Linkages between Energy Delivery and Economic Growth from the Point of View of Sustainable Development and Seaports

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Abstract: This paper presents the synchronisation of economic cycles of GDP and crude oil and oil products cargo volumes in major Polish seaports. On the one hand, this issue fits into the concept of sustainable development including decoupling; on the other hand, the synchronisation may be an early warning tool. Crude oil and oil products cargo volumes are a specific barometer that predicts the next economic cycle, especially as they are primary sources of energy production. The research study applies a number of TRAMO/SEATS methods, the Hodrick–Prescott filter, spectral analysis, correlation and cross-correlation function. Noteworthy is the modern approach of using synchronisation of economic cycles as a tool, which was described in the paper. According to the study results, the cyclical components of the cargo traffic and GDP were affected by the leakage of other short-term cycles. However, based on the cross-correlation, it was proved that changes in crude oil and oil products cargo volumes preceded changes in GDP by 1–3 quarters, which may be valuable information for decision-makers and economic development planners.

Keywords: cargo volumes; crude oil and oil products; economic cycles; economic management; decoupling; liquid bulk cargoes; maritime ports; seaports; sustainable development concept; synchronisation

1. Introduction

1.1. Presentation of Research Problems

This study focuses on the synchronisation of economic cycles of gross domestic product (GDP) and crude oil and oil products cargo volumes in major Polish seaports (energy delivery; crude oil is the primary world source of energy production). It approaches economic cycle synchronisation as an early warning tool in economic management in the context of the sustainable development concept, which includes the paradigm of decoupling. While issues related to economic cycles and their synchronisation are quite common research problems addressed in the literature, the approach presented in this article is innovative, as no similar research study has thus far been completed on the basis of seaports. In this paper, crude oil and oil products cargo volumes are considered to be a leading indicator to predict the next economic cycle. Economic cycle synchronisation, in turn, is treated as an early warning tool for the purposes of economic management. The authors have emphasised the need to follow the assumptions of sustainable development along with decoupling and inclusive economy, watching out for any kinds of ‘traps’ related to treating GDP as the indicator of prosperity or to a pursuit of so-called ‘wild’ economic growth. The authors have taken an interdisciplinary approach to these issues, firstly, by presenting the genesis of and problems related to the concepts (theoretical approach); secondly, by referring to the academic achievements found in other papers or research studies (empirical and pragmatic approach) and thirdly, by combining the former and the latter in the form of policies, tools, strategies and types of measures (hybrid approach).
1.2. Organisation of the Paper

The research hypothesis was formulated as follows: synchronisation of economic cycles of GDP and crude oil cargo traffic volumes is significant from the point of view of economic management, and it constitutes an early warning tool. The purpose of this article is to identify economic cycles of GDP and primary energy sources such as crude oil and oil products cargo volumes. The study comprises major maritime ports with importance for the Polish economy (Gdańsk, Gdynia, Szczecin, Świnoujście and Police).

The paper consists of five sections. The first one is an introduction. Section 2 provides a literature review in the following four directions: (1) sustainable development including the concept of decoupling in relation to economic growth, (2) seaports as the integration factor of global economic system, (3) the concept of smart ports in the context of sustainable development and global economic system, (4) and the synchronisation of the economics cycles in the light of economic management and governance. In Section 3, the materials and methods used in the study are summarised. The next section contains the empirical results of the research conducted on the example of major Polish seaports. This section presents the decomposition of the variable that represents the main economic category of economy and the crude oil and oil products cargo volume using the TRAMO/SEATS method and then using the Hodrick–Prescott filter. This section also includes the results in the context of the synchronisation of cycles with optimal lags. At the end of the section the cross-correlation is shown, which is important from the point of view of an early warning system. The last section summarises the paper, discusses the empirical results and concludes the paper in the light of future research.

2. Literature Review

2.1. The Concept of Sustainable Development and Decoupling

Economic growth constitutes a priority for most countries that continuously take measures aimed at increasing their GDP. In most of the cases, economic growth means a rise in CO$_2$ emissions. The leading countries in terms of GDP volume and the top five emitters of CO$_2$ in 2018 were China, the USA, India, Russia and Japan [1]. In market economies, economic growth enables enterprises to make profits that are further invested in their development, thus leading to further economic growth and increased employment. Economic growth entails numerous problems related to the natural environment, which are addressed by the concept of sustainable development [2]. Hence, achieving economic goals in many cases is incompatible with implementation of the sustainability concept. It should be noted that treating GDP as a barometer for any country’s general prosperity is not entirely justified [3,4], as there is a specific relation between economic growth and environmental issues: economic growth is accompanied by pollution growth; however, the increased pollution also constitutes a benefit for the economy, as new jobs are provided in order to eliminate the pollution effects [5].

In the 1980s, the so-called ecological economy was developed, which further evolved to become the sustainable economy. Later on, it was proposed that economic growth should focus not only on the economy but should be a complete macrosystem including the society and the environment [6]. The concept of sustainable development is not new. Its first precise definition may be found in the report of the UN’s World Commission on Environment and Development (WCED) of 1987, entitled ‘Our Common Future’, also known as ‘The Brundtland Report’ after the Commission’s chairman Gro Harlem Brundtland. The document aptly presented the idea of sustainable development and constituted a milestone in introducing and understanding the idea of sustainable development, also taking into account issues connected with transport [7]. It also stated that at the current level of civilisation, it is possible to have sustainable development, which means development that meets ‘the needs of the present generation without compromising the ability of future generations to meet their own needs’. The report addressed three major areas that required an integration of measures, including economic growth and a balanced distribution of benefits; the conservation of natural resources and the environment; and social development [8].
As early as the 1980s, researchers started to pay attention to issues of sustainability, i.e., appropriate and conscious development of relations between social, economic and environmental issues [9,10]. Those three pillars are the basic ones, and more scientists put emphasis on culture as the fourth pillar. Culture, perceived as human identities, shape the environment in which we live and how it is perceived [11,12]. According to Hanley [13], the idea of sustainable development is broad, and it is defined in various ways, but in its essence, it boils down to provide a stable level of prosperity for future generations.

In 2015, the United Nations General Assembly adopted a resolution titled, ‘Transforming our world: the 2030 Agenda for Sustainable Development’ [14] containing the Sustainable Development Goals. These regarded achievements in five areas called the 5Ps: people, planet, prosperity, peace and partnership. The implementation of these goals and tasks was subject to evaluation by means of appropriate indexes [15]. Agenda 2030 is a universal document and requires adjusting to each country’s realities (implementation of the Sustainable Development Goals, SDG) [16]; hence, the essential role is on the side of individual countries to meet those objectives [17].

The elements that distinguish the traditional economy from the sustainable economy are listed in the table below (Table 1).

| Traditional Economy | Sustainable Economy |
|---------------------|---------------------|
| Valued goods | Private goods | Private good, collective goods, factual |
| Main production factors | Labour, capital, information and technology | Natural resources, labour, capital, information and technology |
| Homo economicus | Homo cooperativus |
| Weak (strong and absolute anthropocentrism) | Strong (weak and relative anthropocentrism) |
| Means to achieve global prosperity | Free trade, acceptance of currently functioning institutions and structures of world trade | Fair system of global economy with social and ecological minimum standards and charges for using global environmental goods |

Source: Ganowicz-Bączyk, A. Ekonomia w Służbie Zrównoważonego Rozwoju. Studia Ecologica Bioethicae UKSW 2013, 11, 36 [18].

To a certain extent, the sustainable economy stands in opposition to the traditional economy, accounting for a wider range of issues, also those referring to social and environmental problems (the need to protect ecosystems for ethical reasons, e.g., ecocentrism) [18,19]. Sustainable development is strongly connected to economic growth and related with environmental protection and social inclusion [20–22]. Hence, there is a need for an inclusive economy [23], understood in terms of including all resources [24]. Initially, measures taken with regard to sustainable development were limited mainly to the need to reduce [25] the negative impacts of economies on the natural environment. Over time, the concept gained importance and entered the mainstream of discussions on social and economic development, at the same time becoming a horizontal principle reflected at the level of both individual countries and the whole European Community.

Economic growth is the goal of economic policy due to its positive consequences for the growth of social welfare, improvement of the competitive position in the world economy and the development of innovation. In the light of the theory of sustainable development, it has been noticed that economic growth, due to the excessive use of resources, also becomes a source of undesirable phenomena. This issue was reflected in the concept of decoupling. Its essence is to decouple economic growth from resource intensity.

Decoupling as a theoretical concept appeared in Western European literature in the mid-nineties of the last century [26] and was developed in relation to the transport intensity of the economy [27]. Model approaches to decoupling were proposed by Tapio [28], and the connection of this concept with environmental protection by Zhang [29]. The first political
references to decoupling are contained in the following two documents from 2001: A European Union Strategy for Sustainable Development [30] and The OECD Environmental Strategy for the First decade of 21st Century [31]. The first document describes ‘decoupling environmental degradation and resource consumption from economic and social development’, the second defines decoupling as ‘breaking the link’ between ‘environmental bads’ and ‘economic goods’. Decoupling, understood as ‘a determined breaking the link between transport growth and gross domestic product growth in order to reduce pollution and other negative side-effects of transport development’, has become the paradigm of EU transport policy [32]. Initially, it was aimed at reducing the volume of transport by modifying the economic and social factors generating those with transport origin (consumption, production, location). However, along with the new global approach to the existing resources efficient usage (first decade of the 21st century), it was modified to separate economic growth from the increase in the negative environmental effects caused by transport. The current understanding of decoupling means ‘such a reconstruction of economic relations that enables the decoupling of economic growth from the rate of consumption of scarce natural resources and environmental degradation’ [33]. Action in this order requires attention, both to the volume of resource use in connection with economic activity, and to the environmental effects associated with their use at all stages of the life cycle [34]. Practical guidelines for measuring the progress in decoupling have been prepared by the OECD [35]. Research shows that countries with policy frameworks that are more supportive of renewable energy and of climate change tend to decouple the emissions trend from GDP more closely, and for both production- and consumption-based emissions [36].

As for transport, which has a particular impact on the natural environment and that, due to its very nature, should meet the sustainability requirements, it is possible to notice some concrete measures taken in that regard [37]. Transport focuses on the sustainable development goals [38] that relate mainly to energy consumption, alternative sources of energy and pollution reduction technologies [39,40]. In the case of maritime transport, these measures predominantly include air and water pollution, with a particular focus on terminal operations and vessel handling at ports.

Maritime transport constitutes an important link in global transport chains and plays a key role in regional economies. Nevertheless, the activity of seaports is connected with environmental impacts, mainly resulting from works performed within the port as such (transport, transshipment, storage) [41]. Thus, economic growth related to seaport operations must meet the requirements of environmental protection and social development, in line with the principles of sustainable development [42,43]. In view of the significance of seaports and their role of nodes in global supply chains, measures taken by them to implement the idea of sustainable development and functioning are particularly important. They also have an impact on the functioning of other entities being part of the chain. The concept of Green Ports is defined as ‘a product of a long-term strategy for sustainable and environmentally-friendly development of port infrastructure’ [44,45]. The functioning of ‘green ports’ focuses mainly on the aspects related to the environment and climate changes, which further then relate to the aforementioned Agenda 2030 published by the UN. Additionally, the importance of seaports in global trade is directly related to the GDP of the countries that make use of the seaports [46].

2.2. Seaports as a Major Element of Integration in Global Economic System

Over the past few decades, the definition of a maritime port has been evolving, starting from a facility for handling transoceanic vessels in international trade, to viewing it as a logistics platform in relation to the trans-European complex and basal network [47]. Seaports are one of the major elements of the general transport sector and are currently connected with the developing global economy [48–52]. In the academic literature, seaports are described as means of integration with the global economic system [53]. Seaports evolve and harmonise with social and economic changes, also adapting to technical and technological advancements.
In Poland, seaports are regulated by the provisions of the Act of 20 December 1996 on maritime ports and harbours [54]. It defines a maritime port or harbour ‘as the port basins and grounds as well as the related port infrastructure located on the premises of the maritime port or harbour’ and introduces the concept of ‘a maritime port of primary significance for the national economy’. In Poland there are four such seaports, i.e., those located in Gdańsk, Gdynia, Szczecin and Świnoujście. They are managed by the following three companies, respectively: Zarząd Morskiego Portu Gdańsk S.A., Zarząd Morskiego Portu Gdynia S.A. and Zarząd Morskich Portów Szczecińskich i Świnoujści S.A. [55].

In 1994, the United Nations Conference on Trade and Development attempted to categorise maritime ports by means of the so-called UNCTAD model. It divides maritime ports into the following three generations in respective periods: prior to 1960, from 1960 to 1980, and after 1980. The following criteria were applied in preparing the classification: main types of cargoes, attitude to and strategies of seaport development, scope of activities, characteristics of the organisation and products, decision-making factors [56]. The attempts at port classification, presented in the academic literature, result from their complexity and heterogeneity (‘<<Fourth-generation ports>> which are physically separated but linked through common operators or through a common administration’ [57]) [57,58]. The three-generation port model was critically evaluated by the WORKPORT project team financed by the European Union in the years 1998–1999. The main goal of the WORKPORT project was to identify the impact of new technologies applied in ports on their work environments [59]. The WORKPORT consortium rejected the idea found in the UNCTAD model (United Nations Conference on Trade and Development model), according to which the evolution process can be best described in the categories of subsequent port generations, where each category has its own, well-defined set of characteristics [60]. The evidence resulting from the study proves that seaports evolve continuously, adapting to new technologies, new regulations, changed work practices and other impacts, depending on the needs. Moreover, it was proven that several evolution streams may be observed simultaneously, and the rate of changes in each of them may be considerably diverse [61]. This model ignored factors such as port size, geographical location and the extent of public and private sector engagement in investment activities. Undoubtedly, the evolution of ports and their further categorisation were affected by factors such as mechanisation and automation; containerisation; investments in the infrastructure, suprastructure and IT systems; systems to support cargo and information handling; labour culture; occupational health and safety; environment; the computerisation of ports; provision of training and taking care of improving the organisational culture [56,62]. In contrary to the UNCTAD model, the WORKPORT model put emphasis on working cultures, health and safety and increasing the awareness of the environment [60].

Based on the Polish and other academic literature on the subject, Kaliszewski presented models of the fifth and sixth generation ports. The quoted authors include Lee and Lam [62]; according to their hierarchisation, a fifth-generation port is characterised by a greater complexity and greater possibilities of creating added value, compared to ports of previous generations. It is also important that fifth-generation ports develop their strategies and solve problems of local communities in a way that ensures sustainable development; the port of Singapore is provided as an example. Even though the sixth generation of ports has been outlined, no port in the world met its criteria by 2017.

2.3. A ‘Smart Port’ Concept

Nowadays, the more and more discussed concept is that of a ‘smart port’. In relation to this concept, there are legal regulations based on provisions derived from the United Nations Conference on Trade and Development (UNCTAD), the International Maritime Organisation (IMO, London, UK), and the European Union (EU) (The Motorways of the Sea Digital Multi-Channel Platform, 2015) [63]. Quoting Molavi et al., the regulations are aimed at improving the sustainable character of ports, motivating them to implement new technologies and ensure standards for evaluating ports’ efficiency. There is no official,
uniform definition of ‘smart ports’. The studies completed by Molavi et al. outline the smart port concept and present a quantitative evaluator—the smart port index. A smart port attracts better educated people, a qualified workforce, smart infrastructure and automation in order to facilitate development and knowledge-sharing, the optimisation of port operations, increasing the port’s resilience, ensuring sustainable development and guaranteeing security and safe operations. A smart port comprises the following four major areas of activity: operations, environment, energy and safety and security.

The ‘smart port’ concept derives from and is fully integrated with the concept of the ‘smart city’ [63–65]. González et al. point out that the study presented by Molavi et al. ignored one of the pillars of a ‘smart port’—the social aspect. According to some researchers [65], a smart port must be designed for citizens and by citizens, putting them in the centre of the future port. Therefore, a port must be sustainably integrated with the city or the environment, ensuring space that can be used by inhabitants, promoting its relation with the sea and making it possible to make use of it. The authors presented the concept in a way that is easy to understand. A smart port is based on the application of new technologies to transform port services into interactive and dynamic services that are more efficient and transparent. Its goal is to meet the needs and requirements of customers and users. Moreover, from the point of view of environmental protection, the sustainable development of a port constitutes its fundamental pillar as well as its orientation to the city and its citizens in order to ensure high quality of the space and the services. The new technologies that are being considered include artificial intelligence (AI), Blockchain, and the Internet of Things (IoT) [66].

On the basis of the quantitative studies based on the example of 14 seaports (Hamburg, Rotterdam, Antwerp, Busan, Singapore, Los Angeles, Vancouver, Jebel Ali, New York and New Jersey, Houston, Shanghai, Tanjung Priok, Jeddah, Hong Kong), Molavi et al. observed a positive correlation between the value of the SPI (Smart Port Index) and GDP per capita of the given country. This means that seaports located in richer countries show higher SPI values. Moreover, they found a positive correlation between the national spending on R&D (Research and Development) per capita and the port’s SPI value, which they explained as follows: when a country is more open to innovations and higher education systems, seaports in that country are more interested in implementing new technologies and taking an innovative approach. A negative correlation, in turn, was found between the country’s energy consumption per GDP and the SPI. The higher values of energy intensity show that production and services require greater industrial efficiency and more effort. This means that the country’s industry is not productive or energy efficient.

The smart port concept was also presented as an extension of the UNCTAD model to describe a fifth-generation port (Table 2). The cut-off dates to distinguish between the generations have been a problem to researchers since the very beginning. In the table below, fourth- and fifth-generation ports are dated, respectively, from 2000 and 2020, whereas the quoted studies of Molavi et al. date the generations 10 years earlier.

| Table 2. UNCTAD Smart Port Model. |
|-----------------------------------|
| **1st Generation** | **2nd Generation** | **3rd Generation** | **4th Generation** | **5th Generation** |
| 1940 | 1960 | 1980 | 2000 | 2020 |
| Mechanic Port | Container Port | EDI Port | Internet Port | Smart Port |
| Mechanical operation | Free Zone | International network | Global network | ITS port |
| Handicraft works | Industrial area | Integrated centre | Port community | Logistic community |
| | Free tax port | Commercial area | Logistic area | Smart city |
| | | EDI services | Internet services | Smart Hinterland |
| | | | Intermodal services | Multimodal services |
| | | | Internet services | Sustainable port |

Source: [https://www.onthemosway.eu/wp-content/uploads/2015/07/Seaports-development-v-2.0.pdf](https://www.onthemosway.eu/wp-content/uploads/2015/07/Seaports-development-v-2.0.pdf) (accessed on 13 November 2020).
2.4. Economic Cycles and Their Synchronisation for Economic Management

The studies conducted by the aforementioned researchers fall within the areas of economic management and governance. They are particularly important from the point of view of seaports [67–71]. On the one hand, it is possible to refer to a global approach with its underlying world order and its legal and economic consequences, on the other—to focus on the national level from the point of view of the country’s development in the context of global trends, or to think of it as of economic management on a microscale, i.e., at the level of the ports themselves [72–74]. The concept of governance, as opposed to economic management, has a broader meaning; it can also be considered in interdisciplinary terms. In relation to ports, the term ‘governance’ relates to multi-directional relationships between the multi-layer management on the global, national and local level in the legal, economic, environmental and social governance. The main components of port governance are governmental organisations, port organisations, institutional arrangements, port regulatory and managerial and operating activities; the directional relationships between them answer the question who controls and who interacts; its effects are goals that may be measured by means of tools, i.e., effectiveness or efficiency [70,75].

The latter concept pertains to economic management exclusively on one of the levels in relation to the socio-economic policy aspects. On the one hand, it regards the management of financial, human and material resources, i.a., focusing on issues related to multi-speed Europe [76]. On the other hand, it pertains to any given entity’s economic and financial management [67]. One of the tools of economic management (apart from the ones mentioned above in the context of port evolution) is the analysis of economic cycles and their synchronisation [77–80]. Cycles are one of the basic elements of the early warning system/model in case of crisis situations [81]. In addition to the analysis of the irregular element (shock impulse), trend (economy drifting) and the cycles overlapping (leakage effect), the cycle analysis is also interesting in terms of forming a positive or negative output gap [82]. Moreover, maritime ports, and more specifically cargo volumes (particularly crude oil) in the ports, are deemed to be the barometer of the Polish economy [83,84]. For that reason, the further parts of this paper present studies based on economic cycles for GDP (representing economic growth) and for crude oil and oil products cargo volumes (representing the economic, environmental and governance aspects).

3. Data and Methods

The research study was based on secondary data. The figures for monthly crude oil and oil products cargo volumes (thousand tonnes) were obtained from the Statistical Yearbooks of Maritime Economy [85–91] (the data are presented in Table 3), whereas the figures for the Gross Domestic Product (PLN billion, at constant prices) were derived from the OECD statistics database [92] (the data are shown in Table 4). The monthly crude oil and oil products cargo volumes were aggregated via summing up the figures to obtain quarterly values (Table 4). The analysis was based on quarterly data and covered the 2012–2018 period. The choice of the time scope was dictated by procedural premises due to analysing short-term cycles in the nearest time perspective (the 2018 data were the latest data available).

Based on Tables 3 and 4, it is possible to surmise that the data are characterised by seasonality and show a growth pattern. However, a detailed analysis will be presented further on in this paper.

The authors used Gretl software with TRAMO/SEATS packages. The data were analysed by means of a few methods. The first of them, the TRAMO/SEATS (Time series Regression with ARIMA noise, Missing observations and Outliers/Signal Extraction in ARIMA Time Series) method was applied to seasonally adjust the data, and to decompose them into trend-cycle and irregular (shock) components. Those 3 components summarised together are equal to the original data. The time-series model plus seasonal adjustment estimated. The critical value for outliers set on the threshold, which was equal to 3.3 (it is universal value). Parameters set to detect and correct for outliers besides additive
outliers, allowed for transitory changes and shifts of level. In transformation, the mean correction in automatic form was used (optimal choice between log transformation and no log transformation). The ARIMA parameters were non-seasonal differences equal to 1, seasonal differences equal to 1, non-seasonal AR terms equal to 0, seasonal AR terms equal to 0, non-seasonal MA terms equal 1, seasonal MA terms equal to 1.

Table 3. Monthly crude oil and oil products cargo volumes in major Polish seaports (k tonnes).

| Month    | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|----------|------|------|------|------|------|------|------|
| January  | 562.8| 1477.2| 1191.6| 1264.7| 1327.8| 1640.2| 1716.3|
| February | 506.8| 1149.8| 1031.8| 1166.4| 1352.0| 1567.1| 1804.3|
| March    | 797  | 891.1| 1281.4| 1442.5| 894.8 | 1392.6| 1985.6|
| April    | 796.8| 321  | 1512.4| 920.6 | 1444.8| 1252.9| 2005.0|
| May      | 534.9| 610.8| 681.4| 1427.4| 1159.7| 1556.2| 1499.1|
| June     | 507.5| 858.8| 767.4| 1821.6| 1004.6| 1534.5| 1399.2|
| July     | 1092.9| 1079.6| 759.8| 1300.3| 1472.1| 1199.6| 1551.8|
| August   | 1153.5| 1172.8| 1234.3| 1744.2| 1711.9| 1551.7| 1500.1|
| September| 1634.2| 1551.9| 1281.7| 1507.2| 1886.8| 1215.1| 1405.1|
| October  | 1525  | 1312.2| 1577.5| 1340.6| 1322.3| 1656.7| 1767.6|
| November | 1908  | 1136.3| 1302.3| 1285.2| 1480.1| 1445.3| 2028.4|
| December | 1303  | 1177.7| 1506.9| 1473.2| 1705.0| 2306.3| 1442.1|

Source: own work based on data obtained from the Statistical Yearbooks of Maritime Economy [85–91].

Table 4. Quarterly crude oil and oil products cargo volumes (in k tonnes) in major Polish seaports and quarterly GDP figures (in PLN bln at constant prices).

**Crude Oil and Oil Products Cargo Volumes**

| Quarter | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---------|------|------|------|------|------|------|------|
| Q1      | 1866.6| 3518.1| 3504.8| 3873.6| 3574.6| 4600.1| 5506.2|
| Q2      | 1839.2| 1790.6| 2961.2| 4169.6| 3609.1| 4343.6| 4903.3|
| Q3      | 3880.6| 3804.3| 3275.8| 4551.7| 5070.8| 3966.4| 4457.0|
| Q4      | 4736.0| 3626.2| 4386.7| 4099.0| 4507.4| 5408.3| 5238.1|

**Gross Domestic Product**

| Quarter | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---------|------|------|------|------|------|------|------|
| Q1      | 413.50| 412.41| 425.47| 442.94| 456.34| 478.60| 503.15|
| Q2      | 412.49| 416.85| 430.32| 446.43| 462.33| 482.83| 509.85|
| Q3      | 414.30| 420.01| 433.92| 452.09| 463.51| 488.26| 516.88|
| Q4      | 412.11| 421.12| 436.73| 457.64| 474.00| 496.58| 520.82|

In the table, the GDP is in PLN bln at constant prices. For comparison purposes, the authors have included the weighted average exchange rate from the National Bank of Poland for 2018: EUR/PLN equal to 4.2623 (EUR 1 = PLN 4.2623) and USD/PLN equal to 3.6134 (USD 1 = PLN 3.6134) [93]. Source: own work based on data obtained from the Statistical Yearbooks of Maritime Economy [85–91] and the OECD statistics database [92].

The second step was to apply the Hodrick–Prescott filter (with smoothing parameter $\lambda = 1600$), as this is one of the best filters for a time series of this type. As a result of the filtration, it was possible to decompose trend, cycle and shock by using the following formula by the minimisation problem [94,95]:

$$\min_{\tau_t} \left\{ \sum_{t=1}^{T} (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} [\tau_{t+1} - \tau_t]^2 \right\}$$  \hspace{1cm} (1)

where:

$$y_t = \tau_t + c_t + \epsilon_t$$  \hspace{1cm} (2)

$T$ is the number of observations;
$t$ is the index of time, $t = 1, 2, \ldots, T$;
$\lambda$ is the smoothing parameter;
\( \tau_t \) is the smoothed series, trend; 
\( y_t \) is the input series: decompose into trend, cycle and shock; 
\( c_t \) is the cycle, cyclical component; 
\( \epsilon_t \) is the shock, irregular component.

The first term in the loss function imposes a specific penalty for the variance of cycle \( (c_t) \), while the second term imposes a specific penalty for the lack of smoothed trend (in \( \tau_t \)).

Figure 1 presents an original proposal for framework of the methodology.

![Figure 1. An original proposal for a framework. Source: own elaboration.](image)

In the next step, correlation and spectral analyses were applied to the cycles. The following representative variables were adopted:

- GDP—Gross Domestic Product (raw data in bln PLN, at constant prices)
- CTCO—cargo traffic of crude oil and oil products (k tonnes)
- GDP\_sa—seasonally adjusted GDP (estimated using TRAMO/SEATS)
- GDP\_trcl—trend/cycle for GDP (estimated using TRAMO/SEATS)
- GDP\_sh—irregular/shock component for GDP (estimated using TRAMO/SEATS)
- GDP\_tr—trend for GDP (filtered using the Hodrick–Prescott filter)
- GDP\_cl—cycle for GDP (filtered using the Hodrick–Prescott filter)
- CTCO\_sa—seasonally adjusted CTCO (estimated using the TRAMO/SEATS)
- CTCO\_trcl—trend/cycle for CTCO (estimated using the TRAMO/SEATS)
- CTCO\_sh—irregular/shock component for CTCO (estimated using the TRAMO/SEATS)
- CTCO\_tr—trend for CTCO (filtered using the Hodrick–Prescott filter)
- CTCO\_cl—cycle for CTCO (filtered using the Hodrick–Prescott filter)
4. Empirical Results

Table 5 presents the basic descriptive statistics for GDP and CTCO.

Table 5. Summary statistics, using the observations 2012: 1–2018: 4 (quarterly data).

| Variable         | Time Range | Mean     | Standard Deviation | Coefficient of Variation | Minimum  | Maximum  | Skewness | Excess Kurtosis |
|------------------|------------|----------|--------------------|--------------------------|----------|----------|----------|----------------|
| CTCO (k tonnes) | all        | 3966.75  | 989.22             | 0.2494                   | 1790.6   | 5506.2   | -0.7284  | 0.1842         |
| GDP (PLN bln)   | all        | 453.63   | 35.09              | 0.0774                   | 412.11   | 520.82   | 0.1665   | -1.7808        |
| CTCO (k tonnes) | 2012       | 3080.60  | 1460.00            | 0.4740                   | 1839.20  | 4736.00  | -1.0994  | -0.7069        |
| GDP (PLN bln)   | 2012       | 413.10   | 0.99               | 0.0024                   | 412.11   | 414.30   | 0.2341   | -1.5346        |
| CTCO (k tonnes) | 2013       | 3184.80  | 936.93             | 0.2942                   | 1790.60  | 3804.30  | -1.0994  | -0.7069        |
| GDP (PLN bln)   | 2013       | 417.60   | 3.9044             | 0.0093                   | 412.41   | 421.12   | -0.5335  | -1.2513        |
| CTCO (k tonnes) | 2014       | 3532.10  | 611.75             | 0.1732                   | 2961.20  | 4386.70  | -1.0994  | -0.7069        |
| GDP (PLN bln)   | 2014       | 431.61   | 4.86               | 0.0113                   | 425.47   | 436.73   | 0.2046   | -1.2986        |
| CTCO (k tonnes) | 2015       | 4173.50  | 281.98             | 0.0676                   | 3873.60  | 4551.70  | 0.4588   | -0.9908        |
| GDP (PLN bln)   | 2015       | 449.77   | 6.46               | 0.0144                   | 442.94   | 457.64   | 0.2046   | -1.4250        |
| CTCO (k tonnes) | 2016       | 4199.60  | 728.63             | 0.1739                   | 3574.60  | 5070.80  | 0.2825   | -1.6301        |
| GDP (PLN bln)   | 2016       | 464.05   | 7.34               | 0.0158                   | 456.34   | 474.00   | 0.5103   | -0.9567        |
| CTCO (k tonnes) | 2017       | 4579.60  | 610.70             | 0.1334                   | 3966.40  | 5408.30  | 0.5499   | -1.0314        |
| GDP (PLN bln)   | 2017       | 486.57   | 7.76               | 0.0159                   | 478.60   | 496.58   | 0.3717   | -1.2479        |
| CTCO (k tonnes) | 2018       | 5026.10  | 452.55             | 0.0900                   | 4457.00  | 5506.20  | -0.2744  | -1.3015        |
| GDP (PLN bln)   | 2018       | 512.68   | 7.81               | 0.0152                   | 503.15   | 520.82   | -0.2200  | -1.4421        |

Mean was computed by formula: quotient of the sum of all data points for each variable and number of data points. Standard deviation is a square root of the variance. Variance is the quotient of two values. The first value is the sum of all squared differences between the data point and mean. The second value of the quotient is the number of data points minus 1. Coefficient of variation is the quotient standard deviation and mean. Minimum is the lowest value. Maximum is the highest value. Skewness is a measure of asymmetry; it presents its distortion from the normal distribution for a given data set or a symmetrical bell-shaped curve. It is quotient of the sample third central moment and the cube of the sample standard deviation. Excess kurtosis is a kurtosis minus 3. It compares the kurtosis coefficient with the normal distribution coefficient. Its interpretations may vary. If positive, it represents the leptokurtic distribution, if negative—the platykurtic distribution, if the value is equal to or nearly equal to zero—the mesokurtic distribution. It is a very good indicator for early warning, indicating sensitivity to extreme values. It can be expressed as the quotient of the fourth central moment to the fourth power, the value of the result minus 3; also, as the quotient of the fourth sample moment about the mean and square of the second moment about the mean, value of the result minus 3. Source: own computations in Gretl software based on Table 4.

As it can be derived from Table 5, more variation is shown by the CTCO variable (the coefficient of variation at the level of 24.94%) compared to GDP (7.74%). The coefficient of variation indicates the share of the standard deviation in the mean. The variables vary in terms of quarterly variation, which may be caused by cycle variability, seasonality or shocks.

Figures 2 and 3 show the frequency distribution for CTCO and GDP (histograms). It can be assumed that they have a normal or close to normal distribution (no grounds to reject the null hypothesis, that they have a normal distribution, because the p-value is greater than 0.05). The same conclusion was drawn from the analysis of the statistical results to test the normality of the distribution using the Doornik–Hansen test, Shapiro–Wilk W, Lilliefors test and Jarque–Bera test (Table 6).

Table 6. Tests for normality for CTCO and GDP, using the observations 2012: 1–2018: 4.

| Test for Normality | CTCO | GDP |
|-------------------|------|-----|
| Doornik–Hansen test | 3.1404 [0.2080] | 5.0893 [0.0785] |
| Shapiro–Wilk W     | 0.9306 [0.0639] | 0.9174 [0.0299] |
| Lilliefors test     | 0.1417 [=0.15] | 0.1184 [=0.39] |
| Jarque–Bera test    | 2.5158 [0.2843] | 2.2056 [0.3319] |

The p-values are in square brackets s, threshold p-value < 0.05. We could only reject null hypothesis about normality in Shapiro–Wilk W test for GDP, because p-value < 0.05. Source: own computation in Gretl based on Table 4.
Figure 2. Frequency distribution for CTCO. Test for null hypothesis of normal distribution: Chi-square \((2) = 3.140\) with \(p\)-value = 0.2080; threshold \(p\)-value < 0.05; number of bins = 7, mean = 3966.75, \(sd = 989.22\). Source: own computation in Gretl software based on Table 4.

Figure 3. Frequency distribution for GDP. Test for null hypothesis of normal distribution: Chi-square \((2) = 5.089\) with \(p\)-value = 0.0785; threshold \(p\)-value < 0.05; number of bins = 7, mean = 453.63, \(sd = 35.09\). Source: own computation in Gretl software based on Table 4.

Table 6. Tests for normality for CTCO and GDP, using the observations 2012: 1–2018: 4.

| Test for Normality         | CTCO               | GDP               |
|----------------------------|--------------------|-------------------|
| Doornik–Hansen test        | 3.1404 [0.2080]    | 5.0893 [0.0785]   |
| Shapiro–Wilk W             | 0.9306 [0.0639]    | 0.9174 [0.0299]   |
| Lilliefors test            | 0.1417 \([\approx 0.15]\) | 0.1184 \([\approx 0.39]\) |
| Jarque–Bera test           | 2.5158 [0.2843]    | 2.2056 [0.3319]   |

The \(p\)-values are in square brackets s; threshold \(p\)-value < 0.05. We could only reject null hypothesis about normality in Shapiro–Wilk W test for GDP, because \(p\)-value < 0.05. Source: own computation in Gretl based on Table 4.

Table 7 presents the results for the occurrence of the unit root (non-stationarity). The time series up to and including the fourth order of delay are non-stationary, which implied the need to transform \((d = 1, \text{first differences})\) the series in the TRAMO/SEATS method (see Appendix A, Tables A1 and A2).

Figures 4 and 5 present decomposed CTCO and GDP raw time series, following the seasonal adjustment for the shock component and trend-cycle component.

The data analysis has shown that CTCO was characterised by seasonality, whereas GDP showed small seasonal adjustments. What is worth noting is that the trend-cycle component of GDP reflected the raw data, while the decomposed CTCO became a totally new constituent, which is interesting from the point of view of the analysis. As for the shock component, it was found that in the case of CTCO, the shock impulses were stronger than for GDP; however, in the case of GDP, these were more frequent.
Table 7. Tests for unit root existing for CTCO and GDP with optimal number of lag, using the observations 2012: 1–2018: 4.

| Unit Root Test                  | CTCO          | GDP           |
|--------------------------------|---------------|---------------|
| Augmented Dickey–Fuller test   | 1.3817 [0.9587] | 3.1662 [0.9997] |
| Kwiatkowski–Phillips–Schmidt–Shin test | 0.7775 [<0.01] | 0.6574 [0.0190] |
| Local Whittle Estimator:       |               |               |
| z = 2.8007 [0.0051]            |               |               |
| Fractional integration         |               |               |
| /estimated degree of integration = 0.8085 | /estimated degree of integration = 1.0472 |
| (0.2887)                      | (0.2500)      |
| GPH test:                     |               |               |
| t(1) = 3.4814 [0.1781]        | t(2) = 30.4587 [0.0011] |
| (0.2380)                      | (0.0351)      |

Optimal lag for Augmented Dickey–Fuller test is equal to 3 for CTCO and equal 4 for GDP; max was 4, criterion modified AIC. In square brackets is p-value; threshold p-value < 0.05. In normal brackets is standard deviation. Note that z and t(1) or t(2) in fractional integration are test statistics. Null hypothesis in the Kwiatkowski–Phillips–Schmidt–Shin test is opposite to null hypothesis in the Augmented Dickey–Fuller test. Null hypothesis in the Kwiatkowski–Phillips–Schmidt–Shin test is that time series are stationary (alternative: they are non-stationary). Null hypothesis in Augmented Dickey–Fuller test is that the time series are non-stationary (alternative: they are stationary). In fractional integration, if test statistics are close to 1 it means that the time series are non-stationary, if close to 0—they are stationary. Source: own computation in Gretl software based on Table 4.

Figure 6 shows the seasonal fluctuations for CTCO and GDP. The seasonal fluctuations for CTCO decrease with time (lower amplitudes).

Figures 7 and 8 present on separate graphs the trend and the cycle components of the GDP and CTCO variables (filtration using the Hodrick–Prescott filter).

It follows from the analysis of Figures 7 and 8 that both variables showed a steady upward trend. However, the core of the analysis is the cycles. It should be noted that cycles are measured from one trough (depression) to another trough (depression). Based on the graphic analysis of the cycle, it can be concluded that there was at least one cycle for CTCO, and at least two cycles for GDP. In the case of CTCO, the highest cycle peak was seen in the fourth quarter of 2012, while the lowest cycle trough was identified in the first quarter of 2014. As for GDP, the highest cycle peak was seen in the first quarter of 2012, and the lowest depression in the second quarter of 2016.

To address a supposition that the cycles were not synchronised, a Pearson’s correlation analysis (Table 8) and a spectral analysis (Figure 9) were immediately carried out.

Table 8 presents the Pearson correlation coefficients aimed at evaluating the correlation between the GDP and CTCO cycles.

Table 8. Correlation coefficients, using the observations 2012: 1–2018: 4.

| GDP_cl | CTCO_cl |
|--------|---------|
| 1.0000 | 0.2757  |
| 0.2757 | 1.0000  |

5% critical value (two-tailed) = 0.3739 for n = 28. On the main diagonal of the correlation matrix there is always the value 1 (the variable is correlated 100% with itself); if the correlation coefficient is higher than the 5% critical value, then such a coefficient is considered statistically significant. Source: own computation in Gretl software based on Table 4.

As seen in Table 8, it is not possible to confirm a statistically significant correlation between the GDP and CTCO cycles, as the correlation coefficient amounting to 0.2757 was lower than the value of the two-tailed rejection region (critical value) of 5% (0.3739). There is no reason to interpret the correlation coefficient between CTCO_cl and GDP_cl (equal to 0.2757), as this correlation was not confirmed to be statistically significant (it may be apparent).

In view of this fact, a spectral analysis was applied for the GDP and CTCO cycles (Figure 9).
Figure 4. Decomposition of CTCO into components by means of the TRAMO/SEATS method (in k tonnes). CTCO
sh is calculated as difference between CTCO_sa and CTCO_trcl. In the figure, this is shown two times (as difference
and as absolute value). Source: own computation in Gretl software with TRAMO/SEATS packages based on data
obtained from the Statistical Yearbooks of Maritime Economy [85–91].

It follows from Figure 9 that in both the CTCO cycle and the GDP cycle, a leakage effect can be observed, i.e., cycles of various lengths and speeds are overlapping. Thus, a simple immediate synchronisation did not reveal a correlation between the cycle phases.

Based on the spectral density analysis, it was found that CTCO was characterised by three cycle types (the first lasted 9.33 quarters, the second—3.11 quarters, the third—2.33 quarters). The spectral density analysis carried out for GDP identified the first cycle duration of 7 quarters, the second cycle—4.67 quarters, the third—3.11 quarters, the fourth—2.80 quarters. Thus, the supposition was confirmed, i.e., the cyclic component of CTCO and GDP were different, and their synchronisation should take into account the time lag.

In view of the observations, the cross-correlation function was computed, taking into account the lags (maximum lag: four quarters) (Figure 10). Along with that, it is important to note, that this type of recognition of the economic cycle phases plays a significant role in sustainable development, in terms of efficiency and the balanced distribution of benefits.

An extension of the above test results is included in Appendix A (Tables A1–A4).
Figure 5. Decomposition of GDP into components by means of the TRAMO/SEATS method. GDP_sh is calculated as difference between GDP_sa and GDP_trcl. In the figure, this is shown three times (as difference, as absolute value and in zoom window as absolute value). The differences between all components are very small; therefore, in the graph the grey lines overlap with the black line. Source: own computation in Gretl software with TRAMO/SEATS packages based on data obtained from the OECD statistics database [92].
Figure 6 shows the seasonal fluctuations for CTCO and GDP. The seasonal fluctuations for CTCO decrease with time (lower amplitudes).

Figure 6. Seasonality of GDP and CTCO. The left axis is for seasonal component of GDP. The right axis is for seasonal component of CTCO. Source: own computation in Gretl software with TRAMO/SEATS packages based on data obtained from the Statistical Yearbooks of Maritime Economy [85–91] and the OECD statistics database [92].

Figures 7 and 8 present on separate graphs the trend and the cycle components of the GDP and CTCO variables (filtration using the Hodrick–Prescott filter).

Figure 7. Decomposition of the trend-cycle component of CTCO by means of the Hodrick–Prescott filter (λ = 1600) (in k tonnes). The left axis is for CTCO_trcl and CTCO_tr. The right axis is for CTCO_cl. Source: own computation in Gretl software based on data obtained from the Statistical Yearbooks of Maritime Economy [85–91].

It follows from the analysis of Figures 7 and 8 that both variables showed a steady upward trend. However, the core of the analysis is the cycles. It should be noted that cycles are measured from one trough (depression) to another trough (depression). Based on the graphic analysis of the cycle, it can be concluded that there was at least one cycle for CTCO, and at least two cycles for GDP. In the case of CTCO, the highest cycle peak was seen in the fourth quarter of 2012, while the lowest cycle trough was identified in the first quarter of 2014. As for GDP, the highest cycle peak was seen in the first quarter of 2012, and the lowest depression in the second quarter of 2016.
To address a supposition that the cycles were not synchronised, a Pearson's correlation analysis (Table 8) and a spectral analysis (Figure 9) were immediately carried out. Table 8 presents the Pearson correlation coefficients aimed at evaluating the correlation between the GDP and CTCO cycles.

Table 8. Correlation coefficients, using the observations 2012: 1–2018: 4.

|          | CTCO_cl | GDP_cl  |
|----------|---------|---------|
| CTCO_cl  | 1.0000  | 0.2757  |
| GDP_cl   | 1.0000  | CTCO_cl |

5% critical value (two-tailed) = 0.3739 for \( n = 28 \). On the main diagonal of the correlation matrix there is always the value 1 (the variable is correlated 100% with itself); if the correlation coefficient is higher than the 5% critical value, then such a coefficient is considered statistically significant.

Source: own computation in Gretl software based on Table 4.

As seen in Table 8, it is not possible to confirm a statistically significant correlation between the GDP and CTCO cycles, as the correlation coefficient amounting to 0.2757 was lower than the value of the two-tailed rejection region (critical value) of 5% (0.3739). There is no reason to interpret the correlation coefficient between CTCO_cl and GDP_cl (equal to 0.2757), as this correlation was not confirmed to be statistically significant (it may be apparent).

In view of this fact, a spectral analysis was applied for the GDP and CTCO cycles (Figure 9).

It follows from Figure 9 that in both the CTCO cycle and the GDP cycle, a leakage effect can be observed, i.e., cycles of various lengths and speeds are overlapping. Thus, a simple immediate synchronisation did not reveal a correlation between the cycle phases. Based on the spectral density analysis, it was found that CTCO was characterised by three cycle types (the first lasted 9.33 quarters, the second—3.11 quarters, the third—2.33 quarters). The spectral density analysis carried out for GDP identified the first cycle duration of 7 quarters, the second cycle—4.67 quarters, the third—3.11 quarters, the fourth—2.80 quarters. Thus, the supposition was confirmed, i.e., the cyclic component of CTCO and GDP were different, and their synchronisation should take into account the time lag.

In view of the observations, the cross-correlation function was computed, taking into account the lags (maximum lag: four quarters) (Figure 10). Along with that, it is important to note, that this type of recognition of the economic cycle phases plays a significant role in sustainable development, in terms of efficiency and the balanced distribution of benefits.

An extension of the above test results is included in Appendix A (Tables A1–A4).
2. Firstly, the obtained warning information may be used for development programming or planning via a shock analysis and analysing when they occur and phase out.

3. Secondly, they are significant from the point of view of trends and development rate evaluation.

4. Thirdly, they are valuable for the forecasting of development, as they take into account the cycle spans, multiplexity and complexity of various cycle occurrences (their leakage) and time lags (via specifying their lengths) as well as the depth of their occurrence. Thanks to the obtained results, it is known for how long the cycle phases may be extended.

5. Fourthly, the possibility to forecast the cycles and development gives the chance to effectively distribute and manage goods that stand in line with sustainable development and a fair system of global economy. It also leads to necessary changes in the business sector, which needs to improve sustainability conditions. As Vuong [96] stated, there is a need to move away from the downward spiral of eco-deficits to a new

![Cross-correlations of CTCO and lagged GDP_cl. XCF crossing the black lines are statistically significant at the level of p-value equal to 5%. Source: own computation in Gretl software based on the data presented in Table 4.](image)
eco-surplus culture and that value created for the environment should be rewarded with money.

Much effort was made through an investigation of the literature specialising in and proposing the synchronisation of economic cycles as an early warning tool in economic management in the context of the sustainable development concept. In the article, a holistic approach to the sustainable development of maritime ports through economic management was presented. The novelty was to introduce the early warning tool on the example of main maritime ports.

It is worth noting that analysed data did not cover the time of SARS-CoV-2, which had and still has a huge impact on global and national economies. The authors are preparing a study including this issue, as a very specific anomaly. COVID-19 had an impact on conditions in the crude oil and oil products market. On the demand side, containment measures and economic disruptions related to the COVID-19 pandemic have led to a slowdown in production and mobility worldwide [96–98]. The COVID-19 pandemic revealed the importance of seaports in the global supply chain. Since the port services were ‘essential services’, they could remain operational, whereas other national branches were shutdown. The reorganising of the working procedure, communication or at least minimising the number of people on shifts caused minor delays in cargo maritime ports. For the future, it is advisable to accelerate the digitalisation process [99]. The first quarter of the pandemic in 2020 in Polish ports (Gdansk, Gdynia, Szczecin-Swinoujście) caused limited drops, mostly noticed in container turnover [100].

The article omits other important topics, such as oil price forecasts or air emission empirical research, which are crucial in the context of the development of early warning indicators and the decision-making process. However, it is impossible to refer to all of the important, interesting and future-oriented research. Currently, in-depth global research in this field is conducted by researchers [101–104]. In the context of future research, it is worth extending the analysis to the problem of forecasting oil prices and air emissions, paying attention to the interaction of such variables as oil prices, inflation, exchange rates and purchasing power parity. In this context, it is worth extending the tool apparatus with the Cobb–Douglas function and the Phillips curve for the Vector Error Correction Model. However, such a study requires a separate article.

Additionally, the study will be continued in order to estimate the cargo traffic output gap, and to estimate the size of the negative output gap, as well as the impact of the shock on the output gap. The authors plan to expand the research in the direction of Vector Error Correction Models with their structural form (AB model with shock system—Blanchard and Quah). It will be interesting from the point of view of decompose variance and structural shock. It is probably the one way to deeply capture the window of shock distinction.

Author Contributions: All the authors have equally contributed to this paper. Conceptualisation, E.S., Z.K.-A., A.G. and E.Z.; methodology, E.S., Z.K.-A. and A.G.; validation, E.Z.; analysis, E.S., Z.K.-A. and A.G.; investigation, E.S., Z.K.-A. and A.G.; resources, E.S., Z.K.-A., A.G. and E.Z.; writing—original draft preparation, E.S., Z.K.-A., A.G. and E.Z.; visualisation, E.S., Z.K.-A. and A.G.; supervision, E.S., Z.K.-A., A.G. and E.Z.; project administration, E.S., Z.K.-A., A.G. and E.Z.; funding acquisition, E.S., Z.K.-A., A.G. and E.Z. All authors have read and agreed to the published version of the manuscript.

Funding: The project is financed within the framework of the program of the Minister of Science and Higher Education under the name ‘Regional Excellence Initiative’ in the years 2019–2022; project number 001/RID/2018/19; the amount of financing PLN 10,684,000.00. Part of the publication is also the result of a preliminary/pilot study entitled ‘Polskie porty morskie w obsłudze obrotów ładunkowych’ (in English: ‘Polish seaports handling of cargo volume’), registration number: 2019/03/X/HS4/02039 as part of the MINIATURA 3 competition financed by ‘National Science Centre, Poland’.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.
Data Availability Statement: Data are contained within the article or supplementary material. To estimate the analysed results, the authors used raw data from the databases included in the references listed as [85–92].

Acknowledgments: We would like to thank Joanna Krzemień-Rusche for her assistance in translating this paper.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

| Abbreviation | Description |
|--------------|-------------|
| AI           | artificial intelligence |
| bln          | billion |
| c_t          | cycle, cyclical component in Hodrick–Prescott filter formula |
| CO_2         | carbon dioxide |
| CTCO         | cargo traffic of crude oil and oil products (k tonnes) |
| CTCO_cl      | cycle for CTCO (filtered using the Hodrick–Prescott filter) |
| CTCO_sa      | seasonally adjusted CTCO (estimated using TRAMO/SEATS) |
| CTCO_sh      | irregular/shock component for CTCO (estimated using TRAMO/SEATS) |
| CTCO_tr      | trend for CTCO (filtered using the Hodrick–Prescott filter) |
| CTCO_trcl    | trend/cycle for CTCO (estimated using TRAMO/SEATS) |
| EU           | European Union |
| EUR          | euro currency |
| GDP          | Gross Domestic Product (raw data in bln PLN, at constant prices) |
| GDP_cl       | cycle for GDP (filtered using the Hodrick–Prescott filter) |
| GDP_sa       | seasonally adjusted GDP (estimated using TRAMO/SEATS) |
| GDP_sh       | irregular/shock component for GDP (estimated using TRAMO/SEATS) |
| GDP_tr       | trend for GDP (filtered using the Hodrick–Prescott filter) |
| GDP_trcl     | trend/cycle for GDP (estimated using TRAMO/SEATS) |
| IMO          | International Maritime Organisation |
| IoT          | Internet of Things |
| n            | number of observations for correlation coefficients |
| OECD         | Organisation for Economic Co-operation and Development |
| p-value      | probability value, asymptotic significance |
| PLN          | Polish currency, Polish zloty |
| R&D          | Research and Development |
| SDG          | Sustainable Development Goals |
| SEATS        | Signal Extraction in ARIMA Time Series |
| SPI          | Smart Port Index |
| T            | number of observations in the formula of the Hodrick–Prescott filter |
| t            | index of time, \( t = 1, 2, \ldots, T \) |
| TRAMO        | Time series Regression with ARIMA noise, Missing observations, and Outliers |
| UN           | United Nations |
| UNCTAD       | United Nations Conference on Trade and Development |
| USD          | currency of the USA, American dollar |
| WCED         | United Nation’s World Commission on Environment and Development |
| XCF          | cross-correlation function |
| \( \epsilon_t \) | shock, irregular component |
| \( \lambda \) | smoothing parameter in the formula of the Hodrick–Prescott filter |
| \( \tau_t \) | smoothed series in the formula of the Hodrick–Prescott filter, trend |
| \( y_t \)    | input series in formula of the Hodrick–Prescott filter: decompose into trend, cycle and shock |
## Appendix A

**Table A1.** Signal Extraction in ‘ARIMA’ Time Series for CTCO.

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2012 | 1866.600 | 1839.200 | 3880.600 | 4736.000 |
| 2013 | 3518.100 | 1790.600 | 3804.300 | 3626.200 |
| 2014 | 3504.800 | 2961.200 | 3275.800 | 4386.700 |
| 2015 | 3873.600 | 4169.600 | 4551.700 | 4099.000 |
| 2016 | 3574.600 | 3609.100 | 5070.800 | 4507.400 |
| 2017 | 4600.100 | 4343.600 | 3966.400 | 5408.300 |
| 2018 | 5506.200 | 4903.300 | 4457.000 | 5238.100 |

**FIRST PART: ARIMA ESTIMATION**

**SERIES TITLE:** CTCO

**PREADJUSTED WITH TRAMO:** YES

**METHOD:** MAXIMUM LIKELIHOOD

**NO OF OBSERVATIONS:** 28

**INPUT PARAMETERS**

| LAM = 1 | IMEAN = 0 | RSA = 0 | MQ = 4 |
|---------|-----------|---------|-------|
| P = 0   | BP = 0    | Q = 1   | BQ = 1 |
| D = 1   | BD = 1    | NOADMISS = 1 | RMOD = 0.500 |
| M = 36  | QMAX = 36 | BIAS = 1 | SMTR = 0 |
| THTR = −0.400 | MAXBIAS = 0.500 | IQM = 16 | OUT = 1 |
| EPSPHI = 2.000 | MAXIT = 20 | XL = 0.990 | SEK = 3.000 |

**TRANSFORMATION:** $Z \rightarrow Z$

**NONSEASONAL DIFFERENCING D = 1**

**SEASONAL DIFFERENCING BD = 1**

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Thanks are due to G. FIORENTINI and C. PLANAS for their research assistance

(Based on an original program developed by J. P. BURMAN at the Bank of England, version 1982)

(*) Copyright: V. GOMEZ, A. MARAVALL (1994, 1996)
Table A1. Cont.

| YEAR | 1ST     | 2ND     | 3RD     | 4TH     |
|------|---------|---------|---------|---------|
| 2013 | −1700.100 | −27.700 | −1033.500 | −1033.500 |
| 2014 | 1096.500 | 1183.900 | −1699.100 | 1289.000 |
| 2015 | −391.700 | 839.600 | 67.500 | −1563.600 |
| 2016 | −11.300 | −261.500 | 1079.600 | −110.700 |
| 2017 | 617.100 | −291.000 | −1838.900 | 2005.300 |
| 2018 | 5.200 | −346.400 | −69.100 | −660.800 |

MEAN OF DIFFERENCED SERIES = −0.7920E+02
MEAN SET EQUAL TO ZERO

VARIANCE OF Z SERIES = 0.9436E+06
VARIANCE OF DIFFERENCED SERIES = 0.1048E+07

AUTOCORRELATIONS OF STATIONARY SERIES

|         | −0.3547 | −0.0206 | −0.0072 | −0.3347 | 0.4402 |
|---------|---------|---------|---------|---------|--------|
| SE      | 0.2085  | 0.2333  | 0.2334  | 0.2334  | 0.2334 |
| 0.1370  | −0.2394 | −0.0033 | 0.2356  | −0.1264 | 0.3036 |
| SE      | 0.2925  | 0.2952  | 0.3036  | 0.3036  | 0.3036 |
| −0.3459 | 0.1586  | −0.1106 | 0.3417  | 0.3417  | 0.3447 |
| SE      | 0.3261  | 0.3417  | 0.3417  | 0.3417  | 0.3449 |

PARTIAL AUTOCORRELATIONS

|         | −0.3547 | −0.1675 | −0.0884 | −0.4429 | 0.1750 | −0.1285 |
|---------|---------|---------|---------|---------|--------|---------|
| SE      | 0.2085  | 0.2085  | 0.2085  | 0.2085  | 0.2085  | 0.2085  |
| 0.0781  | −0.4014 | 0.0580  | −0.0773 | 0.1178  | 0.1088  | 0.1088  |
| SE      | 0.2085  | 0.2085  | 0.2085  | 0.2085  | 0.2085  | 0.2085  |
| 0.0062  | −0.1237 | 0.1370  | −0.0079 | −0.0526 | 0.0278  | 0.0278  |
| SE      | 0.2085  | 0.2085  | 0.2085  | 0.2085  | 0.2085  | 0.2085  |

MODEL FITTED

NONSEASONAL P = 0 D = 1 Q = 1
SEASONAL BP = 0 BD = 1 BQ= 1
PERIODICITY MQ = 4

CONVERGED AFTER 11 ITERATIONS AND 29 FUNCTION VALUES F = 0.13265435E+08
0.990000E+00 0.462399E+00

PARAMETERS FIXED
Table A1. Cont.

### PARAMETER ESTIMATES

- **MEAN**: 0.00000
- **SE**: ******

### CORRELATION MATRIX

******
****** 1.000

### ARIMA PARAMETERS

- **THETA**: −0.9900
- **SE**: ******
- **BTHETA**: −0.4624
- **SE**: 0.1678

### RESIDUALS

| YEAR | 1ST       | 2ND       | 3RD       | 4TH       |
|------|-----------|-----------|-----------|-----------|
| 2012 | −531.546  | −55.657   | 302.937   | 626.179   |
| 2013 | 1072.403  | −420.828  | −278.764  | −1158.608 |
| 2014 | 158.707   | 655.510   | −986.401  | −95.666   |
| 2015 | 117.359   | 1186.241  | 485.691   | −675.451  |
| 2016 | −581.937  | −342.824  | 421.755   | −227.828  |
| 2017 | 431.668   | 244.226   | −1245.160 | 474.174   |
| 2018 | 778.530   | 339.667   | −420.391  | −287.726  |

### TEST-STATISTICS ON RESIDUALS

- **MEAN**: −0.4907E+00
- **ST.DEV.**: 0.1171E+03
- **T-VALUE**: −0.0042
- **NORMALITY TEST**: 0.5396 (CHI-SQUARED (2))
- **SKEWNESS**: −0.1451 (SE = 0.4629)
- **KURTOSIS**: 2.3850 (SE = 0.9258)
- **SUM OF SQUARES**: 0.1076E+08
Table A1. Cont.

DURBIN–WATSON = 1.8390

STANDARD DEVI. = 0.7156E+03
OF RESID.
VARIANCE = 0.5121E+06
OF RESID.

AUTOCORRELATIONS OF RESIDUAL

|       |         |         |         |         |         |
|-------|---------|---------|---------|---------|---------|
|       | 0.0636  | −0.3430 | −0.3254 | −0.0905 | 0.2781  |
| SE    | 0.1890  | 0.1897  | 0.2107  | 0.2280  | 0.2292  |
|       | −0.0029 | −0.2030 | 0.0156  | 0.2835  | 0.1447  |
| SE    | 0.2426  | 0.2426  | 0.2486  | 0.2486  | 0.2599  |
|       | −0.3836 | −0.1436 | 0.1633  | 0.1171  | 0.0161  |
| SE    | 0.2644  | 0.2835  | 0.2861  | 0.2894  | 0.2911  |

THE LJUNG–BOX Q VALUE IS 29.04
IF RESIDUALS ARE RANDOM, IT SHOULD BE DISTRIBUTED AS CHI-SQUARED (14)

INPUT PARAMETERS

|       |         |         |         |         |         |
|-------|---------|---------|---------|---------|---------|
| LAM   | 1       | IMEAN   | 0       | RSA     | 0       |
| P     | 0       | BP      | 0       | Q       | 1       |
| D     | 1       | BD      | 1       | NOADMISS| 1       |
| M     | 23      | QMAX    | 36      | RMOD    | 0.500   |
| THTR  | −0.400  | MAXBIAS | 0.500   | IQM     | 16      |
| EPSPHI| 2.000   | MAXIT   | 20      | XL      | 0.990   |
|       |         |         |         | SEK     | 3.000   |

TRANSFORMATION: \( Z \rightarrow Z \)

NONSEASONAL DIFFERENCING \( D = 1 \)
SEASONAL DIFFERENCING \( BD = 1 \)

DIFFERENCED SERIES

| YEAR | 1ST      | 2ND      | 3RD      | 4TH      |
|------|----------|----------|----------|----------|
| 2013 | −1700.100| −27.700  | −1033.500|          |
| 2014 | 1096.500 | 1183.900 | −1699.100| 1289.000 |
| 2015 | −391.700 | 839.600  | 67.500   | −1563.600|
| 2016 | −11.300  | −261.500 | 1079.600 | −110.700 |
| 2017 | 617.100  | −291.000 | −1838.900| 2005.300 |
| 2018 | 5.200    | −346.400 | −69.100  | −660.800 |

MEAN OF DIFFERENCED SERIES

\[ −0.7920 \times 10^2 \]

MEAN SET EQUAL TO ZERO
**Table A1. Cont.**

VARIANCE OF Z SERIES = $0.9436 \times 10^6$

VARIANCE OF DIFFERENCED SERIES = $0.1048 \times 10^7$

**Autocorrelations of Stationary Series**

| lags | 0.3547 | -0.0206 | -0.0072 | -0.3347 | 0.4402 | -0.2271 |
|------|--------|----------|----------|---------|--------|----------|
| SE   | 0.2085 | 0.2333   | 0.2334   | 0.2334  | 0.2534 | 0.2847   |
|      | 0.1370 | -0.2394  | -0.0033  | 0.2356  | -0.1264| 0.3032   |
| SE   | 0.2925 | 0.2952   | 0.3036   | 0.3036  | 0.3114 | 0.3136   |
|      | -0.3459| -0.0064  | 0.1586   | -0.1106 | 0.1547 | -0.1622  |
| SE   | 0.3261 | 0.3417   | 0.3417   | 0.3449  | 0.3464 | 0.3494   |

**Partial Autocorrelations**

| lags | 0.3547 | -0.1675 | -0.0884 | -0.4429 | 0.1750 | -0.1285 |
|------|--------|----------|----------|---------|--------|----------|
| SE   | 0.2085 | 0.2085   | 0.2085   | 0.2085  | 0.2085 | 0.2085   |
|      | 0.0781 | -0.4014  | 0.0580   | -0.0773 | 0.1178 | 0.1088   |
| SE   | 0.2085 | 0.2085   | 0.2085   | 0.2085  | 0.2085 | 0.2085   |
|      | 0.0062 | -0.1237  | 0.1370   | -0.0079 | -0.0526| 0.0278   |
| SE   | 0.2085 | 0.2085   | 0.2085   | 0.2085  | 0.2085 | 0.2085   |

**Model Fitted**

Nonseasonal P = 0 D = 1 Q = 1
Seasonal BP = 0 BD = 1 BQ = 1
Periodicity MQ = 4

Converged after 11 iterations and 29 function values $F = 0.13265435E+08$

0.990000E+00 0.462399E+00

Parameters fixed
1

Parameter estimates

Mean = 0.00000
Table A1. Cont.

SE = ********

CORRELATION MATRIX

******
****** 1.000

ARIMA PARAMETERS

THETA = −0.9900
SE = ********

BTHETA = −0.4624
SE = 0.1678

RESIDUALS

| YEAR | 1ST  | 2ND | 3RD   | 4TH   |
|------|------|-----|-------|-------|
| 2012 | -531.546 | -55.657 | 302.937 | 626.179 |
| 2013 | 1072.403 | -420.828 | -278.764 | -1158.608 |
| 2014 | 158.707  | 655.510  | -986.401 | -95.666  |
| 2015 | 117.359  | 1186.241 | 485.691  | -675.451 |
| 2016 | -581.937 | -342.824 | 421.755  | -227.828 |
| 2017 | 431.668  | 244.226  | -1245.160 | 474.174  |
| 2018 | 778.530  | 339.667  | -420.391 | -287.726 |

TEST-STATISTICS ON RESIDUALS

MEAN = −0.4907E+00
ST.DEV. = 0.1171E+03
OF MEAN
T-VALUE = −0.0042

NORMALITY TEST = 0.5396 (CHI-SQUARED (2))
SKEWNESS = −0.1451 (SE = 0.4629)
KURTOSIS = 2.3850 (SE = 0.9258)
SUM OF SQUARES = 0.1076E+08
DURBIN–WATSON = 1.8390
STANDARD DEVI. = 0.7156E+03
OF RESID.
VARIANCE = 0.5121E+06
OF RESID.
Table A1. Cont.

**AUTOCORRELATIONS OF RESIDUAL**

|         | −0.0636 | −0.3430 | −0.3254 | −0.0905 | 0.2781 | −0.1048 |
|---------|---------|---------|---------|---------|--------|---------|
| SE      | 0.1890  | 0.1897  | 0.2107  | 0.2280  | 0.2292 | 0.2410  |
|         | −0.0029 | −0.2030 | 0.0156  | 0.2835  | 0.1447 | 0.1077  |
| SE      | 0.2426  | 0.2426  | 0.2486  | 0.2486  | 0.2599 | 0.2628  |
|         | −0.3836 | −0.1436 | 0.1633  | 0.1171  | 0.0161 | −0.2165 |
| SE      | 0.2644  | 0.2835  | 0.2861  | 0.2894  | 0.2911 | 0.2912  |

**THE LJUNG–BOX Q VALUE IS 29.04**
**IF RESIDUALS ARE RANDOM, IT SHOULD BE DISTRIBUTED AS CHI-SQUARED (14)**

**APPROXIMATE TEST OF RUNS ON RESIDUALS**

NUM. DATA = 28  
NUM. (+) = 14  
NUM. (−) = 14  
T VALUE = −0.770

**AUTOCORRELATIONS OF SQUARED RESIDUAL**

|         | −0.2569 | −0.1377 | 0.2115  | −0.2014 |
|---------|---------|---------|---------|---------|
| SE      | 0.1890  | 0.2011  | 0.2044  | 0.2121  |
|         | −0.0975 | −0.1342 | 0.3623  | −0.1160 |
| SE      | 0.2384  | 0.2399  | 0.2425  | 0.2611  |
|         | −0.0688 | −0.1339 | 0.2076  | −0.0929 |
| SE      | 0.2636  | 0.2642  | 0.2666  | 0.2723  |

**THE LJUNG–BOX Q VALUE IS 21.34**
**IF RESIDUALS ARE RANDOM, IT SHOULD BE DISTRIBUTED AS CHI-SQUARED (14)**

**BACKWARD RESIDUALS**

| YEAR | 1ST      | 2ND      | 3RD      | 4TH      |
|------|----------|----------|----------|----------|
| 2012 | −1161.151| −144.921 | 635.738  | 1354.892 |
| 2013 | 382.797  | −1104.070| 515.712  | −195.358 |
| 2014 | 66.066   | −570.972 | −761.273 | 497.780  |
| 2015 | 216.779  | 673.934  | 429.115  | −242.701 |
| 2016 | −888.413 | −484.704 | 1324.585 | −366.122 |
| 2017 | −412.914 | −160.287 | −255.526 | 437.112  |
| 2018 | 359.691  | 161.981  | −189.797 | −131.714 |

**SECOND PART: DERIVATION OF THE MODELS FOR THE COMPONENTS**

SERIES TITLE: CTCO

MODEL PARAMETERS  
(0,1,1) (0,1,1)
| Table A1. Cont. |
|----------------|
| PARAMETER VALUES PASSED FROM ARIMA ESTIMATION (TRUE SIGNS) |
| THETA PARAMETERS |
| 1.00 – 0.99 |
| 1.00 0.00 0.00 0.00 -0.46 |
| BTHETA PARAMETERS |
| 1 |
| PHI PARAMETERS |
| 1 |
| BPHI PARAMETERS |
| 1 |
| NUMERATOR OF THE MODEL |
| 1.0000 -0.9900 0.0000 0.0000 -0.4624 0.4578 |
| STATIONARY AUTOREGRESSIVE TREND-CYCLE |
| 1 |
| 1.0000 -2.0000 1.0000 |
| NON-STATIONARY AUTOREGRESSIVE TREND-CYCLE |
| 1 |
| 1.0000 |
| AUTOREGRESSIVE TREND-CYCLE |
| 1 |
| 1.0000 -2.0000 1.0000 |
| STATIONARY AUTOREGRESSIVE TRANSITORY COMP. |
| 1 |
| 1 |
| NON-STATIONARY AUTOREGRESSIVE TRANSITORY COMP. |
| 1 |
| AUTOREGRESSIVE TRANSITORY COMP. |
| 1 |
| STATIONARY AUTOREGRESSIVE SEASONAL COMPONENT |
| 1 |
| 1.0000 1.0000 1.0000 1.0000 |
| NON-STATIONARY AUTOREGRESSIVE SEASONAL COMPONENT |
| 1 |
| 1.0000 |
| AUTOREGRESSIVE SEASONAL COMPONENT |
| 1 |
| 1.0000 |
| STATIONARY AUTOREGRESSIVE SEASONALLY ADJUSTED COMPONENT |
| 1 |
| 1 |
| NON-STATIONARY AUTOREGRESSIVE SEASONALLY ADJUSTED COMPONENT |
| 1 |
| 1.0000 -2.0000 1.0000 |
| AUTOREGRESSIVE SEASONALLY ADJUSTED COMPONENT |
| 1 |
| 1.0000 -2.0000 1.0000 |
### Table A1. Cont.

| TOTAL DENOMINATOR | 1.0000 | −1.0000 | 0.0000 | 0.0000 | −1.0000 | 1.0000 |
|---|---|---|---|---|---|---|

#### MA Roots of Trend–Cycle

| REAL PART | IMAGINARY PART | MODULUS | ARGUMENT (DEG.) | PERIOD |
|---|---|---|---|---|
| 0.990 | 0.000 | 0.990 | 0.000 | − |
| −1.000 | 0.000 | 1.000 | 180.000 | 2.0 |

TOTAL SQUARED ERROR = $0.1194682 \times 10^{-35}$

#### MA Roots of Seas.

| REAL PART | IMAGINARY PART | MODULUS | ARGUMENT (DEG.) | PERIOD |
|---|---|---|---|---|
| −0.410 | 0.420 | 0.587 | 134.295 | 2.681 |
| 1.000 | 0.000 | 1.000 | 0.000 | − |

TOTAL SQUARED ERROR = $0.3123552 \times 10^{-29}$

#### MA Roots of Seasonally Adjusted Series

| REAL PART | IMAGINARY PART | MODULUS | ARGUMENT (DEG.) | PERIOD |
|---|---|---|---|---|
| 0.825 | 0.000 | 0.825 | 0.000 | − |
| 0.990 | 0.000 | 0.990 | 0.000 | − |

TOTAL SQUARED ERROR = $0.3729890 \times 10^{-30}$

#### Models for the Components

| TREND-CYCLE NUMERATOR | 1.0000 | 0.0100 | −0.9900 |
|---|---|---|---|
| TREND-CYCLE DENOMINATOR | −2.0000 | 1.0000 |

INNOV. VAR. (*) $0.00453$
### Table A1. Cont.

| SEAS. NUMERATOR | SEAS. DENOMINATOR |
|-----------------|------------------|
| 1.0000          | 1.0000           | −0.1805         | −0.4752         | −0.3442         |

**SEASONALLY ADJUSTED NUMERATOR**

| 1.0000 | 1.0000 | −1.8147 |

**SEASONALLY ADJUSTED DENOMINATOR**

| 1.0000 | −2.0000 | 1.0000 |

| INNOV. VAR. (*) 0.06494 |

**INNOV. VAR. (*) 0.48461**

### MOVING AVERAGE REPRESENTATION OF ESTIMATORS (NONSTATIONARY)

The last column (the sum of the Psi-Weights) should be zero for negative lags, 1 for lag = 0, and equal to the Box–Jenkins Psi-Weights for positive lags.

**PSIEP (LAG), for example, represents the effect of the overall innovation a (t-lag) on the estimator of the trend for period t.**

Similarly for the other components.

| LAG  | PSIEP  | PSIES  | PSIEC  | PSIEA  | PSIUE  | PSIEP + PSIES + PSIUE |
|------|--------|--------|--------|--------|--------|-----------------------|
| −8   | 0.0310 | 0.0914 | 0.0000 | −0.0914 | −0.1225 | 0.0000                |
| −7   | 0.0386 | −0.0366| 0.0000 | 0.0366  | −0.0020 | 0.0000                |
| −6   | 0.0473 | −0.0453| 0.0000 | 0.0453  | −0.0020 | 0.0000                |
| −5   | 0.0561 | −0.0541| 0.0000 | 0.0541  | −0.0020 | 0.0000                |
| −4   | 0.0675 | 0.1978 | 0.0000 | −0.1978 | −0.2652 | 0.0000                |
| −3   | 0.0838 | −0.0791| 0.0000 | 0.0791  | −0.0047 | 0.0000                |
| −2   | 0.1027 | −0.0979| 0.0000 | 0.0979  | −0.0048 | 0.0000                |
| −1   | 0.1218 | −0.1170| 0.0000 | 0.1170  | −0.0048 | 0.0000                |
| 0    | 0.1366 | 0.3788 | 0.0000 | 0.6212  | 0.4846  | 1.0000                |
| 1    | 0.1424 | −0.1324| 0.0000 | 0.1424  | 0.0000  | 0.0100                |
| 2    | 0.1437 | −0.1337| 0.0000 | 0.1437  | 0.0000  | 0.0100                |
| 3    | 0.1451 | −0.1351| 0.0000 | 0.1451  | 0.0000  | 0.0100                |
| 4    | 0.1464 | 0.4012 | 0.0000 | 0.1464  | 0.0000  | 0.5476                |
| 5    | 0.1478 | −0.1324| 0.0000 | 0.1478  | 0.0000  | 0.0154                |
| 6    | 0.1491 | −0.1337| 0.0000 | 0.1491  | 0.0000  | 0.0154                |
| 7    | 0.1504 | −0.1351| 0.0000 | 0.1504  | 0.0000  | 0.0154                |
| 8    | 0.1518 | 0.4012 | 0.0000 | 0.1518  | 0.0000  | 0.5530                |
**Table A1. Cont.**

**WIENER–KOLMOGOROV FILTERS (ONE SIDE)**

**TREND-CYCLE COMPONENT**

|                |                  |                  |                  |                  |                  |
|----------------|------------------|------------------|------------------|------------------|------------------|
|                | 0.0859           | 0.0798           | 0.0674           | 0.0550           | 0.0443           | 0.0369           |
|                | 0.0311           | 0.0254           | 0.0205           | 0.0170           | 0.0144           | 0.0117           |
|                | 0.0095           | 0.0079           | 0.0067           | 0.0054           | 0.0044           | 0.0036           |
|                | 0.0031           | 0.0025           | 0.0020           | 0.0017           | 0.0014           | 0.0012           |
|                | 0.0009           | 0.0008           | 0.0006           | 0.0005           | 0.0004           | 0.0004           |
|                | 0.0003           | 0.0002           | 0.0002           | 0.0002           | 0.0001           | 0.0001           |
|                | 0.0001           | 0.0001           | 0.0001           | 0.0000           | 0.0000           | 0.0000           |
|                | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           |
|                | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           |

**SA SERIES COMPONENT**

|                | 0.7552           | 0.0796           | 0.0672           | 0.0548           | -0.1358          | 0.0368           |
|                | 0.0311           | 0.0254           | 0.0205           | 0.0170           | 0.0144           | 0.0117           |
|                | -0.0290          | 0.0079           | 0.0066           | 0.0054           | -0.0134          | 0.0036           |
|                | 0.0031           | 0.0025           | -0.0062          | 0.0017           | 0.0014           | 0.0012           |
|                | -0.0029          | 0.0008           | 0.0007           | 0.0005           | -0.0013          | 0.0004           |
|                | 0.0003           | 0.0002           | -0.0006          | 0.0002           | 0.0001           | 0.0001           |
|                | -0.0003          | 0.0001           | 0.0001           | 0.0001           | -0.0001          | 0.0000           |
|                | 0.0000           | 0.0000           | -0.0001          | 0.0000           | 0.0000           | 0.0000           |
|                | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           |

**SEASONAL COMPONENT**

|                | 0.2448           | -0.0796          | -0.0672          | -0.0548          | 0.1358           | -0.0368          |
|                | -0.0311          | -0.0254          | 0.0628           | -0.0170          | -0.0144          | -0.0117          |
|                | 0.0290           | -0.0079          | -0.0066          | -0.0054          | 0.0134           | -0.0036          |
|                | -0.0031          | -0.0025          | 0.0062           | -0.0017          | -0.0014          | -0.0012          |
|                | -0.0003          | -0.0008          | -0.0007          | -0.0005          | 0.0013           | -0.0004          |
|                | 0.0003           | -0.0001          | -0.0001          | -0.0001          | 0.0001           | 0.0000           |
|                | 0.0000           | 0.0000           | 0.0001           | 0.0000           | 0.0000           | 0.0000           |
|                | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           |
|                | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           |

**IRREGULAR COMPONENT**

|                | 0.6692           | -0.0002          | -0.0002          | -0.0001          | -0.1801          | -0.0001          |
|                | -0.0001          | -0.0001          | -0.0833          | 0.0000           | 0.0000           | 0.0000           |
|                | -0.0385          | 0.0000           | 0.0000           | 0.0000           | -0.0178          | 0.0000           |
|                | 0.0000           | 0.0000           | -0.0082          | 0.0000           | 0.0000           | 0.0000           |
|                | -0.0038          | 0.0000           | 0.0000           | 0.0000           | -0.0017          | 0.0000           |
|                | 0.0000           | 0.0000           | -0.0008          | 0.0000           | 0.0000           | 0.0000           |
|                | -0.0004          | 0.0000           | 0.0000           | 0.0000           | -0.0002          | 0.0000           |
|                | 0.0000           | 0.0000           | -0.0001          | 0.0000           | 0.0000           | 0.0000           |
|                | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           |
|                | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           | 0.0000           |

**AUTOCORRELATION FUNCTION OF COMPONENTS (STATIONARY TRANSFORMATION)**

|                |                  |                  |                  |                  |                  |
|----------------|------------------|------------------|------------------|------------------|------------------|
|                | TREND-CYCLE      | ADJUSTED         |                  |                  |                  |


Table A1. Cont.

| LAG | COMPONENT | ESTIMATOR | ESTIMATE | COMPONENT | ESTIMATOR | ESTIMATE |
|-----|-----------|-----------|----------|-----------|-----------|----------|
| 1   | 0.000     | 0.667     | 0.508    | −0.665    | −0.662    | −0.598   |
| 2   | −0.500    | 0.122     | −0.258   | 0.165     | 0.119     | 0.112    |
| 3   | 0.000     | −0.178    | −0.496   | 0.000     | 0.178     | 0.079    |
| 4   | 0.000     | −0.268    | −0.235   | 0.000     | −0.269    | −0.343   |

VAR. (*) 0.009 0.000 0.000 2.917 1.959 1.297

(*) IN UNITS OF VAR (A)

AUTOCORRELATION FUNCTION OF COMPONENTS (STATIONARY TRANSFORMATION)

| LAG | COMPONENT | ESTIMATOR | ESTIMATE | COMPONENT | ESTIMATOR | ESTIMATE |
|-----|-----------|-----------|----------|-----------|-----------|----------|
| 1   | 0.000     | 0.077     | 0.050    | −0.156    | 0.058     |         |
| 2   | 0.000     | −0.224    | −0.300   | −0.522    | −0.781    |         |
| 3   | 0.000     | −0.365    | −0.250   | −0.230    | −0.255    |         |
| 4   | 0.000     | −0.269    | −0.285   | 0.614     | 0.531     |         |

VAR. (*) 0.485 0.324 0.263 0.089 0.027 0.029

(*) IN UNITS OF VAR (A)

For all components it should happen that:
- Var (Component) > Var (Estimator)
- Var (Estimator) close to Var (Estimate)

CROSSCORRELATION BETWEEN STATIONARY TRANSFORMATION OF ESTIMATORS

| ESTIMATOR | ESTIMATE |
|-----------|----------|
| TREND/SEASONAL | −0.208 | −0.420 |
| SEASONAL/IRREGULAR | 0.223 | 0.122 |
| TREND-CYCLE/IRREGULAR | −0.408 | −0.359 |

PSEUDO-INNOVATIONS IN THE COMPONENTS

PSEUDO INNOVATIONS IN TREND-CYCLE
Table A1. Cont.

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2012 | 1.29 | 4.44 | 4.71 | −0.40|
| 2013 | −6.70| −4.82| −0.43| −0.76|
| 2014 | 1.04 | −2.49| −5.30| 1.83 |
| 2015 | 9.17 | 9.08 | 0.44 | −6.32|
| 2016 | −8.52| −4.30| 0.85 | −0.09|
| 2017 | 3.42 | 6.81 | 10.67| 10.76|
| 2018 | 0.06 | −8.95| −11.17|−5.26|

**PSEUDO INNOVATIONS IN SEASONAL**

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2012 | 6.43 | 11.78| −9.71| −50.48|
| 2013 | −20.87| 98.15| 47.08| −73.89|
| 2014 | −130.08| 146.66| 38.63| −55.92|
| 2015 | 0.43 | −2.75| −48.00| −42.55|
| 2016 | 106.03| 83.07| −99.34| −62.87|
| 2017 | 16.90 | 172.35| −87.56| −154.34|
| 2018 | 31.35 | 74.57| 80.36| −75.40|

**PSEUDO INNOVATIONS IN SEASONALLY ADJUSTED SERIES**

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2012 | −138.15| −169.71| 241.55| 412.81|
| 2013 | 253.23 | −607.35| 27.64 | −2.49 |
| 2014 | −207.53| 610.11| −366.37| −517.66|
| 2015 | −226.93| 445.16| 687.41| 45.90 |
| 2016 | 45.79 | −690.94| 41.11 | 78.88 |
| 2017 | −456.70| 170.87| −429.09| 662.73|
| 2018 | 727.65 | 239.23| −204.89| −682.81|

**THIRD PART: ERROR ANALYSIS**

**FINAL ESTIMATION ERROR**

| ACF (LAG) | TREND-CYCLE | ADJUSTED | TREND-CYCLE | ADJUSTED |
|-----------|-------------|----------|-------------|----------|
| 1         | 0.912       | −0.320   | 0.827       | −0.104   |
| 2         | 0.752       | −0.277   | 0.677       | −0.216   |
| 3         | 0.620       | −0.224   | 0.555       | −0.313   |
| 4         | 0.511       | 0.553    | 0.460       | 0.462    |
| VAR. (*)  | 0.043       | 0.120    | 0.047       | 0.087    |

**REVISION IN CONCURRENT ESTIMATOR**

| ACF (LAG) | TREND-CYCLE | ADJUSTED | TREND-CYCLE | ADJUSTED |
|-----------|-------------|----------|-------------|----------|
| 1         | 0.867       | −0.229   | −0.229      | 0.515    |
| 2         | 0.713       | −0.251   | −0.251      | 0.515    |
| 3         | 0.586       | −0.262   | −0.262      | 0.515    |
| 4         | 0.484       | 0.515    | 0.515       | 0.515    |
| VAR. (*)  | 0.089       | 0.207    | 0.207       | 0.207    |
Table A1. Cont.

(*) IN UNITS OF VAR (A)

VARIANCE OF THE REVISION ERROR (*)

| ADDITIONAL PERIODS | TREND-CYCLE PERIODS | ADJUSTED PERIODS |
|--------------------|---------------------|------------------|
| 0                  | 0.4687E-01          | 0.8729E-01       |
| 4                  | 0.9909E-02          | 0.1866E-01       |
| 8                  | 0.02071E-02         | 0.3990E-02       |
| 12                 | 0.4239E-03          | 0.8532E-03       |
| 16                 | 0.8437E-04          | 0.1824E-03       |
| 20                 | 0.1723E-04          | 0.3900E-04       |

PERCENTAGE REDUCTION IN THE STANDARD ERROR OF THE REVISION AFTER ADDITIONAL YEARS (COMPARISON WITH CONCURRENT ESTIMATORS)

|                      | AFTER 1 YEAR | AFTER 2 YEAR | AFTER 3 YEAR | AFTER 4 YEAR | AFTER 5 YEAR |
|----------------------|--------------|--------------|--------------|--------------|--------------|
|                      | 54.02        | 78.98        | 90.49        | 95.76        | 98.08        |

VARIANCE OF THE REVISION ERROR FOR THE SEASONAL COMPONENT (ONE YEAR AHEAD ADJUSTMENT)

| PERIODS AHEAD | VARIANCE (*) |
|---------------|--------------|
| 0             | 0.8729E-01   |
| 1             | 0.2308       |
| 2             | 0.2483       |
| 3             | 0.2662       |
| 4             | 0.2845       |

AVERAGE PERCENTAGE REDUCTION IN RMSE FROM CONCURRENT ADJUSTMENT 35.24

(*) IN UNITS OF VAR (A)

DECOMPOSITION OF THE SERIES: RECENT ESTIMATES
### Table A1. Cont.

| PERIOD | SERIES | TREND-CYCLE | ADJUSTED |
|--------|--------|-------------|----------|
|        |        | ESTIMATE   | STANDARD ERROR |
|        |        | TOTAL OF REVISION |                      |
|        |        | ESTIMATE   | STANDARD ERROR |
|        |        | TOTAL OF REVISION |                      |
| −8    | 4507   | 4438       | 151.3    | 32.57   | 4238 | 251.6 | 45.21 |
| −7    | 4600   | 4520       | 152.9    | 39.41   | 4526 | 260.0 | 79.54 |
| −6    | 4344   | 4604       | 155.4    | 48.11   | 4634 | 261.3 | 83.73 |
| −5    | 3966   | 4691       | 159.0    | 58.83   | 4193 | 263.3 | 89.78 |
| −4    | 5408   | 4785       | 164.0    | 71.24   | 5088 | 266.1 | 97.77 |
| −3    | 5506   | 4875       | 171.0    | 86.06   | 5254 | 301.4 | 172.0 |
| −2    | 4903   | 4953       | 181.2    | 104.9   | 5121 | 306.7 | 181.1 |
| −1    | 4457   | 5026       | 195.5    | 128.1   | 4824 | 314.6 | 194.2 |
| 0     | 5238   | 5103       | 214.1    | 154.9   | 4963 | 325.5 | 211.4 |

**STANDARD ERROR OF 147.7 247.5**

**FINAL ESTIMATOR**

| PERIOD | SEASONAL | ESTIMATE |
|--------|----------|----------|
|        | TOTAL OF REVISION |     |
| −8    | 269.2    | 251.6    | 45.21 |
| −7    | 73.99    | 260.0    | 79.54 |
| −6    | −290.0   | 261.3    | 83.73 |
| −5    | −226.1   | 263.3    | 89.78 |
| −4    | 320.3    | 266.1    | 97.77 |
| −3    | 252.5    | 301.4    | 172.0 |
| −2    | −217.4   | 306.7    | 181.1 |
| −1    | −366.6   | 314.6    | 194.2 |
| 0     | 274.9    | 325.5    | 211.4 |

**STANDARD ERROR OF 247.5**

**FINAL ESTIMATOR**

**DECOMPOSITION OF THE SERIES: FORECAST**

| PERIOD | SERIES | TREND-CYCLE | ADJUSTED |
|--------|--------|-------------|----------|
|        | FORECAST | S.E. | FORECAST | STANDARD ERROR |
|        | TOTAL OF REVISION |                      |
|        | FORECAST | S.E. | FORECAST | STANDARD ERROR |
|        | TOTAL OF REVISION |                      |
| 1     | 5478    | 715.6 | 5184    | 235.3    | 183.2  | 5184 | 551.0 | 492.3 |
| 2     | 5074    | 715.7 | 5266    | 256.4    | 209.6  | 5266 | 560.3 | 502.7 |
| 3     | 4978    | 715.7 | 5349    | 276.3    | 233.5  | 5349 | 569.7 | 513.1 |
| 4     | 5700    | 715.8 | 5431    | 295.2    | 255.5  | 5431 | 579.1 | 523.5 |
| 5     | 5808    | 816.0 | 5514    | 313.2    | 276.2  | 5514 | 588.5 | 533.9 |
| 6     | 5404    | 816.1 | 5596    | 330.6    | 295.7  | 5596 | 597.9 | 544.3 |
| 7     | 5308    | 816.2 | 5679    | 347.4    | 314.4  | 5679 | 607.3 | 554.6 |
| 8     | 6029    | 816.2 | 5761    | 363.7    | 332.3  | 5761 | 616.8 | 565.0 |
Table A1. Cont.

| PERIOD | SEASONAL FORECAST | TOTAL OF REVISION | STANDARD ERROR |
|--------|------------------|-------------------|----------------|
| 1      | 294.1            | 423.6             | 343.8          |
| 2      | −191.9           | 434.1             | 356.6          |
| 3      | −370.8           | 444.5             | 369.2          |
| 4      | 268.5            | 454.9             | 381.7          |
| 5      | 294.1            | 537.9             | 477.6          |
| 6      | −191.9           | 546.2             | 486.9          |
| 7      | −370.8           | 554.5             | 496.2          |
| 8      | 268.5            | 562.9             | 505.6          |

CONFIDENCE INTERVAL AROUND A SEASONAL COMPONENT OF 0

| FINAL ESTIMATOR | CONCURRENT ESTIMATOR |
|-----------------|-----------------------|
| 95% CONFIDENCE INTERVAL | −485.1 485.1 |
| 70% CONFIDENCE INTERVAL   | −256.7 256.7 |

SAMPLE MEANS

| SERIES          | COMPLETE PERIOD | LAST THREE YEARS |
|-----------------|-----------------|------------------|
| SERIES          | 3967            | 4599             |
| TREND-CYCLE     | 3995            | 4649             |
| ADJUSTED        | 3995            | 4621             |
| SEASONAL        | −27.94          | −22.18           |

STANDARD ERROR OF ALTERNATIVE MEASURES OF GROWTH (NONANNUALISED GROWTH)

1. PERIOD TO PERIOD GROWTH OF THE SERIES

| TRENDS CYCLE | SEASONALLY ADJ. SERIES |
|--------------|------------------------|
| CONCURRENT ESTIMATOR | 67.534 503.460 |
| 1—PERIOD REVISION     | 66.137 503.275 |
| 2—PERIOD REVISION     | 64.737 503.094 |
| 3—PERIOD REVISION     | 63.674 462.453 |
| 4—PERIOD REVISION     | 63.155 425.890 |
| 5—PERIOD REVISION     | 62.838 425.843 |
| 6—PERIOD REVISION     | 62.526 425.798 |
| 7—PERIOD REVISION     | 62.292 415.829 |
| 8—PERIOD REVISION     | 62.179 407.393 |
### Table A1. Cont.

| QUARTER 1 | 270.135 | 2013.839 | 247.645 | 1608.859 |
| QUARTER 2 | 230.983 | 1006.489 | 208.088 | 791.175  |
| QUARTER 3 | 194.733 | 669.655  | 171.699 | 516.343  |
| QUARTER 4 | 168.324 | 260.152  | 146.033 | 234.006  |

### 3. ACCUMULATED GROWTH OVER THE LAST QUARTER OF PREVIOUS YEAR

| QUARTER 1 | FINAL ESTIMATOR | 61.911 | 402.215 |
| QUARTER 2 | CONCURRENT ESTIMATOR | TREND-CYCLE | SEASONALLY ADJ. SERIES | FINAL ESTIMATOR | TREND-CYCLE | SEASONALLY ADJ. SERIES |
| QUARTER 3 | 270.135 | 2013.839 | 247.645 | 1608.859 |
| QUARTER 4 | 230.983 | 1006.489 | 208.088 | 791.175  |

(CENTERED) ESTIMATOR OF THE PRESENT ANNUAL GROWTH

| STANDARD ERROR | TREND-CYCLE | SEAS. ADJ. SERIES | ORIGINAL SERIES |
| CONCURRENT ESTIMATOR | 182.745 | 643.638 | 715.714 |
| FINAL ESTIMATOR | 146.033 | 234.006 | 0.000 |

### FOURTH PART: ESTIMATES OF THE COMPONENTS (LEVELS)

#### ORIGINAL SERIES

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | 1866.600 | 1839.200 | 3880.600 | 4736.000 |
| 2013 | 3518.100 | 1790.600 | 3804.300 | 3626.200 |
| 2014 | 3504.800 | 2961.200 | 3275.800 | 4386.700 |
| 2015 | 3873.600 | 4169.600 | 4551.700 | 4099.000 |
| 2016 | 3574.600 | 3609.100 | 5070.800 | 4507.400 |
| 2017 | 4600.100 | 4343.600 | 3966.400 | 5408.300 |
| 2018 | 5506.200 | 4903.300 | 4457.000 | 5238.100 |

#### SEASONAL COMPONENT

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | -450.816 | -1075.008 | 485.251 | 904.432 |
| 2013 | -209.543 | -1007.740 | 354.343 | 636.675 |
| 2014 | -88.342 | -669.293 | 167.830 | 468.889 |
| 2015 | -117.503 | -418.540 | 204.620 | 298.699 |
| 2016 | -113.237 | -379.628 | 135.842 | 269.207 |
| 2017 | 73.989 | -289.983 | -226.118 | 320.264 |
| 2018 | 252.491 | -217.390 | -366.567 | 274.923 |

#### STANDARD ERROR OF SEASONAL

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | 325.516 | 314.570 | 306.666 | 301.403 |
| 2013 | 266.112 | 263.283 | 261.281 | 259.968 |
| 2014 | 251.597 | 250.960 | 250.512 | 250.220 |
| 2015 | 248.384 | 248.149 | 248.246 | 248.384 |
Table A1. Cont.

| YEAR | 1ST   | 2ND   | 3RD   | 4TH   |
|------|-------|-------|-------|-------|
| 2016 | 250.220 | 250.512 | 250.960 | 251.597 |
| 2017 | 259.968 | 261.281 | 263.283 | 266.112 |
| 2018 | 301.403 | 306.666 | 314.570 | 325.516 |

TREND-CYCLE

| YEAR | 1ST   | 2ND   | 3RD   | 4TH   |
|------|-------|-------|-------|-------|
| 2012 | 2880.125 | 2978.811 | 3080.988 | 3171.839 |
| 2013 | 3243.089 | 3303.945 | 3368.921 | 3441.254 |
| 2014 | 3520.524 | 3602.370 | 3688.396 | 3783.659 |
| 2015 | 3880.790 | 3968.908 | 4041.723 | 4105.986 |
| 2016 | 4177.612 | 4263.672 | 4353.976 | 4437.923 |
| 2017 | 4520.136 | 4603.811 | 4691.496 | 4785.336 |
| 2018 | 4874.685 | 4952.665 | 5025.900 | 5102.613 |

STANDARD ERROR OF TREND-CYCLE

| YEAR | 1ST   | 2ND   | 3RD   | 4TH   |
|------|-------|-------|-------|-------|
| 2012 | 214.081 | 195.529 | 181.186 | 170.973 |
| 2013 | 164.011 | 159.016 | 155.370 | 152.899 |
| 2014 | 151.280 | 150.151 | 149.346 | 148.811 |
| 2015 | 148.466 | 148.060 | 148.228 | 148.466 |
| 2016 | 148.811 | 149.346 | 150.151 | 151.280 |
| 2017 | 152.899 | 155.370 | 159.016 | 164.011 |
| 2018 | 170.973 | 181.186 | 195.529 | 214.081 |

SEASONALLY ADJUSTED SERIES

| YEAR | 1ST   | 2ND   | 3RD   | 4TH   |
|------|-------|-------|-------|-------|
| 2012 | 2317.416 | 2914.208 | 3395.349 | 3831.568 |
| 2013 | 3727.643 | 2798.340 | 3449.957 | 2989.525 |
| 2014 | 3593.142 | 3630.493 | 3107.970 | 3917.811 |
| 2015 | 3991.103 | 4588.140 | 4347.080 | 3800.301 |
| 2016 | 3687.837 | 3988.728 | 4934.958 | 4238.193 |
| 2017 | 4526.111 | 4633.583 | 4192.518 | 5088.036 |
| 2018 | 5253.709 | 5120.690 | 4823.567 | 4963.177 |

STANDARD ERROR OF SEASONALLY ADJUSTED SERIES

| YEAR | 1ST   | 2ND   | 3RD   | 4TH   |
|------|-------|-------|-------|-------|
| 2012 | 325.516 | 314.570 | 306.666 | 301.403 |
| 2013 | 266.112 | 263.283 | 261.281 | 259.968 |
| 2014 | 251.597 | 250.960 | 250.512 | 250.220 |
| 2015 | 248.384 | 248.149 | 248.228 | 248.384 |
| 2016 | 250.220 | 250.512 | 250.960 | 250.512 |
| 2017 | 259.968 | 261.281 | 263.283 | 266.112 |
| 2018 | 301.403 | 306.666 | 314.570 | 325.516 |

IRREGULAR COMPONENT

| YEAR | 1ST   | 2ND   | 3RD   | 4TH   |
|------|-------|-------|-------|-------|
| 2012 | −562.710 | −64.604 | 314.361 | 659.729 |
| 2013 | 484.554 | −505.605 | 81.036 | −451.729 |
| 2014 | 72.618 | 28.123 | −580.425 | 134.152 |
| 2015 | 110.313 | 619.232 | 305.357 | −305.686 |
| 2016 | −498.775 | −274.944 | 580.982 | −199.730 |
| 2017 | 5.975 | 29.772 | −498.978 | 302.699 |
Table A1. Cont.

| Year | 1st   | 2nd   | 3rd   | 4th   |
|------|-------|-------|-------|-------|
| 2018 | 379.024 | 168.025 | −202.333 | −139.436 |

** PROCESSING COMPLETED **

Source: own computation in Gretl software with TRAMO/SEATS packages based on Table 4.

Table A2. Signal Extraction in ‘ARIMA’ Time Series for GDP.

SIGNAL EXTRACTION IN ‘ARIMA’ TIME SERIES (BETA VERSION) (*)

BY

V. GOMEZ and A. MARAVALL,

with the programming assistance of G. CAPORELLO

Thanks are due to G. FIORENTINI and C. PLANAS for their research assistance

(Based on an original program developed by J. P. BURMAN at the Bank of England, version 1982)

(*) Copyright: V. GOMEZ, A. MARAVALL (1994,1996)

FIRST PART:

ARIMA ESTIMATION

SERIES TITLE: GDP

PREADJUSTED WITH TRAMO: YES

METHOD: MAXIMUM LIKELIHOOD

NO OF OBSERVATIONS = 28

| Year | 1st | 2nd | 3rd | 4th |
|------|-----|-----|-----|-----|
| 2012 | 413.498 | 412.485 | 414.295 | 412.108 |
| 2013 | 412.408 | 416.854 | 420.011 | 421.123 |
| 2014 | 425.472 | 430.316 | 433.917 | 436.726 |
| 2015 | 442.944 | 446.427 | 452.085 | 457.642 |
| 2016 | 456.344 | 462.331 | 463.510 | 474.004 |
| 2017 | 478.603 | 482.829 | 488.264 | 496.584 |
| 2018 | 503.152 | 509.849 | 516.884 | 520.822 |

INPUT PARAMETERS

| Parameter | Value |
|-----------|-------|
| LAM | 1 |
| P | 0 |
| D | 1 |
| M | 36 |
| THTR | −0.400 |
| EPSPHI | 2.000 |
| I = IMEAN | 1 |
| BP | 0 |
| BD | 1 |
| Q | 1 |
| QMAX | 36 |
| MAXBIAS | 0.500 |
| RSA | 0 |
| NOADMISS | 1 |
| QM | 16 |
| MQ | 4 |
| BQ | 1 |
| RMOD | 0.500 |
| SMTR | 0 |
| OUT | 1 |
| XL | 0.990 |
| SEK | 3.000 |

TRANSFORMATION: Z → Z

NONSEASONAL DIFFERENCING D = 1

SEASONAL DIFFERENCING BD = 1
Table A2. Cont.

### DIFFERENCED SERIES

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2013 | 5.459| 1.347| 3.299|      |
| 2014 | 4.049| 0.398| 0.444| 1.697|
| 2015 | 1.869| −1.361| 2.057| 2.748|
| 2016 | −7.516| 2.504| −4.479| 4.937|
| 2017 | 5.897| −1.761| 4.256| −2.174|
| 2018 | 1.969| 2.471| 1.600| −4.382|

SERIES HAS BEEN MEAN CORRECTED

### DIFFERENCED AND CENTERED SERIES

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2013 | 4.358| 0.246| 2.198|      |
| 2014 | 2.948| −0.703| −0.657| 0.596|
| 2015 | 0.768| −2.462| 0.956| 1.647|
| 2016 | −8.617| 1.403| −5.580| 3.836|
| 2017 | 4.796| −2.862| 3.155| −3.275|
| 2018 | 0.868| 1.570| 0.499| −5.483|

MEAN OF DIFFERENCED SERIES 0.1101E+01

VARIANCE OF Z SERIES = 0.1188E+04

VARIANCE OF DIFFERENCED SERIES = 0.1091E+02

### AUTOCORRELATIONS OF STATIONARY SERIES

|       | −0.2790 | 0.1059 | 0.0428 | −0.2485 | 0.1982 | −0.0861 |
|-------|---------|--------|--------|---------|--------|---------|
| SE    | 0.2085  | 0.2242 | 0.2263 | 0.2267  | 0.2382 | 0.2453  |
|       | 0.0100  | −0.1925| 0.0074 | −0.0569 | 0.0277 | 0.0559  |
| SE    | 0.2466  | 0.2466 | 0.2531 | 0.2531  | 0.2536 | 0.2538  |
|       | −0.1045 | 0.1487 | 0.0480 | −0.0832 | 0.0882 | −0.0228 |
| SE    | 0.2543  | 0.2562 | 0.2599 | 0.2603  | 0.2614 | 0.2627  |

### PARTIAL AUTOCORRELATIONS

|       | −0.2790 | 0.0304 | 0.0868 | −0.2388 | 0.0738 | 0.0231  |
|-------|---------|--------|--------|---------|--------|---------|
| SE    | 0.2085  | 0.2085 | 0.2085 | 0.2085  | 0.2085 | 0.2085  |
|       | −0.0148 | −0.2932| −0.0428| −0.0584 | 0.0085 | −0.0450 |
| SE    | 0.2085  | 0.2085 | 0.2085 | 0.2085  | 0.2085 | 0.2085  |
|       | −0.0546 | 0.0925 | 0.1576 | −0.1486 | −0.0489| 0.0870  |
| SE    | 0.2085  | 0.2085 | 0.2085 | 0.2085  | 0.2085 | 0.2085  |
Table A2. Cont.

MODEL FITTED

NONSEASONAL $P = 0$ $D = 1$ $Q = 1$
SEASONAL $BP = 0$ $BD = 1$ $BQ = 1$
PERIODICITY $MQ = 4$

20 ITERATIONS COMPLETED
58 FUNCTION VALUES $F = 0.18578351E+03$
$0.276250E+00$ $0.940575E+00$

PARAMETERS FIXED
0

PARAMETER ESTIMATES

MEAN = 1.10122
SE = 0.226077

CORRELATION MATRIX

\[
\begin{array}{ccc}
1.000 & & \\
0.141 & 1.000 & \\
& & 1.000
\end{array}
\]

ARIMA PARAMETERS

THETA = $-0.2762$
SE = 0.1965
BTHETA = $-0.9406$
SE = 0.1811

RESIDUALS

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2012 | 0.482| $-1.680$ | 0.642 | $-2.966$ |
| 2013 | $-1.520$ | 2.233 | 1.902 | $-0.233$ |
| 2014 | 2.225 | 2.406 | 1.217 | 0.218 |
| 2015 | 2.981 | 0.046 | 1.488 | 1.947 |
| 2016 | $-5.332$ | $-0.801$ | $-4.414$ | 4.061 |
| 2017 | 0.397 | $-2.121$ | $-1.375$ | 1.312 |
| 2018 | 0.548 | $-0.577$ | $-0.403$ | $-4.003$ |

TEST-STATISTICS ON RESIDUALS
Table A2. Cont.

\[
\begin{align*}
\text{MEAN} &= -0.4711E-01 \\
\text{ST.DEV.} &= 0.4233E+00 \\
\text{OF MEAN} &
\end{align*}
\]

\[
\begin{align*}
\text{T-VALUE} &= -0.1113 \\
\text{NORMALITY TEST} &= 1.516 \text{ (CHI-SQUARED (2))} \\
\text{SKEWNESS} &= -0.5638 \text{ (SE = 0.4629)} \\
\text{KURTOSIS} &= 2.8329 \text{ (SE = 0.9258)} \\
\text{SUM OF SQUARES} &= 0.1405E+03 \\
\text{DURBIN–WATSON} &= 1.9335 \\
\text{VARIANCE} &= 0.7026E+01 \\
\text{STANDARD DEVI.} &= 0.2651E+01 \text{ OF RESID.} \\
\text{OF RESID.} &= \\
\text{AUTOCORRELATIONS OF RESIDUAL} &
\end{align*}
\]

\[
\begin{array}{cccccc}
\text{SE} & -0.0239 & 0.0514 & -0.0728 & 0.0292 & 0.1018 & -0.0367 \\
\text{SE} & 0.1890 & 0.1891 & 0.1896 & 0.1906 & 0.1907 & 0.1927 \\
\text{SE} & -0.0842 & -0.2723 & 0.0634 & -0.0344 & 0.0437 & -0.1325 \\
\text{SE} & 0.1929 & 0.1942 & 0.2074 & 0.2081 & 0.2083 & 0.2086 \\
\text{SE} & -0.0027 & 0.0900 & 0.0348 & -0.1867 & 0.0267 & -0.0489 \\
\text{SE} & 0.2116 & 0.2116 & 0.2130 & 0.2132 & 0.2190 & 0.2191 \\
\end{array}
\]

\[
\text{THE LJUNG–BOX Q VALUE IS 8.44} \\
\text{IF RESIDUALS ARE RANDOM, IT SHOULD BE DISTRIBUTED AS CHI-SQUARED (14)}
\]

\[
\begin{align*}
\text{INPUT PARAMETERS} &
\end{align*}
\]

\[
\begin{align*}
\text{LAM} &= 1 \\
\text{IMEAN} &= 1 \\
\text{RSA} &= 0 \\
\text{MQ} &= 4 \\
\text{P} &= 0 \\
\text{BP} &= 0 \\
\text{Q} &= 1 \\
\text{BQ} &= 1 \\
\text{D} &= 1 \\
\text{BD} &= 1 \\
\text{NOADMISS} &= 1 \\
\text{RMOD} &= 0.500 \\
\text{M} &= 23 \\
\text{QMAX} &= 36 \\
\text{BIAS} &= 1 \\
\text{SMTR} &= 0 \\
\text{THTR} &= -0.400 \\
\text{MAXBIAS} &= 0.500 \\
\text{IQM} &= 16 \\
\text{OUT} &= 1 \\
\text{EPSPHI} &= 2.000 \\
\text{MAXIT} &= 20 \\
\text{XL} &= 0.990 \\
\text{SEK} &= 3.000 \\
\end{align*}
\]

\[
\text{TRANSFORMATION: Z → Z} \\
\text{NONSEASONAL DIFFERENCING D = 1} \\
\text{SEASONAL DIFFERENCING BD = 1}
\]

\[
\begin{align*}
\text{DIFFERENCED SERIES} &
\end{align*}
\]

\[
\begin{array}{cccccc}
\text{YEAR} & \text{1ST} & \text{2ND} & \text{3RD} & \text{4TH} & \\
2013 & 5.459 & 1.347 & 3.299 & \\
2014 & 4.049 & 0.398 & 0.444 & 1.697 & \\
2015 & 1.869 & -1.361 & 2.057 & 2.748 & \\
2016 & -7.516 & 2.504 & -4.479 & 4.937 & \\
2017 & 5.897 & -1.761 & 4.256 & -2.174 & \\
2018 & 1.969 & 2.471 & 1.600 & -4.382 & \\
\end{array}
\]

\[
\text{SERIES HAS BEEN MEAN CORRECTED}
\]
Table A2. Cont.

DIFFERENCED AND CENTERED SERIES

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2013 | 4.358| 0.246| 2.198|      |
| 2014 | 2.948| −0.703|−0.657|0.596|
| 2015 | 0.768| −2.462| 0.956|1.647|
| 2016 | −8.617| 1.403|−5.580|3.836|
| 2017 | 4.796| −2.862| 3.155|−3.275|
| 2018 | 0.868| 1.370| 0.499|−5.483|

MEAN OF DIFFERENCED SERIES 0.1101E+01

VARIANCE OF Z SERIES = 0.1188E+04
VARIANCE OF DIFFERENCED SERIES = 0.1091E+02

AUTOCORRELATIONS OF STATIONARY SERIES

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2013 | 0.2085| 0.2242|0.2263|0.2267|
| 2014 | 0.0100|−0.1925|0.0074|−0.0569|
| 2015 | 0.2466| 0.2466| 0.2531| 0.2531|
| 2016 |−0.1045| 0.1487| 0.0480|−0.0832|
| 2017 | 0.2543| 0.2562| 0.2599| 0.2603|

PARTIAL AUTOCORRELATIONS

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2013 | 0.2085| 0.2085|0.2085|0.2085|
| 2014 |−0.0148|−0.2932|−0.0428|−0.0584|
| 2015 | 0.2085| 0.2085| 0.2085| 0.2085|
| 2016 |−0.0546| 0.0925| 0.1576|−0.1486|
| 2017 | 0.2085| 0.2085| 0.2085| 0.2085|

MODEL FITTED

NONSEASONAL P = 0 D = 1 Q = 1
SEASONAL BP = 0 BD = 1 BQ = 1
PERIODICITY MQ = 4

20 ITERATIONS COMPLETED
58 FUNCTION VALUES F = 0.18578351E+03
0.276250E+00 0.940575E+00
Table A2. Cont.

PARAMETERS FIXED

0

PARAMETER ESTIMATES

MEAN = 1.10122  
SE = 0.226077

CORRELATION MATRIX

1  
0.141 1.000

ARIMA PARAMETERS

THETA = −0.2762  
SE = 0.1965

BTHETA= −0.9406  
SE = 0.1811

RESIDUALS

| YEAR | 1ST  | 2ND  | 3RD  | 4TH  |
|------|------|------|------|------|
| 2012 | 0.482| −1.680| 0.642| −2.966|
| 2013 | −1.520| 2.233| 1.902| −0.233|
| 2014 | 2.225| 2.406| 1.217| 0.218|
| 2015 | 2.981| 0.046| 1.488| 1.947|
| 2016 | −5.332| −0.801| −4.414| 4.061|
| 2017 | 0.397| −2.121| −1.375| 1.312|
| 2018 | 0.548| −0.577| −0.403| −4.003|

TEST-STATISTICS ON RESIDUALS

MEAN = −0.4711E−01  
ST.DEV. = 0.4233E+00  
OF MEAN  
T-VALUE = −0.1113

NORMALITY TEST = 1.516 (CHI-SQUARED (2))  
SKEWNESS = −0.5638 (SE = 0.4629)  
KURTOSIS = 2.8329 (SE = 0.9258)

SUM OF SQUARES = 0.1405E+03
### Table A2. Cont.

**DURBIN–WATSON** = 1.9335  
**STANDARD DEVI.** = 0.2651E+01  
**OF RESID.**  
**VARIANCE** = 0.7026E+01  
**OF RESID.**

| AUTOCORRELATIONS OF RESIDUAL |
|-----------------------------|
| -0.0239 | 0.0514 | -0.0728 | 0.0292 | 0.1018 | -0.0367 |
| SE | 0.1890 | 0.1891 | 0.1896 | 0.1906 | 0.1907 | 0.1927 |
| -0.0842 | -0.2723 | 0.0634 | -0.0344 | 0.0437 | -0.1325 |
| SE | 0.1929 | 0.1942 | 0.2074 | 0.2081 | 0.2083 | 0.2086 |
| -0.0027 | 0.0900 | 0.0348 | -0.1867 | 0.0267 | -0.0489 |
| SE | 0.2116 | 0.2116 | 0.2130 | 0.2132 | 0.2190 | 0.2191 |

**THE LJUNG–BOX Q VALUE IS 8.44**  
**IF RESIDUALS ARE RANDOM, IT SHOULD BE DISTRIBUTED AS CHI-SQUARED (14)**

**APPROXIMATE TEST OF RUNS ON RESIDUALS**

| NUM. DATA = 28 | NUM. (+) = 14 | NUM. (−) = 14 | T-VALUE = 0.385 |
|----------------|----------------|----------------|-----------------|

**AUTOCORRELATIONS OF SQUARED RESIDUAL**

| -0.0519 | 0.1505 | 0.1234 | -0.0679 | -0.2469 | -0.1222 |
| SE | 0.1890 | 0.1895 | 0.1937 | 0.1965 | 0.1973 | 0.2081 |
| -0.1180 | -0.1166 | 0.0266 | -0.0928 | 0.2000 | -0.0806 |
| SE | 0.2106 | 0.2130 | 0.2152 | 0.2154 | 0.2168 | 0.2233 |
| 0.1145 | -0.1318 | 0.0713 | -0.1000 | -0.0715 | -0.0202 |
| SE | 0.2243 | 0.2264 | 0.2291 | 0.2299 | 0.2315 | 0.2322 |

**THE LJUNG–BOX Q VALUE IS 10.46**  
**IF RESIDUALS ARE RANDOM, IT SHOULD BE DISTRIBUTED AS CHI-SQUARED (14)**

**BACKWARD RESIDUALS**

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | 1.855 | -0.263 | 3.303 | -0.139 |
| 2013 | -2.972 | -1.407 | 0.377 | -3.037 |
| 2014 | -2.271 | -0.984 | -0.275 | -3.383 |
| 2015 | -0.019 | -1.852 | 0.468 | 5.494 |
| 2016 | -0.278 | 2.498 | -4.809 | 1.393 |
| 2017 | 2.060 | 0.168 | -1.976 | 0.231 |
| Year | Theta 1 | Theta 2 | Theta 3 | Bthet 1 | Phi 1 | Bphi 1 |
|------|---------|---------|---------|---------|-------|--------|
| 2018 | 1.005   | 1.161   | 3.374   | −1.040  | 0.94  | 0.2598 |

**SECOND PART:**

**DERIVATION OF THE MODELS FOR THE COMPONENTS**

**SERIES TITLE:** GDP

**MODEL PARAMETERS**

\[(0,1,1) (0,1,1)\]

**PARAMETER VALUES PASSED FROM ARIMA ESTIMATION (TRUE SIGNS)**

**THETA PARAMETERS**

1.00 – 0.28

**BTHETA PARAMETERS**

1.00 0.00 0.00 0.00 –0.94

**PHI PARAMETERS**

1

**BPHI PARAMETERS**

1

**NUMERATOR OF THE MODEL**

|          | 1.0000 | −0.2762 | 0.0000 | 0.0000 | −0.9406 | 0.2598 |
|----------|--------|---------|--------|--------|---------|--------|

**STATIONARY AUTOREGRESSIVE TREND-CYCLE**

1

**NON-STATIONARY AUTOREGRESSIVE TREND-CYCLE**

|          | 1.0000 | −2.0000 | 1.0000 |
|----------|--------|---------|--------|

**AUTOREGRESSIVE TREND-CYCLE**

|          | 1.0000 | −2.0000 | 1.0000 |
|----------|--------|---------|--------|

**STATIONARY AUTOREGRESSIVE TRANSITORY COMP.**

1

**NON-STATIONARY AUTOREGRESSIVE TRANSITORY COMP.**

1

**AUTOREGRESSIVE TRANSITORY COMP.**

1

**STATIONARY AUTOREGRESSIVE SEASONAL COMPONENT**

1

**NON-STATIONARY AUTOREGRESSIVE SEASONAL COMPONENT**

|          | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
|----------|--------|--------|--------|--------|

**AUTOREGRESSIVE SEASONAL COMPONENT**

|          | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
|----------|--------|--------|--------|--------|

**STATIONARY AUTOREGRESSIVE SEASONALLY ADJUSTED COMPONENT**

1

**NON-STATIONARY AUTOREGRESSIVE SEASONALLY ADJUSTED COMPONENT**

|          | 1.0000 | −2.0000 | 1.0000 |
|----------|--------|---------|--------|
### Table A2. Cont.

#### Autoregressive Seasonally Adjusted Component

| REAL PART | IMAGINARY PART | MODULUS | ARGUMENT (DEG.) | PERIOD |
|-----------|----------------|---------|-----------------|--------|
| 0.985     | 0.000          | 0.985   | 0.000           | -      |
| −1.000    | 0.000          | 1.000   | 180.000         | 2.0    |

**Total Squared Error = 0.3830257E−32**

#### MA Roots of Trend-Cycle

| REAL PART | IMAGINARY PART | MODULUS | ARGUMENT (DEG.) | PERIOD |
|-----------|----------------|---------|-----------------|--------|
| 0.525     | 0.522          | 0.740   | 135.201         | 2.663  |
| 1.000     | 0.000          | 1.000   | 0.000           | -      |

**Total Squared Error = 0.5704740E−36**

#### MA Roots of Seasonally Adjusted Series

| REAL PART | IMAGINARY PART | MODULUS | ARGUMENT (DEG.) | PERIOD |
|-----------|----------------|---------|-----------------|--------|
| 0.276     | 0.000          | 0.276   | 0.000           | -      |
| 0.985     | 0.000          | 0.985   | 0.000           | -      |

**Total Squared Error = 0.2770076E−30**

#### Models for the Components

**Trend-Cycle Numerator**

| 1.0000 | 0.0152 | −0.9848 |

**Trend-Cycle Denominator**

| 1.0000 | −2.0000 | 1.0000 |

**Innov. Var. (*) 0.12513**

**Seas. Numerator**

| 1.0000 | 0.0506 | −0.5026 | −0.5480 |

**Seas. Denominator**

| 1.0000 | 1.0000 | 1.0000 | 1.0000 |

**Innov. Var. (*) 0.00036**

**Irregular Var. 0.38326**
Table A2. Cont.

| LAG | PSIEP | PSIES | PSIEC | PSIEA | PSIUE | PSIEP + PSIES + PSIUE |
|-----|-------|-------|-------|-------|-------|------------------------|
| −8  | −0.0043 | 0.0254 | 0.0000 | −0.0254 | −0.0211 | 0.0000 |
| −7  | −0.0022 | 0.0011 | 0.0000 | −0.0011 | 0.0011 | 0.0000 |
| −6  | 0.0047  | −0.0088 | 0.0000 | 0.0088  | 0.0041 | 0.0000 |
| −5  | 0.0039  | −0.0188 | 0.0000 | 0.0188  | 0.0149 | 0.0000 |
| −4  | 0.0017  | 0.0270  | 0.0000 | −0.0270 | −0.0286 | 0.0000 |
| −3  | 0.0200  | 0.0012  | 0.0000 | −0.0012 | −0.0212 | 0.0000 |
| −2  | 0.0859  | −0.0093 | 0.0000 | 0.0093  | −0.0766 | 0.0000 |
| −1  | 0.2973  | −0.0199 | 0.0000 | 0.0199  | −0.2774 | 0.0000 |
| 0   | 0.5885  | 0.0282  | 0.0000 | 0.9718  | 0.3833 | 1.0000 |
| 1   | 0.7225  | 0.0013  | 0.0000 | 0.7225  | 0.0000 | 0.7238 |
| 2   | 0.7332  | −0.0095 | 0.0000 | 0.7332  | 0.0000 | 0.7238 |
| 3   | 0.7440  | −0.0202 | 0.0000 | 0.7440  | 0.0000 | 0.7238 |
| 4   | 0.7547  | 0.0284  | 0.0000 | 0.7547  | 0.0000 | 0.7832 |
| 5   | 0.7655  | 0.0013  | 0.0000 | 0.7655  | 0.0000 | 0.7668 |
| 6   | 0.7762  | −0.0095 | 0.0000 | 0.7762  | 0.0000 | 0.7668 |
| 7   | 0.7870  | −0.0202 | 0.0000 | 0.7870  | 0.0000 | 0.7668 |
| 8   | 0.7977  | 0.0284  | 0.0000 | 0.7977  | 0.0000 | 0.8262 |

WIENER–KOLMOGOROV FILTERS (ONE SIDE)

| TREND-CYCLE COMPONENT |
|-----------------------|
| 0.3582 0.2309 0.0674 0.0177 0.0014 0.0013 |
| 0.0038 0.0002 −0.0033 −0.0001 0.00032 0.0001 |
| −0.0031 −0.0001 0.0030 0.0001 −0.0029 −0.0001 |
| 0.0028 0.0001 −0.0027 −0.0001 0.0027 0.0001 |
| −0.0026 −0.0001 0.0025 0.0001 −0.0024 −0.0001 |
| 0.0024 0.0001 −0.0023 −0.0001 0.0022 0.0000 |
| −0.0021 0.0000 0.0021 0.0000 −0.0020 0.0000 |
### Table A2. Cont.

|                      | TREND-CYCLE |                  |                  | ADJUSTED |                  |                  |
|----------------------|-------------|------------------|------------------|----------|------------------|------------------|
|                      | LAG         | COMPONENT        | ESTIMATOR        | ESTIMATE | COMPONENT        | ESTIMATOR        |
|                      | 1           | 0.000            | 0.367            | 0.369    | -0.602           | -0.602           |
|                      | 2           | -0.500           | -0.386           | -0.419   | 0.102            | 0.099            |
|                      | 3           | 0.000            | -0.338           | -0.335   | 0.000            | 0.018            |
|                      | 4           | 0.000            | -0.118           | 0.088    | 0.000            | -0.030           |
|                      | VAR. (*)    | 0.247            | 0.072            | 0.051    | 2.546            | 2.470            |

**SA SERIES COMPONENT**

|                      | 0.9775      | 0.0075           | 0.0074           | 0.0073   | -0.0216          | 0.0071           |
|                      | 0.0070      | 0.0069           | -0.0203          | 0.0067   | 0.0066           | 0.0065           |
|                      | -0.0191     | 0.0063           | 0.0062           | 0.0061   | -0.0180          | 0.0059           |
|                      | 0.0058      | 0.0057           | -0.0169          | 0.0056   | 0.0055           | 0.0054           |
|                      | -0.0159     | 0.0052           | 0.0051           | 0.0051   | -0.0150          | 0.0049           |
|                      | 0.0048      | 0.0048           | -0.0141          | 0.0046   | 0.0046           | 0.0045           |
|                      | -0.0132     | 0.0043           | 0.0043           | 0.0042   | -0.0125          | 0.0041           |
|                      | 0.0040      | 0.0040           | -0.0117          | 0.0038   | 0.0038           | 0.0037           |
|                      | -0.0110     | 0.0036           | 0.0036           | 0.0035   | -0.0104          | 0.0034           |
|                      | 0.0034      | 0.0033           | -0.0097          | 0.0032   | 0.0032           | 0.0031           |

**SEASONAL COMPONENT**

|                      | 0.0225      | -0.0075          | -0.0074          | -0.0073  | 0.0216           | -0.0071          |
|                      | -0.0070     | 0.0069           | 0.0203           | -0.0067  | -0.0066          | -0.0065          |
|                      | 0.0191      | -0.0063          | -0.0062          | -0.0061  | 0.0180           | -0.0059          |
|                      | -0.0058     | -0.0057          | 0.0169           | -0.0056  | -0.0055          | -0.0054          |
|                      | 0.0159      | -0.0052          | -0.0051          | -0.0051  | 0.0150           | -0.0049          |
|                      | -0.0048     | -0.0048          | 0.0141           | -0.0046  | -0.0046          | -0.0045          |
|                      | 0.0132      | -0.0043          | -0.0043          | -0.0042  | 0.0125           | -0.0041          |
|                      | -0.0040     | -0.0040          | 0.0117           | -0.0038  | -0.0038          | -0.0037          |
|                      | 0.0110      | -0.0036          | -0.0036          | -0.0035  | 0.0104           | -0.0034          |
|                      | -0.0034     | -0.0033          | 0.0097           | -0.0032  | -0.0032          | -0.0031          |

**IRREGULAR COMPONENT**

|                      | 0.6193      | -0.2235          | -0.0600          | -0.0104  | -0.0230          | 0.0058           |
|                      | 0.0032      | 0.0067           | -0.0171          | 0.0067   | 0.0034           | 0.0064           |
|                      | -0.0160     | 0.0063           | 0.0032           | 0.0060   | -0.0151          | 0.0060           |
|                      | 0.0030      | 0.0057           | -0.0142          | 0.0056   | 0.0028           | 0.0053           |
|                      | -0.0133     | 0.0053           | 0.0026           | 0.0050   | -0.0125          | 0.0050           |
|                      | 0.0025      | 0.0047           | -0.0118          | 0.0047   | 0.0023           | 0.0044           |
|                      | -0.0111     | 0.0044           | 0.0022           | 0.0042   | -0.0104          | 0.0041           |
|                      | 0.0021      | 0.0039           | -0.0098          | 0.0039   | 0.0019           | 0.0037           |
|                      | -0.0092     | 0.0037           | 0.0018           | 0.0035   | -0.0087          | 0.0034           |
|                      | 0.0017      | 0.0033           | -0.0082          | 0.0032   | 0.0016           | 0.0031           |

**AUTOCORRELATION FUNCTION OF COMPONENTS (STATIONARY TRANSFORMATION)**
**Table A2. Cont.**

(*) IN UNITS OF VAR (A)

**AUTOCORRELATION FUNCTION OF COMPONENTS (STATIONARY TRANSFORMATION)**

| LAG | COMPONENT | ESTIMATOR | ESTIMATE | COMPONENT | ESTIMATOR | ESTIMATE |
|-----|-----------|-----------|----------|-----------|-----------|----------|
| 1   | 0.000     | −0.361    | −0.393   | 0.193     | −0.152    | −0.074   |
| 2   | 0.000     | −0.097    | −0.018   | −0.341    | −0.677    | −0.617   |
| 3   | 0.000     | −0.017    | −0.132   | −0.352    | −0.170    | −0.346   |
| 4   | 0.000     | −0.037    | 0.011    | 0.000     | 0.966     | 0.697    |

VAR. (*) 0.383 0.237 0.176 0.001 0.000 0.000

(*) IN UNITS OF VAR (A)

For all components it should happen that:
- Var (Component) > Var (Estimator)
- Var (Estimator) close to Var (Estimate)

**CROSSCORRELATION BETWEEN STATIONARY TRANSFORMATION OF ESTIMATORS**

| ESTIMATOR | ESTIMATE |
|-----------|----------|
| TREND/SEASONAL | −0.078    | −0.331    |
| SEASONAL/IRREGULAR | 0.056    | 0.087    |
| TREND-CYCLE/IRREGULAR | −0.106 | −0.124 |

**PSEUDO-INNOVATIONS IN THE COMPONENTS**

**PSEUDO INNOVATIONS IN TREND-CYCLE**

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | 0.49| 0.67| 0.29| 0.07|
| 2013 | −0.26| −0.11| 0.38| 0.30|
| 2014 | −0.50| −0.14| 0.56| 0.87|
| 2015 | 0.64| −0.32| −0.38| −0.57|
| 2016 | −0.58| −0.36| −0.62| −0.78|
| 2017 | −0.44| −0.32| −0.61| −0.24|
| 2018 | 0.54| 0.46| 0.27| 0.23|

**PSEUDO INNOVATIONS IN SEASONAL**
X 10.0D − 2
### Table A2. Cont.

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | 0.08 | −0.06 | −0.09 | −0.11 |
| 2013 | 0.30 | −0.05 | −0.01 | −0.21 |
| 2014 | 0.05 | 0.19 | 0.16 | −0.19 |
| 2015 | −0.46 | 0.40 | 0.10 | 0.16 |
| 2016 | −0.59 | 0.33 | 0.15 | −0.01 |
| 2017 | −0.39 | 0.31 | 0.04 | 0.00 |
| 2018 | −0.17 | 0.13 | −0.12 | 0.07 |

#### PSEUDO INNOVATIONS IN SEASONALLY ADJUSTED SERIES

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | −1.04 | 3.39 | 1.13 | 0.95 |
| 2013 | 0.10 | −1.84 | 0.20 | 2.08 |
| 2014 | 1.26 | −4.81 | 2.56 | −0.15 |
| 2015 | 5.46 | 0.12 | −1.76 | 0.04 |
| 2016 | −3.14 | −0.54 | −0.92 | −2.14 |
| 2017 | −2.89 | 0.18 | −1.30 | −2.88 |
| 2018 | −0.06 | 3.18 | −0.22 | 1.77 |

#### THIRD PART: ERROR ANALYSIS

### FINAL ESTIMATION ERROR

| ACF (LAG) | TREND-CYCLE | ADJUSTED | TREND-CYCLE | ADJUSTED |
|-----------|-------------|----------|-------------|----------|
| 1         | 0.636       | −0.270   | 0.283       | −0.247   |
| 2         | 0.172       | −0.446   | 0.069       | −0.439   |
| 3         | 0.048       | −0.272   | 0.020       | 0.941    |
| 4         | 0.017       | 0.958    |             |          |
| VAR. (*)  | 0.139       | 0.010    | 0.097       | 0.011    |

### TOTAL ESTIMATION ERROR (CONCURRENT ESTIMATOR)

| ACF (LAG) | TREND-CYCLE | ADJUSTED |
|-----------|-------------|----------|
| 1         | 0.491       | −0.259   |
| 2         | 0.126       | −0.442   |
| 3         | 0.032       | −0.278   |
| 4         | 0.018       | 0.950    |
| VAR. (*)  | 0.236       | 0.021    |

(*) IN UNITS OF VAR (A)

VARIANCE OF THE REVISION ERROR (*)
| Periods AHEAD | Variance (*) |
|--------------|--------------|
| 0            | 0.1053E−01   |
| 1            | 0.1132E−01   |
| 2            | 0.1132E−01   |
| 3            | 0.1141E−01   |
| 4            | 0.1182E−01   |

AVERAGE PERCENTAGE REDUCTION IN RMSE FROM CONCURRENT ADJUSTMENT 2.828

(*) IN UNITS OF VAR (A)
### Table A2. Cont.

| PERIOD | SERIES | TREND-CYCLE | ADJUSTED |
|--------|--------|-------------|----------|
|        |        | ESTIMATE    | STANDARD ERROR |
|        |        | TOTAL OF REVISION |     |
|        |        | ESTIMATE    | STANDARD ERROR |
|        |        | TOTAL OF REVISION |     |
| −8     | 474.0  | 472.2       | 0.9902   | 0.5000E−01 | 473.9  | 0.3628   | 0.2406 |
| −7     | 478.6  | 478.1       | 0.9902   | 0.5125E−01 | 478.8  | 0.3690   | 0.2499 |
| −6     | 482.8  | 483.3       | 0.9902   | 0.5159E−01 | 482.7  | 0.3690   | 0.2499 |
| −5     | 488.3  | 489.2       | 0.9903   | 0.5305E−01 | 488.2  | 0.3698   | 0.2509 |
| −4     | 496.6  | 496.0       | 0.9904   | 0.5406E−01 | 496.5  | 0.3731   | 0.2558 |
| −3     | 503.2  | 502.9       | 0.9904   | 0.5424E−01 | 503.4  | 0.3799   | 0.2656 |
| −2     | 509.8  | 509.5       | 0.9918   | 0.7582E−01 | 509.7  | 0.3799   | 0.2657 |
| −1     | 516.9  | 515.9       | 1.018    | 0.7847E−01 | 516.8  | 0.3807   | 0.2668 |
| 0      | 520.8  | 522.3       | 1.287    | 0.8237     | 520.8  | 0.3843   | 0.2720 |

**STANDARD ERROR OF 0.9889 0.2716**

**FINAL ESTIMATOR**

| PERIOD | SEASONAL | ESTIMATE | STANDARD ERROR |
|--------|----------|----------|----------------|
|        |          | TOTAL OF REVISION |     |
| −8     | 0.7847E−01 | 0.3628   | 0.2406 |
| −7     | −0.2377  | 0.3690   | 0.2499 |
| −6     | 0.1058   | 0.3690   | 0.2499 |
| −5     | 0.5415E−01 | 0.3698   | 0.2509 |
| −4     | 0.7434E−01 | 0.3731   | 0.2558 |
| −3     | −0.2353  | 0.3799   | 0.2656 |
| −2     | 0.1075   | 0.3799   | 0.2657 |
| −1     | 0.5713E−01 | 0.3807   | 0.2668 |
| 0      | 0.6937E−01 | 0.3843   | 0.2720 |

**STANDARD ERROR OF 0.2716**

**FINAL ESTIMATOR**

**DECOMPOSITION OF THE SERIES: FORECAST**

| PERIOD | FORECAST | S.E. | FORECAST | S.E. | TREND-CYCLE | ADJUSTED |
|--------|----------|------|----------|------|-------------|----------|
|        | FORECAST | S.E. | FORECAST | S.E. | TOTAL OF REVISION | STANDARD ERROR |
|        | FORECAST | S.E. | FORECAST | S.E. | TOTAL OF REVISION | STANDARD ERROR |
| 1      | 529.4    | 2.651 | 529.7    | 2.022 | 1.764       | 529.7    | 2.604   | 2.590 |
| 2      | 537.9    | 3.272 | 537.8    | 2.785 | 2.604       | 537.8    | 3.233   | 3.221 |
| 3      | 546.3    | 3.793 | 546.2    | 3.396 | 3.249       | 546.2    | 3.772   | 3.762 |
| 4      | 555.0    | 4.251 | 554.9    | 3.927 | 3.801       | 554.9    | 4.256   | 4.248 |
| 5      | 563.6    | 4.731 | 563.9    | 4.408 | 4.295       | 563.9    | 4.703   | 4.695 |
| 6      | 573.2    | 5.149 | 573.1    | 4.852 | 4.750       | 573.1    | 5.122   | 5.115 |
| 7      | 582.7    | 5.535 | 582.6    | 5.270 | 5.177       | 582.6    | 5.520   | 5.513 |
| 8      | 592.5    | 5.897 | 592.4    | 5.668 | 5.581       | 592.4    | 5.901   | 5.895 |
| PERIOD | SEASONAL FORECAST | STANDARD ERROR | TOTAL OF REVISION |
|--------|------------------|----------------|------------------|
| 1      | -0.2352          | 0.3916         | 0.2821           |
| 2      | 0.1082           | 0.3916         | 0.2821           |
| 3      | 0.5845E–01       | 0.3924         | 0.2832           |
| 4      | 0.6857E–01       | 0.3960         | 0.2882           |
| 5      | -0.2352          | 0.4031         | 0.2979           |
| 6      | 0.1082           | 0.4031         | 0.2980           |
| 7      | 0.5845E–01       | 0.4039         | 0.2990           |
| 8      | 0.6857E–01       | 0.4075         | 0.3038           |

CONFIDENCE INTERVAL AROUND A SEASONAL COMPONENT OF 0

| FINAL ESTIMATOR | CONCURRENT ESTIMATOR |
|-----------------|----------------------|
| 95% CONFIDENCE  | 0.5323               |
| INTERVAL        | 0.7533               |
| 70% CONFIDENCE  | 0.2816               |
| INTERVAL        | 0.3986               |

SAMPLE MEANS

| SERIES | COMPLETE | PERIOD | LAST THREE | YEARS |
|--------|----------|--------|------------|-------|
| SERIES | 453.6    | 487.8  | 488.0      |       |
| TREND-CYCLE | 453.6 | 488.0 |        | 453.6 |
| ADJUSTED | 453.6 | 487.8 |        |       |
| SEASONAL | -0.9266E–04 | -0.6442E–03 |       |       |

STANDARD ERROR OF ALTERNATIVE MEASURES OF GROWTH (NONANNUALISED GROWTH)

1. PERIOD TO PERIOD GROWTH OF THE SERIES TRENDS-CYCLE SEASONALLY ADJ. SERIES

| CONCURRENT ESTIMATOR | 1.032 | 0.607 |
|----------------------|-------|-------|
| 1—PERIOD REVISION    | 0.866 | 0.607 |
| 2—PERIOD REVISION    | 0.847 | 0.602 |
| 3—PERIOD REVISION    | 0.847 | 0.590 |
| 4—PERIOD REVISION    | 0.847 | 0.589 |
| 5—PERIOD REVISION    | 0.847 | 0.589 |
| 6—PERIOD REVISION    | 0.847 | 0.585 |
| 7—PERIOD REVISION    | 0.847 | 0.574 |
| 8—PERIOD REVISION    | 0.847 | 0.433 |
| FINAL ESTIMATOR      | 0.844 |       |
### Table A2. Cont.

|            | 3. ACCUMULATED GROWTH OVER THE LAST QUARTER OF PREVIOUS YEAR |
|------------|-------------------------------------------------------------|
|            | CONCURRENT ESTIMATOR | FINAL ESTIMATOR |
|            | TREND-CYCLE          | SEASONALLY ADJ. SERIES | TREND-CYCLE          | SEASONALLY ADJ. SERIES |
| QUARTER 1  | 4.126                | 2.430                | 3.375                | 1.731                |
| QUARTER 2  | 2.981                | 1.300                | 2.544                | 0.924                |
| QUARTER 3  | 2.121                | 0.816                | 1.819                | 0.578                |
| QUARTER 4  | 1.606                | 0.080                | 1.387                | 0.078                |

(CENTERED) ESTIMATOR OF THE PRESENT ANNUAL GROWTH

|            | STANDARD ERROR | TREND-CYCLE | SEAS. ADJ. SERIES | ORIGINAL SERIES |
|------------|----------------|-------------|------------------|-----------------|
| CONCURRENT ESTIMATOR |                | 3.378       | 3.792             | 3.793           |
| FINAL ESTIMATOR        |                | 1.387       | 0.078             | 0.000           |

FOURTH PART: ESTIMATES OF THE COMPONENTS (LEVELS)

#### ORIGINAL SERIES

| YEAR | 1ST   | 2ND   | 3RD   | 4TH   |
|------|-------|-------|-------|-------|
| 2012 | 413.498 | 412.485 | 414.295 | 412.108 |
| 2013 | 412.408 | 416.854 | 420.011 | 421.123 |
| 2014 | 425.472 | 430.316 | 433.917 | 436.726 |
| 2015 | 442.944 | 446.427 | 452.085 | 457.642 |
| 2016 | 456.344 | 462.331 | 463.510 | 474.004 |
| 2017 | 478.603 | 482.829 | 488.264 | 496.584 |
| 2018 | 503.152 | 509.849 | 516.884 | 520.822 |

#### SEASONAL COMPONENT

| YEAR | 1ST   | 2ND   | 3RD   | 4TH   |
|------|-------|-------|-------|-------|
| 2012 | −0.249 | 0.107 | 0.090 | 0.052 |
| 2013 | −0.250 | 0.109 | 0.086 | 0.056 |
| 2014 | −0.248 | 0.108 | 0.077 | 0.064 |
| 2015 | −0.246 | 0.106 | 0.067 | 0.075 |
| 2016 | −0.243 | 0.105 | 0.056 | 0.078 |
| 2017 | −0.238 | 0.106 | 0.054 | 0.074 |
| 2018 | −0.235 | 0.107 | 0.057 | 0.069 |

#### STANDARD ERROR OF SEASONAL

| YEAR | 1ST   | 2ND   | 3RD   | 4TH   |
|------|-------|-------|-------|-------|
| 2012 | 0.384 | 0.381 | 0.380 | 0.380 |
| 2013 | 0.373 | 0.370 | 0.369 | 0.369 |
| 2014 | 0.363 | 0.360 | 0.359 | 0.359 |
| 2015 | 0.354 | 0.350 | 0.351 | 0.354 |
Table A2. Cont.

| YEAR | 1ST   | 2ND   | 3RD   | 4TH   |
|------|-------|-------|-------|-------|
| 2016 | 0.359 | 0.359 | 0.360 | 0.363 |
| 2017 | 0.369 | 0.369 | 0.370 | 0.373 |
| 2018 | 0.380 | 0.380 | 0.381 | 0.384 |

**TREND-CYCLE**

| YEAR | 1ST                  | 2ND                  | 3RD                  | 4TH                  |
|------|----------------------|----------------------|----------------------|----------------------|
| 2012 | 413.036              | 412.993              | 413.008              | 413.045              |
| 2013 | 414.059              | 416.484              | 419.251              | 422.110              |
| 2014 | 425.690              | 429.697              | 433.544              | 437.620              |
| 2015 | 442.159              | 446.759              | 451.376              | 455.250              |
| 2016 | 458.230              | 461.593              | 466.251              | 472.235              |
| 2017 | 478.053              | 483.273              | 489.178              | 495.992              |
| 2018 | 502.902              | 509.544              | 515.871              | 522.287              |

**STANDARD ERROR OF TREND-CYCLE**

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | 1.287 | 1.018 | 0.992 | 0.990 |
| 2013 | 0.990 | 0.990 | 0.990 | 0.990 |
| 2014 | 0.990 | 0.990 | 0.990 | 0.990 |
| 2015 | 0.990 | 0.990 | 0.990 | 0.990 |
| 2016 | 0.990 | 0.990 | 0.990 | 0.990 |
| 2017 | 0.990 | 0.990 | 0.990 | 0.990 |
| 2018 | 0.990 | 0.990 | 1.018 | 1.287 |

**SEASONALLY ADJUSTED SERIES**

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | 413.747 | 412.378 | 414.205 | 412.056 |
| 2013 | 412.658 | 416.745 | 419.925 | 421.067 |
| 2014 | 425.720 | 430.208 | 433.840 | 436.662 |
| 2015 | 443.190 | 446.321 | 452.018 | 457.567 |
| 2016 | 456.587 | 462.226 | 463.454 | 473.926 |
| 2017 | 478.841 | 482.723 | 488.210 | 496.510 |
| 2018 | 503.387 | 509.742 | 516.827 | 520.753 |

**STANDARD ERROR OF SEASONALLY ADJUSTED SERIES**

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | 0.384 | 0.381 | 0.380 | 0.380 |
| 2013 | 0.373 | 0.370 | 0.369 | 0.369 |
| 2014 | 0.363 | 0.360 | 0.359 | 0.359 |
| 2015 | 0.354 | 0.350 | 0.351 | 0.354 |
| 2016 | 0.359 | 0.359 | 0.360 | 0.363 |
| 2017 | 0.369 | 0.369 | 0.370 | 0.373 |
| 2018 | 0.380 | 0.380 | 0.381 | 0.384 |

**IRREGULAR COMPONENT**

| YEAR | 1ST | 2ND | 3RD | 4TH |
|------|-----|-----|-----|-----|
| 2012 | 0.711 | −0.615 | 1.197 | −0.989 |
| 2013 | −1.401 | 0.261 | 0.675 | −1.044 |
| 2014 | 0.030 | 0.511 | 0.296 | −0.958 |
| 2015 | 1.030 | −0.438 | 0.642 | 2.317 |
| 2016 | −1.643 | 0.633 | −2.797 | 1.690 |
| 2017 | 0.787 | −0.549 | −0.969 | 0.518 |
| 2018 | 0.486 | 0.197 | 0.956 | −1.534 |
**Table A2. Cont.**

* * PROCESSING COMPLETED * *

Source: own computation in Gretl software with TRAMO/SEATS packages based on Table 4.

**Table A3. Decomposed data.**

| Year | Month | CTCO_sa | CTCO_trcl | CTCO_sh | CTCO_tr | CTCO_cl |
|------|-------|---------|-----------|---------|---------|---------|
| 2012:1 | | 2317.416 | 2880.126 | –562.7096 | 2896.450 | –16.32410 |
| 2012:2 | | 2914.208 | 2978.811 | –64.6035 | 2977.155 | 1.65699 |
| 2012:3 | | 3395.349 | 3080.988 | 314.3607 | 3057.849 | 23.13869 |
| 2012:4 | | 3831.568 | 3171.839 | 659.7289 | 3138.525 | 33.14455 |
| 2013:1 | | 3727.643 | 3243.089 | 484.5538 | 3219.186 | 23.90319 |
| 2013:2 | | 2998.340 | 3303.945 | –505.6046 | 3299.859 | 4.08558 |
| 2013:3 | | 3449.957 | 3668.921 | 81.0361 | 3380.586 | –11.66452 |
| 2013:4 | | 2989.525 | 3441.254 | –451.7288 | 3461.409 | –20.15473 |
| 2014:1 | | 3593.142 | 3520.524 | 72.6185 | 3542.365 | –21.84086 |
| 2014:2 | | 3630.493 | 3602.371 | 28.1229 | 3623.478 | –21.10714 |
| 2014:3 | | 3107.970 | 3688.396 | –580.4253 | 3704.757 | –16.36174 |
| 2014:4 | | 3917.811 | 3783.659 | 134.1521 | 3786.201 | –2.54144 |
| 2015:1 | | 3991.103 | 3880.790 | 110.3134 | 3867.794 | 12.99510 |
| 2015:2 | | 4588.140 | 3968.908 | 619.2323 | 3949.524 | 19.38453 |
| 2015:3 | | 4347.080 | 4041.723 | 305.3574 | 4031.381 | 10.34146 |
| 2015:4 | | 3800.301 | 4105.987 | –305.6855 | 4113.373 | –7.38662 |
| 2016:1 | | 3687.837 | 4177.612 | –489.7751 | 4195.510 | –17.89938 |
| 2016:2 | | 3988.728 | 4263.672 | –274.9444 | 4277.801 | –14.12876 |
Table A3. Cont.

| Year | CTCO | GDP | GDP change | CTCO change |
|------|------|-----|------------|-------------|
| 2016: 3 | 4934.958 | 4353.976 | −199.7303 | 4442.815 |
| 2016: 4 | 4238.193 | 4785.336 | 302.6994 | 4774.091 |
| 2017: 1 | 5253.709 | 4520.136 | 5.9752 | 4525.509 |
| 2017: 2 | 4633.583 | 4603.811 | 29.7721 | 4608.302 |
| 2017: 3 | 4192.518 | 4691.496 | −498.9777 | 4691.171 |
| 2017: 4 | 4823.567 | 4925.900 | −202.3331 | 4922.931 |
| 2018: 1 | 4963.177 | 5102.613 | −139.4358 | 5105.876 |

Source: own computation in Gretl software based on Table 4.

Table A4. Spectral analysis for CTCO and GDP.

| Periodogram for CTCO_cl |
|-------------------------|
| Number of observations = 28 |
| Omega | Scaled frequency | Periods | Spectral density |
| 0.22440 | 1 | 28.00 | 57.010 |
| 0.44880 | 2 | 14.00 | 42.457 |
| 0.67320 | 3 | 9.33 | 267.32 |
| 0.89760 | 4 | 7.00 | 60.761 |
| 1.12200 | 5 | 5.60 | 52.130 |
| 1.34640 | 6 | 4.67 | 8.1813 |
| 1.57080 | 7 | 4.00 | 0.88524 |
| 1.79520 | 8 | 3.50 | 0.81654 |
| 2.01960 | 9 | 3.11 | 1.4170 |
| 2.24399 | 10 | 2.80 | 0.52653 |
| 2.46839 | 11 | 2.55 | 0.50149 |
| 2.69279 | 12 | 2.33 | 0.55875 |
| 2.91719 | 13 | 2.15 | 0.44997 |
| 3.14159 | 14 | 2.00 | 0.44093 |

| Periodogram for GDP_cl |
|-------------------------|
| Number of observations = 28 |
| Omega | Scaled frequency | Periods | Spectral density |
| 0.22440 | 1 | 28.00 | 22.124 |
| 0.44880 | 2 | 14.00 | 10.838 |
| 0.67320 | 3 | 9.33 | 0.57519 |
| 0.89760 | 4 | 7.00 | 0.92954 |
| 1.12200 | 5 | 5.60 | 0.034227 |
| 1.34640 | 6 | 4.67 | 0.36354 |
| 1.57080 | 7 | 4.00 | 0.081006 |
| 1.79520 | 8 | 3.50 | 0.016806 |
| 2.01960 | 9 | 3.11 | 0.034768 |
| 2.24399 | 10 | 2.80 | 0.032412 |
| 2.46839 | 11 | 2.55 | 0.029733 |
| 2.69279 | 12 | 2.33 | 0.028376 |
| 2.91719 | 13 | 2.15 | 0.028376 |
| 3.14159 | 14 | 2.00 | 0.028376 |

Source: own computation in Gretl software based on Table 4.

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