Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2020, 62 (134), 36–42
ISSN 1733-8670 (Printed)
ISSN 2392-0378 (Online)
DOI: 10.17402/417

Received: 20.10.2019
Accepted: 10.06.2020
Published: 29.06.2020

Rationalization of the energy consumption of road transport for sustainable development

Elżbieta Szaruga

University of Szczecin, Faculty of Economics, Finance and Management
8 Cukrowa St., 71-004 Szczecin, Poland
e-mail: elzbieta.szaruga@usz.edu.pl

Key words: energy consumption, freight road transport, rationalization, steady-state economy, sustainable development, vector error correction model

Abstract

This paper presents an approach to rationalize the energy consumption of road transport towards sustainability in a steady-state economy. The research hypothesis is that the rationalization of the energy consumption of road transport is affected by drift and shocks, which desynchronizes the adjustment mechanism from equilibrium. The objective of this research was to incorporate the model of energy consumption of road freight transport with the goals of sustainability by considering ecological and constructivist rational orders, the issue of order drift, and the occurrence of shocks. The research investigated Poland from the first quarter of 2004 to the fourth quarter of 2018. A model for rationalizing the energy consumption of road transport was constructed using the vector error correction model and cointegration techniques. The model revealed one cointegrating relationship and showed statistically significant unlimited drift. The level of changes to long-term equilibrium appeared respectively for GDP – 1.8%, PPI for energy – 7.3%, and for energy consumption – 10.9%. We observed a weak sustainability between the energy consumption of road transport and GDP and a strong sustainability between energy consumption of road transport and PPI energy. It was determined that price shocks had a positive impact (at the estimated point level around 0.06) and supply and demand shocks had a negative impact (at the level estimated point around –3).

Introduction

The aim of rationalizing the energy consumption of road transport is to achieve sustainable development. Defining sustainable development and sustainability determines the rationalization process. In the context of rationalization, the importance of information asymmetry is raised, which results from shocks and economic drift; therefore, these issues were investigated in this paper.

The research hypothesis is that the rationalization of the energy consumption of road transport is affected by both drift and shocks, which desynchronize the equilibrium adjustment mechanism. The aim of this article is to provide a model to rationalize the energy consumption of freight road transport towards sustainability by considering ecological and constructivist rational orders and the problem of drift and the occurrence of shocks. The research investigated Poland from the first quarter of 2004 to the fourth quarter of 2018.

The article consists of five sections: introduction, literature review, description of data and methods, research results, and conclusions. The first part discusses the concepts of a steady-state economy, strong and weak sustainability, sustainable development, orders (also rational orders), drift, rationalization, and energy consumption. A commonality in all concepts was observed, and they were shown to affect each other. The data and methods section describes the subject, time, and spatial scope of the study and the research methodology, with particular emphasis on the construction of the vector error correction model. Attention was paid to tests that will supplement the study, making it possible to verify the accuracy of the model. The third part presents the results of stationarity and cointegration tests, model estimate results, Granger causality tests, and impulse response to shocks. The last part presents the conclusions.

Literature background

Prevailing fluctuations, impermanence, instability, and imbalances in the global economy encourage the exploration of prospective concepts and tools that will help achieve the goals of sustainable development, including the pursuit of openness to "knowledge civilizations" and reducing the sensitivity to widespread erosion. They should also operate effectively and efficiently and have a reference to existing system models (Mączyńska, 2015, p. 43).

Sustaining socioeconomic development is a fundamental challenge in the 21st century. During unstable conditions, a multidirectional relationship between the economy and other spheres arises. Energy is the primary driver for economic development and growth, and the production and consumption of energy have significantly influenced the development of current civilizations and environmental exploitation (Szaruga, 2018, p. 16). The economy is dynamic and operates in changing and unstable conditions; therefore, steady-state economics must be mentioned, which is often linked to sustainable development (Szaruga, 2018, p. 19).

The creator of the concept of steady-state economics was Daly, who noticed the dynamic nature of economies. The common denominator for economies in the sense of sustainable development and the steady-state economy is that economic subsystems undergo disturbances and adaptation to the environmental ecosystem and, at the same time, economic subsystems maintain a dynamic equilibrium (Daly, 1993, p. 814).

A steady-state economy has various definitions in the literature, but most are related to the steady-state or state of sustainability (Daly, 1991; Schmitt-Grohé & Uribe, 2003; Coeurdacier, Rey & Winant, 2011; García-Olivares & Ballabrera-Poy, 2015; Huang, Meng & Xue, 2017). A steady-state economy, according to Daly, is an economy whose growth is limited (i.e., it will not last indefinitely), and it is characterized by a time-limited state of human and manmade resources. Maintaining a constant level of resources is possible if low performance rates are maintained, i.e., by maintaining minimum material and energy flows during production and consumption (Daly, 1991, p. 17). Daly also claims that a growth economy is the antithesis of a steady-state economy (Daly, 1991, p. xv), and he equates a growth economy with quantitative change and a steady-state economy with qualitative change (Daly, 1991, p. 17). The steady-state economy approach is still evolving, as is the concept of development (which has both qualitative and quantitative aspects). Daly's assumptions are criticized for omitting socioeconomic indicators, in particular the gross domestic product (GDP) growth rate in favor of defining growth limits within an environmental framework (O'Neil, 2015, p. 1214). It should be noted that Daly did not completely omit measurable aspects, as he included the GNP (gross national product) (Szaruga, 2018, p. 23).

García-Olivares & Ballabrera-Poy assumed that a steady-state economy is the best possible scenario in which fossil fuel alternatives can be introduced. This scenario mitigates random economic and ecological effects because the technologies of modern economies strongly impact the natural environment. They also noticed that in the short and medium-term, no fossil fuel alternatives can be introduced as primary energy sources without disrupting the functioning of modern economies (García-Olivares & Ballabrera-Poy, 2015, p. 596).

The steady-state approach presented by Schmitt-Grohé & Uribe in models of small open economy includes temporary shocks with long-term economic impacts. Drift is particularly important for shaping a dynamic balance because it causes infinite and unlimited variance. Modifications to the models cause a stationary dynamic equilibrium (Schmitt-Grohé & Uribe, 2003). This approach is particularly important because it includes the concept of shocks and drift.

As mentioned before, steady-state and sustainability have been correlated and integrated. As noted by Mitra et al., sustainability is incorporated into models of depleting resources. Increasing the spectrum of substitution possibilities for aggregate capital relative to exhaustible and non-renewable resources is part of the sustainability concept (Mitra, 2013). A commonality between both steady-state and sustainability is the issue of depleting resources, while the concept of sustainability attempts to assess substitution possibilities.

Dedeurwaerdere also referred to substitution possibilities within the context of sustainability, by separating weak sustainability and strong sustainability (Dedeurwaerdere, 2013, pp. 16–17, 19–22). He explains that weak sustainability occurs during full substitution between natural capital and technological or produced capital. Technical innovation can help reduce the consumption of natural resources and serve as an economic growth factor; however, strong sustainability occurs during limited substitution between manmade capital and natural resources. This situation occurs when natural resource deficiencies cannot be fully compensated for using other types of capital (Dedeurwaerdere, 2013, pp. 16–17, 19–22).

Litman approached the concept of sustainability holistically. He noted that sustainability refers to a global and long-term perspective, and the main challenge is to harmonize economic, environmental, and social goals by fully integrating the possibilities, effects, and planning processes. He draws attention to the need to integrate development programming process with the interests of various social groups and the interests of various economies (including its sectors) (Litman, 2016, pp. 3–13). Therefore, it can be assumed that sustainability is the effect of a dynamic and long-term balancing of orders. This process consists of partial, temporary, and transitional stages for balancing the orders and results of implementing 21st-century challenges, consistent with the ideals of sustainable development (Szaruga, 2018, p. 26).

Referring to the interpretation of the concept of sustainability (proposed by Szaruga), this thread should be developed by defining three aspects of the concept of sustainable development. First, sustainable development should be understood as a long-term process of self-sustaining development, whose overarching goal is to identify common conflict areas (particularly those requiring improvement) in various orders (economic, social, environmental, political, and spatial) and to prevent self-destabilizing events in these areas. Secondly, it is a development that is subject to economic, social, and environmental drifts (including dynamics, cyclicality, and innovative shocks). Third, its essence is to temporarily tune processes from imbalances to equilibrium, to evolve into a new dynamic imbalance (development involves disruption because equilibrium is a transient state) (Szaruga, 2018, p. 25).

Załoga also approached the concept of sustainable development in three ways. She notes that the concept of sustainable development represents the harmonization of economic, social, and environmental orders. The goal is to strive for socioeconomic development while respecting human capital (first approach). The second approach concerns the strategic dimension in the global dimension of problems such as: energy saving, pollution and noise emission reduction, as well as social cohesion. The third approach refers to the socioeconomic imbalance resulting from the limited uses of natural capital (Załoga, 2013, p. 30).

In the context of the above concepts, two other terms were used, i.e. drift and order. *Drift* is a bottom-up process of spontaneous actions, i.e. shocks, technological changes, conflicts, and changes in thinking patterns (Pysz, 2015, p. 50). *Order* refers to the comprehensive and planned connection of independent factors into established structures, organizations, or institutions. Each of these components is independent from the others, although interactions between them are determined by certain rules (Kaczmarek, 2015, p. 57). Smith emphasizes that order is essential when attempting to empirically understand the reality of a socioeconomic environment. He distinguishes two rational orders: constructivist and ecological order. In the constructivist order, the reality and operation of rational units are modelled. In the ecological order, there are adjustment mechanisms during the decision-making process of rational individuals (Smith, 2013, pp. 13–15).

Smith's rational order concept involves rationalization, which is part of the decision-making process for sustainability (Schrettle et. al., 2014). Rationalization is otherwise an optimization process that is limited by information asymmetry (Cherepanov, Feddersen & Sandroni, 2013).

The fundamental measure of sustainable development is energy consumption because it informs about the scale of energy consumption and environmental pollution (Załoga, 2013, pp. 94–95). It also represents transport activity and reflects the efficiency of the economy and environmental strain (Szaruga, 2018, p. 49). It can be assumed that energy consumption due to transport is the energy consumption of the vehicles used for basic transport functions. This indicator can be presented as the relation of energy consumption in liters of oil equivalents relative to transport performance (Lu, 2016, p. 503).

Research on energy management in transport and the rationalization of energy consumption of transport have been carried out by numerous researchers (Karplus et. al., 2013; Barla, Gilbert-Gonthier & Kuelah, 2014, p. 316; Winebrake et al., 2015; Załoga & Szaruga, 2015; Sierra, 2016; Gerboni et. al., 2017; Saidi, Shahbaz & Akhtar, 2018; Szaruga, 2018; Szaruga et. al., 2018; Szaruga & Załoga, 2019). However, there is still a research gap regarding the rationalization of energy consumption of road transport. This is particularly manifested in terms of the dynamic balance and mechanism of adjustments to this balance (taking into account economic drift); therefore, this article will explore this research direction.

Data & methods

The model of rationalization of energy consumption of freight road transport was constructed based on a quarterly time series. The time period covered the first quarter of 2004 to the fourth quarter of 2018. The spatial scope of the research was Poland. The adopted time range meets the condition for providing a sufficient number of degrees of freedom for the vector error correction model with accepted delays and restrictions. The following symbols were adopted as representative variables (the prefix *l_* before the variable means logarithmic transformation):

- *l_EN* – logarithmic energy consumption of freight road transport; raw data expressed as the relation of energy consumption demand in kg per transport unit in t·km; kg/(t·km);
- *l_GDP* – logarithmic gross domestic product; raw data expressed in constant prices as an index, 2015 = 100;
- *l_PPI* – logarithmic index of production prices for energy; raw data expressed as an index, 2015 = 100.

Logarithmic transformation was necessary to provide a multiplicative formula of the relationships between variables.

Raw secondary data were obtained from the OECD.Stat database (OECD, 2019), with the energy consumption index determined as the quotient of energy demand for road transport and freight performance (Lu, 2016, p. 503).

All series were subjected to stationary analysis using the augmented Dickey-Fuller (ADF) test, taking into account the optimal number of lags. The optimal number of lags was determined based on the information criteria: Akaike (AIC), Final Prediction Error (FPE), Hannan-Quinn (HQ), and Schwarz (SC). In the absence of the confirmation of a stationary time series, the study was supplemented with a cointegration test, i.e. the Johansen trace test. The model was estimated by a two-stage procedure and verified in terms of correctness by appropriate tests for stationarity, autocorrelation, and multidimensional ARCH effects. The model was also verified using the Granger causality test in terms of causal relationships.

Results

The studied variables were subjected to the analyzing the occurrence of the unit root using an ADF test (Table 1). The research included drift and constant.

The results shown in Table 1 indicate that it is not possible to confirm the stationarity of the tested series with the optimal number of lags. Thus, the cointegration analysis was performed using the Johansen trace test (Table 2).

The data in Table 2 indicate that there is one long-term cointegrative equation that includes the variables representing the energy consumption of freight road transport, energy prices, and economic growth (taking into account the first rank of lags). Based on the stationary and cointegration tests, it has been concluded that VECM (Vector Error Correction Model) better depicted this relationship than VAR (Vector Autoregressive Model). Based on the information criteria – AIC, HQ, SC, FPE – the optimal number of lags was determined to be 1. Specifying the model, the conditions for the cointegrating relationship were established: unlimited drift, limited constant, and unlimited seasonal variables.

Table 1. Results of ADF tests for *l_EN*, *l_GDP*, *l_PPI* (OECD, 2019)

Tests	*l_EN* [4]	*l_GDP* [4]	*l_PPI* [1]
ADF test statistics	−2.7619	−3.0101	−1.2738

The study took into account the optimal number of lags, drift, and a constant.
The optimal number of lags determined by at least two information criteria is given in square brackets: AIC, FPE, HQ, or SC. The main information criterion with which the optimal rank was determined is AC.

Table 2. Johansen trace test for *l_EN*, *l_GDP*, *l_PPI* (OECD, 2019)

r0	LR	*p*-value	90%	95%	99%
0	46.55	0.0191	39.73	42.77	48.87
1	12.11	0.8024	23.32	25.73	30.67
2	4.76	06358	10.68	12.45	16.22

The study included the optimal number of lags, drift, constant, and seasonal dummies.
The optimal number of lags was 1, which was determined using four information criteria.

The estimations provided by this model are presented in matrix form (the dashes indicate no statistical significance – which were not useful and were omitted from the computations):

$$\begin{bmatrix} \Delta l\_EN(t) \\ \Delta l\_GDP(t) \\ \Delta l\_PPI(t) \end{bmatrix} =$$

$$= \begin{bmatrix} -0.109 \\ -0.018 \\ 0.073 \end{bmatrix} \left[\begin{bmatrix} 1.000 & 7.254 & -0.213 \end{bmatrix} \begin{bmatrix} l\_EN(t-1) \\ l\_GDP(t-1) \\ l\_PPI(t-1) \end{bmatrix} + \right.$$

$$\left. + \begin{bmatrix} -28.510 \end{bmatrix} \begin{bmatrix} \text{CONST} \end{bmatrix} \right] +$$

$$+ \begin{bmatrix} -0.204 & -2.064 & --- \\ 0.023 & --- & --- \\ --- & --- & --- \end{bmatrix} \begin{bmatrix} \Delta l\_EN(t-1) \\ \Delta l\_GDP(t-1) \\ \Delta l\_PPI(t-1) \end{bmatrix} +$$

$$+ \begin{bmatrix} -0.096 & -0.054 & --- & 0.006 \\ 0.007 & 0.006 & 0.005 & 0.001 \\ 0.026 & 0.044 & 0.027 & -0.004 \end{bmatrix} \begin{bmatrix} S1(t) \\ S2(t) \\ S3(t) \\ \text{TREND}(t) \end{bmatrix} +$$

$$+ \begin{bmatrix} u1(t) \\ u2(t) \\ u3(t) \end{bmatrix} \tag{1}$$

In this relation, the importance of unlimited drift (< 0.05 p-value, i.e. 0.043), constant, and seasonal dummies (p-values below 0.01 and 0.05, respectively) is noted.

Based on the standardized cointegration vector of VECM, the equation describing the long-term equilibrium between the energy consumption of road transport, GDP, and the price index of energy producers was obtained:

$$l\_EN_t = -7.254\ l\_GDP_t + 0.213\ l\_PPI_t + 28.510\ \text{CONST} \tag{2}$$

This equation can be used to determine the flexibility of the energy consumption of freight road transport in relation to GDP and PPI, which were −7.254 and 0.213 respectively. However, the flexibility of freight road transport relative to PPI was not statistically significant. Thus, there is weak sustainability between the energy consumption of freight road transport and GDP and a strong sustainability between the energy consumption of freight road transport and PPI energy.

The mechanism for adjusting the energy consumption of freight road transport to the long-term equilibrium after equilibrium disturbance was analyzed based on the vector:

$$\Delta l\_EN_t = -0.109(-7.254\ l\_GDP_{t-1} + 0.213\ l\_PPI_{t-1} + 28.510\ \text{CONST}) + \ldots \tag{3}$$

$$\Delta l\_GDP_t = -0.018(-7.254\ l\_GDP_{t-1} + 0.213\ l\_PPI_{t-1} + 28.510\ \text{CONST}) + \ldots \tag{4}$$

$$\Delta l\_PPI_t = 0.073(-7.254\ l\_GDP_{t-1} + 0.213\ l\_PPI_{t-1} + 28.510\ \text{CONST}) + \ldots \tag{5}$$

From vector estimates, it is noted that the energy equilibrium equation for road transport is affected by energy consumption, GDP, and the energy producer price index. The balance correction is respectively for GDP – 1.8%, PPI for energy – 7.3%, and for the energy consumption of road transport – 10.9%. Return to GDP equilibrium required about 8 years and 1 quarter, 2 years for PPI, and about 1 year and 1 quarter for the energy consumption of road transport.

The estimated model was characterized by the desired properties because the residuals did not show an autocorrelation, were normally distributed, and there was no multidimensional ARCH effect. The estimated model was subjected to a Granger causality test, which identified the causal relationships between the variables (Table 3).

Seven general and immediate causal relationships were identified using Granger's test. The first is particularly interesting in the context of shock analysis. Figure 1 shows the shocks represented by all variables. The shocks were presented using the impulse response function.

When analyzing the impact of GDP and PPI shocks on the energy consumption of road transport, it can be seen that the shock from GDP was negative (at the estimated point level around −3); however, the price shock from PPI of energy was positive (at the estimated point level around 0.06). These shocks eventually stabilize – after 37 quarters for the GDP, and after 27 quarters for the PPI of energy.

Conclusions

Sustainable development is a recent concept, but the challenges of the 21st century are rapidly changing due to economic drift and shocks. Rationalization can contribute to the pursuit of sustainability, as it includes a mechanism to adjust the equilibrium level. By their very nature, shocks unbalance a given system, but it is important to assess how long they last.

Table 3. Identification of causal relationships between the energy producer price index, GDP, and the energy consumption of freight road transport (OECD, 2019)

Granger causality		Instantaneous causality	
Causes → Effects	Test results	Causes → Effects	Test results
l_PPI, *l_GDP* → *l_EN*	Test statistics $l = 2.6867$ p-value-F(l; 4, 130) = 0.0341	*l_PPI*, *l_GDP* → *l_EN*	Test statistics: $c = 0.3199$ p-value-Chi(c; 2) = 0.8522
Conclusion: There is a causality of 5% significance.		Conclusion: There is no evidence of causality at the significance level of less than 10%, 5%, 1%.	
l_EN → *l_PPI*, *l_GDP*	Test statistics $l = 1.7789$ p-value-F(l; 4, 130) = 0.1369	*l_EN* → *l_PPI*, *l_GDP*	Test statistics: $c = 0.3199$ p-value-Chi(c; 2) = 0.8522
Conclusion: There is no evidence of causality at the significance level of less than 10%, 5%, 1%.		Conclusion: There is no evidence of causality at the significance level of less than 10%, 5%, 1%.	
l_EN, *l_PPI* → *l_GDP*	Test statistics $l = 0.7667$ p-value-F(l; 4, 130) = 0.5488	*l_EN*, *l_PPI* → *l_GDP*	Test statistics: $c = 8.0764$ p-value-Chi(c; 2) = 0.0176
Conclusion: There is no evidence of causality at the significance level of less than 10%, 5%, 1%.		**Conclusion: There is a causality of 5% significance.**	
l_GDP → *l_EN*, *l_PPI*	Test statistics $l = 2.9930$ p-value-F(l; 4, 130) = 0.0211	*l_GDP* → *l_EN*, *l_PPI*	Test statistics: $c = 8.0764$ p-value-Chi(c; 2) = 0.0176
Conclusion: There is a causality of 5% significance.		**Conclusion: There is a causality of 5% significance.**	
l_EN, *l_GDP* → *l_PPI*	Test statistics $l = 2.0980$ p-value-F(l; 4, 130) = 0.0847	*l_EN*, *l_GDP* → *l_PPI*	Test statistics: $c = 8.1872$ p-value-Chi(c; 2) = 0.0167
Conclusion: There is a causality of 10% significance.		**Conclusion: There is a causality of 5% significance.**	
l_PPI → *l_EN*, *l_GDP*	Test statistics $l = 1.1626$ p-value-F(l; 4, 130) = 0.3304	*l_PPI* → *l_EN*, *l_GDP*	Test statistics: $c = 8.1872$ p-value-Chi(c; 2) = 0.0167
Conclusion: There is no evidence of causality at the significance level of less than 10%, 5%, 1%.		**Conclusion: There is a causality of 5% significance.**	

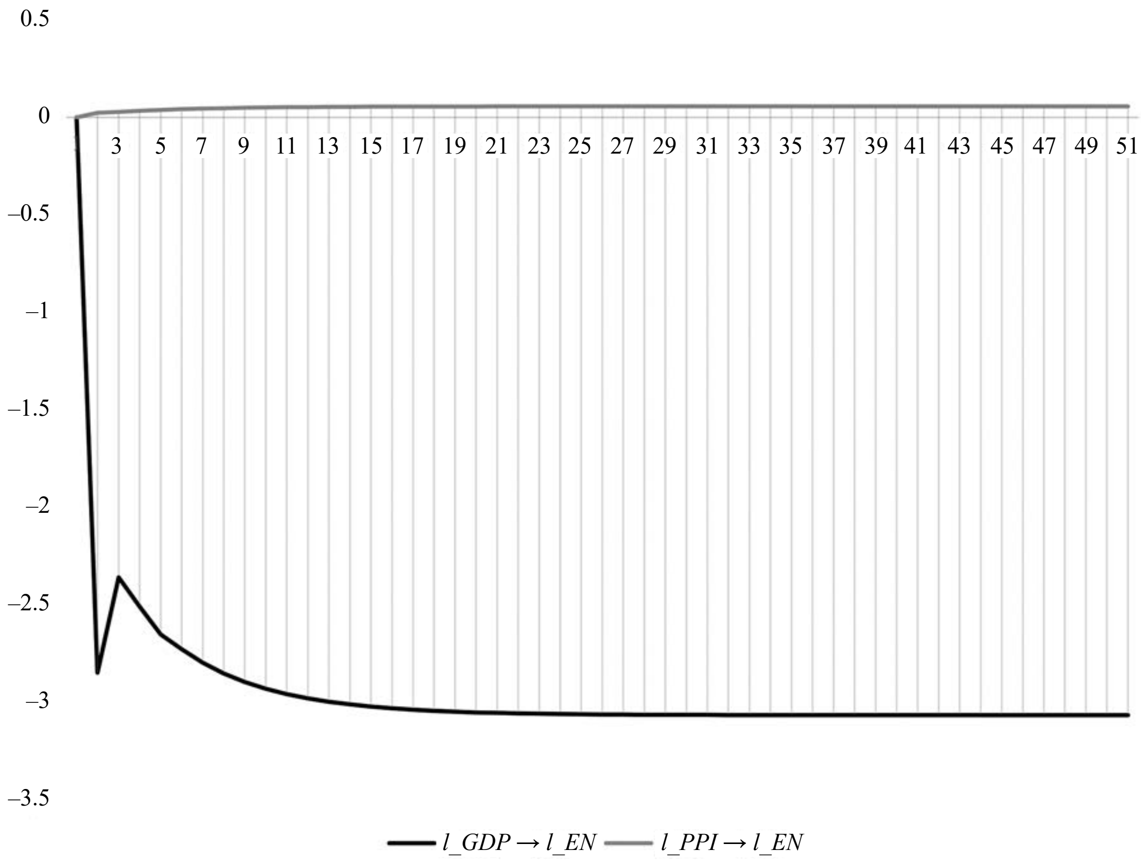

Figure 1. Changes in energy consumption of road transport due to shocks from GDP (demand and supply) and PPI (price) (OECD, 2019)

The criteria for rationalizing the energy consumption of freight road transport should correspond to a macroeconomic adjustment mechanism. This means that they should involve both cointegrating relations and a path to return to equilibrium after being disrupted from this state. In light of the results of this research, the main hypothesis is that rationalizing the energy consumption of road transport is affected by drift and shocks, which desynchronizes the adjustment mechanism from equilibrium (sustainability).

Acknowledgments

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.

References

1. Barla, P., Gilbert-Gonthier, M. & Kuelah, J.-R.T. (2014) The demand for road diesel in Canada. *Energy Economics* 43, pp. 316–322.
2. Cherepanov, V., Feddersen, T. & Sandroni, A. (2013) Rationalization. *Theoretical Economics* 8, 3, pp. 775–800.
3. Coeurdacier, N., Rey, H. & Winant, P. (2011) The Risky Steady State. *The American Economic Review* 101, 3, pp. 398–401.
4. Daly, H.E. (1991) *Steady-State Economics*. Washington: Island Press.
5. Daly, H.E. (1993) Steady-State Economics: A New Paradigm. *New Library History* 24, 4, pp. 811–816.
6. Dedeurwaerdere, T. (2013) *Sustainability science for strong sustainability. Report prepared in the context of the public tender on a Scientific Report on the Organisation of Scientific Research, with the support of the Minister for Sustainable Development and Public Administration of the Walloon Government of Belgium*. Leuven: Université catholique de Louvain and Fonds National de la Recherche Scientifique, FSR-FNRS.
7. García-Olivares, A. & Ballabrera-Poy, J. (2015) Energy and mineral peaks, and a future steady state economy. *Technological Forecasting and Social Change* 90, B, pp. 587–598.
8. Gerboni, R., Grosso, D., Carpignano, A. & Chiara, B.D. (2017) Linking energy and transport models to support policy making. *Energy Policy* 111, pp. 336–345.
9. Huang, K.X., Meng, Q. & Xue, J. (2017) Balanced-budget income taxes and aggregate stability in a small open economy. *Journal of International Economics* 105, pp. 90–101.
10. Kaczmarek, T. (2015) *The need for order in a market economy*. *Biuletyn PTE* 2(69), pp. 54–61 (in Polish).
11. Karplus, V.J., Paltsev, S., Babiker, M. & Reily, J.M. (2013) Applying engineering and fleet detail to represent passenger vehicle transport in a computable general equilibrium model. *Economic modelling* 30, pp. 295–305.
12. Litman, T. (2016) *Well Measured: Developing Indicators for Sustainable and Livable Transport Planning*. Victoria: Victoria Transport Policy Institute.
13. Lu, S.-M. (2016) A low-carbon transport infrastructure in Taiwan based on the implementation of energy-saving measures. *Renewable and Sustainable Energy Reviews* 58, pp. 499–509.
14. Mączyńska, E. (2015) Bankruptcy of enterprises – global context. In Mączyńska, E. (ed.). *Bankruptcy, bankruptcy and recovery processes of enterprises. Selected regulatory aspects*. Warsaw: Publishing House – Warsaw School of Economics (in Polish).
15. Mitra, T. (2013) Characterizing the sustainability problem in an exhaustible resource model. *Journal of Economic Theory* 148, 5, pp. 2164–2182.
16. O'neil, D.W. (2015) The proximity of nations to a socially sustainable steady-state economy. *Journal of Cleaner Production* 108, pp. 1213–1231.
17. OECD (2019) *OECD Statistics*. [Online] Available from: https://stats.oecd.org/ [Accessed: September 11, 2019].
18. Pysz, P. (2015) Drift of economic order in the modern world. *Biuletyn PTE* 2(69), pp. 49–53 (in Polish).
19. Saidi, S., Shahbaz, M. & Akhtar, P. (2018) The long-run relationships between transport energy consumption, transport infrastructure, and economic growth in MENA countries. *Transportation Research Part A: Policy and Practice* 111, pp. 78–95.
20. Schmitt-Grohé, S. & Uribe, M. (2003) Closing small open economy models. *Journal of International Economics* 61, 1, pp. 163–185.
21. Schrettle, S., Hinz, A., Scherrer-Rathje, M. & Friedli, T. (2014) Turning sustainability into action: Explaining firms' sustainability efforts and their impact on firm performance. *International Journal of Production Economics* 147, pp. 73–84.
22. Sierra, J.C. (2016) Estimating road transport fuel consumption in Ecuador. *Energy Policy* 92, pp. 359–368.
23. Smith, V.L. (2013) *Rationality in economics.* Warszawa: Oficyna a Wolters Kluwer business (in Polish).
24. Szaruga, E. (2018) *Rationalization of energy consumption of road transport. The challenge of the 21st century*. Kraków-Legionowo: edu-Libri (in Polish).
25. Szaruga, E., Skąpska, E., Załoga, E. & Matwiejczuk, W. (2018) Trust and distress prediction in modal shift potential of long-distance road freight in containers: modeling approach in transport services for sustainability. *Sustainability* 10, 7, 2370, pp. 1–19.
26. Szaruga, E. & Załoga, E. (2019) Rationalization of Energy Consumption of Road Transport of Member Countries of the International Energy Agency. In: Suchanek, M. (ed.). *Challenges of Urban Mobility, Transport Companies and Systems*, pp. 333–342. Cham: Springer Proceedings in Business and Economics. Springer Nature Switzerland AG.
27. Winebrake, J.J., Green, E.H., Comer, B., Li, C., Froman, S. & Shelby, M. (2015) Fuel price elasticities in the U.S. combination trucking sector. *Transportation Research Part D: Transport and Environment* 38, pp. 166–177.
28. Załoga, E. (2013) *Trends in European Union land transport.* Szczecin, Poland: University of Szczecin Publishing House (in Polish).
29. Załoga, E. & Szaruga, E. (2015) Analysis of the relationship between consumption of carbon dioxide emissions and energy consumption, unit energy consumption and productivity of freight road transport. *Logistyka* 4, pp. 6973–6982 (in Polish).