Panel Analysis to Investigate the Relationship Between Economic Growth, Import, Consumption of Materials and Energy

Anna Bluszcz 1, Anna Manowska 1

1 Akademicka 2A, 44-100 Gliwice, Poland, The Silesian University of Technology, Poland

Anna.bluszcz@polsl.pl

Abstract. Nature conservation, or the preservation of the natural capital, is an important factor in ensuring prosperity for present and future generations. The essence of the concept of sustainable development is to ensure the use of natural resources in such a way that society's needs can be met most effectively while maintaining the possibility of biological regeneration of the environment. This concept does not mean abandoning the production and consumption of goods but indicates the need for a number of structural and technological changes that will allow for the relatively smallest depreciation of natural capital. An effective tool for monitoring progress in this area can be the continuously developed material flow account. Studies indicate that in highly developed countries GDP growth is possible with a relatively smaller increase in material demand and energy use. The aim of the article is to examine the dependencies that occur between the GDP growth rate and the growth rate of imports of goods and services, while reducing energy consumption and consumption of materials. The study was based on data concerning the economies of selected European Union and Poland. The article presents the method of modeling the decoupling phenomenon using the panel data technique.

1. Introduction
The constant need to achieve economic growth in high developed economies in recent years has caused unfavourable tendencies in the aspect of changing the lifestyle of societies, based on a high level of consumption. These behaviours have a negative impact on the natural environment (increase in the consumption of natural resources, increase in the amount of waste, increase in water wasting, air and soil pollution), which was the basis for a new socio-economic trend based on sustainable development. Unrestrained like consumerism in high developed countries, it has a strong impact on the consumption of natural resources in other regions of the world and on environmental pollution, which phenomena can be a serious problem for future generations. The growing ecological awareness of societies leads to a shift towards responsible use of natural resources. Economic development means transformation process of low-income economies into modern industrial economies. The term economic development is a broader concept than economic growth, because it applies to positive economic transformations not only quantitative but also qualitative. Economic development combines technological progress, structural changes in production processes, changes on social, political and institutional grounds, balanced increase in the value of GDP (Gross domestic product) or GNP (Gross national product) as well as improvement of living conditions of the country's population. This can be seen in the example of the research on the structure of gross national income, in which highly developed economies have the highest share in GDP of services or new technologies, while in countries with a lower level of economic
development, the structure of GDP is dominated by the share of heavy industry, which has a negative impact on the environment. The issue of economic changes is closely related to the degradation of the natural environment; hence the term sustainable economic development began to exist in the current of economic development from the 1970s.

For the first time the term sustainable development appeared at the UN conference in Stockholm in 1972, where it was stated, among others, that man has the fundamental right to freedom, equality and adequate living conditions in an environment that would allow a decent life in prosperity. Man has a serious responsibility to protect and improve the environment for present and future generations. The declaration also raises the issues of the necessary reduction of human impact on Earth's resources, on air, water, soil, flora and fauna, on special responsibility for the protection and wise management of wild game residues and places where it resides, on the need for responsible and equitable use of non-renewable resources, preventing them from being exhausted [1].

In theory, we can still find many other definitions of sustainable development, because it is assumed to be a multidimensional problem, hence the differences in emphasizing the most important issues. Generally, sustainable development refers to such development in which balance is achieved in three main dimensions simultaneously, i.e. in the economic dimension meaning the pursuit of sustainable economic development; in the social dimension, which means protection of public health and social integration; and in the environmental dimension putting a significant emphasis on protecting the environment and natural resources in such a way as not to threaten the possibilities of meeting the needs of future generations [2-6]. One of goals of European environmental policy is sustainable consumption and production which more effectively achieves sustainable development goals. The EU Sustainable Development Strategy sets out the objective of promoting sustainable consumption and production patterns. Addressing social and economic development within the carrying capacity of ecosystems and decoupling economic growth from environmental degradation is an essential requirement for sustainable development. Table 1 presents indicators of sustainable consumption and production.

Table 1. Sustainable consumption and production indicators.

| Headline indicator | Operational indicators | Explanatory indicators |
|--------------------|------------------------|------------------------|
| **Resource productivity** | **Ressource use and waste** | Components of domestic material consumption |
| | | Domestic material consumption |
| | | Municipal waste generation and treatment, by type of treatment method |
| | | Generation of hazardous waste, by economic activity |
| | | Emissions of sulphur oxides (SO\textsubscript{x}), by source sector |
| | | Emissions of nitrogen oxides (NO\textsubscript{x}), by source sector |
| | | Emissions of non-methane volatile organic compounds (NMVOC), by source sector |
| | | Emissions of ammonia (NH\textsubscript{3}), by source sector |
| **Consumption patterns** | Electricity consumption of households | Final energy consumption by sector |
| | Motorisation rate | |
| **Production patterns** | Organisations and sites with eco-management and audit scheme (EMAS) registration | Ecolabel licenses |
| | | Area under agri-environmental commitment |
| | | Area under organic farming |
| | | Livestock density index |

Source: own elaboration based on: [7]
The path to achieving ambitious ecological goals is to constantly increase the efficiency of using natural resources and to decouple economic growth and prosperity from resource consumption [8]. The main indicator of efficiency use of natural resources is resource productivity presented in the table 2 in EU countries in 2000, 2010 and 2016. The indicator is defined as the gross domestic product (GDP) divided by domestic material consumption (DMC). DMC measures the total amount of materials directly used by an economy. It is defined as the annual quantity of raw materials extracted from the domestic territory of the local economy, plus all physical imports minus all physical exports. It is important to note that the term ‘consumption’, as used in DMC, denotes apparent consumption and not final consumption. DMC does not include upstream flows related to imports and exports of raw materials and products originating outside of the local economy.

**Table 2. Resource productivity in EU countries in 2000, 2010 and 2016**

| Resource productivity | Resource productivity | Resource productivity |
|-----------------------|-----------------------|-----------------------|
| Index, 2000=100       | Army                  | Army                  |
|                       | 2000      2010 2016   | 2000      2010 2016   | 2000      2010 2016   |
| Romania 100 66 64 Bulgaria 0.24 0.32 0.29 Bulgaria 0.45 0.70 0.68 |
| Malta 100 155 99 Romania 0.48 0.32 0.31 Romania 0.67 0.66 0.70 |
| Croatia 100 96 102 Latvia 0.35 0.48 0.48 Latvia 0.48 0.76 0.82 |
| Sweden 100 108 104 Estonia 0.47 0.44 0.53 Estonia 0.51 0.66 0.85 |
| Greece 100 103 114 Poland 0.46 0.56 0.68 Finland 0.69 0.86 0.95 |
| Estonia 100 95 114 Lithuania 0.63 0.73 0.82 Poland 0.66 0.95 1.22 |
| Finland 100 112 116 Hungary 0.66 0.99 1.03 Portugal 0.85 1.13 1.44 |
| Bulgaria 100 131 120 Finland 0.91 1.01 1.05 Sweden 1.29 1.49 1.50 |
| Denmark 100 128 121 Croatia 1.05 1.01 1.08 Lithuania 0.89 1.24 1.50 |
| Austria 100 119 122 Czech Republic 0.63 0.93 0.98 Cyprus 0.77 0.91 1.57 |
| Portugal 100 110 130 Portugal 0.83 0.92 0.98 Greece 1.21 1.35 1.61 |
| Lithuania 100 116 131 Slovakia 0.77 0.94 1.17 Czech Republic 0.79 1.32 1.67 |
| Belgium 100 109 134 Cyprus 0.85 0.84 0.84 Austria 1.11 1.48 1.70 |
| Latvia 100 137 135 Greece 1.24 1.28 1.41 Croatia 1.24 1.45 1.71 |
| Germany 100 126 137 Slovenia 0.82 1.10 1.45 Denmark 1.07 1.71 1.74 |
| EU (28 countries) 100 123 141 Malta 1.48 2.29 1.46 Hungary 0.88 1.65 1.80 |
| Luxembourg 100 133 143 Austria 1.37 1.62 1.67 Slovakia 0.99 1.43 1.80 |
| France 100 127 145 Sweden 1.70 1.84 1.77 Slovenia 0.92 1.32 1.89 |
| Poland 100 123 150 EU (28 countries) 1.47 1.81 2.07 Malta 1.71 3.07 2.02 |
| Slovakia 100 122 151 Denmark 1.79 2.28 2.17 EU (28 countries) 1.27 1.81 2.23 |
| Netherlands 100 120 153 Germany 1.62 2.04 2.22 Ireland 0.79 1.43 2.26 |
| Hungary 100 149 155 Ireland 0.98 1.59 2.26 Germany 1.35 1.94 2.30 |
| Cyprus 100 99 167 Belgium 2.04 2.22 2.72 Belgium 1.64 2.03 2.70 |
| United Kingdom 100 150 170 Spain 1.26 1.84 2.84 France 1.58 2.28 2.79 |
| Czech Republic 100 149 172 France 2.00 2.55 2.92 Spain 1.11 1.93 3.17 |
| Slovenia 100 135 177 United Kingdom 2.12 3.18 3.61 United Kingdom 1.82 2.97 3.59 |
| Italy 100 144 225 Italy 1.64 2.35 3.69 Luxembourg 1.90 3.04 3.65 |
| Spain 100 146 225 Luxembourg 2.76 3.68 3.95 Netherlands 2.17 2.93 3.96 |
| Ireland 100 162 231 Netherlands 2.74 3.27 4.18 Italy 1.42 2.33 3.98 |

Source: own elaboration based on: [9]

Because the fact that the main explanatory indicator of resource productivity is: domestic material consumption and final energy consumption the aim of the article is investigation of the relationship between these indicators and the GDP. Resources consumption in high developed countries influenced in the other region of the word that in the analysis import will be included.
2. Methodology and data
The study examined the significance of relationship economic growth, import, consumption of materials and energy in selected European Union countries such as: Croatia, Bulgaria, Romania compare with Poland and Czech Republic.

The research question of the study was formulated as: What is the nature of the relationship between GDP and FEC_energy, DMC_material_consumption and import in developing countries? Table 3 presents a summary of the statistics and the VIF values of the variables. Data for selected fifth countries was analyzed in the years 2006-2017. Figure 1 represents the heterogeneity across countries.

| Variable            | Average   | Minimum | Maximum   | Standard deviation |
|---------------------|-----------|---------|-----------|--------------------|
| GDP_Poland          | 9833.33   | 7200.00 | 12100.00  | 1419.560           |
| GDP_Czech Republic  | 15150.00  | 12100.00| 18100.00  | 1526.434           |
| GDB_Croatia         | 10550.00  | 9300.00 | 11800.00  | 628.852            |
| GDP_Bulgaria        | 5483.33   | 3500.00 | 7100.00   | 1033.822           |
| GDP_Romania         | 7058.33   | 4600.00 | 9600.00   | 1325.593           |

Source: Own elaboration based on data from Eurostat

![Figure 1. Averages chart of GDP for selected countries (own elaboration based on data from Eurostat)](image)

In order to check the hypothesis, panel cointegration tests were performed and the impact of macroeconomic variables on gross domestic product was estimated. The assumed hypothesis can be tested in a long-term relationship. Therefore, the considerations presented in this article have been focused on methods for detecting long-term relationships for cross-sectional data. Panel-based basic cointegration tests include the procedures proposed by McCoskey and Kao [9], Kao [10], Pedroni [11, 12] and the use of Fisher's test for individual results of the Jansen cointegration test [13]. The McCoskey and Kao, Kao and Pedroni tests are used to search for one long-term relationship [14]. On the other hand, applying the Johansen method allows to determine the number of cointegrating vectors in panel models with many explanatory variables.
3. Panel tests of cointegration in the Johansen procedure

The application of the Johansen procedure to study panel cointegration consists in using the results of the study on the cointegration of individual panel units in order to obtain panel statistics in accordance with Fisher's proposal from 1932 [13]. The procedure for combining individual independent results is based on the appropriate combination of empirical probabilities. In panel analysis, modelling of each panel unit is independent of the others, which means that the order of cointegration is determined for each unit separately, and the parameters of the long and short periodic structure are not in any relationship. It should be noted that these tests allow to conclude about the co-integration of variables in the panel model.

4. Results and discussion

A panel data model with permanent effects, in the form, was used to verify the hypothesis [15]:

\[ GDP_t = \beta_0 + \beta_1 X_{it} + \epsilon_{it} \]  

(1)

where:
- \( GDP_t \) – dependent variable,
- \( \beta_0, \beta_1 \) – model coefficients,
- \( X_{it} \) – set of explanatory variables such as: final energy consumption; domestic material consumption, import,
- \( \epsilon_{it} \) – statistical errors,
- \( i, t \) – are indicators for the individual variable and the time,

Table 4 - 8 contains the results of panel estimation using the least squares method.

| Table 4. GDP_Poland Fixed Effects Model (Source: autor’s own study) |
|---------------------------------------------------------------|
| **Coefficients** | **Estimate** | **Std.Error** | **t-value** | **p-value** |
| Const | 1936.00 | 1903.00 | 1.017 | 0.339 |
| FEC | 9.99 | 34.64 | 0.289 | 0.780 |
| DMC | 65.58 | 39.57 | 1.657 | 0.136 |
| Import | 0.037 | 0.023 | 16.17 | 0.000*** |
| Multiple R2 | 0.98 | | | |
| Adjusted R2 | 0.98 | | | |
| F-statistic (3,8) | 182.30 | | | 0.000 |
| Residual standards error | 199.90 | | | |

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1,

| Table 5. GDP_Czech Republic Fixed Effects Model (Source: autor’s own study) |
|---------------------------------------------------------------|
| **Coefficients** | **Estimate** | **Std.Error** | **t-value** | **p-value** |
| Const | -12440 | 778.20 | -1.598 | 0.149 |
| FEC | 44.59 | 31.30 | 0.142 | 0.890 |
| DMC | 734.00 | 224.30 | 3.271 | 0.012* |
| Import | 0.13 | 0.017 | 7.823 | 0.000*** |
| Multiple R2 | 0.93 | | | |
| Adjusted R2 | 0.90 | | | |
| F-statistic (3,8) | 36.48 | | | 0.000 |
| Residual standards error | 467.10 | | | |

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1,
The results of panel models with constant effects are presented in Tables 2 to 6. The relationship between the GDP growth rate and the growth rate of imports of goods and services was examined, while analysing energy consumption and material consumption. Models were built for Poland, the Czech Republic, Croatia, Bulgaria and Romania.

In the model built for Poland, the coefficient of determination (R2) is 98% and indicates that changes in GDP can be explained by the import of goods and services, energy consumption and material consumption. The value of F is also large with a value of p practically equal to zero. Therefore, the relation is very significant and it can be stated that the explanatory variables together explain the changes in the dependent variable and are statistically significant. It can therefore be concluded that, together, macroeconomic variables have a significant impact on GDP. The FEC, DMC and Import coefficients are positive, hence there is a growing relationship between GDP and FEC, DMC and Import. If GDP increased by 1%, FEC would increase by 0.2%, DMC by 0.03%, and Imports would increase by 0.8%.

In the model built for the Czech Republic, the coefficient of determination (R2) is 93% and indicates that changes in GDP can be explained by the import of goods and services, energy consumption and material consumption. The value of F is also large with a value of p practically equal to zero. Model
coefficients for FEC, DMC and Import are positive, hence there is also a growing relationship between GDP and FEC, DMC and Import for the Czech Republic. However, if GDP increased by 1%, FEC would increase by 0.02%, DMC by 0.0015%, and Imports would increase by 0.45%. The model built for Romania has the same relations as for Poland and the Czech Republic. The coefficient of determination (R2) is 94% and indicates that changes in GDP can be explained by a positive (growing) link between imports of goods and services, energy consumption and material consumption. The value of F is also large with a value of p practically equal to zero. If GDP increased by 1%, FEC would increase by 2%, DMC by 0.01%, and Import would increase by 0.9%. Surprising results were obtained in the models built for Bulgaria and Croatia. There is also a positive realization in the case of DMC and Import coefficients and a negative one in the case of FEC. The R2 determination coefficient is 89% for Bulgaria, while only 53% for Croatia. Thus, for an increase of 1% of GDP, there will be an increase in DMC for Bulgaria by 0.01% and 0.0015% for Croatia and imports by 0.7% for each country, and a decrease in FEC by 1% for Croatia and by 3% for Bulgaria.

5. Conclusions
Along with the increasing availability of cross-sectional databases, there has been an era of panel models, as well as a dynamic increase in interest in methods of non-stationary, heterogeneous statistical data analysis, and here the analysis of panel integration and cointegration has become a popular research tool. The article presents the method of modelling the phenomenon of separation using panel data techniques. These models cause many problems related to the conditions that dependent variables and the rest of the model must meet. Despite all these problems, they are good tools for identifying relationships between variables and are therefore widely used. The article demonstrates the causality of gross domestic product growth for developing countries. The result obtained from the built models prove that the assumed H1 hypothesis defining the nature of the relationship between the GDP growth rate and the growth rate of imports of goods and services, when analyzing energy consumption and material consumption, can be adopted at an acceptable level of probability. In the analyzes performed, the FEC, DMC and imports variables had a significant impact on GDP. Only in two countries have the models confirmed the phenomenon of decoupling, which means that in Bulgaria and Croatia there is a significant reduction in energy consumption while maintaining economic growth. DMC and Import were of increasing character in all analyzed countries.

Acknowledgment(s)
The work was elaborated in frames of the statutory research 06/030/BK_19/0044

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