Cambridge journal of economics, 28*(2), 229–252. https://doi.org/10.1093/cje/28.2.229

Göransson, B. & Söderberg, J. (2005). Long waves and information technologies—On the transition towards the information society. *Technovation, 25*(3), 203–211. https://doi.org/10.1016/S0166-4972(03)00115-9

Grace, A. & Butler, T. (2005). Beyond knowledge management: Introducing learning management systems. *Journal of cases on information technology, 7*(1), 53–70. https://doi.org/10.4018/jcit.2005010104

Hayo, B. & Seifert, W. (2003). Subjective economic well-being in Eastern Europe. *Journal of economic psychology, 24*(3), 329–348. https://doi.org/10.2139/ssrn.304041

Holbauer H. (2003). Ost Erweiterung: vom Drang nach Osten zur peripheren EU-Integration. Promedia.

Hummels, D., Ishii, J., & Yi, K. M. (2001). The nature and growth of vertical specialization in world trade. *Journal of international economics, 54*(1), 75–96. https://doi.org/10.1016/S0022-1996(00)00093-3

Hunt, S.D. (2000). *A General theory of competition: resources, competences, productivity.* Sage Publications.

Huseman, R. C. & Goodman, J. P. (1999). The emergence and growth of the knowledge economy. *Leading with knowledge: the nature of competition in the 21st century.* Sage Publications, Inc. http://dx.doi.org/10.4135/9781452220673

Kim, S. & Shin, E. H. (2002). A longitudinal analysis of globalization and regionalization in international trade: A social network approach. *Social
Krugman, P. & Obstfeld, M. (1997). *International Economics.* Addison Wesley Longman.

Leydesdorff, L. (2004). The university–industry knowledge relationship: Analyzing patents and the science base of technologies. *Journal of the association for information science and technology,* 55(11), 991–1001. https://doi.org/10.1002/asi.20045

Liu, X., Wen, T., Liu, S., & Zhong, X. (2019). Evaluating economic growth efficiency and its determinants under low carbon economy in the Chinese context. *Applied ecology and environmental research,* 17(3), 6429–6444. http://dx.doi.org/10.15666/aeer/1703.64296444

Melnikas, B. (2011). *Transformation society: Economy, culture, innovation, internationalization processes.* Technika.

Melnikas B. (2013). *Žinimis grindžiamos visuomenės kūrimas: globalizacija, darni plėtra, ekonominiai sprendimai* [Building a knowledge society: globalization, sustainable development, economic solutions]. Vilniaus universiteto leidykla.

Melnikas, B. (2017). Development of global economy and international business: New network and networking ideas. *International Business and Global Economy,* 36, 21–30. https://doi.org/10.4467/23539496IB.17.001.7449

Melnikas, B. & Reichelt, B. (2004). *Wirtschaft und Mentalitäten: Tendenzen der EU-Osterweiterung [Economy and Mentalities: Tendencies of the EU Enlargement].* Lefim–Verlag.

Mougayar, W. (2016). *The Business blockchain: promise, practice, and application of the next internet technology.* John Wiley & Sons, Inc.

Olsen, T. E. & Osmundsen, P. (2003). Spillovers and international competition for investments. *Journal of international economics,* 59(1), 211–238. https://doi.org/10.1016/S0022-1996(02)00086-7

Ott, I. & Soretz, S. (2018). Green attitude and economic growth. *Environmental and resource economics,* 70(4), 757–779. https://doi.org/10.1007/s10640-016-0061-z

Ouyang, X., Shao, Q., Zhu, X., He, Q., Xiang, Ch. & Wei, G. (2019). Environmental regulation, economic growth and air pollution: Panel threshold analysis for OECD countries. *Science of the total environment,* 657, 234–241. https://doi.org/10.1016/j.scitotenv.2018.12.056

Perraton, J. (2001). The global economy—myths and realities. *Cambridge journal of economics,* 25(5), 669–684. https://doi.org/10.1016/S0308-5305(01)00107-9

Rosenzweig, P. M. (2001). *Accelerating international growth.* John Wiley & Sons, Inc.

Spetzler, C., Winter, H., & Meyer, J. (2016). *Decision quality: value creation from better business decision.* John Wiley & Sons, Inc.

Steinmueller, W. E. (2002). Knowledge-based economies and information and communication technologies. *International social science journal,* 54(171), 141–153. https://doi.org/10.1111/1468-2451.00365

The World Bank database, Indicator: GINI index. https://data.worldbank.org/indicator/SI.POV.GINI

Tomaselli, M. F., Sheppard, S. R. J., Kozak, R. & Gifford, R. (2019). What do Canadians think about economic growth, prosperity and the environment? *Ecological Economics,* 161, 41–49. https://doi.org/10.1016/j.ecolecon.2019.03.007

Voudouris, V., Ayres, R., Serrenho, A. C. & Kiose, D. (2015). The economic growth enigma revisited: The EU-15 since the 1970s. *Energy Policy,* 86, 812–832. https://doi.org/10.1016/j.enpol.2015.04.027
## Appendix

### Table A. Statistical data used for modeling.

| Country   | Year | GDP/capita (in EUR) | R&D/capita (in EUR) | ELET (% of the population aged 18-24) | DMC/capita (in tons) | GHGE/capita (in units of CO2 equivalents)* | MENI (in euros per person in household) | IFUFE (% of persons in the total population) |
|-----------|------|---------------------|---------------------|---------------------------------------|----------------------|---------------------------------------------|----------------------------------------|------------------------------------------|
| **Belgium** |      |                     |                     |                                       |                      |                                             |                                        |                                          |
|           | 2007 | 32400               | 600.6               | 12.1                                  | 16.9                 | 13.5                                        | 19143                                 | 20.9                                     |
|           | 2008 | 33100               | 638.7               | 12.0                                  | 16.8                 | 13.4                                        | 19986                                 | 23.9                                     |
|           | 2009 | 32300               | 644.0               | 11.1                                  | 15.1                 | 12.1                                        | 21002                                 | 23.8                                     |
|           | 2010 | 33500               | 690.7               | 11.9                                  | 15.1                 | 12.6                                        | 21353                                 | 25.4                                     |
|           | 2011 | 34500               | 742.8               | 12.3                                  | 15.8                 | 11.5                                        | 21628                                 | 26.1                                     |
|           | 2012 | 35000               | 795.3               | 12.0                                  | 14.1                 | 11.1                                        | 21897                                 | 25.2                                     |
|           | 2013 | 35300               | 822.1               | 11.0                                  | 13.6                 | 11.0                                        | 23279                                 | 24.2                                     |
|           | 2014 | 35800               | 854.3               | 9.8                                   | 13.1                 | 10.5                                        | 23429                                 | 24.0                                     |
|           | 2015 | 36600               | 900.4               | 10.1                                  | 12.9                 | 10.8                                        | 23673                                 | 25.7                                     |
|           | 2016 | 37600               | 955.6               | 8.8                                   | 12.9                 | 10.6                                        | 24256                                 | 25.9                                     |
| **Bulgaria** |      |                     |                     |                                       |                      |                                             |                                        |                                          |
|           | 2007 | 4200                | 18.4                | 14.9                                  | 18.8                 | 9.1                                         | 1721                                  | 79.2                                     |
|           | 2008 | 4900                | 22.2                | 14.8                                  | 20.4                 | 9.0                                         | 2662                                  | 57.4                                     |
|           | 2009 | 4900                | 24.7                | 14.7                                  | 16.4                 | 7.8                                         | 3278                                  | 58.4                                     |
|           | 2010 | 5100                | 29.0                | 12.6                                  | 16.3                 | 8.3                                         | 3498                                  | 65.0                                     |
|           | 2011 | 5600                | 29.8                | 11.8                                  | 18.2                 | 9.0                                         | 3429                                  | 65.3                                     |
|           | 2012 | 5700                | 34.6                | 12.5                                  | 17.6                 | 8.4                                         | 3276                                  | 68.6                                     |
|           | 2013 | 5800                | 36.6                | 12.5                                  | 17.1                 | 7.7                                         | 3509                                  | 64.1                                     |
|           | 2014 | 5900                | 46.9                | 12.9                                  | 18.8                 | 8.2                                         | 3907                                  | 49.6                                     |
|           | 2015 | 6300                | 60.4                | 13.4                                  | 21.3                 | 8.7                                         | 4093                                  | 53.4                                     |
|           | 2016 | 6800                | 52.5                | 13.8                                  | 18.9                 | 8.4                                         | 3857                                  | 54.2                                     |
| **Czechia** |      |                     |                     |                                       |                      |                                             |                                        |                                          |
|           | 2007 | 13400               | 175.6               | 5.2                                   | 19.1                 | 14.8                                        | 6148                                  | 38.5                                     |
|           | 2008 | 15500               | 193.3               | 5.6                                   | 18.6                 | 14.2                                        | 6810                                  | 37.9                                     |
|           | 2009 | 14200               | 184.6               | 5.4                                   | 16.9                 | 13.3                                        | 8262                                  | 37.9                                     |
|           | 2010 | 14900               | 200.3               | 4.9                                   | 16.0                 | 13.5                                        | 7981                                  | 37.9                                     |
|           | 2011 | 15600               | 243.4               | 4.9                                   | 16.9                 | 13.3                                        | 8440                                  | 40.4                                     |
|           | 2012 | 15400               | 273.9               | 5.5                                   | 15.0                 | 12.9                                        | 8765                                  | 42.4                                     |
|           | 2013 | 15000               | 285.0               | 5.4                                   | 14.8                 | 12.4                                        | 8695                                  | 41.7                                     |
|           | 2014 | 14900               | 294.0               | 5.5                                   | 15.2                 | 12.2                                        | 8600                                  | 40.8                                     |
|           | 2015 | 16000               | 308.4               | 6.2                                   | 15.9                 | 12.3                                        | 8345                                  | 36.0                                     |
|           | 2016 | 16700               | 280.8               | 6.6                                   | 15.6                 | 12.4                                        | 8808                                  | 32.1                                     |
| **Denmark** |      |                     |                     |                                       |                      |                                             |                                        |                                          |
|           | 2007 | 42700               | 1077.7              | 12.9                                  | 28.4                 | 13.2                                        | 25113                                 | 18.7                                     |
| Year | Denmark | Germany | Estonia | Ireland |
|------|---------|---------|---------|---------|
| 2008 | 44000   | 1223.8  | 12.5    | 27.0    |
| 2009 | 41900   | 1282.0  | 11.3    | 22.5    |
| 2010 | 43800   | 1281.6  | 11.0    | 21.0    |
| 2011 | 44500   | 1312.7  | 9.6     | 23.3    |
| 2012 | 45500   | 1360.0  | 9.1     | 23.3    |
| 2013 | 46100   | 1371.8  | 8.0     | 21.9    |
| 2014 | 47100   | 1376.2  | 7.8     | 21.9    |
| 2015 | 48000   | 1473.7  | 7.8     | 22.6    |
| 2016 | 49200   | 1534.2  | 7.2     | 23.8    |

| Year | Denmark | Germany | Estonia | Ireland |
|------|---------|---------|---------|---------|
| 2007 | 30900   | 747.1   | 12.5    | 16.3    |
| 2008 | 31500   | 810.0   | 11.8    | 16.2    |
| 2009 | 30400   | 818.0   | 11.1    | 15.4    |
| 2010 | 31900   | 855.9   | 11.8    | 15.5    |
| 2011 | 33600   | 942.0   | 11.6    | 17.0    |
| 2012 | 34100   | 984.8   | 10.5    | 16.4    |
| 2013 | 34900   | 990.1   | 9.8     | 16.3    |
| 2014 | 36100   | 1043.1  | 9.5     | 16.8    |
| 2015 | 37100   | 1093.4  | 10.1    | 15.6    |
| 2016 | 38100   | 1121.7  | 10.3    | 15.7    |

| Year | Denmark | Germany | Estonia | Ireland |
|------|---------|---------|---------|---------|
| 2007 | 12100   | 129.3   | 14.4    | 29.0    |
| 2008 | 12300   | 155.4   | 14.0    | 26.3    |
| 2009 | 10600   | 147.8   | 13.5    | 24.7    |
| 2010 | 11000   | 174.6   | 11.0    | 25.0    |
| 2011 | 12500   | 289.1   | 10.6    | 26.9    |
| 2012 | 13500   | 287.3   | 10.3    | 27.0    |
| 2013 | 14300   | 247.0   | 9.7     | 28.8    |
| 2014 | 15200   | 217.9   | 12.0    | 28.3    |
| 2015 | 15700   | 230.3   | 12.2    | 27.0    |
| 2016 | 16500   | 205.4   | 10.9    | 26.8    |

| Year | Denmark | Germany | Estonia | Ireland |
|------|---------|---------|---------|---------|
| 2007 | 44800   | 560.4   | 12.0    | 41.2    |
| 2008 | 41800   | 584.5   | 11.7    | 35.5    |
| 2009 | 37500   | 605.0   | 11.8    | 26.9    |
| 2010 | 36800   | 586.8   | 11.9    | 22.9    |
| 2011 | 37300   | 583.2   | 11.1    | 21.4    |
| 2012 | 38100   | 595.7   | 9.9     | 19.6    |
| 2013 | 38900   | 610.3   | 8.7     | 21.6    |
| 2014 | 41900   | 629.9   | 6.7     | 20.6    |
| 2015 | 56000   | 669.8   | 6.8     | 20.6    |
|                | 2007     | 2008     | 2009     | 2010     | 2011     | 2012     | 2013     | 2014     | 2015     | 2016     |
|----------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| **Ireland**    |          |          |          |          |          |          |          |          |          |          |
| 2016           | 57200    | 686.2    | 6.0      | 22.0     | 13.4     | 25586    | 45.2     |          |          |          |
| 2007           | 21100    | 121.6    | 14.3     | 22.2     | 12.5     | 12130    | 29.6     |          |          |          |
| 2008           | 21800    | 144.8    | 14.4     | 21.0     | 12.2     | 12766    | 26.6     |          |          |          |
| 2009           | 21400    | 133.9    | 14.2     | 17.8     | 11.5     | 13505    | 26.6     |          |          |          |
| 2010           | 20300    | 121.6    | 13.5     | 15.9     | 10.9     | 13974    | 28.2     |          |          |          |
| 2011           | 18600    | 125.1    | 12.9     | 14.3     | 10.6     | 12626    | 34.4     |          |          |          |
| 2012           | 17300    | 120.7    | 11.3     | 13.2     | 10.4     | 10676    | 40.5     |          |          |          |
| 2013           | 16500    | 133.2    | 10.1     | 12.3     | 9.6      | 9303     | 47.1     |          |          |          |
| 2014           | 16400    | 136.2    | 9.0      | 12.7     | 9.4      | 8879     | 51.8     |          |          |          |
| 2015           | 16400    | 156.9    | 7.9      | 12.2     | 9.1      | 8683     | 53.4     |          |          |          |
| 2016           | 16400    | 162.7    | 6.2      | 11.5     | 8.8      | 8673     | 53.6     |          |          |          |
| **Greece**     |          |          |          |          |          |          |          |          |          |          |
| 2007           | 23900    | 297.9    | 30.8     | 20.6     | 10.1     | 13266    | 30.8     |          |          |          |
| 2008           | 24300    | 321.9    | 31.7     | 17.7     | 9.2      | 16190    | 29.9     |          |          |          |
| 2009           | 23300    | 315.4    | 30.9     | 14.3     | 8.3      | 17042    | 36.5     |          |          |          |
| 2010           | 23200    | 313.8    | 28.2     | 12.6     | 7.9      | 16922    | 38.7     |          |          |          |
| 2011           | 22900    | 303.9    | 26.3     | 11.1     | 7.9      | 16280    | 37.7     |          |          |          |
| 2012           | 22200    | 286.0    | 24.7     | 8.8      | 7.8      | 16119    | 42.1     |          |          |          |
| 2013           | 22000    | 278.5    | 23.6     | 8.3      | 7.2      | 15635    | 42.1     |          |          |          |
| 2014           | 22300    | 275.6    | 21.9     | 8.4      | 7.3      | 15405    | 42.7     |          |          |          |
| 2015           | 23300    | 283.6    | 20.0     | 8.8      | 7.6      | 15408    | 39.8     |          |          |          |
| 2016           | 24100    | 285.5    | 19.0     | 8.6      | 7.4      | 15842    | 38.7     |          |          |          |
| **Spain**      |          |          |          |          |          |          |          |          |          |          |
| 2007           | 30300    | 617.5    | 12.8     | 14.3     | 8.6      | 18383    | 34.5     |          |          |          |
| 2008           | 31000    | 641.6    | 11.8     | 13.9     | 8.5      | 22462    | 34.1     |          |          |          |
| 2009           | 29900    | 665.7    | 12.4     | 12.4     | 8.1      | 23191    | 32.5     |          |          |          |
| 2010           | 30700    | 672.3    | 12.7     | 12.1     | 8.1      | 23421    | 33.0     |          |          |          |
| 2011           | 31500    | 694.3    | 12.3     | 12.4     | 7.7      | 23882    | 33.0     |          |          |          |
| 2012           | 31800    | 712.6    | 11.8     | 12.0     | 7.7      | 24499    | 33.0     |          |          |          |
| 2013           | 32100    | 722.0    | 9.7      | 12.0     | 7.6      | 24713    | 34.0     |          |          |          |
| 2014           | 32400    | 726.7    | 8.8      | 11.7     | 7.1      | 24612    | 33.4     |          |          |          |
| 2015           | 33000    | 750.0    | 9.2      | 11.1     | 7.2      | 24982    | 32.8     |          |          |          |
| 2016           | 33400    | 750.8    | 8.8      | 10.9     | 7.2      | 25278    | 31.8     |          |          |          |
| **France**     |          |          |          |          |          |          |          |          |          |          |
| 2007           | 10200    | 80.7     | 4.5      | 13.6     | 7.4      | 6291**   | 60.8**   |          |          |          |
| 2008           | 11200    | 98.7     | 4.4      | 15.6     | 7.2      | 6401**   | 61.3**   |          |          |          |
| 2009           | 10500    | 88.3     | 5.2      | 12.3     | 6.7      | 6512**   | 61.8**   |          |          |          |
| 2010           | 10500    | 77.9     | 5.2      | 10.4     | 6.6      | 6622     | 62.3     |          |          |          |
| 2011           | 10500    | 78.4     | 5.0      | 10.3     | 6.6      | 6217     | 64.4     |          |          |          |
| 2012           | 10300    | 77.2     | 5.1      | 9.4      | 6.1      | 5988     | 67.4     |          |          |          |
| 2013           | 10300    | 83.2     | 4.5      | 10.0     | 5.9      | 5817     | 65.1     |          |          |          |

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| Year | Croatia | Italy | Cyprus | Latvia | Lithuania |
|------|---------|-------|--------|--------|-----------|
| 2014 | 10300 | 80.0 | 2.8 | 9.1 | 5.7 | 5799 | 63.7 |
| 2015 | 10600 | 88.7 | 2.8 | 9.7 | 5.8 | 6070 | 59.8 |
| 2016 | 11200 | 96.0 | 2.8 | 10.1 | 5.9 | 6337 | 57.7 |
| 2007 | 27400 | 313.1 | 19.5 | 14.2 | 9.8 | 17314 | 32.2 |
| 2008 | 27600 | 323.8 | 19.6 | 13.7 | 9.5 | 17711 | 31.9 |
| 2009 | 26400 | 331.6 | 18.6 | 11.5 | 8.7 | 18221 | 33.8 |
| 2010 | 26800 | 333.7 | 17.8 | 11.1 | 8.5 | 18149 | 38.2 |
| 2011 | 27300 | 345.2 | 17.3 | 9.5 | 8.1 | 18267 | 42.1 |
| 2012 | 26700 | 358.3 | 15.0 | 7.8 | 7.2 | 17914 | 38.8 |
| 2013 | 27200 | 364.5 | 14.7 | 8.3 | 7.3 | 17890 | 39.9 |
| 2014 | 27900 | 382.0 | 13.8 | 8.1 | 7.3 | 18286 | 40.4 |
| 2007 | 22900 | 92.9 | 12.5 | 27.3 | 14.0 | 18565 | 42.0 |
| 2008 | 24200 | 94.5 | 13.7 | 40.1 | 13.8 | 18571 | 40.1 |
| 2009 | 23100 | 104.1 | 11.7 | 30.7 | 13.1 | 19103 | 41.3 |
| 2010 | 23300 | 105.2 | 12.7 | 27.8 | 12.4 | 18929 | 49.9 |
| 2011 | 23200 | 107.0 | 11.3 | 26.6 | 11.7 | 19621 | 52.9 |
| 2012 | 22600 | 99.0 | 11.4 | 19.2 | 10.9 | 20218 | 50.5 |
| 2013 | 21000 | 101.0 | 9.1 | 13.9 | 10.0 | 19426 | 54.3 |
| 2014 | 20700 | 104.3 | 6.8 | 14.0 | 10.6 | 18418 | 59.8 |
| 2015 | 20900 | 100.7 | 5.2 | 14.2 | 10.7 | 16944 | 60.5 |
| 2016 | 21700 | 116.5 | 7.6 | 15.7 | 11.3 | 16943 | 56.6 |
| 2007 | 10300 | 56.9 | 15.6 | 15.0 | 5.7 | 4080 | 61.3 |
| 2008 | 11200 | 64.6 | 15.5 | 13.5 | 5.6 | 5798 | 57.0 |
| 2009 | 8800 | 39.2 | 14.3 | 8.2 | 5.4 | 6479 | 71.4 |
| 2010 | 8500 | 51.2 | 12.9 | 9.5 | 6.0 | 5466 | 78.1 |
| 2011 | 9800 | 67.8 | 11.6 | 11.2 | 5.8 | 5131 | 80.4 |
| 2012 | 10800 | 71.7 | 10.6 | 11.4 | 5.8 | 5463 | 73.6 |
| 2013 | 11300 | 69.1 | 9.8 | 12.4 | 5.8 | 5732 | 69.5 |
| 2014 | 11800 | 81.3 | 8.5 | 12.0 | 5.8 | 6324 | 67.4 |
| 2015 | 12300 | 76.6 | 9.9 | 13.0 | 5.9 | 6970 | 60.4 |
| 2016 | 12800 | 56.1 | 10.0 | 11.6 | 6.0 | 7526 | 60.0 |
| 2007 | 9000 | 71.6 | 7.8 | 15.1 | 7.9 | 3938 | 42.4 |
| 2008 | 10200 | 80.2 | 7.5 | 16.2 | 7.7 | 4902 | 40.1 |
| 2009 | 8500 | 70.2 | 8.7 | 11.0 | 6.3 | 5843 | 53.3 |
| 2010 | 9000 | 69.9 | 7.9 | 12.4 | 6.7 | 4975 | 62.3 |
| 2011 | 10300 | 92.6 | 7.4 | 13.8 | 7.1 | 4503 | 61.3 |
### Economic Growth and Investment in R&D: Contemporary Challenges for the European Unions

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| Country  | Year | GDP (Billions) | GDP Growth (%) | Investment in R&D (Billions) | R&D as % of GDP | Employment (Billions) | Employment Growth (%) | FTE as % of GDP |
|----------|------|----------------|----------------|-----------------------------|----------------|---------------------|----------------------|-----------------|
| Lithuania | 2012 | 11200          | 99.3           | 6.5                         | 12.8           | 7.2                 | 5124                 | 60.4            |
|           | 2013 | 11800          | 111.9          | 6.3                         | 15.7           | 6.8                 | 5648                 | 56.9            |
|           | 2014 | 12500          | 128.0          | 5.9                         | 14.8           | 6.9                 | 5975                 | 54.7            |
|           | 2015 | 12900          | 133.4          | 5.5                         | 15.0           | 7.0                 | 6558                 | 53.2            |
|           | 2016 | 13500          | 113.4          | 4.8                         | 15.7           | 7.1                 | 7033                 | 53.2            |
| Luxembourg | 2007 | 77300          | 1242.4         | 12.5                        | 26.5           | 28.2                | 34223                | 21.5            |
|           | 2008 | 77900          | 1279.0         | 13.4                        | 22.7           | 27.5                | 35448                | 19.6            |
|           | 2009 | 74200          | 1256.9         | 7.7                         | 21.8           | 25.8                | 36475                | 25.4            |
|           | 2010 | 79200          | 1202.4         | 7.1                         | 21.6           | 26.5                | 36410                | 24.4            |
|           | 2011 | 83100          | 1233.6         | 6.2                         | 21.0           | 25.6                | 36662                | 23.0            |
|           | 2012 | 83000          | 1069.6         | 8.1                         | 20.3           | 24.3                | 36925                | 24.8            |
|           | 2013 | 85300          | 1127.9         | 6.1                         | 20.8           | 22.7                | 38442                | 23.8            |
|           | 2014 | 89200          | 1145.8         | 6.1                         | 21.3           | 21.5                | 38555                | 23.8            |
|           | 2015 | 90600          | 1176.5         | 9.3                         | 24.0           | 20.4                | 39707                | 23.0            |
|           | 2016 | 91300          | 1198.1         | 5.5                         | 23.9           | 19.8                | 39415                | 21.9            |
| Hungary  | 2007 | 10200          | 97.1           | 11.4                        | 11.8           | 7.3                 | 4363                 | 67.0            |
|           | 2008 | 10800          | 105.4          | 11.7                        | 13.3           | 7.1                 | 4827                 | 67.6            |
|           | 2009 | 9400           | 106.4          | 11.5                        | 10.7           | 6.5                 | 5201                 | 75.2            |
|           | 2010 | 9900           | 112.4          | 10.8                        | 9.8            | 6.6                 | 4631                 | 73.9            |
|           | 2011 | 10200          | 120.6          | 11.4                        | 9.9            | 6.4                 | 5055                 | 74.4            |
|           | 2012 | 10000          | 126.6          | 11.8                        | 8.7            | 6.1                 | 5250                 | 75.0            |
|           | 2013 | 10300          | 142.8          | 11.9                        | 10.0           | 5.8                 | 5027                 | 74.9            |
|           | 2014 | 10700          | 144.7          | 11.4                        | 12.9           | 5.9                 | 5124                 | 75.9            |
|           | 2015 | 11300          | 153.3          | 11.6                        | 12.7           | 6.2                 | 5165                 | 72.2            |
|           | 2016 | 11600          | 139.5          | 12.4                        | 12.2           | 6.3                 | 5396                 | 50.8            |
| Malta    | 2007 | 14200          | 77.9           | 30.2                        | 8.8            | 8.2                 | 10200                | 33.7            |
|           | 2008 | 15000          | 80.1           | 27.2                        | 7.7            | 8.2                 | 11165                | 32.8            |
|           | 2009 | 14900          | 77.3           | 25.7                        | 8.2            | 7.6                 | 11866                | 29.4            |
|           | 2010 | 15900          | 96.7           | 23.8                        | 7.0            | 7.8                 | 11794                | 28.2            |
|           | 2011 | 16400          | 111.0          | 22.7                        | 9.1            | 8.0                 | 12097                | 27.2            |
|           | 2012 | 17100          | 141.9          | 21.7                        | 10.3           | 8.3                 | 12663                | 25.0            |
|           | 2013 | 17900          | 139.8          | 20.8                        | 8.9            | 7.5                 | 13438                | 23.0            |
|           | 2014 | 19600          | 141.0          | 20.9                        | 11.9           | 7.4                 | 14315                | 24.6            |
|           | 2015 | 21700          | 162.6          | 20.2                        | 13.7           | 5.7                 | 15172                | 21.4            |
|           | 2016 | 22700          | 130.3          | 19.2                        | 13.7           | 5.0                 | 15505                | 20.8            |
| Netherlands | 2007 | 37800          | 632.2          | 11.9                        | 11.7           | 13.4                | 20809                | 21.3            |
|           | 2008 | 39400          | 640.2          | 11.4                        | 12.4           | 13.3                | 22303                | 19.4            |
|           | 2009 | 37800          | 631.3          | 11.3                        | 11.6           | 12.8                | 22790                | 18.7            |

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| Year | Netherlands | Austria | Poland | Portugal | Romania |
|------|-------------|---------|--------|----------|---------|
| 2010 | 38500       | 657.1   | 10.1   | 11.5     | 13.5    | 22692   | 22.2 |
| 2011 | 39000       | 734.6   | 9.2    | 11.2     | 12.6    | 22556   | 21.7 |
| 2012 | 39000       | 747.9   | 8.9    | 10.7     | 12.3    | 22951   | 22.0 |
| 2013 | 39300       | 759.6   | 9.3    | 10.1     | 12.3    | 23125   | 23.4 |
| 2014 | 39800       | 788.4   | 8.7    | 10.3     | 11.8    | 23190   | 23.7 |
| 2015 | 40700       | 810.4   | 8.2    | 11.0     | 12.2    | 23925   | 22.9 |
| 2016 | 41600       | 833.0   | 8.0    | 9.9      | 12.2    | 25366   | 22.5 |
| 2007 | 34200       | 829.1   | 10.8   | 21.4     | 10.8    | 20342   | 28.7 |
| 2008 | 35300       | 908.5   | 10.2   | 20.3     | 10.7    | 21681   | 28.7 |
| 2009 | 34500       | 897.4   | 8.8    | 18.9     | 9.9     | 22756   | 24.4 |
| 2010 | 35400       | 965.9   | 8.3    | 19.2     | 10.4    | 23576   | 25.0 |
| 2011 | 37000       | 988.2   | 8.5    | 20.3     | 10.1    | 23922   | 23.6 |
| 2012 | 37800       | 1104.6  | 7.8    | 19.3     | 9.7     | 24423   | 22.2 |
| 2013 | 38200       | 1132.4  | 7.5    | 18.8     | 9.7     | 24366   | 23.2 |
| 2014 | 39000       | 1207.7  | 7.0    | 18.6     | 9.2     | 26080   | 23.9 |
| 2015 | 39900       | 1223.0  | 7.3    | 18.2     | 9.4     | 25958   | 22.6 |
| 2016 | 40800       | 1279.6  | 6.9    | 19.0     | 9.4     | 26054   | 22.6 |
| 2007 | 8200        | 46.3    | 5.0    | 16.5     | 11.0    | 4150    | 54.4 |
| 2008 | 9600        | 57.6    | 5.0    | 16.9     | 10.8    | 4940    | 50.7 |
| 2009 | 8200        | 55.0    | 5.3    | 16.2     | 10.3    | 5984    | 50.0 |
| 2010 | 9400        | 68.6    | 5.4    | 17.0     | 10.9    | 5116    | 50.6 |
| 2011 | 9900        | 74.5    | 5.6    | 21.0     | 10.8    | 5813    | 51.2 |
| 2012 | 10100       | 90.1    | 5.7    | 18.3     | 10.6    | 5902    | 54.1 |
| 2013 | 10300       | 90.3    | 5.6    | 17.3     | 10.6    | 5976    | 50.5 |
| 2014 | 10700       | 101.6   | 5.4    | 17.2     | 10.2    | 6163    | 48.6 |
| 2015 | 11200       | 113.6   | 5.3    | 16.9     | 10.3    | 6376    | 42.3 |
| 2016 | 11100       | 108.3   | 5.2    | 17.7     | 10.6    | 6659    | 37.9 |
| 2007 | 16600       | 187.3   | 36.5   | 21.2     | 7.7     | 9929    | 19.7 |
| 2008 | 16900       | 245.0   | 34.9   | 22.2     | 7.5     | 10288   | 26.2 |
| 2009 | 16600       | 262.4   | 30.9   | 20.0     | 7.2     | 10393   | 27.8 |
| 2010 | 17000       | 260.8   | 28.3   | 18.6     | 6.8     | 10540   | 27.2 |
| 2011 | 16700       | 242.7   | 23.0   | 17.3     | 6.7     | 10407   | 29.1 |
| 2012 | 16000       | 220.1   | 20.5   | 15.9     | 6.5     | 10227   | 35.9 |
| 2013 | 16300       | 215.4   | 18.9   | 14.0     | 6.4     | 9899    | 43.2 |
| 2014 | 16600       | 214.1   | 17.4   | 14.8     | 6.4     | 9856    | 42.2 |
| 2015 | 17400       | 215.4   | 13.7   | 15.0     | 6.9     | 9996    | 40.7 |
| 2016 | 18100       | 231.0   | 14.0   | 14.9     | 6.7     | 10562   | 38.3 |
| 2007 | 6100        | 30.9    | 17.3   | 20.5     | 7.4     | 1940    | 46.2 |
| Romania          | 2008 | 7100  | 39.2   | 15.9 | 22.2 | 7.3 | 2318 | 41.9 |
|------------------|------|-------|--------|------|------|-----|------|------|
|                  | 2009 | 6100  | 27.2   | 16.6 | 17.4 | 6.4 | 2524 | 41.6 |
|                  | 2010 | 6200  | 28.2   | 19.3 | 13.7 | 6.1 | 2371 | 44.8 |
|                  | 2011 | 6500  | 32.5   | 18.1 | 19.0 | 6.4 | 2401 | 50.8 |
|                  | 2012 | 6600  | 32.1   | 17.8 | 18.0 | 6.3 | 2356 | 53.9 |
|                  | 2013 | 7200  | 27.9   | 17.3 | 18.0 | 5.8 | 2324 | 53.0 |
|                  | 2014 | 7600  | 28.8   | 18.1 | 18.8 | 5.9 | 2443 | 52.7 |
|                  | 2015 | 8100  | 39.4   | 19.1 | 22.5 | 5.9 | 2674 | 51.4 |
|                  | 2016 | 8600  | 41.4   | 18.5 | 22.9 | 5.8 | 2746 | 54.5 |

| Slovenia         | 2007 | 17400 | 249.0  | 4.1  | 23.7 | 10.4 | 10724 | 41.6 |
|------------------|------|-------|--------|------|------|------|--------|------|
|                  | 2008 | 18800 | 306.9  | 5.1  | 20.8 | 10.7 | 11709 | 44.5 |
|                  | 2009 | 17700 | 323.2  | 5.3  | 17.0 | 9.6  | 12743 | 40.6 |
|                  | 2010 | 17700 | 364.4  | 5.0  | 16.0 | 9.6  | 12653 | 45.1 |
|                  | 2011 | 18000 | 436.2  | 4.2  | 14.4 | 9.6  | 12885 | 46.7 |
|                  | 2012 | 17500 | 451.6  | 4.4  | 12.5 | 9.3  | 12972 | 45.7 |
|                  | 2013 | 17600 | 454.1  | 3.9  | 12.2 | 8.9  | 12706 | 45.8 |
|                  | 2014 | 18200 | 431.9  | 4.4  | 13.1 | 8.1  | 12843 | 45.8 |
|                  | 2015 | 18800 | 413.5  | 5.0  | 13.3 | 8.2  | 13211 | 42.9 |
|                  | 2016 | 19500 | 393.4  | 4.9  | 12.8 | 8.6  | 13193 | 41.7 |

| Slovakia         | 2007 | 10400 | 46.9   | 6.5  | 14.0 | 9.2  | 4378  | 43.3 |
|------------------|------|-------|--------|------|------|------|-------|------|
|                  | 2008 | 12200 | 56.7   | 6.0  | 15.4 | 9.3  | 5180  | 38.5 |
|                  | 2009 | 11800 | 56.3   | 4.9  | 13.6 | 8.5  | 6290  | 36.0 |
|                  | 2010 | 12400 | 77.2   | 4.7  | 13.3 | 8.6  | 6785  | 38.2 |
|                  | 2011 | 13100 | 86.9   | 5.1  | 13.5 | 8.5  | 6979  | 35.8 |
|                  | 2012 | 13400 | 108.3  | 5.3  | 11.9 | 8.0  | 7556  | 36.1 |
|                  | 2013 | 13700 | 112.9  | 6.4  | 11.4 | 7.9  | 7266  | 39.5 |
|                  | 2014 | 14000 | 123.6  | 6.7  | 12.6 | 7.5  | 7484  | 38.9 |
|                  | 2015 | 14600 | 171.0  | 6.9  | 12.7 | 7.7  | 7293  | 36.7 |
|                  | 2016 | 15000 | 118.1  | 7.4  | 13.4 | 7.8  | 7391  | 37.9 |

| Finland          | 2007 | 35300 | 1183.0 | 9.1  | 38.8 | 15.4 | 20787 | 30.2 |
|------------------|------|-------|--------|------|------|------|-------|------|
|                  | 2008 | 36500 | 1296.3 | 9.8  | 39.0 | 13.8 | 22008 | 29.7 |
|                  | 2009 | 33900 | 1274.1 | 9.9  | 32.0 | 13.0 | 23119 | 29.7 |
|                  | 2010 | 34900 | 1302.7 | 10.3 | 34.4 | 14.4 | 23528 | 28.1 |
|                  | 2011 | 36500 | 1332.7 | 9.8  | 34.6 | 13.0 | 24150 | 27.4 |
|                  | 2012 | 36900 | 1264.9 | 8.9  | 33.1 | 11.9 | 25148 | 27.9 |
|                  | 2013 | 37400 | 1231.7 | 9.3  | 37.3 | 11.9 | 25901 | 27.5 |
|                  | 2014 | 37600 | 1194.6 | 9.5  | 31.0 | 11.1 | 26130 | 27.2 |
|                  | 2015 | 38300 | 1109.5 | 9.2  | 30.5 | 10.4 | 26240 | 28.4 |
| Country    | 2016   | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   |
|------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Finland    |        |        |        |        |        |        |        |        |        |        |        |
|            | 39300  | 39000  | 38300  | 33300  | 39400  | 42900  | 44500  | 45400  | 44700  | 45800  | 46700  |
|            | 1080.0 | 1273.7 | 1341.0 | 1154.1 | 1270.8 | 1397.4 | 1464.9 | 1507.6 | 1411.3 | 1504.3 | 1537.0 |
|            | 7.9    | 8.0    | 7.9    | 7.0    | 6.5    | 6.6    | 7.5    | 7.1    | 6.7    | 7.0    | 7.4    |
|            | 31.5   | 22.9   | 22.7   | 19.6   | 22.1   | 23.1   | 22.8   | 23.3   | 23.6   | 23.1   | 23.4   |
|            | 10.9   | 7.3    | 7.1    | 6.5    | 7.1    | 6.6    | 6.2    | 6.0    | 5.8    | 5.7    | 5.6    |
|            | 26379  | 20178  | 21544  | 22050  | 20070  | 23001  | 25353  | 27094  | 27935  | 27218  | 27347  |
|            | 29.4   | 18.0   | 21.3   | 21.3   | 18.8   | 19.4   | 20.7   | 21.0   | 20.4   | 19.8   | 20.7   |
| Sweden     |        |        |        |        |        |        |        |        |        |        |        |
|            | 36700  | 32100  | 27700  | 29500  | 45800  | 42900  | 44500  | 45400  | 44700  | 45800  | 46700  |
|            | 598.1  | 523.0  | 467.9  | 491.6  | 1504.3 | 1397.4 | 1464.9 | 1507.6 | 1411.3 | 1504.3 | 1537.0 |
|            | 16.6   | 16.9   | 15.7   | 14.8   | 7.0    | 6.6    | 7.5    | 7.1    | 6.7    | 7.0    | 7.4    |
|            | 11.7   | 10.9   | 9.5    | 9.2    | 23.4   | 23.1   | 22.8   | 23.3   | 23.6   | 23.1   | 23.4   |
|            | 11.5   | 11.1   | 10.1   | 10.2   | 5.8    | 5.7    | 6.2    | 6.0    | 5.8    | 5.7    | 5.6    |
|            | 24823  | 22805  | 19391  | 20517  | 27935  | 27218  | 25353  | 27094  | 27935  | 27218  | 27347  |
|            | 26.6   | 28.6   | 31.1   | 34.7   | 20.7   | 19.8   | 20.7   | 21.0   | 20.4   | 19.8   | 20.7   |
| United      |        |        |        |        |        |        |        |        |        |        |        |
| kingdom    |        |        |        |        |        |        |        |        |        |        |        |
|            | 36700  | 32100  | 27700  | 29500  | 45800  | 42900  | 44500  | 45400  | 44700  | 45800  | 46700  |
|            | 598.1  | 523.0  | 467.9  | 491.6  | 1504.3 | 1397.4 | 1464.9 | 1507.6 | 1411.3 | 1504.3 | 1537.0 |
|            | 16.6   | 16.9   | 15.7   | 14.8   | 7.0    | 6.6    | 7.5    | 7.1    | 6.7    | 7.0    | 7.4    |
|            | 11.7   | 10.9   | 9.5    | 9.2    | 23.4   | 23.1   | 22.8   | 23.3   | 23.6   | 23.1   | 23.4   |
|            | 11.5   | 11.1   | 10.1   | 10.2   | 5.8    | 5.7    | 6.2    | 6.0    | 5.8    | 5.7    | 5.6    |
|            | 24823  | 22805  | 19391  | 20517  | 27935  | 27218  | 25353  | 27094  | 27935  | 27218  | 27347  |
|            | 26.6   | 28.6   | 31.1   | 34.7   | 20.7   | 19.8   | 20.7   | 21.0   | 20.4   | 19.8   | 20.7   |

Source: prepared by authors using Eurostat data.

* This indicator shows trends in man-made emissions of the 'Kyoto basket' of greenhouse gases. The 'Kyoto basket' of greenhouse gases includes: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and the so-called F-gases (hydrofluorocarbons, perfluorocarbons, nitrogen trifluoride (NF3) and sulphur hexafluoride (SF6)). These gases are aggregated into a single unit using gas-specific global warming potential (GWP) factors. The aggregated greenhouse gas emissions are expressed in units of CO2 equivalents.

** Estimated by authors.