

How to Anticipate Recession via Transport Indices¹

Petr JAKUBIK* – Seyit KERIMKHULLE** – Saida TELEUOVA***

Abstract

This article focuses on transport industry development as a leading economic indicator. We investigate the dynamics of growth in the Cass Freight Index: Expenditures and Shipments, capturing the US transport industry, and apply a system of logistic models of population growth and competition to transport industry indices. We show that the constructed structure identifies the signs of a US economic downturn/recession well in advance.

Keywords: *Cass Freight Index: Expenditures and Shipments, logistic growth, stochastic dynamics, economic growth*

JEL Classification: C43, C62, L91, O47

Introduction

The transport industry has a long history in business cycle research. Burns and Mitchell (1946) and Hultgren (1948) pointed out that cyclical movements of railroads coincided with the economic vicissitudes at large. Furthermore, a number of transport indicators were included in the list of the National Bureau of Economic Research (NBER), containing 21 cyclical indicators refined by

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Geoffrey Moore (Fels and Hinshaw, 1968). Transportation represents a significant part of services and plays a critical role in promoting economic activities between different sectors (Ghosh and Wolf, 1997). However, most existing literature on leading economic indicators focuses on financial, commodity or auction markets, while substantially less relates to the transport industry. Hence, we focus on transport cycles that may be used to obtain additional indications of future economic development, complementing standard toolkits, to design appropriate policy measures.

Different econometric growth models have begun to play an important role among researchers in capturing the overall economic reality. In this regard, the existing academic literature offers a great variety of studies dealing with econometric growth modelling. We focus on papers that employ a system of models of population growth using stochastic processes, which are able to capture economic uncertainties and can be applied to the transport industry. Among these models, logistic growth models with elements of diffusion of innovations, competition, and others are often used (Bai and Wand, 2007; Balanov, Krawcewicz and Ruan, 2008; Chakraborty et al., 2007; Jin and Zhao, 2008).

In general, the transport service industry is characterised by a high level of innovation and cyclical patterns driven by economic development (Angelidis and Skiadopoulos, 2008; Kavussanos and Dimitrakopoulos, 2011), and represents a significant part of the service industry in developed countries, particularly in the US where the tertiary sector, and specifically the transport industry, contributes significantly to economic growth. Many indices have been introduced to capture growth in the transport industry. We focus on the US economy with its wide range of available transport indices providing extensive historical time series data.² We opt for the Cass Freight Index: Expenditure & Shipment (CFI: E&S) for its specific features that meet the requirements of our applied modelling framework: in particular, high volatility, monthly frequency, broad coverage and availability of extensive time series. Since 1995, the CFI has been one of the leading measures of North American freight volumes and expenditures. The monthly CFI figures provide valuable insight into freight trends as they relate to other economic and supply chain indicators and the overall economy.

² The following indices are available for the US economy: Cass Freight Index, Moving 12 – Month Total Vehicle Miles Traveled, Truck Tonnage, Vehicle Miles Traveled, Rail Freight Carloads, Freight Transportation Services Index, Rail Freight Intermodal Traffic, Total Transportation Services Index, Revenue Passenger Miles for U.S. Air Carrier Domestic and International, Scheduled Passenger Flights, Air Revenue Passenger Miles, Natural Gas Consumption, Passenger Transportation Services Index, Load Factor for U.S. Air Carrier Domestic and International, Scheduled Passenger Flights, Air Revenue Ton Miles of Freight and Mail, Tonnage for Internal U.S. Waterways, Public Transit Ridership, Pipeline Petroleum Movement, Available Seat Miles for U.S. Air Carrier Domestic, Domestic Load Factor, Scheduled Passenger Flights.

In order to determine the sustainability of the sector, we use a system of differential equations. A stable structure for each stochastic system can be found, for example as a stochastic dynamic of attractors, which formulates the structure of dynamic development in the long-run (Drobotz, Richter and Wambach, 2012; Erdogan et al., 2013; Goulielmos and Psifia, 2009; Jing, Marlow and Hui, 2008; Lee, Lun and Yan, 2013).

We implement differential equations of logistic growth selecting the specification of the system to arrive at a sustainable equilibrium. Moreover, we use an ordinary least square estimate to calibrate the parameters of the growth model for the CFI: E&S. Overall, our study follows the fundamental research of Verhulst (1838), Volterra (1926), Gause and Witt (1935), Bass (1969), and Tilman (1985), among others. We contribute to applied science in the stochastic modelling of logistic growth by applying the existing theory and methodology to the transport industry. Our results enable us to identify the signs of a US GDP recession/downturn well in advance, and provide policy makers with time to respond and mitigate the negative implications and risks stemming from a potential economic drop. To our knowledge, this is the first study to use the Cass Freight Index to identify the cyclical pattern of GDP growth for the US economy. Although we apply the proposed methodology to the US economy, it could be used similarly for the EU or the Czech Republic. However, in the EU the majority of inland freight transport statistics are based on movements in each reporting country, regardless of the nationality of the vehicle or vessel involved, and the measure of tonne-kilometres is generally considered to be more reliable, as the use of tonnes entails a higher risk of double-counting, particularly for international transport. Moreover, the methodology used across the EU Member States is not completely harmonised.

This article is structured as follows. The next chapter provides an overview of the relevant papers for our study. Subsequently, we explain the methodology and research objectives in detail. Finally, we present the results obtained and our conclusion.

1. Literature Review

Over the years, leading economic indicators have been revised several times in order to find effective techniques for predicting economic recessions (Moore, 1961; Zarnowitz, 1992). Initially, capital market indicators were considered the most effective to represent US economic movements (Compton and Silva, 2005). However, their importance in the analysis of business cycles dramatically declined, particularly after Kydland and Prescott (1982) showed that at least two

thirds of business fluctuations in the US could be explained by a dynamic stochastic general equilibrium model without the influence of monetary factors. Since then, the theory of real business cycles, which associates short-term business cycle movements with real factors, has been investigated in the literature more extensively (Correa et al., 2004). Hence, the development of leading indicators has become a part of business cycle studies.

Many leading indicators for the aggregate economy that are conceptually similar to the Cass Freight Index are found in the existing literature. According to Temin (1998), the relationship between transportation and the aggregate economy reflects complex linkages between sectors. First, the transport sector is sensitive to monetary policy due to the use of capital equipment and fuel consumption. Second, transport demand often reflects producers' expectations about future profits. Finally, deregulation and the adoption of just-in-time inventory control methods improve the productivity of the economy and contribute positively to the transportation business. Everts (2006) analysed the correlation between different sectors, industries, and the overall economy. He found a high correlation of the transport industry with the aggregate economy exhibiting the features of a two quarters leading indicator. Lahiri and Yao (2004) investigated the Transport Service Output Index (TSOI), which includes the monthly output index and its two components, freight and passenger. They found strong cyclical movements observed in transport output to be well synchronized with downturns in the US economy. Yao (2005) studied the asymmetric predictive power of freight transport to anticipate aggregate fluctuation in the US economy and found that cargo traffic cycles precede recessions while being coincident with recovery in economy-wide business cycles. He estimated that the forecasting power of freight transport could anticipate aggregate economic fluctuation one-year in advance for downturns and about half a year for upturns.

In this study, we apply models of growth population to the US transport sector to describe the growth dynamic. Based on the relevant literature, there is a stable structure in chaotic development using a spatiotemporal approach. The dynamics are generally measured as the difference between the inflow and outflow of population within a spatial dimension and over time. However, there is no common method of how to choose the appropriate specification of the population representation. Malthus (1798) tested the hypothesis that the difference between the previous and the current population has a constant proportion. As Malthus's equation included only linear terms, Verhulst (1938) used a logistic growth equation that captures a qualitative behaviour. The assumptions applied by Verhulst might not always be fulfilled, particularly in terms of finding the saturation of objects in space, i.e. his model is valid for the objects of population

with unrestricted space. The classic example of population growth and intraspecific competition is the experimental design used by Gause and Wit (1935), who formulates an explicit and mechanistic model for the growth of yeast in a closed container. He was the first who explored the model of logistic growth.

The interaction of competing populations can be described by a system of equations, one of which is the Lotka-Volterra system assuming the absence of common resources reflected in a competition between the indexes. The victim is food; the predator eats prey – expenditure/shipment represents the victim/predator in our case. Overall, the current focus of researchers is on the stability of steady states³ and assessment of the effects of developments. Spatially heterogeneous populations imply the class of reaction-diffusion equations and their systems. Tilman (1982) shows that the stability analysis, itself provides much more contribution than in the spatially homogeneous case. Hence, the solutions of the diffusive Lotka-Volterra competition model do not always show patterns. The literature provides a number of diffusion models that allow for nonhomogeneous steady states (Lotka, 1925; Ei and Mimura, 1990; Galiano, Garz'on, and Jungel, 2003; Dreher, 2008; Fu, Gao and Cui, 2008). They are used at both micro (Li and Sui, 2011) and macro levels (introduced by Fourt and Woodlock, 1960; Mansfield, 1961; and Bass, 1969). The main idea of micro-simulation models is to receive macro results by simulating the behaviour of individuals and their interactions. The fact that economic agents have become more sensitive to global macroeconomic cycles as a result of globalisation is addressed by percolation models (Goldenberg et al., 2000) or multi-agent models (Gong and Li, 2003), which are widely used to analyse complex systems, such as finance, infectious diseases, IT security products (Carayannis and Turner, 2006), and transportation or service industries, among others. During the last 20 years, the in-depth study of innovation diffusion models has mainly focused on two areas. One is the amendment or expansion of the Bass model, including technical update (Bass and Bass 2004; Kim, Chang and Shocker, 2000), repetitive purchase (Steffens, 2002), adding diffusion channels (Morgan and Ritz, 1991; Rangaswamy and Gupta, 2000). The other is the development of new models different from the Bass model which have focused on the simulation of individual consumer behaviour.

There is no universal concept of sustainability or methodology to measure it due to the different objectives of research studies (Simpson and Kohers, 2002). Several studies focus on a possible link between indicators of performance and sustainability (e.g. McWilliams and Siegel, 2000; Teplý and Tripe, 2015). In order to define and measure sustainability, the existing literature contains the

³ Steady state is a special dynamic equilibrium in which an additional condition is satisfied. In the population dynamic models, steady state is a special solution of dynamic equilibrium where the isocline is zero.

implementation of one-dimensional (Davidson and Worell, 1988; Reed et al., 1990) and multi-dimensional (Wenzel and Thiewes, 1999) measures. Sustainability practices contain a potential element for long-term value creation, which is reflected in the positive development of financial markets, such as the Dow Jones Sustainability Group Index, the FTSE4Good, or the Domini Social Index.

Several studies focus on the concept of network externalities assuming that the diffusion of innovations is carried out by social networks (Goldenberg et al., 2009), while few investigate the space and time dimensions of innovations' diffusion. Currently, the development of society has become highly technological and innovative, which requires studying new methods of evaluation. Hence, this article proposes a methodology that attempts to assess the development of a high-tech environment, namely the dynamic of transport industry development.

2. Research Objectives and Methodology

The Cass Freight Index is a measurement of the monthly aggregate shipment of freight processed by Cass Information Systems. The index ultimately serves as one of the national indicators of shipping activities, consisting of the actual freight expenses of the underlying companies in the index and using January 1990 as its base.⁴ It is updated with monthly freight expenditures and shipment volumes from the entire Cass client base. Volumes represent the month in which transactions are processed by Cass, not necessarily the month in which the corresponding shipments took place. This study focuses on the US transport market as the most developed in the world.

The aim of our study is to analyse the stochastic dynamics of the CFI: E&S to anticipate a US economic downturn/recession well in advance. First, we provide the theoretical background of the ordinary least square estimate of the parameters corresponding to the specification of stochastic differential equations (2) – (4). Second, we analyse and forecast systemic indicators of the stochastic dynamics of the CFI: E&S. Third, we select parameters that imply a stability of equilibrium. Our model is constructed based on two equations (Cass Freight Index: Expenditures and Cass Freight Index: Shipment), which are characterised by a cyclic process. The proposed framework applies a system of logistic models of population growth and competition to the transport industry indices. The aim is not to predict directly economic growth via transport indices, but rather to identify

⁴ The Index points for each subsequent month represents that month's volume in relation to the January 1990 baseline. Each month's volumes are adjusted to provide an average 21-day work month. Adjustments are also made to compensate for business additions/deletions to the volume figures. These adjustments help normalise the data to provide a sound basis for ongoing monthly comparison.

entry points of transport cycles using the Cass Freight Index that could provide leading information about an upcoming economic downturn/recession.

We employ the Heaviside step function of a discrete variable y_t at time t (see e.g. Sterman, 2000; Yamaguchi, 2015) defined as

$$\Delta_t = \begin{cases} 1, & \text{if } y_{t+1} - y_t > 0 \\ 0, & \text{if } y_{t+1} - y_t \leq 0 \end{cases} \quad (1a)$$

and the moment of time is defined as the sum of Δ_t i.e.

$$\tau = \sum_{j=0}^{t-1} \Delta_j = \sum_{j=0}^{k-1} 1 + \sum_{j=k}^{t-1} 0 = k \leq \sum_{j=0}^{t-1} 1 = t \quad (1b)$$

Further, we assume a Wiener process ΔW_t with independent increments at time, mean $E(\Delta W_t) = 0$ and variance $Var(\Delta W_t) = \Delta_t$. Subsequently, the corresponding differential equation is $W_t \stackrel{a.s.}{=} \sum_{j=0}^{t-1} \Delta W_j \sim N\left(0, \sqrt{\sum_{j=0}^{t-1} \Delta_j}\right) = N(0, \sqrt{k})$ for all $0 < t < \infty$, where $W(0) \stackrel{a.s.}{=} 0$ and $N(0, \sqrt{k})$ is the process of normal distribution with mean 0 and dispersion \sqrt{k} .⁵ The following equations provide specification of stochastic differential equations:

$$\Delta X_t \stackrel{a.s.}{=} r_{XX} X_t \left(1 - \frac{1}{q_{XX}} X_t\right) \Delta_t + \sigma_{XX} X_t \left(1 - \frac{1}{q_{XX}} X_t\right) \Delta W_t \quad (2)$$

where

X_t correspond to Cass Freight Index: Expenditures (CFIE) for all $t = 0, 1, 2, \dots$

$$\Delta S_t \stackrel{a.s.}{=} r_{SS} S_t \left(1 - \frac{1}{q_{SS}} S_t\right) \Delta_t + \sigma_{SS} S_t \left(1 - \frac{1}{q_{SS}} S_t\right) \Delta W_t \quad (3)$$

where

S_t represents Cass Freight Index: Shipments (CFIS) for all $t = 0, 1, 2, \dots$

$$\begin{cases} \Delta X_t \stackrel{a.s.}{=} r_{XS} X_t \left(1 - \frac{X_t + \omega_{XS} S_t}{q_{XS}}\right) \Delta_t + \sigma_{XS} X_t \left(1 - \frac{X_t + \omega_{XS} S_t}{q_{XS}}\right) \Delta W_t \\ \Delta S_t \stackrel{a.s.}{=} r_{SX} S_t \left(\frac{S_t + \omega_{SX} X_t}{q_{SX}} - 1\right) \Delta_t + \sigma_{SX} S_t \left(\frac{S_t + \omega_{SX} X_t}{q_{SX}} - 1\right) \Delta W_t \end{cases} \quad (4)$$

⁵ We use the symbol $\stackrel{a.s.}{=}$ for an event that almost certainly occurs. In probability theory, it corresponds to an event that occurs with probability one. In other words, the set of possible exceptions may be non-empty, but it has probability zero.

The equation (4) represents a system of logistic growth models for simultaneous growth development of X_t and S_t , where X_t corresponds to CFIE, S_t corresponds to CFIS and Δ_t is the Heaviside step function of a discrete variable X_t and S_t respectively defined by equation (1a), for all $t = 0, 1, 2, \dots$, $\Delta X_t = X_{t+1} - X_t$ is differential equation for X_t , $\Delta S_t = S_{t+1} - S_t$ is differential equation for S_t , q_{XX} , q_{XS} , q_{SS} , and q_{SX} are expert parameters representing potential “scale” of growth of X_t and S_t , respectively, ω_{XS} and ω_{SX} are unknown parameters representing the potential effect of S_t on the growth of X_t and vice-versa, r_{XX} , r_{XS} , r_{SS} , r_{SX} , σ_{XX} , σ_{XS} , σ_{SS} and σ_{SX} , are unknown parameters.

We employ the following time series to investigate the stochastic dynamics of the US transport industry and to identify entry points to a new phase of transport cycles to detect economic recession/downturn well in advance.

- Cass Freight Index: Expenditures (CFIE), index January 1990 = 1, 1999 – 2015, monthly frequency; FRED (2015a);
- Cass Freight Index: Shipments (CFIS), index January 1990 = 1, 1999 – 2015, monthly frequency; FRED (2015b);
- NBER based Recession Indicators Series for the United States, +1 or 0, 1999 – 2015, monthly frequency; FRED (2015c);
- Recession Indicators Series for the Cass Freight Index: Expenditures & Shipments, +1 or 0, 1999 – 2015, monthly frequency (compiled by the authors).

Furthermore, we employ the following econometric model specification:

$$Y_t \stackrel{a.s.}{=} \beta_0 + \beta_1 \tau + \beta_2 \sqrt{\tau} z_t + \varepsilon_t \quad (5)$$

where

- Y_t – observations for $t = 0, 1, 2, \dots$, dependent variables of the model (5);
- z_t – a random variable with a standard normal distribution;
- $\beta_0, \beta_1, \beta_2$ – unknown parameters;
- ε_t – independent identically distributed (i.i.d.) normal random errors with variance;
- σ and τ – the function of time defined by equations (1a) and (1b).

We process the above methodology in the following sequence:

1. Determination of steady state⁶ conditions of the simultaneous system of logistic growth equations (4) of the stochastic dynamics of the CFI: E&S;
2. Simultaneous reduction of the logistic model (4) into the logistic growth equations (2) and (3) of the stochastic dynamics of the CFI: E&S;

⁶ A steady state corresponds to a situation in which the recently observed behaviour of the system will be repeated in the future.

3. Selection of the OLS estimates of unknown parameters of logistic growth equations (2) and (3) of the stochastic dynamic of the CFI: E&S;

4. Analysis, diagnosis, and prognosis of condition and phase portraits of the stochastic dynamics of the CFI: E&S.

The applied methodology allows us to identify the entry points of the transport cycle that could provide leading information on economic growth.

3. Empirical Results

3.1. Estimation of Model Parameters

The dynamics of the indicators X_t and S_t is described by the system of stochastic differential equations (4). In these equations X_t and S_t represent the CFIE and CFIS, respectively. We can introduce the specific cases of the stochastic growth rate of the CFIE and CFIS as $r_{XS}\Delta_t + \sigma_{XS}\Delta W_t$ and $r_{SX}\Delta_t + \sigma_{SX}\Delta W_t$ for variables X_t and S_t respectively. Then the stochastic growth rate of X_t corresponds to $r_{XS}\sum_{j=0}^{t-1}\Delta_j + \sigma_{XS}\sum_{j=0}^{t-1}\Delta W_j = r_{XS}\tau + \sigma_{XS}\sqrt{\tau}z_t$, where z_t is a random variable with a standard normal distribution.

After several derivations and under some assumptions, we arrive at the following specification of the regression for the CFIE.

$$\ln\left(\frac{1 - \frac{1}{q_{SX}/\omega_{SX}} X_t}{X_t}\right) \stackrel{a.s.}{=} \ln\left(\frac{1 - \frac{1}{q_{SX}/\omega_{SX}} X_0}{X_0}\right) - r_{XX}\tau - \sigma_{XX}\sqrt{\tau}z_t + \varepsilon_{XX,t} \quad (6)$$

Similarly, for the CFIS

$$\ln\left(\frac{1 - \frac{S_t}{q_{XS}/\omega_{XS}}}{S_t}\right) \stackrel{a.s.}{=} \ln\left(\frac{1 - \frac{S_0}{q_{XS}/\omega_{XS}}}{S_0}\right) - r_{SS}\tau - \sigma_{SS}\sqrt{\tau}z_t + \varepsilon_{SS,t} \quad (7)$$

where

- τ and $\sqrt{\tau}$ – factor variables;
- $\varepsilon_{..t}$ – errors of the models;
- z_t – a random variable with a standard normal distribution;
- r_{XX} , r_{SS} , σ_{XX} , σ_{SS} , ω_{XS} , ω_{SX} – unknown parameters and the estimate of the unknown parameters;
- ω_{XS} and ω_{SX} – based on a system of simultaneous equations

$$\begin{cases} q_{XS} - 2X_t = \omega_{XS}S_t + \varepsilon_{XS,t} \\ q_{SX} - 2S_t = \omega_{SX}X_t + \varepsilon_{SX,t} \end{cases}$$

The OLS estimates for the parameters of stochastic dynamics models are selected by generating random variables, where the selection criteria are to ensure the maximum specific growth rate of dependent variables CFI: E&S. The results of the estimates for the CFI: E&S are provided in Table 1. We further consider two scenarios. First, under an optimistic scenario $\sum_{j=0}^{t-1} \Delta_j = t$. Second, under a realistic scenario $\sum_{j=0}^{t-1} \Delta_j = k \leq t$.

Table 1

OLS Estimate of Parameters for the Models (6) and (7)

Coefficients/ Dependent variable	CFIE (formula 6, optimistic scenario)	CFIE (formula 6, realistic scenario)	CFIS (formula 7, optimistic scenario)	CFIS (formula 7, realistic scenario)
r_{XX}	0.0081*** (0.001)	0.0104*** (0.000)		
σ_{XX}	0.0444*** (0.017)	0.0365*** (0.006)		
r_{SS}			-0.0019** (0.001)	-0.0022* (0.001)
σ_{SS}			-0.0382*** (0.015)	-0.0436** (0.018)
Constant	-0.5328*** (0.067)	-0.4896*** (0.021)	-0.3415*** (0.059)	-0.3162*** (0.063)
Number of observations	202	202	202	202
R-square	0.7960	0.9770	0.0397	0.0643

Note: The dependent variable – Cass Freight Index: Expenditures & Shipments, Index Jan 1990 = 1, 1999 – 2015, monthly. Standard errors in parentheses; *, **, *** – estimate is significant at 10%, 5%, 1% level.

Source: Authors' estimates.

3.2. Analysis of the Model for the CFIE

The parameter q_{SX} representing the potential scale of growth of X_t in the long-term and ω_{SX} corresponding to the effect of the impact of S_t on growth X_t were calibrated based on the condition for a stable equilibrium solution.⁷ Subsequently, the logistic regression equation for the dependent variable X_t of the optimistic growth scenario corresponds to:

⁷ The parameter q_{SX} was calibrated based on the estimated steady state (see Figure 1): $q_{SX} = 3.2690$ that implies the value of $\omega_{SX} = 0.5330$.

$$\ln\left(\frac{1-0.1631X_t}{X_t}\right) = -0.5328 - 0.0081\tau - 0.0444\sqrt{\tau} \quad (8)$$

where according to equation (6) (Table 1) $r_{xx} = 0.0081$ and $\sigma_{xx} = 0.0444$ represent the deterministic and stochastic growth of X_t in the absence of S_t for the optimistic scenario.

The logistic regression equation for the realistic scenario corresponds to:

$$\ln\left(\frac{1-0.1631X_t}{X_t}\right) = -0.4896 - 0.0104\tau - 0.0365\sqrt{\tau} \quad (9)$$

where according to equation (6) (Table 1) $r_{xx} = 0.0104$ and $\sigma_{xx} = 0.0365$ represent the deterministic and stochastic growth of X_t in the absence of S_t for the realistic scenario.

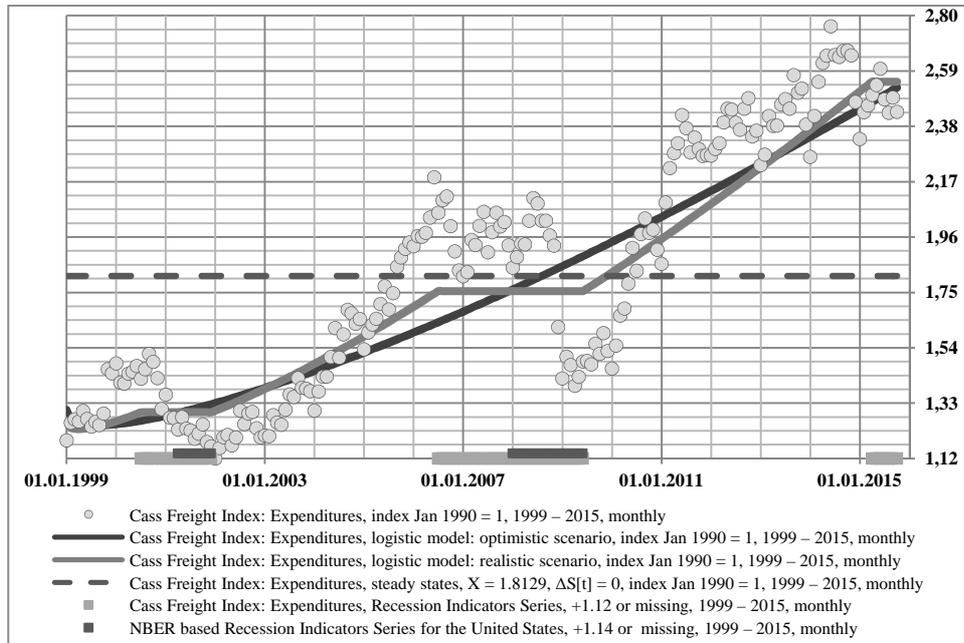
The estimated models allow us to identify entry points to a downturn/recession of the transport cycle in mid-2000, mid-2006 and the beginning of 2015 (see the light grey solid lines on axis x in Figures 1, 2 and 3, respectively). The optimistic scenario serves as a medium-term trend and the realistic scenario fluctuates around this trend. The intersecting points between the optimistic and realistic scenarios signal transition points from one phase of transport cycle to another. The points corresponding to the beginning of an economic downturn/recession could be clearly identified in 05/2001 and 01/2008. The rest of the interactions could be associated with the upward trend, for example 01/2003 or 01/2013. The turning points of the realistic scenario helps to identify the phase of the cycle (see e.g. the changing trend of the line in mid-2006 – entering a transport downturn/recession or in mid-2009 – the end of transport recession). In this way, we can identify downturns/recessions in the transport industry (07/2000 – 12/2001, 07/2006 – 06/2009, 04/2015 – 10/2015).

Based on the recession indicators for CFI and GDP (see light and dark grey solid lines in the bottom of Figures 1, 2 and 3, respectively) we clearly see that the CFI is a leading indicator of GDP downturns/recessions. Hence, identifying correctly the current phase of the transport cycle based on the CFI data observed provides us with valuable information on a future economic downturn/recession. Looking forward, we can consider the transport downturn/recession starting in 04/2015 as a sign of a potential economic downturn/recession.

Figure 2 further demonstrates that the CFI could well serve as a leading indicator. Additionally, based on the latest data, the chart shows that the US economy experienced a downturn in the beginning of 2016, but did not fall into recession with growth slightly above 1%.

Figure 1

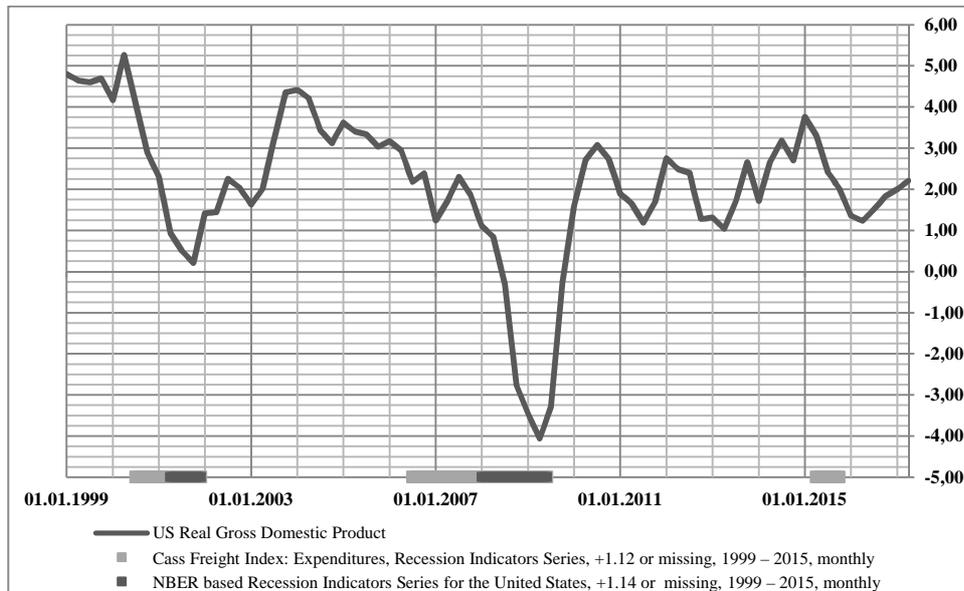
Model of Stochastic Dynamics of the Cass Freight Index: Expenditures
(Index Jan 1990 = 1, 1999 – 2015, monthly)



Source: Authors' calculations.

Figure 2

US Real Economic Growth (year-on-year in %, quarterly)



Source: Federal Reserve Bank of St. Louis.

3.3. Analysis of the Model for the CFIS

Similarly to the previous section, based on the condition for a stable equilibrium we calibrate the potential scale of growth of S_t and the potential effect of the impact X_t on growth S_t .⁸ Subsequently, the logistic regression equation for S_t for the optimistic growth scenario corresponds to:

$$\ln\left(\frac{1-0.3046S_t}{S_t}\right) = -0.3415 + 0.0019\tau + 0.0382\sqrt{\tau} \quad (10)$$

where according to equation (7) (Table 1) parameters $r_{SS} = 0.0019$ and $\sigma_{SS} = 0.0382$ represent the deterministic and stochastic growth of S_t in the absence of X_t for the optimistic scenario.

The logistic regression equation for the realistic scenario corresponds to:

$$\ln\left(\frac{1-0.3046S_t}{S_t}\right) = -0.3162 + 0.0022\tau + 0.0436\sqrt{\tau} \quad (11)$$

where according to equation (7) (Table 1) parameters $r_{SS} = 0.0022$ and $\sigma_{SS} = 0.0436$ represent the deterministic and stochastic growth of S_t in the absence of X_t for the realistic scenario.

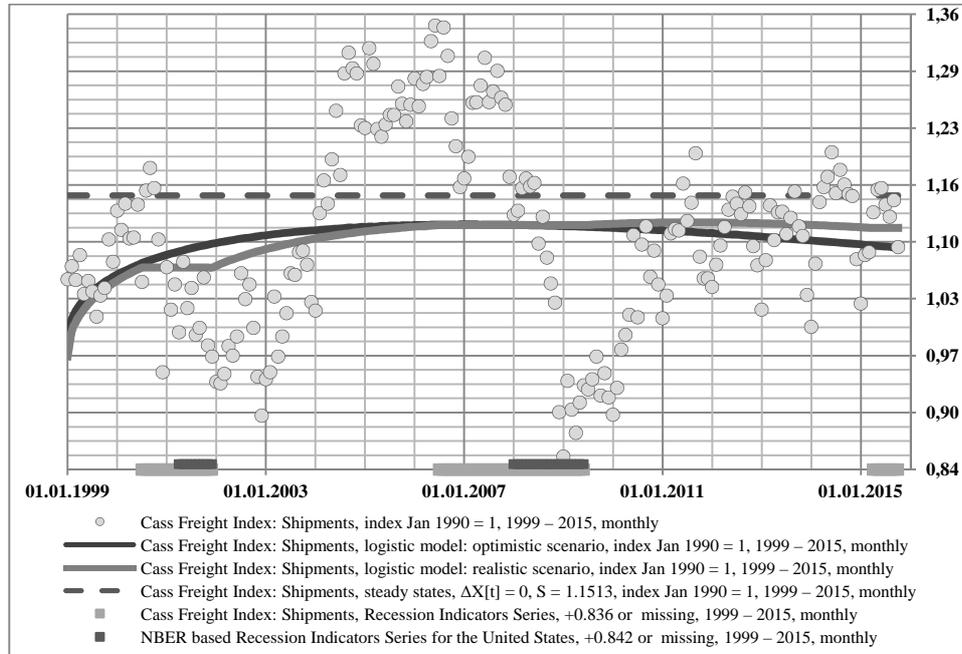
Similarly to the CFIE, we can identify the entry points to a transport downturn/recession. Both Figures 1 and 3 complement each other as the competition model is employed. With the increasing competition in the transport industry, prices for the shipment of goods and services are decreasing. This process is also boost by the increasing globalisation of industry and trade. This means that shipments increase, while expenditures (costs to ship goods and services) decrease. Hence, expenditure represents the victim and shipment corresponds to the predator in the model.

Identifying the entry points to transport downturns/recessions helps to anticipate overall economic downturn/recession as transport cycles precede economic cycles. The CFIE is less volatile and therefore helps to identify the trend more clearly. Conversely, the higher volatility of the CFIS makes this identification more difficult. This is also revealed from the data sample employed in this study and the low coefficients of the determination of the OLS estimate of equation (7) provided in Table 1. Moreover, the data for the CFI are available monthly, while GDP is measured quarterly.

⁸ $q_{XS} = 3.2690$; $\omega_{XS} = 1.7008$.

Figure 3

The Models of Stochastic Dynamics of the Cass Freight Index: Shipments
(Index Jan 1990 = 1, 1999 – 2015, monthly)



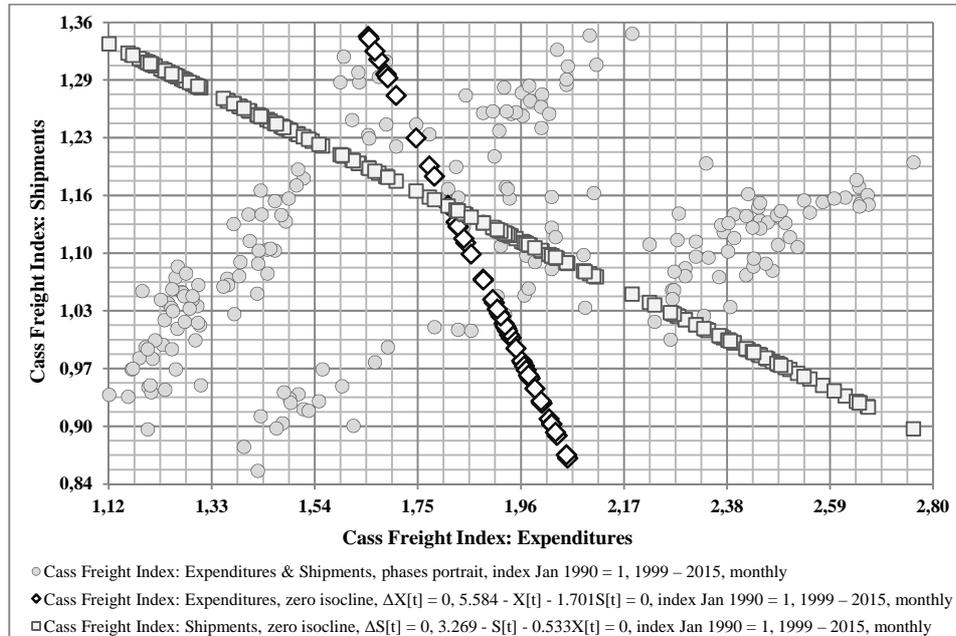
Source: Authors' calculations.

3.4. Stability of the Model

After the estimation of the parameters of the models (2) – (4) in accordance with the above methodology, we can study the stability of the system. The system (4) has two steady states $(\hat{X}_{t,1}, \hat{S}_{t,1}) = (0, 0)$ (see line $X_t = 0, \Delta S_t = 0$ in Figure 1 and line $\Delta X_t = 0, S_t = 0$ in Figure 3) and $(\hat{X}_{t,2}, \hat{S}_{t,2}) = (1.8129, 1.1513)$ (see dotted line $X_t = 1.8129, \Delta S_t = 0$ in Figure 1 and dotted line $\Delta X_t = 0, S_t = 1.1513$ in Figure 3), respectively. The results for non-trivial steady state can be calculated employing previously obtained parameters for the optimistic and realistic scenarios.

Based on the applied methodology (see the Appendix for further details), we find that $q_{XS} = 5.5840 < \frac{q_{SX}}{\omega_{SX}} = \frac{3.2690}{0.5330} = 6.1332$, $q_{SX} = 3.2690 < \frac{q_{XS}}{\omega_{XS}} = \frac{5.5840}{1.7008} = 3.2832$ and $\omega_{XS} \cdot \omega_{SX} = 0.5330 \cdot 1.7008 = 0.9065 < 1$. Hence, the system of difference equations (4) has a stable equilibrium solution with null isoclines $\Delta X_t = 0$, $5.5840 - X_t - 1.7008S_t = 0$, and $\Delta S_t = 0$, $3.2690 - 0.5330 X_t - S_t = 0$ (See Figure 4 with phase portraits of indices and null isoclines of stable equilibrium solutions).

Figure 4
**Analysis of Phase Portraits of the Stochastic Model of the Cass Freight Index:
 Expenditures & Shipments (Index Jan 1990 = 1, 1999 – 2015, monthly)**



Source: Authors' calculations.

Conclusion

In this article, we propose a framework that can help to anticipate economic downturn/recession based on the application of a system of logistic models of population growth and competition to the US transport industry indices, in particular to the Cass Freight Index: Expenditures and Shipments. We apply the methodology of stochastic dynamics in line with the existing literature (e.g. Verhulst, 1838; Volterra, 1926; Gause and Wit, 1935; Bass 1969; and Tilman, 1985, among others) using a stochastic logistic growth with a Wiener process. Although similar research was conducted by Bousquet, Duchesne and Rivest (2008) and Wanga and Ewald (2010), we employ the assumptions that the stochastic growth rate and the asymptotic behaviour of the indicators both in the initial and the final phases of the cycle, are constant. These assumptions are justified by our empirical results and provide grounds for further research.

To our knowledge, this is the first study to use the Cass Freight Index to identify the cyclical pattern of the US transport cycle to anticipate an economic downturn/recession. We show that the index has leading characteristics, i.e. the

constructed structure identifies the signs of a US economic recession a year and a half in advance. The advantage of our index is its availability on a monthly basis. We benefit from this technical feature through its implementation in our model. Every cycle has an entry point to a new phase of economic downturn/recession or conjuncture, and the constructed model allows us to identify these points. Signs of the beginning of a transport downturn/recession are revealed at an earlier stage compared to an economic downturn/recession based on GDP data. In our framework, we define the points of divergence from the trend and transition points from one phase to another. We argue that the signs of downturns/recessions can be detected by identifying these points, e.g. our framework shows signs of the looming February 2008 recession already in July 2006; that is, 19 months earlier. However, for a more precise prediction, further confirmation of the indicated trends by other available leading indicators is needed.

Looking ahead, our framework suggests the beginning of 2015 as the point of entry to a new phase of transport cycle with a flat development period characterised by numerous uncertainties regarding a potential new economic downturn/recession. Although our study examines the US economy, the proposed methodology could be similarly applied to other economies.

References

- ANGELIDIS, T. – SKIADOPOULOS, G. (2008): Measuring the Market Risk of Freight Rates: A Value-at-risk Approach. *International Journal of Theoretical and Applied Finance*, 11, No. 5, pp. 447 – 469.
- BAI, L. – Wang, K. (2007): A Diffusive Single-species Model with Periodic Coefficients and Its Optimal Harvesting Policy. *Applied Mathematics and Computation*, 187, No. 2, pp. 873 – 882. DOI: 10.1016/j.amc.2006.09.007.
- BALANOV, Z. – KRAWCEWICZ, W. – RUAN, H. (2008): G. E. Hutchinson's Delay Logistic System with Symmetries and Spatial Diffusion, *Nonlinear Anal. Nonlinear Analysis: Real World Applications*, 9, No. 1, pp. 154 – 182.
- BASS, F. (1969): A New Product Growth Model for Consumer Durables. *Management Science*, 15, No. 1, pp. 215 – 227.
- BASS, P. – Bass, F. (2004): IT Waves: Two Completed Generational Diffusion Models. [Working Paper.] Dallas: University of Texas at Dallas.
- BOUSQUET, N. – DUCHESNE, T. – RIVEST, L. (2008): Redefining the Maximum Sustainable Yield for the Schaefer Population Model Including Multiplicative Environmental Noise. *Journal of Theoretical Biology*, 254, No. 2, pp. 65 – 75.
- BURNS, A. – MITCHELL, W. (1946): *Measuring Business Cycles*. New York: NBER.
- CARAYANNIS, E. – TURNER, E. (2006): Innovation Diffusion and Technology Acceptance: The Case of PKI Technology. *Technovation*, 26, No. 7, pp. 847 – 855.
- CHAKRABORTY, A. – SINGH, M. – LUCY, D. – RIDLAND, P. (2007): Predator-prey Model with Prey-taxis and Diffusion. *Mathematical and Computational Modelling*, 46, No. 3 – 4, pp. 482 – 498.
- COMPTON, R. – SILVA, R. (2005): Finance and Business Cycle: A Kalman Filter Approach with Markov Switching. [Discussion Paper, No. 97.] Brasilia: Central Bank of Brazil.

- CORREA, R. G. – TERGAONKAR, V. – NG, J. K. – DUBOVA, I. – IZPISÚA BELMONTE, J. C. – VERMA, I. M. (2004): Characterization of NF-kappa B/I Kappa B Proteins in Zebra Fish and their Involvement in Notochord Development. *Molecular and Cellular Biology*, 24, No. 12, pp. 5257 – 5268.
- DAVIDSON, W. – WORRELL, D. (1988): The Impact of Announcements of Corporate Illegalities on Shareholder Returns. *Academy of Management Journal*, 31, No. 1, pp. 195 – 200.
- DREHER, M. (2008): Analysis of a Population Model with Strong Cross-diffusion in an Unbounded Domain. *Royal Society of Edinburgh Section A. Mathematics*, 138, No. 4, pp. 769 – 786.
- DROBETZ, W. – RICHTER, T. – WAMBACH, M. (2012): Dynamics of Time-varying Volatility in the Dry Bulk and Tanker Freight Markets. *Applied Financial Economics*, 2, No. 16, pp. 1367 – 1384.
- EI, S. – MIMURA, M. (1990): Pattern Formation in Heterogeneous Reaction-diffusion Advection Systems with an Application to Population Dynamics. *SIAM Journal on Mathematical Analysis*, 21, No. 2, pp. 346 – 361.
- ERDOGAN, O. – TATA, K. – KARAHASAN, B. – SENGOZ, M. (2013): Dynamics of the Co-movement between Stock and Maritime Markets. *International Review of Economics and Finance*, 25, No. C, pp. 282 – 290.
- EVERTS, P. (2006): Duration of Business Cycles. [Working Paper, No. 1219.] Munich: MPRA.
- FELS, R. – HINSHAW, E. (1968): Forecasting and Recognizing Business Cycle Turning Points. New York: NBER.
- FOURT, L. – WOODLOCK, J. (1960): Early Prediction of Market Success for New Grocery Products. *Journal of Marketing*, 25, No. 2, pp. 31 – 38.
- FRGEXPUSM649NCIS Series of FRED (2015a): Federal Reserve Economic Data: Cass Freight Index: Expenditures, Index Jan 1990 = 1, Monthly, Not Seasonally Adjusted. Available at: <<http://fred.stlouisfed.org>>.
- FRGSHPUSM649NCIS Series of FRED (2015b): Federal Reserve Economic Data: Cass Freight Index: Shipments, Index Jan 1990 = 1, Monthly, Not Seasonally Adjusted. Available at: <<http://fred.stlouisfed.org>>.
- FU, S. – GAO, H. – CUI, S. (2008): On Global Solutions for the Competitor-competitor-mutualist Model with Cross-diffusion. *Chinese Journal of Engineering Mathematics (Gongcheng Shuxue Xuebao)*, 51, No. 1, pp. 153 – 164.
- GALIANO, G. – GARZ'ON, L. – J'UNGEL, A. (2003): Semi-discretization and Numerical Convergence of a Nonlinear Cross-diffusion Population Model. *Numer Math*, 93, No. 4, pp. 655 – 673.
- GAUSE, G. – Witt, A. (1935): Behavior of Mixed Populations and the Problem of Natural Selection. *American Naturalist*, 3, No. 69, pp. 596 – 609.
- GHOSH, A. – WOLF, H. (1997): Geographical and Sectoral Shocks in the U.S. Business Cycle. [NBER, Working Papers 6180.] New York: National Bureau of Economic Research, Inc.
- GOLDENBERG, J. – HAN, S. – LEHMANN, D. – HONG, J. (2009): The Role of Hubs in the Adoption Process. *Journal of Marketing*, 73, No. 2, pp. 1 – 13.
- GOLDENBERG, J. – LIBAI, B. – SOLOMON, S. – STAUFFER, D. (2000): Marketing Percolation. *Physica A: Statistical Mechanics and its Applications*, 284, No. 1, pp. 335 – 347.
- GONG, X. – LI, Z. (2003): Study on Multi-Agent Simulation of New Product Market Diffusion. *Systems Engineering Theory & Practice*, 12, No. 12, pp. 59 – 63.
- GOULIELMOS, A. – PSIFIA, M. (2009): Is History Repeated? Cycles and Recessions in Shipping Markets, 1929 and 2008. *International Journal of Shipping and Transport Logistics*, 1, No. 4, pp. 329 – 360.
- HULTGREN, T. (1948): American Transportation in Prosperity and Depression. New York: National Bureau of Economic Research.
- JIN, Y. – ZHAO, X. (2008): Biostable Waves for a Class of Cooperative Reaction-diffusion Systems. *Journal of Biological Dynamics*, 2, No. 2, pp. 196 – 207.
- JING, L. – MARLOW P. – HUI, W. (2008): An Analysis of Freight Rate Volatility in Dry Bulk Shipping Markets. *Maritime Policy and Management*, 35, No. 3, pp. 237 – 251.

- KAVUSSANOS, M. – DIMITRAKOPOULOS, N. (2011): Market Risk Model Selection and Medium-term Risk with Limited Data: Application to Ocean Tanker Freight Markets. *International Review of Financial Analysis*, 20, No. 5, pp. 258 – 268.
- KIM, N. – CHANG, D. – SHOCKER, A. (2000): Modelling Intercategory and Generational Dynamics for a Growing Information Technology Industry. *Management Science*, 46, No. 4, pp. 496 – 512.
- KYDLAND, F. – PRESCOTT, E. (1982): Time to Build and Aggregate Fluctuations. *Econometrica*, 50, No. 6, pp. 1345 – 1370.
- LAHIRI, K. – YAO, W. (2004): The Predictive Power of an Experimental Transportation Output Index. *Applied Economics Letters*, 11, No. 3, pp. 149 – 152.
- LEE, T – LUN, V. – YAN, H. (2013): Price Volume Relativity in the Dry Bulk Shipping Market. *International Journal of Shipping and Transport Logistics*, 5, No. 4 – 5, pp. 551 – 563.
- LI, Y. – SUI, M. (2011): Literature Analysis of Innovation Diffusion. *Technology and Investment*, 2, No. 3, pp. 155 – 162.
- LOTKA, A. (1925): *Elements of Physical Biology*. Baltimore: Williams & Wilkins.
- MALTHUS, T. (1798): *An Essay on the Principles of Population*. London: J. Johnson, in St. Paul's Church-yard.
- MANSFIELD, E. (1961): Technical Change and the Rate of Imitation. *Econometrica*, 29, No. 4, pp. 741 – 766.
- McWILLIAMS, A. – SIEGEL D. (2000): Corporate Social Responsibility and Financial Performance: Correlation or Misspecification? *Strategic Management Journal*, 21, No. 5, pp. 603 – 609.
- MOORE, G. (1961): *Business Cycle Indicators*. 1. Ed. Princeton, NJ: Princeton University Press for NBER.
- MORGAN, J. – RITZ, C. (1991): Incorporating Distribution into New Product Diffusion Models. *International Journal of Research in Marketing*, 8, No. 1, pp. 91 – 112.
- RANGASWAMY, A. – GUPTA, S. (2000): *Innovation Adoption and Diffusion in the Digital Environment: Some Research Opportunities*. [Working Paper, 02-1999.] Old Main, PA: Pennsylvania State University, E-Business Research Center.
- REED, L. – GETZ, K. – COLLINS, D. – OBERMAN, W. – TOY, R. (1990). Theoretical Models and Empirical Results: A Review and Synthesis of JAI Volumes 1 – 10. In: PRESTON, L. E. (ed.): *Corporation and Society Research: Studies in Theory and Measurement*. Greenwich, CT: JAI Press, pp. 27 – 62.
- SIMPSON, G. – KOHERS, T. (2002): The Link between Corporate Social and Financial Performance: Evidence from the Banking Industry. *Journal of Business Ethics*, 35, No. 2, pp. 97 – 109.
- STEFFENS, P. (2002): The Product Life Cycle Concept: Buried or Resurrected by the Diffusion Literature? *Mathematical and Computational Modelling*, 16, No. 4, pp. 11 – 26.
- STERMAN, J. (2000): *Business Dynamics: Systems Thinking and Modelling for a Complex World*. Boston: McGraw-Hill. ISBN 0-07-231135-5.
- TEMIN, P. (1998): The Causes of American Business Cycles: An Essay in Economic Historiography. In: FUHRER, J. C. and SCHUH, S. (eds): *Beyond Shocks: What Causes Business Cycles*. [Conference Series, No. 42.] Boston: Federal Reserve Bank of Boston.
- TEPLÝ, P. – TRIPE, D. (2015): The TT Index as an Indicator of Macroeconomic Vulnerability of EU New Member States. *Ekonomický časopis/Journal of Economics*, 63, No. 1, pp. 19 – 33.
- TILMAN, D. (1985): The Resource-ratio Hypothesis of Plant Succession. *The American Naturalist*, 125, No. 6, pp. 827 – 852.
- TILMAN, D. (1982): *Resource Competition and Community Structure*. Monogr. Pop. Biol.. Vol. 17. Princeton, NJ: Princeton University Press, 296 pp.
- USREC Series of FRED (2015c): *Federal Reserve Economic Data: NBER Based Recession Indicators for the United States from the Period Following the Peak through the Trough, +1 or 0, 1854-12-01 to 2015-10-01, Monthly, Not Seasonally Adjusted*. Available at: <<http://research.stlouisfed.org/fred2/series/USRECM>>.

- VERHULST, F. (1838): Notice sur la loi que la population poursuit dans son accroissement. Correspondance mathématique et physique, *10*, No. 3, pp. 113 – 121.
- VOLTERRA, V. (1926): Variations and Fluctuations in the Number of Individuals in Animal Species Cohabiting. Memorial R. Academic Lincei Series, *6*, No. 2, pp. 26 – 43.
- WANGA, W. – EWALD, C. (2010): A Stochastic Differential Fishery Game for a Two-species Fish Population with Ecological Interaction. *Journal of Economic Dynamics and Control*, *34*, No. 5, pp. 844 – 857.
- WENZEL, L. – THIEWES, H. (1999): Corporate Social Responsibility: Does It Pay? *Journal of Accounting and Finance Research*, *7*, No. 4, pp. 48 – 58.
- YAMAGUCHI, K. (2015): Money and Macroeconomic Dynamics: Accounting System Dynamics Approach. Osaka: Japan Futures Research Center.
- YAO, V. (2005): Modelling the Predictive Power of Freight Transportation to the Aggregate Economy: An Asymmetric Approach. *International Journal of Transport Economics/Rivista internazionale di economia dei trasporti*, *32*, No. 3, pp. 287 – 303.
- ZARNOWITZ, V. (1992): *Business Cycles: Theory, History, Indicators, and Forecasting*. Chicago: National Bureau of Economic Research, Inc. – The University of Chicago Press, pp. 232 – 264.