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Wei-Bin Zhang · Yuliya Lavrikova *Editors*

Consequences of Social Transformation for Economic Theory

Proceedings of the 2022 Euro-Asian Symposium on Economic Theory (EASET), Ekaterinburg, Russia

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Editorial: Consequences of Social Transformation for Economic Theory

Vikas Kumar, Yuliya Lavrikova, Evgeny Kuzmin, and Wei Bin Zhang

Abstract The chapter summarizes the best research from the 10th Euro-Asian Symposium on Economic Theory (EASET 2022) included in the book. The Editors evaluate the background and trends that have given impetus to the research. A brief overview of the contribution of each chapter is given, and the main conclusions of researchers in the relevant field are noted.

Keywords Economic theory · Social transformation

The modern world is characterised by uncertainty. The continuous transformation of socio-economic relations requires a permanent revision of fundamental concepts, which describe the functioning of systems, and practical approaches suitable for their regulation. Such a revision has become especially relevant considering the recent challenges.

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The global pandemic, technology development gaps, digitalisation and several other factors indicate new threats to sustainable development, especially to the sustainability of the economy. In particular, labour markets, which were not ready for the demand for new specialists, took a hit. In the context of growing inequality, population ageing, employment and education challenges, changes in consumer behaviour led to a distortion in the production structure. This clearly demonstrates that ensuring economic growth and overall sustainability should be discussed in relation to social determinants. Thus, examining the nature of social changes and their impact on the economic system is necessary. Analysis of social challenges allows adjusting the economic research methodology in order to determine transformation patterns and find effective ways to overcome crises.

The 10th Euro-Asian Symposium on Economic Theory (EASET 2022), which was held on June 29–30, 2022, at the Institute of Economics of the Ural Branch of the Russian Academy of Sciences (Ekaterinburg, Russia), discussed urgent issues of modern economic theory in conditions of instability and uncertainty. This year, the conference's key theme was assessing the viability of economic theories. EASET 2022 became a platform for its participants to present their vision of the ongoing socio-economic transformation and describe new patterns and trends. The discussion focused on the verification of assumptions and research hypotheses using the parameters of order and chaos.

This book presents the best scientific studies of the conference. What conclusions are the main conclusions?

- The economic sustainability of countries depends on several inherited and acquired determinants. Countries greatly differ regarding the amount and level of these determinants, while their composition can be unique and specific. The factors most contributing to economic sustainability are the industry and research and development (R&D) potential, production capacity reserves and the predominance of the large business segment with state participation. These factors can reduce the impact of economic shocks.
- The dynamic succession of economic recession and growth periods emphasises the need to revise models presented in the theory of cycles. The researchers pay particular attention to the business cycle models of Goodwin, Kalecki and Kaldor, a brief description of dynamic stochastic general equilibrium vector and autoregression models. Based on recurrence quantification analysis, recurrence plot and correlation index, a correlation structure was identified to assess the suitability of well-known business models in the current conditions. Such regular observations will be useful in expanding methods of monitoring and control in order to make appropriate managerial decisions.
- Economic growth models can be studied from different perspectives. Particular attention should be paid to the driving forces of the economy during crises. Sectoral analysis has highlighted the importance of sustainable manufacturing sectors in sustaining economic growth. During crises, representatives of such sectors strive for innovation and internationalisation. Moreover, they are characterised by the ability to adapt to customer needs.

- The relationship between social patterns, is another important aspect of economic growth models. Human capital is traditionally subject to detailed consideration. Education quality is also considered as an attribute of social influence on the economy. Many studies presented at the conference confirm that these factors affect the welfare of the population and, consequently, ensure countries' economic growth. Additionally, social patterns indirectly affect the population's life expectancy, happiness and quality of life.
- Social transformation clearly affects consumer behaviour. Collective decision-making plays an important role in regulating consumer preferences. Nowadays, social media trends often become dominant. Responsible consumption became a socially acceptable form of consumer demand in this situation. This is fundamentally changing the supply structure, accelerating the transition to a green economy, and posing certain sustainability threats. Since public incentives for green transition sometimes contradict economic efficiency arguments, it is necessary to create conditions for compromise.
- In regard to consumer equilibrium conditions, researchers came to the conclusion that utility is the fundamental criterion. Using this criterion, cardinal and ordinal approaches explain the balance of market demand and supply. Critical discussions combined these approaches, indicating that consumer equilibrium conditions in them cannot be different.
- Due to the gaps in the theory, the question of the target function of institutions and economic agents became relevant. An analysis of modern views on transaction costs clarified the nature of the institutional order. Institutions do not have the goal of minimising transaction costs: on the contrary, they are a catalyst for cost growth since the emergence of any institutional imperative leads to the rise of overall transaction costs. The resistance of economic agents against institutions comes up against an insurmountable minimum of transaction costs, determining the existence and functioning of a given institution or set of institutions. For actors striving to increase their own efficiency, it is only possible to reduce or minimise transaction costs when the improvement of the meta-production function is already limited.
- Separate case studies investigated the issues of economic security, open innovations and protection of property rights. In each case, applied problems became prerequisites for developing appropriate theoretical mechanisms to reduce or eliminate the existing barriers.
- A review of the conference papers indicates the difficulties in the further development of economic theory. The main obstacle is the lack of a conventional conclusion on various issues that have been discussed for many years. While there is a possibility of overcoming the crisis of the theory, the prospects are yet to be clearly determined. The solution is seen in synthesising the mainstream and political economy based on evolutionary genetics. To this end, fundamental research methods should be applied to develop basic categories and concepts. There is still hope that a consensus will be reached.
- The book includes the best papers from the 10th Euro-Asian Symposium on Economic Theory to introduce readers to some of the latest research in the field of

economic theory and its applied aspects. Despite the limited number of considered issues, the collection presents a general review of problem areas. The book will greatly interest to researchers, economists and financial experts, managers and entrepreneurs.

A Survey on Business Cycles: History, Theory and Empirical Findings

Giuseppe Orlando and Mario Sportelli

Abstract This work summarizes recent advances in modelling and econometrics for alternative directions in macroeconomics and cycle theories. Starting from the definition of a cycle and continuing with a historical overview, some basic nonlinear models of the business cycle are introduced. Furthermore, some dynamic stochastic models of general equilibrium (DSGE) and autoregressive models are considered. Advances are then provided in recent applications to economics such as recurrence quantification analysis and numerical tools borrowed from other scientific fields such as physics and engineering. The aim is to embolden interdisciplinary research in the direction of the study of business cycles and related control techniques to broaden the tools available to policymakers.

Keywords Business cycles · Nonlinearities in economics · DSGE models · RQA

JEL Classification C61 · E32 · E37

1 Introduction

The purpose of this paper is to embolden interdisciplinary research in the direction of the study of business cycles and related control techniques to broaden the tools available to policymakers. To do this we provide an overview of the evolution of complex dynamic theory in macroeconomics and then, to conclude, we present a concise treatment of advances in recent applications to economics such as recurrence quantification analysis and numerical tools borrowed from other scientific fields such as physics and engineering.

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With regard to the meaning of "dynamics", it is worthwhile to recall the different views on it. John Stuart Mill (1848), and later Hicks Hicks (1946), meant that "economic dynamics refers to that part of economic theory in which all quantities must be dated". Jevons (1879), followed by Wicksell (1898) and Keynes (1936), similarly to physical mechanics, by "statics" intended the relations of forces at equilibrium, versus the changes in movements towards equilibrium represented by the "dynamics". Those views were rejected by Kuznets (1930) who argued that "statics" concerns the conditions of equilibrium while "dynamics" relates to the changes leading towards equilibrium. An interesting account on the meaning of "statics" and "dynamics" in macroeconomics from a historical perspective is in Rivot and Trautwein (2020).

In the present work, by "economic dynamics" we refer to the definition given by Day (1994): dynamics in economics deals with the systematic study of changes in micro and macro-economic variables. Specifically, since we are focusing on business cycles, other aspects of economic dynamics are neglected.

The paper is organized as follows: Sect. 2 introduces the topic of nonlinear dynamics in economics which encompasses the definition of business cycles, a historical overview of the research, some well known models on business cycles such as the ones by Goodwin, Kalecky and Kaldor and, finally, a brief description of dynamic stochastic general equilibrium (DSGE) vector and autoregressions models. Section 3 describes Recurrence Quantification Analysis (RQA) which highlights the correlation structure of the observed phenomenon along with the Recurrence Plot (RP) and the RQE Correlation Index (RQCI). Section 4 describes an original setup of a Kaldor-Kalecki model on the business cycle displaying common features with real-world data. Section 5 concludes.

2 Background and Literature

Business Cycles

In the dynamics of the economic system, the alternation between recession and expansion is universally known as the business cycle. A recession consists of a decline in economic activity throughout the economy, lasting at least two quarters, and affecting employment, real GDP, real income, consumption, etc. A recession ends when the economy reaches its minimum and corresponds to the period between the minimum and the peak reached during the previous expansion. Such expansion is the norm and most recessions are short and were rare in recent periods.

When studying stock market crises in conjunction with credit and housing market, Claessens et al. (2021) adopted this classical definition and, employing Harding and Pagan (2002) algorithm, found that when "credit downturns coincide with equity price busts, their duration does not become significantly longer, but these downturns are more severe than others. If credit downturns are accompanied by financial crises, they are much longer, deeper, and more violent than other downturns (though these

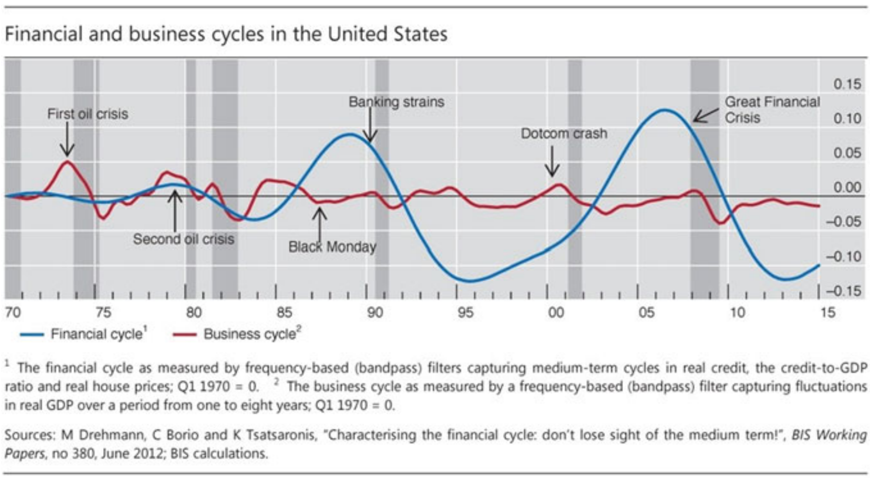

Fig. 1 BIS 85th annual report 2015

differences are not statistically significant)". Figure 1 shows how often economic and financial crises are not synchronized and that the latter is much stronger than the former.

Historical Overview

The study of the business cycle has always been at the core of classical and neo-classical inquiries in economics. However, in the past, economists did not employ mathematical formalizations to explain the ups and downs in economic activity (see, Sherman, 2014; Rosser, 2013). This implied that "logical inconsistencies could not always be avoided" (Lorenz, 1993).

Only after the Keynesian revolution Nicholas Kaldor, Michal Kalecki and Roy Harrod understood that Keynes's multiplier and Clark's (1917) acceleration principle were adequate tools to explain the business cycle. It was their mathematical approach to the business cycle that progressively made it possible to overcome the old theories.

However, it quickly became clear that their models were inadequate to describe the persistence of business cycles because they used linear differences or differential equations that were capable of generating only damped or undamped oscillations. Consequently, the main original purpose, which was the description of persistently oscillating behavior, could not be achieved.

In 1933, one of the first issues of Econometrica published a short note by the French mathematician Philip Le Corbeiller where he suggested the use of non-linear functions to describe cycles (Le Corbeiller, 1933). Referring to the van der Pol equation (e.g., see Ginoux & Letellier, 2012), Le Corbeiller hoped that economists

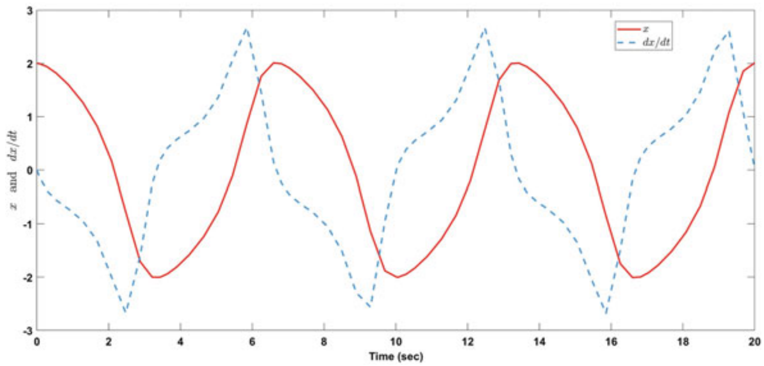

Fig. 2 Solution of the van der Pol equation, $\mu = 1$

would start using it in nonlinear models to describe business cycles. This because that equation produces cycles endogenously (see Fig. 2). However, neither Frisch nor Tinbergen and Schumpeter, the founders of the Econometric Society and its journal, gave credit to Le Corbeiller's arguments. This probably happened because Frisch, as argued by Slutzky (1937), was convinced that economic models should be stable, while cycles were generated and sustained by exogenous shocks.

Only at the beginning of the 1940s, thanks to the meeting with Le Corbeiller at Harvard University, did Richard Goodwin understand the great relevance and potential applications of nonlinear dynamics to Economics. In 1951, Goodwin published an article in Econometrica entitled "The nonlinear accelerator and persistence of business cycles" (Goodwin, 1951) showing that the interaction between accelerator and multiplier yielded a Lienard type equation (Liénard, 1928).

Since that equation can generate stable limit cycles, the persistence of oscillations seemed to well describe the fluctuations of the economic system. Although Goodwin's nonlinear accelerator model did not get much attention among contemporary scholars, it had the merit of opening Economics to the mathematical theory of dynamical systems (see, Orlando & Taglialatela, 2021b). Therefore, it represents a kind of watershed between the old and the new dynamic theory in economics.

In the 1970s, studies on deterministic chaos proliferated in pure and applied mathematics, especially after the paper by Li and Yorke (1975), where the complicated behaviour of iterated maps was investigated. In fact, in their work, Li and Yorke reconsidered a special case of the more general result previously obtained by Sharkovskij (1964), where the family of one-dimensional maps $x_{t+1} = \mathrm{F}(x_t)$ displays chaotic motions when the map has a period-3 cycle.

In 1976, the work by Li and Yorke was successfully publicized by Robert May in a paper published in Nature (May, 1976, 2004), where the Malthus hypothesis of exponential population growth was replaced by the Verhulst (1847) logistic equation $\lambda_{t+1} = \lambda_t(\alpha - \beta\lambda_t)$. . For a wide list of models using a one-dimensional map, see (Lorenz, 1993; Orlando et al., 2021a). For a specific example on the logistic map, see (Orlando & Taglialatela, 2021a; Orlando et al., 2021b).

The emergence of chaos in a one-dimensional map had great success in economics (see, Yoshida, 2021). Through a difference equation like a logistic map, a plethora of contributions appeared in the field of overlapping generation models and optimal economic growth. While the emergence of chaos may seem relatively simple in discrete time models, in contrast, a chaotic movement is very difficult to detect when time is continuous. In this case, chaos appears only when the system is described by at least three nonlinear differential equations. This is because trajectories of two-dimensional systems cannot intersect themselves and therefore only a simple dynamic motion is possible (i.e., limit cycles).

During the first half of the 1980s, economic models only featured discrete-time dynamics. In 1991, a survey of chaotic dynamics and economics by Brock and Dechert (1991) in the volume "Handbook of Mathematical Economics" mentioned as continuous-time models only the Lorenz (1963) geometric butterfly object and the Mackey and Glass (1977) attractor. Both have nothing to do with economics (for example, the MacKey–Glass attractor investigates the hematologic disorder in leukemic patients).

Only in the second half of the 1980s and in the 1990s, models generating chaotic motions in continuous time emerged in economics. For example, Chiarella and Flaschel (1996) and Chiarella et al. (2013), studied macroeconomic models of monetary growth in the Tobin and Keynes-Wicksell tradition. Their purpose was to build a framework where the non-market-clearing approach to macroeconomics led to integrated models of disequilibrium growth. Further examples are the contribution by Goodwin (1990), which is an extension of his predator–prey model, where the Rössler (1977) Rössler (1976); Letellier and Rossler (2006) attractor (which originates in chemical kinetics) is applied to account for aperiodic cycles; the non-linear version of the Metzler (1941) inventory cycle model suggested by Lorenz (1992); the formalization of Harrod's dynamics by Sportelli (2000); Piscitelli and Sportelli (2004).

In summary, there is a long debate on chaos and non-linear dynamics in economics, and even the use of these concepts has been questioned. Although stochastic modeling has proven effective, the theoretical implication is that reality is made up of exogenous randomness. The opposite view of the chaos theory is that reality is deterministic and nonlinearities are endogenous.

To the criticism that chaos theory would explain little in terms of real economics, Orlando and Della Rossa (2019) carried out an empirical test on a chaotic model specification of the Harrod's open economy showing the agreement between theoretical predictions and actual data. Similarly, Araujo and Moreira (2021) tested a Goodwin's model with capacity utilization to the US economy. Furthermore, Orlando and Zimatore (2020a) proved that reality can be represented by a chaotic model as well as a stochastic model. can do. In the same work, it was shown that a chaotic model can reproduce an extreme event such as a black swan. Further evidence can be found in (Orlando & Bufalo, 2022; Orlando, 2022; Orlando et al., 2022; Lampart et al., 2022).

Some Basic Nonlinear Business Cycle Model

In recent decades, a growing number of economists agree with the non-linear approach to the business cycle, because it better describes the complexity of the real economy. Therefore, in this section, we present an overview of three seminal models, which still act as a reference for new and more advanced theoretical works.

Wage Share-Employment Dynamics (Goodwin Model)

A relevant contribution developed by Goodwin in the late 1960s (Goodwin, 1982) was intended to describe how the Marxian class struggle could cause persistent swings in the growth rate of the economic system. That work is an economic translation of the predator–prey model originally developed by Lotka (1925) and Volterra (1931) for the study of the antagonistic growth of two populations (Anisiu, 2014; Orlando & Sportelli, 2021).

Goodwin considered an economy consisting of workers and capitalists. Workers spend all their income on consumption, while capitalists save and invest all their profits. Given the labour productivity $Y/L = a_0 \exp^{\alpha t}$ ($0 < \alpha =$ constant), the labour supply N = N_0exp$^{\{}\beta$t} (0 < β = constant) and the capital/output ratio $K/Y = \sigma$ (σ = constant), Goodwin set v = the employment rate and u = the labor income share and assumed that the real wage rate ($\dot{w}$/w = $-\gamma+$) changes according to a linear Phillips curve.

The logarithmic differentiation of v and u and the necessary rearrangement yields

$$\begin{cases} \frac{\dot{v}}{v} = \left[\frac{1}{\sigma} - (\alpha + \beta)\right] - \frac{1}{\sigma} u \\ \frac{\dot{u}}{u} = (\gamma - \alpha) - \rho v \end{cases} \tag{1}$$

By setting $1/\sigma > \alpha + \beta$ the system has two equilibrium points: the origin, which is a saddle point (every trajectory approaching the equilibrium is always pushed away from it) and (v∗, u∗), which is a center of infinitely many closed orbits. The specific closed orbit the system is in depends on the initial conditions.

In this model (which is a rare example of an integrable system of nonlinear differential equations) the employment rate v serves as the prey, while the wage bill share acts as the predator. When there is no employment, the wage bill tends to zero. When the wage bill tends to zero, the employment rate increases because there are no relevant labor costs (see Figs. 3 and 4).

As mentioned by Semmler (1986) this model explains cyclical growth and was applied by Goodwin to explain the Marxian idea of the industrial reserve labor army and its role in the capitalist economy. Goodwin has the merit of representing a growing economy, while most other non-linear oscillation models refer only to a stationary economy. Moreover, Goodwin's predator–prey model "does not really model business cycles but rather long cycles. On the other hand, for a theory of long cycles, the dynamical interaction of other important variables (such as waves

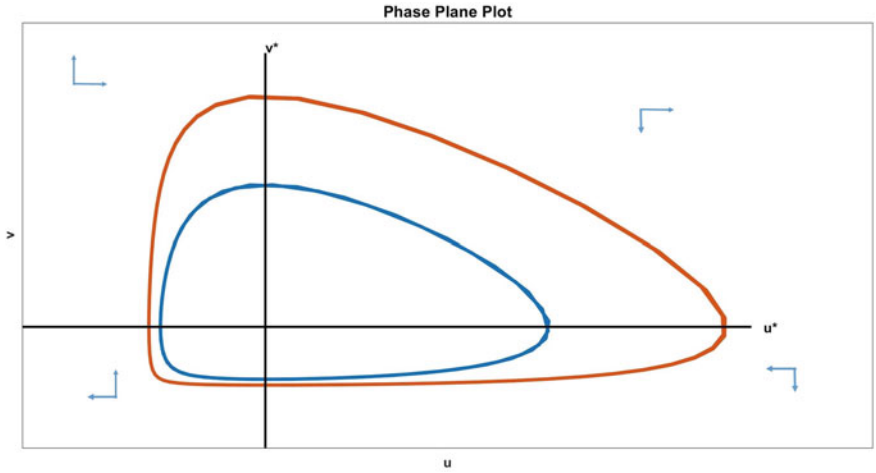

Fig. 3 Ordinate v, abscissa u. In the northwest region (low labor, high employment, share in production) the economy moves north-east (employment increases as well as the share of workers). Once the u∗ line is crossed, the dynamics start moving southwest

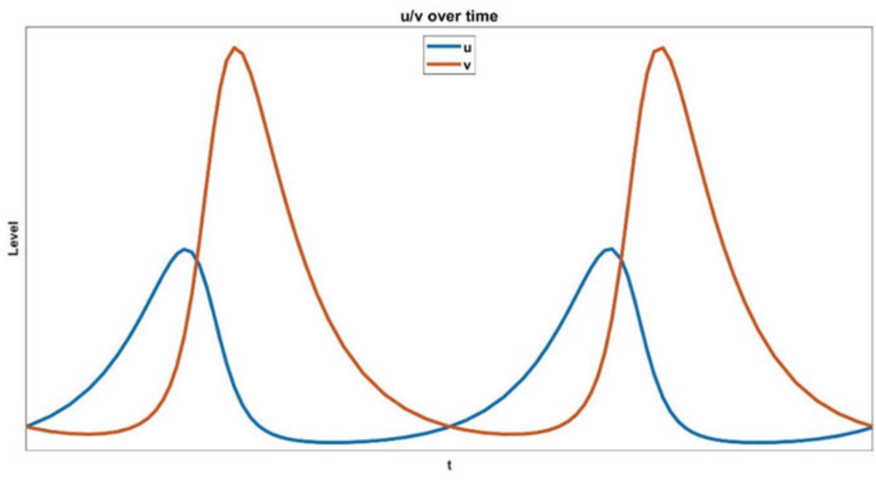

Fig. 4 Ordinate v and u, abscissa t (time). Oscillation of v and u over time

of innovations, changes of capital/output ratio, relative prices and interest rates) are unfortunately neglected" (Semmler, 1986).

As a demonstration of the long-lasting interest in the scientific debate opened by Goodwin, there is a number of recent generalizations and extensions of his model such as Fanti (2003), Yoshida and Asada (2007), Sportelli and De Cesare (2019), Haddad et al. (2020), etc. For a test to the USA economy, see (Araujo & Moreira, 2021) and for a review, see (Gonze & Ruoff, 2021).

Profit-Investment Dynamics (Kalecki Model)

Kalecki (1971) describes cycles as based on the dynamic interaction of profits and accumulation of capital originally developed by Marx and McLellan (2008). Other comparable approaches can be found in Veblen (1904), Lowe (2017), etc.

The aforementioned dynamics of capital (K) and profit (Π) are described by

$$\begin{cases} \dot{K} = \alpha \Pi \\ \dot{\Pi} = -\beta \Pi - \gamma K \end{cases} \tag{2}$$

with $\dot{K} = (I - \delta K) \gtrless 0$ where I and δK represent gross investment and depreciation, respectively.

In this model "the net increment of capital equipment per unit of time affects adversely the rate of investment decision, i.e., without the effect, the rate of investment decision would be higher" (Kalecki, 1971).

Thus, the second equation in (2) has a negative sign. The interaction between Π and $\dot{\Pi}$ implies that whilst profits derive from past investments (of profits), the accumulation of capital leads to $\dot{\Pi} < 0$ at some point. This model "depicts only a stationary economy where the capital stock remains constant in the long run. This and the fact that linear differential (or difference) equations cannot be used to produce limit cycles (i.e. economic cycle) are limitations of his early attempt to model the dynamic interaction of profits and capital accumulation" (Semmler, 1986). However, in the Kalecki (non-formalized) description of business cycles, denoted K^* as equilibrium value, past investment has positive effects on the current change of profits if $K < K^*$ and negative if $K > K^*$. These profit-investment dynamics allow the generation of turning points.

Income-Investment Dynamics (Kaldor Model)

The Kaldor model is based on the geometrical characteristics of the saving and investment function that, depending on their shape and relative positioning, generate endogenously cycles.

A hypothesis adopted by Kaldor is that the propensity to save of the capitalists (S^p) is higher than the propensity of wage earners (S^w). The dynamics of the economy are described by the following equations:

$$\begin{cases} \dot{Y}_t = \alpha (I_t - S_t) \\ \dot{K}_t = I_t - \delta K_t, \end{cases} \tag{3}$$

where the subscripts denote the macroeconomic variables income (Y), investment (I), saving (S) and capital (K) at time t. In the Eqs. (3), α is the rate at which the output responds to the excess investment I-S and δ represents the capital depreciation rate K.

Furthermore, Kaldor assumes that

$$\begin{cases} I_Y > 0, \ I_K < 0, \\ S_Y > 0, \ S_K > 0. \end{cases} \tag{4}$$

A stable equilibrium is the only income level where savings and investment are equal. When S and I are linear, there is only one equilibrium and it is stable or unstable. In the first case the model shows greater stability than what appears to be present in reality (Fig. 5), in the second case the equilibrium is unstable and the resulting income is infinite or zero (Fig. 6).

To explain the dynamics of I and S, Kaldor assumed that $I = I(Y, K)$ and $S = S(Y, K)$ are nonlinear functions of income and capital.

Kaldor's inspiration was to conceive a structure in which nonlinear functions move dynamically. Figure 7 illustrates that the curves $I(Y)$ and $S(Y)$ cross at three

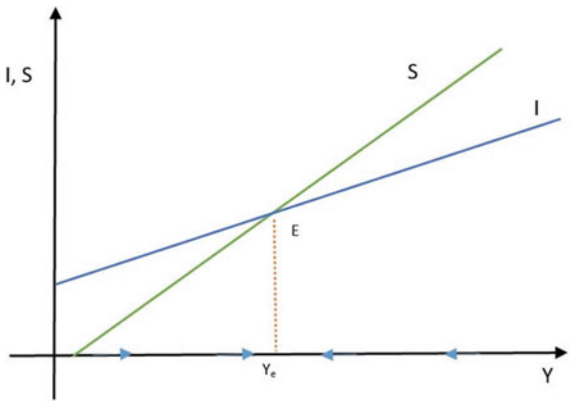

Fig. 5 Ordinate S and Y, abscissa t (time)

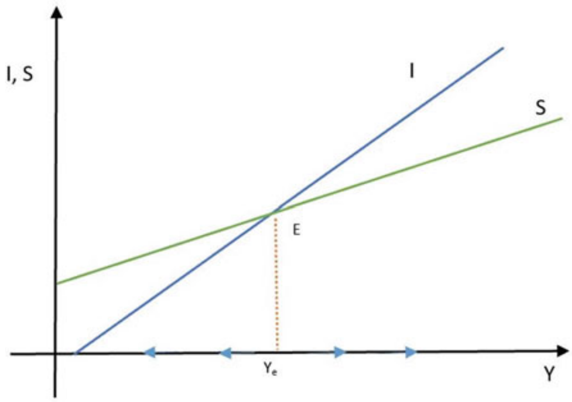

Fig. 6 Savings (green) and investment (blue) versus income (abscissa). Stable equilibrium

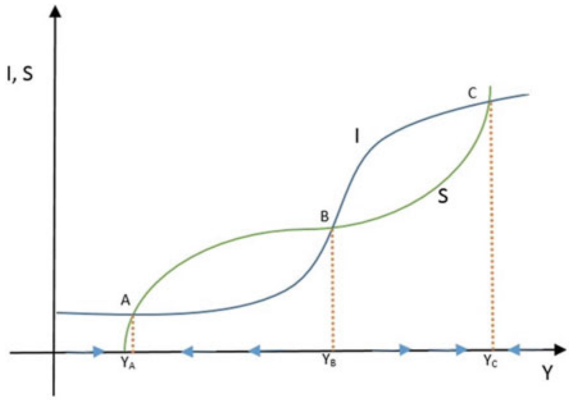

Fig. 7 Savings (green) and investment (blue) versus income (abscissa). Unstable equilibrium

points A, B and C. These points correspond to three different equilibria defined by the equality $I = S$.

The A equilibrium corresponds to a low level of Y_A production and overcapacity. Any increase in aggregate demand is absorbed and, consequently, in this situation, there is little or no investment. In the opposite case, when $Y = Y_C$, the production capacity is full and therefore rises the cost of a further unit of capital. However, the return on investment decreases as more profitable activities have already been funded. This motivates nonlinear investments.

Savings (green) and investment (blue) versus income (abscissa). Equilibrium is when $I = S$. If the income is greater than Y_B the savings are greater than the investments, so the total output decreases. Conversely, income is less than Y_B, investments are greater than savings, and the economy grows.

Equilibrium is when investment equals savings. To the right of Y_B, the high investment pushed the economy further. To the right of Y_B, on the other hand, savings are greater than investments and the economy gradually declines.

The equilibrium exists for the level of income corresponding to the investment equal to the savings as for the savings rates, it can be assumed that they are high both when production is low and when it is high. The cause is that for $Y = Y_A$, the income is almost completely used and families have presumably exhausted their finances. For this reason, in the event of an increase in income, savings are likely to be reinstated. On the other hand, when the income is high and corresponds to $Y = Y_C$, the consumption is already high and therefore the additional income is saved. Figure 8 shows the three equilibria (Y_A, Y_B and Y_C) between investment and savings corresponding to the different output level. Note that while Y_A and Y_C are stable, Y_B is not because on the left the savings exceed investment while on the right the opposite happens.

According to Kaldor, the business cycle is caused by the accumulation of capital. For example, suppose $Y = Y_C$ and I depend on K such that $\frac{dI}{dK} < 0$. This implies that on the one hand, the stock of capital increases and on the other hand the marginal productivity of capital decreases as does the investment curve. For high levels of

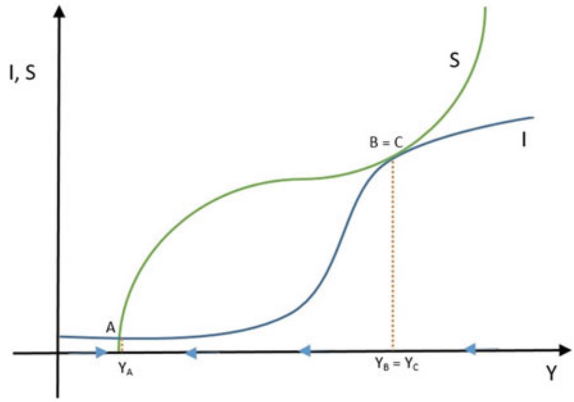

Fig. 8 Dynamic analysis of investments and savings

output, prices decrease with a positive effect on savings. This produces $\frac{dS}{dK} > 0$, which means that the savings curve shifts up.

This implies that on the one hand, the stock of capital increases and on the other hand the marginal productivity of capital decreases as does the investment curve. For high levels of output, prices decrease with a positive effect on savings.

The effect of this process is to move Y_C down and Y_B up (see Fig. 8), until the curves meet at the tangent point. On the left, the next equilibrium point is for $Y = Y_A$ which represents a severe economic downturn.

As regards the equilibrium point $Y_B = Y_C$ it can be observed that it is stable since, on the left, when $S < I$, the economy increases and on the right, when $S > I$, the output shrinks.

Due to the decline in productivity, the investment shifts downwards and the consequent reduction in price shifts savings upwards.

The special characteristics of the cyclical process just described are self-generation and dynamic adjustments of macroeconomic variables. In case the income is high, opposing dynamics keep it under control, producing a downward movement. The opposite thing happens when the income is low. In particular, the dynamics that elastically bring income down or up correspond to the shift of the two investment and savings curves and accumulation towards the reduction of capital. These events occur during the cycle and are embedded in the dynamics of the model. In terms of fiscal policy, the implication of Kaldor's model concerns the observation that the different distribution of income between capitalists and workers has effects on investment and saving. Income distribution can serve to bring the economy back into equilibrium. This aspect differentiates Kaldor's thinking from that of other contemporary economists dealing with cycle theory such as Harrod. While for Kaldor the system dynamically self-regulates and the distribution mechanism can help achieve a higher equilibrium, for Harrod a change in the investment curve triggers a cumulative process of decline (or growth) in income and production without counterweight. Finally, inflation in the Kaldor model plays an important role. In fact, when there is greater use of factors, investments generally grow and are greater than savings.

This increase in investment, accompanied by induced growth in demand, leads to higher prices than wages in the presence of full employment. This changes the share of total income in favor of the capitalists and reduces that in favor of the workers. Since capitalists have a greater propensity to save, the saving will increase more than investment, to the point of re-establishing equality between saving and investment. Furthermore, as investment and consequently demand fall, wage prices will tend to fall. This means that the new balance between saving and investing will be restored for a lower level of income. This process is usually called the "Kaldor Effect".

Dynamic Stochastic General Equilibrium (DSGE) Vector and Autoregressions Models

As a tool for analyzing how in general the entire economy evolves, stochastically and in equilibrium, dynamic stochastic general equilibrium (DSGE) models are used. Their linearized version can be expressed in form of linear vector autoregressions (VARs).

DSGE models stem from the idea of providing microeconomics foundations to econometric models. The process starts with the equilibrium conditions of a nonlinear DSGE model and it is followed by a linearization around the non-stochastic steady state. Then, the log-linearized state transition equation is found in terms of a vector of observable variables represented by a VAR whose parameters are suitably calibrated. DSGE models have been adopted by many central banks for policy analysis and forecasting: the IMF (GEM), Norges Bank (NEMO), Bank of Canada (ToTEM), the European Commission (QUEST III), European CentralBank (NAWM), Sveriges Riksbank (RAMSES), Bank of England (BEQM), the US Federal Reserve (SIGMA).

While the whole framework has provided new insights and helped in identifying the consequence of the change of a given variable (the so-called impulse response analysis), several issues need to be addressed: (a) The mapping from the DSGE to the VAR model (Giacomini, 2013), (b) The wrong microfoundations (Stiglitz, 2018), (c) The lack of regime dependent VAR specification (Mittnik & Semmler, 2012).

On the latter, Mittnik and Semmler (2012) show that a fiscal multiplier that varies according to the state of the business cycle can be modeled with a two-regime VAR. In particular, for the U.S.A. the "expansion multiplier is much higher in a regime of a low economic activity than in a regime of high activity" Mittnik and Semmler (2012). Moreover, they prove that it is size-dependent. So, multi-regime models can capture different states of business cycles and are policy-relevant. Figure 9 provides an example of a DSGE-VAR model.

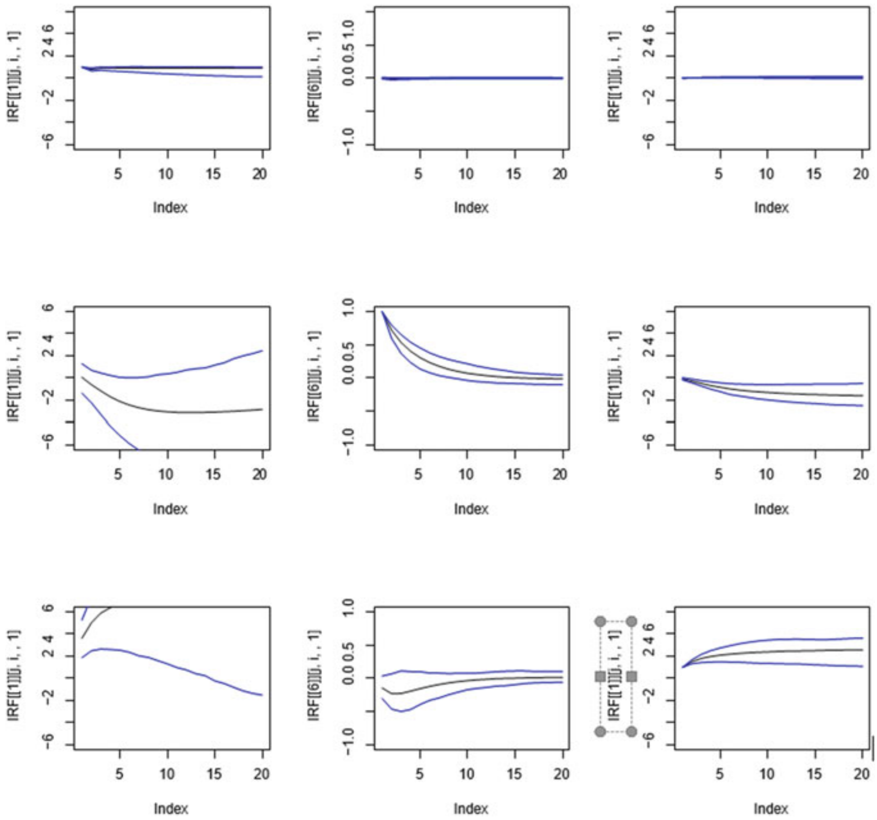

Fig. 9 Impact of a rate cut (see Chen & Semmler, 2021)

3 Recurrence Quantification Analysis (RQA)

Recurrence Quantitation Analysis (RQA) is based on the change in the correlation structure of the observed phenomenon and therefore is used to predict catastrophic changes in various systems: from geophysics (Zimatore et al., 2017) and physiology (Zimatore et al., 2011) to economy (Crowley, 2008; Orlando & Zimatore, 2021). For a brief overview, see (Orlando et al., 2021e).

Among the first applications to economics we can mention the study by Gorban et al. (2010) which demonstrates how, in the UK stock market, correlation (i.e. determinism) increases during a crisis and decreases when the market recovers. More recently, Orlando and Zimatore (2017, 2021) found that RQA and statistical techniques applied to real-world time series highlight potential indicators of structural changes in economic time series that are harbingers of downfall.

Recurrence Plot (RP)

The Recurrence Plot (RP) is also called the Distance Matrix (DM) as it is denoted as R_{ij}^{u} the distance between the vectors $\mathbf{x}_i$ and $\mathbf{x}_j$ based on Phase Space Reconstruction as defined by Eckmann et al. (1987).

For example, Fig. 10 at the top shows the historical series of US GDP % and at the bottom the relative RP. In correspondence with the grey areas that denote periods of economic recession in the USA economy, it is possible to observe the anticipations of the transitions in turbulent phases represented by vertical lines.

Recurrence Quantification Epoch (RQE)

When RQA is performed on windows/sub-intervals, rather than not on the whole time series, it is called Recurrence Quantification Epoch (RQE) analysis. Determinism (DET) and laminarity (LAM) are among the most important pieces of information provided by the RQA, in fact, A Bastos and Caiado (2011) found a reduction in DET and LAM during the sub-prime mortgage crisis. Fabretti and Ausloos (2005) and Kousik et al. (2010) reported the highest value of DET and LAM during the bullish period. Figure 11 shows an example of Recurrence Quantification Epoch (RQE) applied to USA GDP %.

RQE Correlation Index (RQCI)

In this section, we first introduce a newly built RQE Correlation Index (RQCI) based on RQA measures and, then, we show how the RQCI performs in detecting structural changes (such as mean and volatility) in both simulations and real data.

RQE Correlation Index on Test Data

As explained in (Orlando & Zimatore, 2017, 2018), it is possible to define the so-called *RQE correlation index* (RQECI) composed of the correlations of the recurrence quantification measures of the recurrence such as the aforementioned DET and LAM obtained by performing the RQE several times over a given time series.

To test if the RQECI can detect changes in a time series, we take $\varepsilon \sim \mathcal{N}(\mu, \sigma^2)$ normally distributed and simulate two signals, one not perturbed and the other perturbed (both in average and in variance) as shown in Fig. 12.

Although the RQECI on the original time series shows nothing of note (see Fig. 13), the RQECI on the perturbed time series detects 9 out of 10 changes in mean and variance (see Fig. 14).

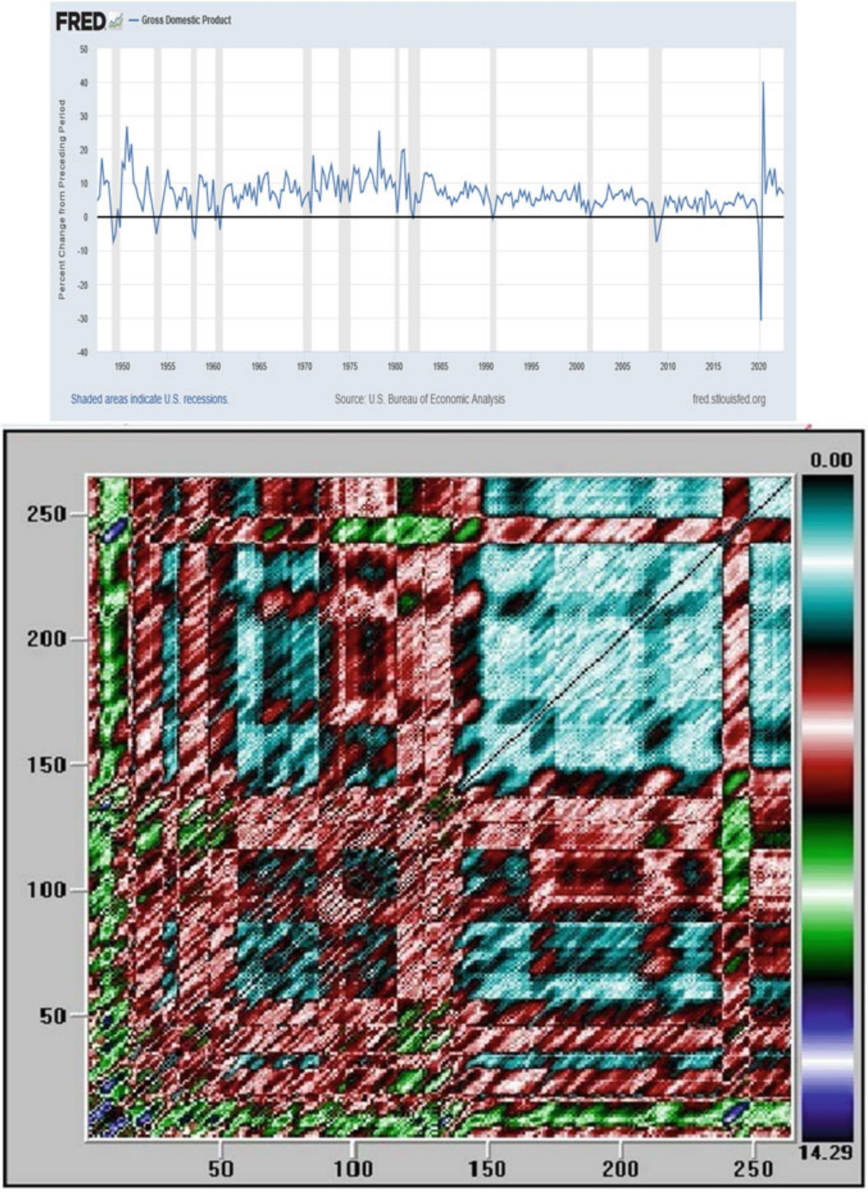

Fig. 10 Percent change of USA GDP-A191RP1Q027SBEA (above) versus the its RP (below). *Source* St. Louis Fed, Orlando and Zimatore (2017, 2021)

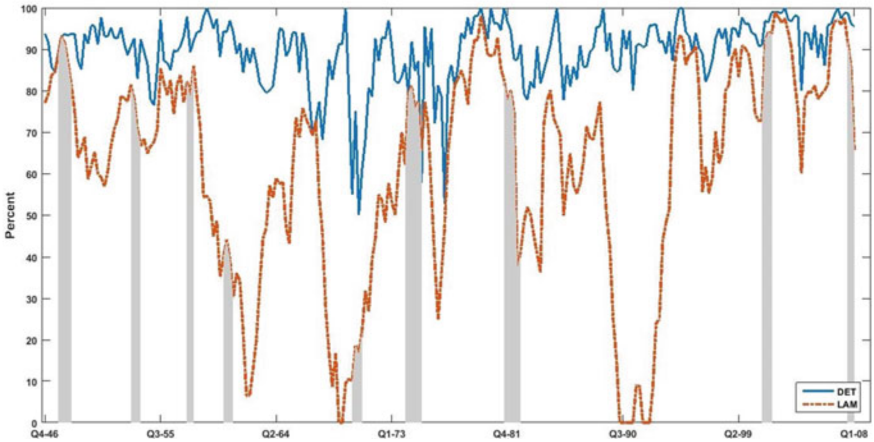

Fig. 11 RQE (i.e., dynamic RQA) with respect to laminarity (LAM) and determinism (DET) applied to the same time series as Fig. 10

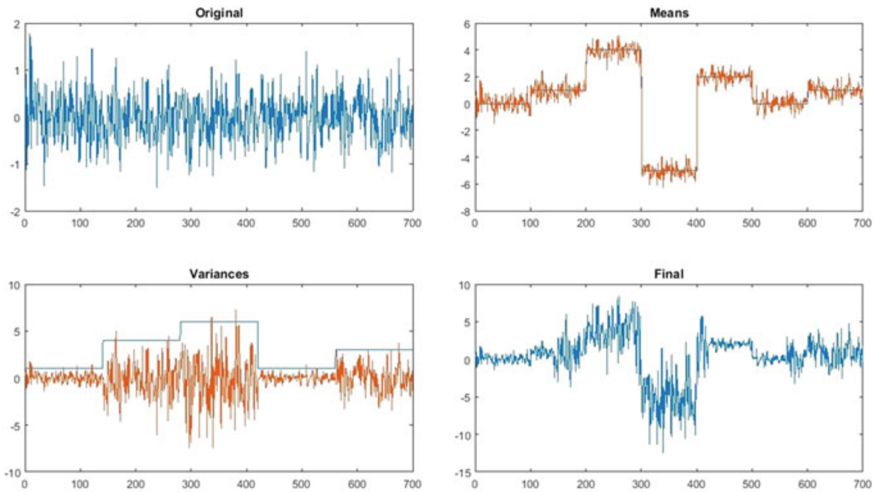

Fig. 12 Clockwise from top left: original non perturbed signal, shifts in mean, changes in variance and resulting final perturbed signal

RQE Correlation Index on Real Data

As shown in the previous paragraph, the RQECI can detect regimes' changes that are difficult to see at a glance. Therefore, the additional potential use of the index is as an early indicator in economics for recessions and market crashes, in seismology for earthquakes, etc. To show an application to economics, we have retrieved from the OECD database the USA GDP OECD (2016) and then we have run an RQE