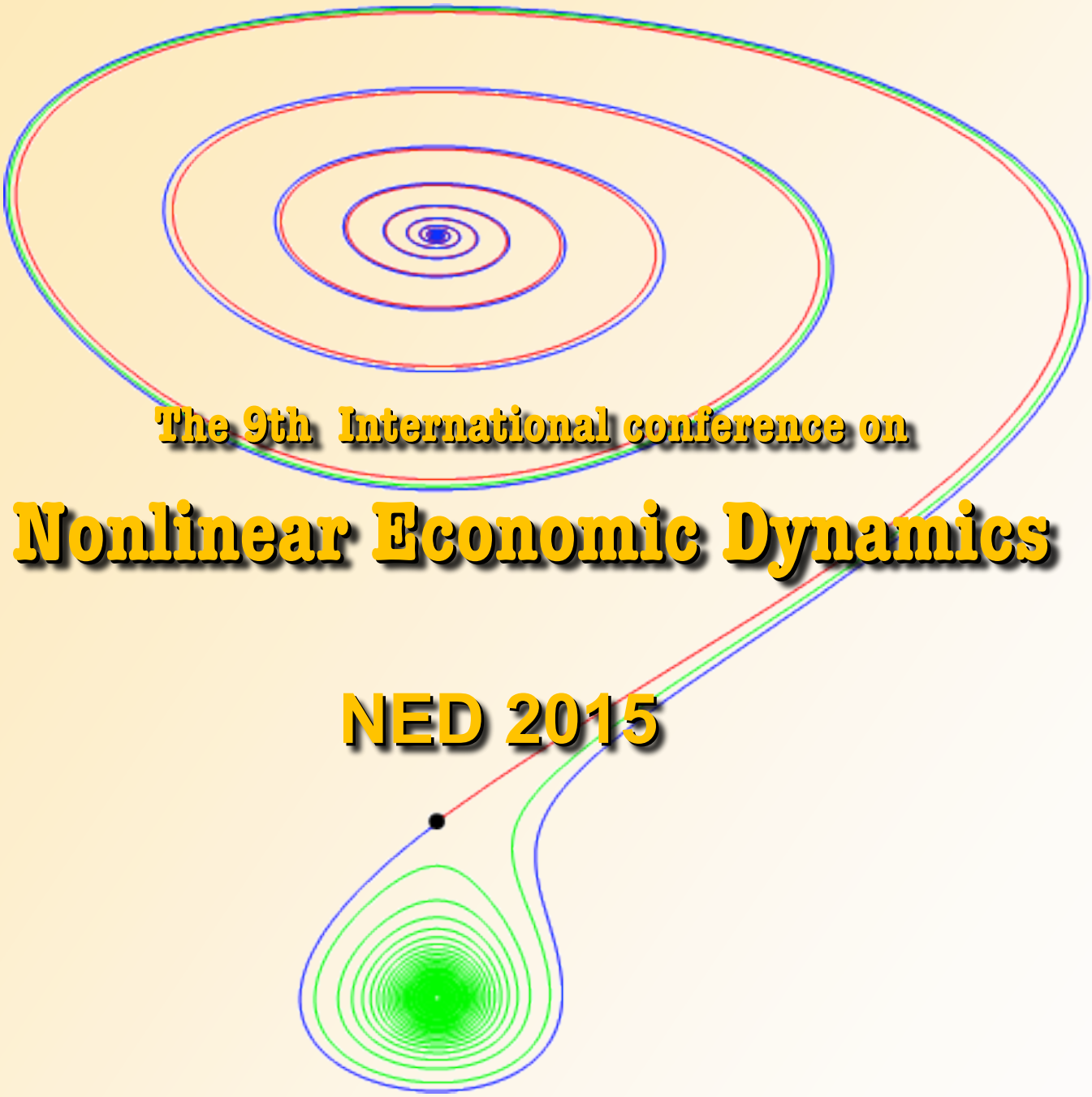
**25-27 June 2015 Chuo University**
**Tokyo, Japan**



The 9th International conference on

# Nonlinear Economic Dynamics

# NED 2015

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- **The MEXT-Supported Program for the Strategic Research Foundation at Private Universities 2013-2017**
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Contact: Local Organizing Committee: dder@tamacc.chuo-u.ac.jp
Akio Matsumoto: akiom@tamacc.chuo-u.ac.jp

# The 9th International Conference on Nonlinear Economic Dynamics NED2015

## at Chuo University, Tokyo, Japan

**Conference Venue**

Room 4 at Institute of Economic Research
2nd Building, Tama Campus, Chuo Univeristy
742-1, Higashi-Nakano, Hachioji
Tokyo, 192-0393, Japan

**Scientific Committee**

G. I. Bischi: Università di Urbino
J. Cánovas: Technical University of Cartagena
H. Dawid: Bilefeld University
R. Dieci: Università di Bologna
C. Hommes: University of Amsterdam
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- Chuo University Joint Research Grant
- Nonlinear Economic Dynamic Society

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# Program

## Thursday, 25 June

**8:30-9:00 Registration**: Room 4 at Institute of Economic Research

**8:50-9:00 Opening Address**: Mashiro Yabuta (Dean, the Graduate School of Economics)

**9:00-9:50 Plenary Session I** (Chair: Barkley Rosser)

Cars Hommes: Nonlinear Dynamics in the Laboratory

9:50-10:00 *Break*

**10:00-11:15 Morning Session I-1** (Chair: Ferenc Szidarovszky)

1. G. Bischi (with U. Merlone): Evolutionary Binary Games with Memory
2. D. Goldbaum (with A. Bostian) : Emergent Coordination among Competitors
3. A. Fiori Maccioni (with A. Antoci and P. Russu): Medical Practice and Malpractice Litigation in an Evolutionary Context

11:15-11:35 *Coffee Break*

**11:35-12:50 Morning Session I-2** (Chair: Rudolf Zimka)

1. I. Sushko (with P. Commendatore, I. Kubin and P. Mossay): Dynamics of a Two-Country New Economic Geography Model with Four Regions
2. U. Merlone (with A. Matsumoto and F. Szidarovszky): Extended Oligopolies with Contingent Workforce
3. N. Pecora (with A. Naimzada and A. Spelta): Monetary Feedback Rules in Pure Exchange Overlapping Generations Models: Local and Global Analysis

12:50-14:00 *Lunch Break*

**14:00-14:50 Plenary Session II** (Chair: Yoshitaka Saiki)

Hiroshi Kokubu: Dynamicsl Time-serise Analysis based on the Topological Computation Theory for Global Dynamics

14:50-15:00 *Break*

**15:00-16:15 Afternoon Session I-1** (Chair: Anastasiia Panchuk)

1. R. Zimka (with T. Asada): The Stability of Normal Equilibrium Point and the Existence of Limit Cycles in a Simple Macrodynamic Model of Monetary Policy
2. S. Sordi: The Multiple-Accelerator Interaction and the Financial System
3. T. Ryazanova (with L. Ryashko): The Generation of SAO and LAO in Kaldor Model under Stochastic Perturbation

16:15-16:35 *Coffee Break*

**16:35-17:50 Afternoon Session I-2** (Chair: Gian-Italo Bischi)

1. M. Sodini (with L. Gori and L. Guerrini): Chaos in Duopoly Pricing: A Re-examination with Time Delays
2. M. Manuel Ruiz (with V. Caballero and M. Matilla): Detecting Dynamic Structure. Independence, Structural Change and Deterministic Chaos
3. H. Murakami: Time Elements and Oscillatory Fluctuations in the Keynesian Macroeconomic System

**18:00-20:30 Special Session I**

Informal Get Together at Room 1406

## Friday 26 June

### 9:00-10:15 Morning Session II-1 (Chair: Tony He)

1. V. Böhm (with T. Hüls): Dynamics of Asset Prices and Geometric Decay
2. M. Pireddu (with A. Naimzada): An Evolutive Financial Market Model: Imitation and Endogenous Fundamental Values
3. G. Campisi: A Simple Financial Market Model with Heterogeneous Interacting Traders

10:15-10:35 *Coffee Break*

### 10:35-11:50 Morning Session II-2 (Chair: Gustav Feichtinger)

1. H. Takahashi: Unbalanced Growth in A Neoclassical Two-sector Optimal Growth Model with Sector Specific Technical Progress: A Turnpike Approach
2. R. Hiraguchi: On a Closed Form Solution to the Ramsey Model with Heterogeneous Agents
3. M. Matilla-Garcia (with R. Ledo, I. Arbués): Can Exchange Rate Forecast Commodity Prices?

11:50-13:00 *Lunch Break*

### 13:00-13:50 Plenary Session III (Chair: Harutaka Takahashi)

Kazuo Nishimura: Growth and Public Debt

13:50-14:00 *Break*

### 14:00-15:15 Afternoon Session II-1 (Chair: Iryna Sushko)

1. G. Feichtinger (with J. Caulkins and D. Grass): Complex Solutions of Optimal Control Models: Public Opinion as Catalyst for Counter-Terror
2. K. Akao (with T. Kamihigashi and K. Nishimura): Critical Capital Stock in a Continuous Time Growth Model with Convex-Concave Production Function
3. S. Takahashi (with T. Nakajima): The Optimum Quantity of Debt for Japan

15:15-15:35 *Coffee Break*

### 15:35-16:50 Afternoon Session II-2 (Chair: Serena Sordi)

1. W. Huang (with Y. Zhang): Impact of Strategy Change on Wealth Accumulation
2. R. Yamamoto: Does High-Frequency Trading Improve Market Quality?
3. F. Nardini (with N. Angelini, G. Bormetti and S. Marmi): A Model for Long-run Index Return Predictability

### 19:00-21:00 Special Session II

*Conference Dinner at AW Kitchen Farm*
*(http://www.eat-walk.com/awfarm/)*

## Saturday 27 June

**9:00-9:50 Plenary Session IV** (Chair: Cars Hommes)

Barkley Rosser: Complexity and Behavioral Economics

9:50-10:00 *Break*

**10:00-11:15 Morning Session III-1** (Chair: Tamotsu Onozaki)

1. T. Puu: Hotelling Duopoly Revisited
2. L. Gori (with M. Sodini): A Nonlinear Duopoly with Price Competition and Isoelastic Demand
3. D. Radi (with G. Bischi and F. Lamantia): An Evolutionary Cournot Model with Heterogeneous Firms

11:15-11:35 *Coffee Break*

**11:35-12:25 Morning Session III-2** (Chair: Volker Böhm)

1. T. He (with K. Li and Y. Li): Optimal Time Series Momentum
2. A. Panchuk: Dynamics of a Stock Market Involving Disequilibrium Trade

12:25-13:30 *Lunch Break*

**13:30-14:45 Afternoon Session III-1** (Chair: Asada Toichiro)

1. T. Onozaki (with K. Esashi and Y. Saiki): Chaotic Itineracy in Regional Business Cycle Synchronization
2. Y. Nonaka: Employment Fluctuations and Signaling Dynamics in a Japanese New Graduates Job Market
3. E. Tsuzuki: Two Time Lags in the Public Sector: Macroeconomic Stability and Complex Behavior

14:45-15:05 *Coffee Break*

**15:05-16:20 Afternoon Session III-2** (Chair: Ugo Merlone)

1. K. Li (with T. He and C. Wang): Volatility Clustering: A Nonlinear Theoretical Approach
2. Y. Kimura (with Y. Arata and H. Murakami): Stabilization Effect Caused by Randomness: Lumpy Investment and Uncertainty
3. M. Nozaki: How to Examine the Total Economic Impact, Stemmed from the Great East Japan Earthquake: within the Interregioal Input-Output Framework

16:20-16:30 *Break*

**16:30-17:20 Plenary Session V** (Chair: Akio Matsumoto)

Ferenc Szidarovszky: Nonlinear Cobweb Model with Production Delays

**17:20-17:30 Closing Session**

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# Abstracts

# Critical Capital Stock in a Continuous Time Growth Model with Convex-Concave Production Function

Ken-Ichi Akao*, Takashi Kamihigashi† and Kazuo Nishimura‡

* Waseda University
†‡ Kobe University

## Abstract

The critical capital stock is a threshold in a nonconcave growth model such that any optimal capital path from a stock level below the threshold converges to a lower optimal steady state, whereas any optimal capital path from one above the threshold converges to a higher optimal steady state. It is different from the one of a concave growth model with wealth effect in the respect that the stock level is not necessarily an optimal steady state. Despite the rich economic implications, its characteristics have not been well known. We show that, in a continuous time growth model with a convex-concave production function, the critical capital stock is continuous and strictly increasing in discount rate, starting from the zero stock level and disappearing at a certain level between the stock levels of the maximum average productivity and the maximum marginal productivity, and this upper bound can be arbitrarily close to both these stock levels, depending on the magnitude of the elasticity of the marginal utility.

Keywords: Continuous time growth model, Convex–concave production function, Critical capital stock

Journal of Economic Literature Classification Numbers: C61; D90; O41

# Evolutionary Binary Games with Memory

Gian Italo Bischi* and Ugo Merlone†

* Università di Urbino "Carlo Bo" (Italy)
email: gian.bischi@uniurb.it
†Universitit di Torino
email: ugo.merlone@unito.it

## Abstract

We propose a simple dynamic adjustment mechanism, equivalent to the standard replicator dynamics in discrete time, to study the time evolution of a population of players facing a binary choice with social influence, and apply this mechanism to some situations including minority games and games where the social influence imply the existence of two interior equilibria. The effects of memory on the stability of the equilibrium points is investigated under two different kinds of memory: One where the players take into account the current and the previous payoffs in order to decide the strategy chosen in the next period, and the other one where the players consider the whole series of payoffs observed in the past through a discounted sum with exponentially fading weights. Both the memory representations proposed lead to an analytically tractable two-dimensional dynamical system, so that analytical results can be given for the stability of the equilibrium points, However, a global analysis of the models performed by numerical methods and guided by the analytical results, shows that some complexities arise for intermediate values of the memory parameter, even if the stabilization effect of uniform memory is stated in both cases.

Keywords: Binary games, Minority games, Replicator dynamics, Memory, Stability.

# Dynamics of Asset Prices and Geometric Decay

Volker Böhm* and Thorsten Hüls†

Department of Economics, Department of Mathematics Bielefeld University
POB 100131, 33501 Bielefeld, Germany
vboehm@wiwi.uni-bielefeld.de huels@math.uni-bielefeld.de
Very preliminary and incomplete, do not quote!

## Abstract

This paper reexamines and extends the results of [4]. It was shown there that the asset price dynamics of a standard CAPM with heterogeneous agents (chartists and fundamentalists) and expectations based on geometric decay were described by a noninvertible two-dimensional map exhibiting chaotic behavior after a period doubling bifurcation of a unique stationary point followed by a global Neimark-Sacker bifurcation. The ensuing alternating quasi-periodic motion on two invariant curves (IC) was destroyed through a sequence of breakups into finite periodic orbits and chaotic attractors parallel to the appearance of homoclinic orbits.

After obtaining the canonical symmetric form of the dynamical system we derive the analytical forms of the bifurcation curves algebraically for a version of the model in two-parameters, one characterizing the behavioral/heterogeneity features and the other the decay parameter $\delta$. These show that global stability of the stationary state or of a two period cycle occurs for sufficiently small or large rates of decay $\delta$ for all levels of the behavioral parameter.

For large levels of the behavioral parameter there exists a non-degenerate interval of the decay parameter within which quasi-periodic motion is destroyed in a diversity of different orbit structures, for example with coexisting finite stable cycles, quasi-periodic, and chaotic orbits. Numerical evidence suggests that the range of parameters of the destruction of the two IC's can be divided into two areas, one where sample autocorrelation is significant but monotonically declining and another one where orbits are chaotic and sample autocorrelation is insignificant but small and variable.

Keywords: Asset pricing, boundedly rational heterogeneous agents, bifurcation, autocorrelation, chaos.

AMS Subject Classification: 37N30, 65P20, 65P30
JEL classification: C22, C61, G12

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[2]Supported by CRC 701 'Spectral Structures and Topological Methods in Mathematics'.

# A Simple Financial Market Model with Heterogeneous Interacting Traders

Giovannni Campisi

## Abstract

In this paper we're going to talk about the application of Discrete Dynamical Systems (DDS for short) in economics and financial models. In this contribute we make use of different works included in different papers of Tramontana, Westerhoff, Gardini and Tramontana respectively. We analyze a financial market populated by three types of agents, fundamentalists, chartists, imitators, using a 2D piecewise linear discontinuous map which is a field of DDS theory. This kind of map can be divided in two subgroups:

- PWL continuous maps;
- PWL discontinuous maps.

We take into account only the second one in our present work. Using the same methodology of the previous authors, our model include a market maker who adjust price with respect to order imbalances, chartists or technical traders who bet on the persistence of bull and bear markets (i.e. markets where price are overvalued or undervalued respectively), fundamentalists who believe in mean reversion; that is, they expect prices to return towards fundamental values. As in Tramontana, the third type of agents, i.e. imitator use a very simple heuristic rule to form their expectations, they look only at the $P_t$ and $P_{t-1}$, if $P_t$ is closer than $P_{t-1}$, to the fundamental value than they conclude that fundamentalists strategy has been successfull and they imitate fundamentalists in time $(t+1)$ . The basic idea of our model consists in demonstrating the amplitude of fluctuations in the dynamic of price when the number of imitators increase respect to the situation where there are not imitators and the market is populated by fundamentalists and chartists. The role previously assumed by chartists, the ones who destabilized the market, now it is assumed by imitators.

# Complex Solutions of Optimal Control Models: Public Opinion as Catalyst for Counter-Terror

Jonathan P. Caulkins, Gustav Feichtinger and Dieter Grass

## Abstract

There is a conventional wisdom that winning the "hearts and minds" of noncombatants is an important strategy in non-conventional conflicts. We capture this idea by introducing a two-state optimal control model that explicitly includes a state variable representing the level of public sympathy for the counterterror forces. The key innovation in this model is to presume that the outflow from the stock of terrorist is increasing (and concave) in the level of public sympathy for those operations, as well as in the level of counter-terror efforts. The analysis yielded interesting results, both mathematically and substantially. In particular, we found a so-called Skiba curve separating different regions in state space, for which it is optimal to drive the system to steady states with either a lower or a higher number of terrorists. There are places in the state space where a slight increase in the initial number of terrorists can tip the optimal strategy, from approaching the lower-level to approaching the higher-level of terrorists. Persistent oscillations are another kind of complexity. While Hopf bifurcations are meanwhile standard in two-state optimal control models, Bautin bifurcations are rather new in dynamic economies. By analyzing this generalized Hopf bifurcation we establish the coexistence of a stable limit cycle and a stable fixed point providing a nice interpretation of the solution. The unstable cycle in between acts as separatrix between two basins of attraction (denoted earlier as "corridor stability").

# Emergent Coordination among Competitors

AJ Bostian and David Goldbaum

## Abstract

Crawford and Haller (1990) describe a repeated two-player coordination game defined by the absence of a common language. Coordination is achieved only through path dependent play relying on time consistent labels. We consider a game played by a large population similarly looking to coordinate but without the consistency in labels over time and with asymmetric coordinated payoff so that players have differing preferences regarding which coordinated structure emerges. In experiments, we link subjects together in a social network with limited ability to observe others. The complexity of the game and multitude of states thwarts solving for optimal play and yet the population demonstrates success in employing path dependency and the consistency of the social relationships to learn to coordinate. To capture this evolution, we model decisions with an experience-weighted attractor having recency, reinforcement, and lock-on biases. We find considerable heterogeneity in biases across individuals. Drawing on the observed biases, we conduct simulations to identify the extent to which individuals and environment determine group dynamics.

With an incentive to cooperate a large population of players is capable of developing the relationships necessary to generate the coordinated outcome. That is, the subjects come to rely on social connections to identify achieve coordination on each new alternative. Success is facilitated by appropriate rewards that emphasize cooperation over competition and by increased social contacts that increase visibility and decrease the distance that information must travel.

The combined Experience Weighted Attractor and Nested Logit model produces insight into how individuals update strategies based on personal experience and recall. There is considerable heterogeneity among players. Those who successfully emerge as leaders reflect the heterogeneity of the larger population, suggesting that environment and luck play a substantial role in determining who becomes a leader.

Simulations reveal some of the important features that are conducive to the emergence of the coordinated structure. A homogeneous population distributed over a regular network of directed links will converge to the coordinated structure for a broad range of parameters for the EWA and nested logit models. Convergence on the coordinated structure arises from appropriately adaptive behavior by individual subjects responding to the events they can observe. The key is that there has to be sufficient response by the subject to give preference towards actions that reinforce lucky outcomes. Such adjustments will give social advantage based on otherwise transient events. Continued adjustment rewards advantage, transforming initial luck into a permanent advantage, eventually producing a leader and followers. For this to occur requires sufficiently observant subjects, meaning that subjects have to pay attention to the counterfactuals offered by following in order to recognize the benefits of following the right contact. Subject also have to be responsive to differences in performance as they emerge. A population that is slow to respond will not adapt the network to take advantage of transient events before they have passed.

The representative agent estimated from the pooled data does not have the characteristics necessary to produce convergence to the cooperative structure. The failure of the representative agent model also points to a failure to capture the heterogeneity of the actual subject population.

Modeling individual behavior generates greater frequency in the emergence of the coordinated structure than the representative agent. Greater adaptation by even a small portion of the population provides the seeds of organization that others can respond to. There is clearly room for improving the model of subject behavior within the experiments. This will be the subject of continued effort.

# A Nonlinear Duopoly with Price Competition and Isoelastic Demand

Luca Gori*and Mauro Sodini†

## Abstract

This paper aims at studying local and global dynamics in a nonlinear duopoly with price competition, horizontal differentiation and general isoelastic demand. To this purpose, we follow the tradition of Bischi et al. (1998) and use a model where players have limited information, i.e. they do not know market demand in every period and do not have expectations on rivals' next period product. Given the importance of product differentiation in the current industrial organization literature, that has developed models with both quantity competition and price competition under profit maximisation (Singh and Vives, 1984) or managerial incentive contracts (Kopel and Lambertini, 2013; Meccheri and Fanti, 2014) with the aim of ranking outcomes in static games, our goal is to clarify local and global dynamic properties of a two-dimensional discrete time model where firms compete on prices. Specifically, we assume that players have limited information and use a behavioural rule to set the price for the subsequent period (i.e., there are no exogenous stochastic shocks that determine the nonlinear behaviour of the economy). This assumption dramatically contrasts models with full information and rational expectations and it is essentially made to try to go beyond some restrictions implied by the rational expectations paradigm. Indeed, models with rational expectations are based on two main assumptions: rationality of agents (i.e., expectations of an economic agent are equivalent to mathematical expectations which exploit all available information) and homogeneity of expectations of all economic agents. The hypothesis of rational expectations implies that any decision-maker use efficiently the set of available information. Since obtaining and using efficiently information is costly, agents may use other rules that allow them to go beyond this concern. With this regard, several models with "bounded rationality" have been studied with different purposes. In particular, the hypothesis of bounded rationality is strictly related with problems of stability of equilibria in economic models. In fact, this kind of models sometimes predicts that instability holds under much weaker conditions than those implied in models with rational expectations (Brock and Hommes, 1997). Rational expectations models tend to explain the volatility of economic variables because of the existence of exogenous (stochastic) shocks, while instability in models with bounded rationality is endogenous to the model. The nonlinear duopoly literature has developed several works to explain on-off intermittency, multistability and other local and global events, in a context where (homogeneous or heterogeneous) players do not have full information. This class of models has essentially concentrated on quantity-setting firms by assuming either linear demand (quadratic utility) or unit-elastic demand (Cobb-Douglas utility). In particular, Bischi et al. (1998) study a duopoly with homogeneous players (symmetric discrete time map) and show that the phenomenon of synchronisation can occur, while also combining the local study of transverse stability with the global behaviour of the map through critical manifolds. In addition, the paper stresses the occurrence of global bifurcations of the basins of attraction that holds through a contact between critical curves and basin boundaries. In a companion paper, Bischi et al. (1999) draw attention on the existence of heterogeneities between players (asymmetric map) that give rise to symmetry-breaking bifurcations, showing that negligible differences in the basic parameters that characterise duopolistic firms may cause qualitatively different dynamic evolutions as compared with the case of symmetric game (such as lack of synchronisation and coexistence of attractors), i.e. the representative agent hypothesis dramatically matters for the final outcome the economy may follow. Subsequently, Bischi et al. (2007) compare the behaviour of firms that use the so-called Local Monopolistic Approximation (LMA) adjustment process (firms maximise profits by assuming a linear demand function and ignoring the effects of competitors' outputs) to choose

*Department of Law, University of Genoa, Via Balbi, 3 0/19, I-16126 Genoa (GE), Italy
e-mail: mailto:luca.gori@unige.it or mailto:dr.luca.gori@gmail.com
tel.; + 39 010 209 95 03; fax: + 39 010 209 55 36

†Department of Economics and Management, University of Pisa, Via Cosimo Ridolfi, 10, I-56124 Pisa (PI), Italy
e-mail: mailto:mauro.sodini@unipi.it
tel.: + 39 050 22 16 234; fax: + 39 050 22 10 603

the quantity that should be produced for the subsequent period, with the behaviour of firms that use an adjustment mechanism based on the Best Reply dynamics (that are assumed to have complete knowledge of the market demand with naïve expectations). They show that 1) in a repeated game firms under LMA rule may converge towards a Nash equilibrium of a game under full information, and 2) less information causes more stability for the case of unit-elastic demand. In this strand of literature, Tramontana (2010) stresses the importance of heterogeneity by assuming a Cournot duopoly market with unit-elastic demand, where one firm has incomplete information and competes by producing goods period by period through an adjustment mechanism based on marginal profits, and the rival has full information with naive expectations. In this context, he shows there exist two different paths of dynamic outcomes. The former route to complex dynamics implies that the interior fixed point of the two-dimensional dynamic system undergoes a flip bifurcation that may cause a cascade of flip bifurcations leading to periodic cycles and chaos. The latter one implies the existence of a Neimark-Sacker bifurcation that gives rise to an attracting invariant closed curve. By assuming quantity-setting managerial firms with relative profits delegation, Fanti et al. (2012) has developed a nonlinear duopoly to show that, in spite of the assumption of homogeneous players (symmetric system), when the degree of competition between managers increases on-off intermittency, blow-out phenomena and multistability may occur. Bischi et al. (1998) find similar events in a model with profit-maximizing (quantity-setting) firms with heterogeneities (asymmetric map). In this class of models, an exception that studies price competition with limited information is Fanti et al. (2013a). Specifically, they consider a homogeneous duopoly with horizontal product differentiation and linear demand (symmetric map) and show that the degree of product differentiation matters for the long-term outcome of the economy. Specifically, depending on the differentiation parameter, there exist synchronised dynamics along the invariant diagonal and intermittency. They also discuss the transition from simple dynamics to complex dynamics and describe the structure of the attractor by using the critical lines technique. Some global bifurcations causing a fractalisation in the basin of attraction are exhibited. The present paper is connected with the work of Fanti et al. (2013b) that characterise local and global dynamic properties of a nonlinear Cournot duopoly with general isoelastic demand (quasi-linear preferences) by assuming that firms use local estimates of marginal profits to adapt production decisions period by period. Although players are homogeneous and thus the dynamics of the model is described by a two-dimensional discrete time symmetric map, they show the elasticity of market demand is responsible for local and global dynamic events that cannot be observed in the case of unit-elastic demand and homogeneous players (coexistence of attractors, coordination failures and complex structures of the basins of attraction). We find several local and global phenomena depending on the size of demand elasticity.

Keywords Chaos; Local and global bifurcations; Price competition
JEL Classification C62; D43; L13

# Optimal Time Series Momentum

XUE-ZHONG HE*, KAI LI† and YOUWEI LI‡

* † University of Technology, Sydney, Business School
PO Box 123 , Broadway, NSW 2007, Australia
‡ School of Management Queen's University Belfast, Belfast, UK
tony.he1@uts.edu.au, kai.li@uts.edu.au, wangchuncheng@hit.edu.cn

## Abstract

We develop a continuous-time asset price model to capture the time series momentum documented recently. The underlying stochastic delay model facilitates the analysis of effects of different time horizons used by momentum trading. By studying an optimal asset allocation problem, we find that the per formance of time series momentum strategy can be significantly improved by combining with market fundamentals and timing opportunity with respect to market trend and volatility. The results also hold for different time horizons, the out-of- sample tests and with short-sale constraints. Furthermore, the outperformance of the optimal strategy is immune to market states, investor sentiment and market volatility.

Key words: Momentum, reversal, optimal asset allocation, profitability.
JEL Classification: G12, G14, E32

# On a Closed Form Solution to the Ramsey Model with Heterogeneous Agents

Ryoji Hiraguchi

## Abstract

We investigate the continuous-time neoclassical growth model in which the agents are heterogeneous with respect to their initial wealth and skill. For simplicity, we assume that they have the same CRRA (Constant Relative Risk Aversion) utility function and also the same discount factor.

We show that the competitive equilibrium path exists and is interior, and obtain a closed-form solution path to the model. We follow the existing literature that studies the explicit solution to the Ramsey model with representative consumer and assume that the elasticity of substitution is equal to the inverse of the capital share.

First, we characterize the optimal path by showing that the optimal level of consumption is proportional to the capital level. The aggregate capital level is subject to the Bernoulli type differential equation. Next, we investigate the dynamics of wealth distribution. Third, we study the effect of capital tax on the equilibrium path.

We finally extend our method to the two-sector endogenous growth model with heterogeneous consumers. We find that the closed-form solution path to the model still exists, as long as the elasticity of substitution is the same as the reciprocal of the capital share.

# Nonlinear Dynamics in the Laboratory

Cars Hommes

University of Amsterdam

## Abstract

This talk summarizes how nonlinear behavioral switching models can explain individual as well as aggregate behaviour in learning-to-forecast laboratory experiments with human subjects.

# Impact of Strategy Change on Wealth Accumulation

Weihong Huang* and Yu Zhang†

* AWHHuang@ntu.edu.sg
† yzhang34@e.ntu.edu.sg

Division of Economics, Nanyang Technological University, Singapore

## Abstract

Diverse investment strategies coexist in financial markets because sometimes some strategies work well while under other circumstances other strategies perform better. The fluctuations of strategies' profitability rationalize investors' strategy adjustment. Without perfect rationality or infinite calculation ability, such adjustment is usually driven by past performance of strategies, revealing investors' desire for higher profit. But at what speed should investors adjust their strategies? Does a road of pursuing short-term payoff necessarily lead to higher final wealth? To clear up our doubts, we build a simple discrete heterogeneous agent model. For the first time, we introduce the level of agents' propensity of strategy switching as the new criterion of grouping. It is found that, though agents with higher propensity of strategy switching adopt the better strategy more frequently, they end up with Jess final wealth. We attribute this interesting phenomenon to the inconsistency between short-run profit and long-run wealth accumulation.

Key words: Heterogeneous agent model, intensity of choice, profitability, wealth accumulation

# Stabilization Effect Caused by Randomness: Lumpy Investment and Uncertainty

Yoshiyuki Arata*, Yosuke Kimura† and Hiroki Murakami‡

* † ‡ Graduate School of Economics, The University of Tokyo

## Abstract

This paper investigates the stability of aggregate investment in the uncertain environment with interacting heterogeneous agents. Researchers have shown that there is a considerable difference between the property of aggregate investment dynamics and the nature of individual investment behavior; the individual investment activities exhibit intermittency and lumpiness at the plant level. In addition, there exists persistent heterogeneity across firms. We demonstrate that heterogeneity in capital adjustment processe of micro-agents contributes to creating the stability of the aggregate process. We also show that this macro-stability is undermined in the uncertain circumstance in which variance of the macroscopic distribution (i.e., the degree of heterogeneity across firms) affects individual behaviors as externality. In other words, while heterogeneous beheviors always enhances the stability of aggregate investment, a coordination of interacting investors weakens the stabilizing force. As a result, a slight shock is sufficient to induce the instability when investors are highly sensitive to uncertainty over the economic environment.

# Dynamical time-series analysis based on the topological computation theory for global dynamics

Hiroshi Kokubu

Kyoto University

## Abstract

Recent development of computational methods including validated numerics make it possible to study global dynamical structures of multi-parameter systems with the aid of computer ([Arai et al, SIADS 2009], [Bush et al, Chaos 2013]), where global structure of dynamics is represented as a Morse decomposition. Morse decomposition of dynamics is a finite collection of regions, each called a Morse component, in the phase space of a given dynamical system, union of which contains all the recurrent dynamics; in other words, outside the Morse sets, the dynamics is non-recurrent, or more precisely, gradient-like. Such a Morse decomposition is a coarse description of the entire structure of the global dynamics that captures attractors and unstable dynamics, both are crucial for understanding various dynamical behaviors of the system of interest. Topological computation theory provides us with several ideas and computational methods for obtaining Morse decompositions of a given dynamical system, as well as the dynamical information of each Morse set in terms of Conley index, a topological representation of dynamical behavior of an isolated invariant set. There is also a software called "Conley-Morse Database" available which implements the theory, see http://chomp.rutgers.edu/ and follow the link to "Software". In this talk, I would like to explain first the basic idea of the topological computation theory for global dynamics very briefly. I then discuss possibility of extending the theory to dynamical time-series analysis of an unknown dynamical system, and show an idea for obtaining a Morse decomposition of a dynamical phenomenon of interest from its time-series data obtained by experiments or observations. As an application, I will study some meteorological data, and show a result which seems to agree with common knowledge of meteorologists. Since the observed meteorological data inevitably contain noise, i will discuss a method to treat the effect of noise in the topological computation method.

# Volatility Clustering: A Nonlinear Theoretical Approach

XUE-ZHONG HE*, KAI LI† and CHUNCHENG WANG‡

* † University of Technology, Sydney, Business School
PO Box 123 , Broadway, NSW 2007, Australia
‡ Department of Mathematics,
Harbin Institute of Technology Harbin 150001, Heilongjiang, China
tony.he1@uts.edu.au, kai.li@uts.edu.au, wangchuncheng@hit.edu.cn

## Abstract

We verify the long-waiting conjecture proposed by Gaunersdorfer, Hommes andWagener (2008) to use the coexistence of two locally stable attractors to explain the volatility clustering in financial market. Through an asset pricing model with two types of boundedly rational traders, fundamentalists and trend followers, we theoretically demonstrate the coexistence of a stable steady state and a stable closed invariant cycle, and numerically show that the interaction of the deterministic dynamics and the noise processes can endogenously generate various stylized facts including volatility clustering, and long range dependence in volatility.

Key words: Volatility clustering, fundamentalists and trend followers, bounded rationality, evolutionary learning, stability, coexisting attractors.
JEL Classification: D84, E32, G12

# Medical Practice and Malpractice Litigation in an Evolutionary Context

Angelo Antoci, Alessandro Fiori Maccioni, and Paolo Russu

University of Sassari, Department of Economics & Business Via Muroni 25, 07100 Sassari, Italy
Corresponding author: alex.fiori.maccioni@gmail.com

## Abstract

We study the interactions between medical practice, malpractice litigation and clinical risk, by means of evolutionary game theory. We propose an original 'medical practice game' played by physicians and patients. Patients can sue their physician for medical malpractice when adverse events occur. In turn, physicians can prevent legal suits by refusing to provide risky medical treatments (which is a form of negative defensive medicine) or by providing unnecessary extra tests or procedures (which is a form of positive defensive medicine). Physicians can also perform unnecessary procedures that are more profitable and less time consuming than the alternatives (which is a form of principal-agent problem). The game can be considered a stylized representation of these situations, but it can also represent other types of medical dilemmas involving both clinical and legal risks.

We use the standard replicator dynamics to study the time evolution of behaviors by physicians and patients. We classify the dynamic regimes, find the possible equilibria, and compare the equilibria in terms of welfare and efficiency. The most interesting types of regimes are: those where patients and physicians exhibit predator-prey relationships and cyclic behaviors; and those where two attractive equilibria contemporary exists.

The policy implications of our findings are various. First, policy makers should consider the overall underlying dynamics of medical practices, malpractice litigation and clinical risk, rather than their irregular (and sometimes misleading) short-term trends. Second, because of eventual predator-prey relationships, clinical advances and legal reforms can have unexpected long-term consequences on the frequency of defensive medical practices and of malpractice claims. Third, increasing safety in clinical practice may increase the risk for doctors of being sued by patients when accidents occur. Fourth, perfect cooperation can be the optimal solution that maximizes the individuals' welfare, but this circumstance may not be reached without public intervention.

# Detecting Dynamic Structure. Independence, Structural Change and Deterministic Chaos

Manuel Ruiz, M. Victoria Caballero and Mariano Matilla

Universidad Politécnica de Cartagena, Universidad de Murcia and UNED

## Abstract

The technique of recurrence plots was proposed by Eckmann as a graphical tool to study the time dependence behavior of any time series without making any a priori assumption on the generator system. In order to quantify the most important features of a recurrence plot, Zbilut and Webber, and Marwan have, over the last ten years, developed *the Recurrence Quantification Analysis* (RQA) . For that, it is crucial to fix a real number e that introduces some noise in the analysis.

We propose the use of *symbolic recurrence plot* based on symbolic correlation integral as recurrence plot are based on correlation Integral. Nevertheless, this new tool doesn't need to fix a value $\epsilon$. Given a vectorial time series

$X = \{\bar{x}_t\}_{t \in I} \in \mathbb{R}^m$, he encoding provided by the symbolization map $s$ defined by

$$s : X \longrightarrow S_m$$

$$\bar{x} \to \pi$$

given by $s(\bar{x}) = \pi$ if and only if $\bar{x}$ is of $\pi$-type that is this symbol (permutation) $\pi$ gives the ordinal pattern of $\bar{x}$. Given the symbolization map $s$ we define t he indicator function

$$I(s(\bar{x}_t), s(\bar{x}_k)) = \begin{cases} 1 & \text{if } s(\bar{x}_t) = s(\bar{x}_k) \\ 0 & \text{otherwise} \end{cases}$$

For each value of $(t, k)$ in the plane we can represent $I(\cdot)$ with a coloured point when $I(s(\bar{x}_t),\ s(\bar{x}_k)) = 1$, each symbol a different colour). Then the indicator function $I(\cdot)$ informs about when the time series re-visit each one of $m!$ areas determined by $\binom{m}{2}$ hyperplanes and therefore it can be a useful tool to study the dynamic structure of the series.

We show examples of the usefulness of symbolic correlation integral and symbolic recurrence plots to detect periodicities, randomness, structural change or deterministic chaos. One of the main points is that we do not need to fix the noisy parameter $\epsilon$ as in classical correlation integral and classical recurrence plots.

# Can Exchange Rate Forecast Commodity Prices?

Marino Matilla-Garcia, R. Ledo and I. Arbués

## Abstract

We revisit the out-of-sample evidence of predictability of commodity prices using exchange rates. This problem has been analyzed by comparing univariate and bivariate models. With pairwise comparisons, the picture is not quite clear because some bivariate models are better that their univariate counterparts, but not all of them. We discuss how to combine these pairwise comparisons to arrive to a decision about the null hypothesis that one of the classes (univariate) has models at least as good as the best ones of the other (bivariate). We argue that there is no evidence that exchange rates anticipate the commodity prices.

Key words: Granger Causality; Out-of-sample forecast; Reality Check; Bootstrap.

# Extended Oligopolies with Contingent Workforce

Akio Matsumoto*, Ugo Merlone† and Ferenc Szidarovszky‡

* Department of Economics, Chuo University,
742-1, Higashi-Nakano, Hachioji, Tokyo 192-0393, Japan
† Department of Psychology, via Verdi 10, University of Torino, Torino, Italy, I 10124
Tel.: +39-011-6702027
Fax: +39-011-6702061
‡ Department of Applied Mathematics University of Pécs, Pécs, Ifúság u. 6 H-7624, Hungary.

## Abstract

In the oligopoly literature the introduction of modified cost functions has added reality into the classical analysis. In particular, some recent contributions analyzed oligopoly dynamics when considering production adjustment costs. Although this is a step in building more realistic models, adjustment costs may be different depending on the adjustment direction. In fact, when quantity decreases firms may decide to lay off workers; by contrast, when quantity increases new workers need to be hired and this entails searching and selection costs. In this paper, dynamic single-product oligopolies without product differentiation are first examined and then we study how this dynamics is affected by the gap between the adjustment costs.

JEL code: C72,C73.
Keywords: oligopolies, repeated games, complex dynamics.

# Time Elements and Oscillatory Fluctuations in the Keynesian Macroeconomic System

Hiroki Murakami*

Graduate School of Economics, University of Tokyo†

## Abstract

In this paper, we discuss the relationship between three time lags (the consumption lag, the investment decision lag and the gestation lag) and oscillatory economic fluctuations in the Keynesian IS-LM system. We first confirm that in the absence of time lags, the monotone convergence to the unique equilibrium is observed. Next, we demonstrate that, in the Keynesian IS-LM system, in the existence of the investment decision lag and the gestation lag, oscillatory fluctuations are generated around the equilibrium if the gestation lag is relatively long, while in the existence of the consumption lag and the gestation lag, oscillatory behaviors may not occur. Further, we show that the local asymptotic stability of the equilibrium is lost if the gestation lag is long enough. Consequently, we conclude that the existence of time lags may be one of the major causes of oscillatory fluctuations and instability in the macroeconomic system.

Keywords: Keynesian Economics, Delay Differential Equations, Oscillations, Time Lags

JEL Classifications: El2, E21, E22, E31, E32, E41, E44 fluctuations and instability in the macroeconomic system.

*e-mail: leafedclover@gmail.com

†7-3- 1 , Hongo, ilunkyo-ku, Tokyo 113-0033, Japan

# A Model for Long-run Index Return Predictability

Natascia Angelini*,Giacomo Bormetti†, Stefano Marmi‡ and Franco Nardini§

* School of Economics, University of Bologna, Viale Filopanti 5, 40126 Bologna, Italy
† Scuola Normale Superiore, P.zza dei Cavalieri 7, 56126 Pisa, Italy
‡ Scuola Normale Superiore, P.zza dei Cavalieri 7, 56/26 Pisa, Italy
§ Dept. of Mathematics, University of Bologna, Viale Filopanti 5, 40126 Bologna, Italy

## Abstract

The random walk model for stock prices is in good agreement with the essential unpredictability of the stock market in the short and medium run (say up to two years) and has been successfully applied to the option pricing problem. In the longer run things don't seem to stay the same. As early as 1998 Campbell and Shiller found statistical evidence "that long-horizon stock returns are highly forecastable". Since then may models have been proposed in which prices display some sort of mean reversion. Clearly what is at stake here is how to define the value about which the mean reversion is centered. A first solution may be to define a long term fundamental value towards which the price must sooner or later revert. A subtler approach maintains that investors perceive different fundamental values, depending on the prevailing market sentiment (see Biagini et al (2013) and de Grauwe and Kaltwasser (2012)). Obviously a mean reverting stochastic dynamics is not enough to generate stock prices which have a life of their own as, for instance, during the exceptional price boom in the late '90. They are not simply responding to earnings or dividends, nor does it appear that they are determined only by information about future. Typically momentum strategies generate these significant transitory components around the equilibrium.

We propose a model of the price dynamics in which the return depends on three components:
a) a momentum component, naturally justified in terms of agents' belief that expected returns are higher in bullish markets than in bearish ones;
b) a fundamental component proportional to the log EP ratio at time zero; the initial value of log EP ratio determines the reference growth level, from which the actual stock price may deviate as an effect of random external disturbances, and
c) a driving component ensuring the diffusive behavior of stock prices.
With a suitable choice of the parameters, the initial perception of the fundamental value is biased in the direction of the most recent performance of the market, i.e., if prices are high (low) the fundamental stock price is perceived to lie above (below) its true counterpart. However optimism (pessimism) does not last forever and within approximately eleven years it reverts to a value independent of the initial one and compatible with the long run mean observed by Shiller.

Under these assumptions, we are prove that, if we consider a sufficiently large number of periods, the expected rate of return and the expected gross return are linear in the initial time value of the log EP ratio, and their variance converges to zero with rate of convergence equal to minus one. This means that, in our model, the stock prices dynamics may exhibit significant and persistent upwards and downwards deviations from the long run mean value of the averaged earning-to-price ratio, nevertheless the averaged earning-to-price ratio is a good predictor of future long-run returns. The result holds for both returns and gross returns; in the latter case we assume that the log dividend-to-price ratio follows a stationary stochastic.

JEL classification: G 12 Keywords: Valuation Ratios, Long Run Stock Market Returns

# Growth and Public Debt

Kazuo Nishimura, Carine Nourry, Thomas Seegmuller and Alain Venditti.

## Abstract

We introduce the public debt in the simple framework of a Barro-type endogenous growth model. We assume that the utility function is homogeneous with a mild public good externality and thus decreasing returns. We consider that debt is a fixed proportion of GDP and that this proportion is used as a policy parameter by the government and discuss the effect of public debt on the endogenous growth rate and on the fluctuations of this growth rate.

# Employment Fluctuations and Signaling Dynamics in a Japanese New Graduates Job Markets

Yasuo Nonaka

College of Economics Kanto Gakuin University
E-mail nonaka@kanto-gakuin.ac.jp

## Abstract

This paper investigates how the new graduates' signaling behaviors affects the early job-leaving rate of themselves. To this end, we construct a simple model which explain the interaction between the employment level of new graduates and their early job leaving rate, in the other words, the retention rate of new graduates. Furthermore, we introduce a signaling dynamics to this model. The signaling level of new graduates depends on the effectiveness of their sign a ling behavior.

With some numerical experiments, this paper demonstrates following two results. First, if the signaling level is low, that is, less new graduates have engaged in signaling behaviors, the adjustment process does not converge to the stationary point. Then, the fluctuations of both employment level and the retention rate occurs. Second, signaling dynamics can stabilize the fluctuations of employment in a job market for university new graduates. The signaling level in present period depends on employment level in last period. In that case, if new graduates sending signal are employed by the firm with high probabilities, the signaling level increase and it stabilizes the fluctuations.

The results of this paper implies the evaluation of signal from firm's viewpoint is crucial to stabilize both the employment level of new graduates and their retention rate. If the firm states a policy to employ signaling graduates with precedence clearly, the signaling level of entire new graduates will increase. Then, employment level becomes stable and it leads to increment of the retention rate of new graduates. However, if the firm does not ensure the precedence to signaling graduates in employment, the signaling level and the retention rate decrease. These can be happened even in the case that the entire new graduates are homogeneous, that is the signaling behavior itself does not ensure each graduate's true type.

# How to Examine the Total Economic Impact, Stemmed from the Great East Japan Earthquake: within the Interregioal Input-Output Framework

Michiya NOZAKI

## Abstract

The purpose of this study is to examine the total economic impact caused by the Great East Japan Earthquake within the Interregional Input-Output Framework. The large amount of the study about the economic impact of the Great East Japan Earthquake on 11 March, 2011 has been estimated and evaluated the forward and backward, and the direct and indirect effects. Thus we have to examine the estimation of the stock damages and economic damages. In this study, the impacts from this event have spilled over from the damaged region to other regions, and the impacts have influenced the national economy as a whole. An extended Interregional Input-Output Table for Chubu region is composed of nine prefectures and the Rest of Japan. We intend to examine the total economic impact by the help of the Interregional Input-Output Analysis.

Keywords: total economic impact, Interregional Input-Output Analysis, the Great East Japan Earthquake.

# Chaotic Itineracy in Regional Business Cycle Synchronization

Kunihiko Esashi*
Department of Mathematics, Hokkaido University,
Kita 10 Nishi 8, Kita-ku, Sapporo, Hokkaido 060-0810, Japan.

Tamotsu Onozaki†
Faculty of Economics, Rissho University,
4-2-16 Osaki, Shinagawa, Tokyo 141-8602, Japan

Yoshitaka Saiki‡
Graduate School of Commerce and Management, Hitotsubashi University,
2-1 Naka, Kunitachi, Tokyo 186-8601, Japan

## Abstract

Chaotic itinerancy is complex behavior in high-dimensional dynamical systems characterized by itinerant motion among many different ordered states through chaotic transition. In this study, we robustly observe this behavior in a model of regional business cycles, in which all regions are homogeneous and connected through producers' adaptive behavior based on global information. Although producers adjust their output quite slowly toward the average level announced by the government, regional business cycles begin to synchronize from the entrainment effect. Moreover, the economy is more likely to exhibit chaotic itinerancy when the producers place greater importance on the expected profit maximization and when they adjust their expectations more slowly toward the average. It is also clarified that behind the dynamics of chaotic itinerancy exist cycles between periodic orbits with different unstable directions, which is called unstable dimension variability.

Key words: Regional business cycle, Nonlinear dynamics, Synchronization, Globally coupled map, Chaotic itinerancy, Riddled basin, Unstable dimension variability
JEL Classifications: C61, E32

*Present address: NTT DATA Corporation, Toyosu Center Building, 3-3-3 Toyosu, Koto-ku, Tokyo 135-6033, Japan.
†Corresponding author. Phone: +81-3-5487-3021. E-mail address: onozaki@ris.ac.jp.

# Dynamics of a Stock Market Involving Disequilibrium Trade

ANASTASIIA PANCHUK

Institute of Mathematics, National Academy of Sciences of Ukraine, Kyiv, Ukraine
e-mail: anastasiia. panchuk@gmail.com

## Abstract

In the present work we focus on pricing and trade dynamics for stock commodity markets. Dealing with flow markets one may define unique demand and supply functions, as well as their equilibria, as the commodities disappear in each period and then reemerge. On the contrary, a durable commodity (a stock) remains on the market to the next period and may just change owner through exchange. However, such a redistribution modifies demand and supply functions, and hence the possible equilibrium state to which a dynamic process may be heading. Thus, such processes are provided with memory of the actual exchange history, and are entirely different from the familiar flow market dynamics. As a result, in stock markets a so-called disequilibrium trade may also occur which should be taken into account. As an example, one may think about the housing markets, being subjected to certain instabilities recently, which is usually explained in terms of speculative bubbles. However, unlike stock exchange, the housing market seems to be dominated by people who use houses and apartments just as habitations. No doubt there exists some speculation through the intervention of real estate dealers, but, there are other issues at work which may explain at least some of the phenomena without reference to speculation. For instance, constant changes in the housing market due to demographical factors, including (im)migration, and trade in disequilibrium states. Using a simplified case with only two traders of two stock commodities, and focusing on pure trade, it is possible to specify the exact conditions for making a deal in each step of the dynamic process. As a result, the trajectory may end up in one of the map equilibria (which are infinitely many), or trade can stick in some disequilibrium point while complex, even chaotic, price dynamics goes on.

# Monetary Feedback Rules in Pure Exchange Overlapping Generations Models: Local and Global Analysis

Ahmad Nailnzada[*1], Nicolò Pecora[†2] and Alessandro Spelta[‡3]

[*] Dept. of Economics, Quantitative Methods and Management,
University of Milano - Bicocca, Milano, Italy
[†] Dept. of Economics and Social Science, Catholic University, Piacenza, Italy
[‡] Dept. of Economics and Finance, Catholic University, Milano, Italy

## Abstract

Equilibrium models are appealing tools to understand economic environment and to provide a framework to design (possibly) successful economic policies. In this sense, such a models are especially useful when they provide unique policy prescriptions for specified policy targets. But very often such a models exhibit multiple equilibria and, as a consequence, different policy prescriptions. Policies targeted to stabilization purposes, such as inflation stabilization policies, often present this kind of drawback.

This paper considers a pure exchange overlapping generations model in which the money growth rate is endogenous and follows a feedback rule. In particular, we identify a mean of stabilization for inflation dynamics through the adoption of an endogenous feedback rule for money supply and show the conditions under which the economy can settle down to the monetary equilibrium. We consider different specifications for the monetary policy rule, namely a so-called current, forward or backward looking feedback rule, depending on whether the monetary authority uses the actual, expected or last observed values of inflation to set the monetary policy. The adoption of an endogenous monetary policy may lead to the occurrence of multiple monetary equilibria: hence we focus on the question of whether the target equilibrium is locally stable (and eventually unique) and how the policy parameters can affect the nature of their basins of attraction Hence, we study how the responsiveness of the policy rule with respect to inflation affects the stability of the target monetary equilibrium. Focusing on the question of whether the monetary equilibrium is a locally stable equilibrium, we show how positive or negative, active or passive feedback rules can lead to different outcomes in terms of inflation stabilization objective.

[*]Piazza Ateneo Nuovo 1, 20126, Milano. ahmad.naimzada@unimib.it
[†]Via Emilia Parmense 84, 29100, Piacenza. nicolo.pecora@unicatt.it
[‡]Largo Gemelli 1, 20100, Milano. alessandro.spelta@unicatt.it

# An Evolutive Financial Market Model: Imitation and Endogenous Fundamental Values

Ahmad Naimzada* and Marina Pireddu†

* Dept. of Economics, Management and Statistics, University of Milano-Bicocca,
U6 Building, Piazza dell'Ateneo Nuovo 1, 20126 Milano, Italy.
E-mail address: ahmad.naimzada@unimib.it
† Dept. of Mathematics and Applications, University of Milano-Bicocca,
U5 Building, Via Cozzi 55, 20125 Milano, Italy. E-mail address: marina.pireddu@unimib.it

## Abstract

Following the line of research started in Naimzada and Pireddu (2015), in this talk we propose a financial market model with heterogeneous speculators, i.e., optimistic and pessimistic fundamentalists, that respectively overestimate and underestimate the true fundamental value due to ambiguity, which prevents them from relying on the true fundamental value in their speculations. Indeed, we assume that agents use in its place fundamental values determined by an imitative mechanism. The papers in the related financial market literature on belief biases that bear more resemblance to ours are those by De Grauwe and Rovira Kaltwasser (2012) and by Naimzada and Pireddu (2014a), even if crucial differences are also present. More precisely, in De Grauwe and Rovira Kaltwasser (2012) both the optimistic and pessimistic belief biases and the perceived fundamental value are exogenously determined, while in Naimzada and Pireddu (2014a) the agents perceive an endogenous fundamental value. Differently from those papers, in the present model even the belief biases are not exogenous, but are rather determined by an imitative process. Namely, in forming their beliefs, speculators consider the relative ability shown by optimists and pessimists in guessing the realized stock price and update their fundamental values proportionally to such criterion. This kind of updating mechanism bears resemblances to the so-called "Proportional Imitation Rules" in Schlag (1998). Moreover, differently from the majority of the literature on the topic and similarly to Naimzada and Pireddu (2014b), the stock price is determined by a nonlinear Walrasian mechanism that prevents divergence issues. With respect to Naimzada and Pireddu (2015), two are the main innovations. First, the updating mechanism for the determination of the fundamental value for optimists and pessimists is no more based on the relative profits realized by the two groups of agents, but rather on their ability in guessing the realized stock price. Second, we do not assume anymore that the two group sizes are fixed, but we now investigate the consequences of heterogeneity from an evolutionary viewpoint, introducing an endogenous switching mechanism, so that agents may not only update their fundamental values according to the relative ability shown by optimists and pessimists, however still remaining optimists and pessimists, but can also switch to the other group of speculators, if they performed better in terms of relative profits. In particular, the switching process is for us described by the logit mechanism in Brock and Hommes (1997), used also in De Grauwe and Rovira Kaltwasser (2012), so that when we make our parameters related to imitation vanish we enter the framework in De Grauwe and Rovira Kaltwasser (2012), except for the presence of our nonlinear price adjustment mechanism which replaces the linear price equation in De Grauwe and Rovira Kaltwasser (2012). When instead those parameters are nonnull, the fundamental values are for us no more constant and we generalize the setting in De Grauwe and Rovira Kaltwasser (2012), with the only exception of our nonlinear price equation. For our model we study, via analytical and numerical tools, the stability of the unique steady state, its bifurcations, as well as the emergence of complex behaviors. We also investigate multistability phenomena, characterized by the presence of coexisting attractors.

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# Hotelling Duopoly Revisited

Tönu Puu

CERUM, Umea University, SE-90 1 87 Umea, Sweden

## Abstract

The enigmatic Hotelling model of duopoly on a fixed line interval appeared in 1929 [2]. In a sense it was the first well structured case of Bertrand oligopoly [1], as heterogeneity of a physically homogenous good was obtained through spatial separation of suppliers and accrued transportation costs.

Unfortunately, Hotelling only analyzed the case where demand was totally inelastic, which resulted in the paradox that both competitors would crowd in the centre. Yet, Hotelling himself in his verbal discussion stated that the paradox would disappear if demand were elastic - there would remain a tendency to gravitate towards the centre, rather than locating at the socially optimal quartiles, though without crowding.

It is a bit surprising that Hotelling did not follow this track . Perhaps he too was as struck by the attraction of paradox, like following authors and so wanted to emphacise this case. There is an immense literature in his aftermath. Unfortunately, citation databases do not extend as far back as to 1929, so it is difficult to give an exact estimate.[1]

Analytically, the crowding version of the model is problematic, and even self-contradictory. With location in the same point, the space Hotelling introduced disappears , and we are back at the problems pointed out by Bertrand [1]. The consumers choose the lowest delivered price, which creates the market areas , but yet each customer buys one unit of commodity, no matter what the price is.

Lerner and Singer in 1937 [3] , provided the first proof that the crowding paradox evaporated, even if one only assumed the consumers to have a reservation price ; if delivered price was higher they would buy nothing, otherwise just one unit as in the original model. The contribution is still most enjoyable through its ingenious use of graphic argument . Very soon after, Smithies 1941 in two articles, [4] , [5] put up the problem with a linear downsloping demand function, which seems to correspond to what Hotelling had in mind. However, Smithies claimed that the integrals were too complicated to evaluate. So it was left to the present author as late as in 2002 [6] to carry out the formal analysisof Smithies ' s case. Dependent on the parameter values (elasticity of demand, transportation rate, unit production cost ) three outcomes were possible:

1) Disjoint monopolies.

2) Genuine duopoly.

3) Cutting out monopoly.

The first case, occurring when transportation costs are so high that the competitors can locate so widely apart that demand goes to zero before they reach eachother's territories , is not very interesting. The third case is still ill structured, as all cases of price war, so still needing a truly convincing layout . The second case, however is genuine duopoly, well structured, and worthy closer study. In [7] professor Laura Gardini and the present author studied the dynamics this genuine duopoly case. The dynamics turned out to be very simple; just a contraction to equilibrium with locations separated in space, not quite at the quartiles, but not crowding in the middle either - quite as conjectured in Hotelling' s original article.[2]

[1] No doubt the paradox created the popularity. Scientists replaced distance by just similarity in some vague sense for competing products or even for political opinions, all with doubtful measurability. Such vague analogies deprive a scientific model of its qualification as science. Further, to escape some consequences of the paradox, the unrealistic and contrived idea of quadratic transportation costs was launched and became popular.[8]

[2] However, the analysis (without motivation) assumed that the competitors shared the market as a duopoly in a common boundary point, and that in the other ends each market extended to the boundary points of Hotelling's fixed interval.

In a communication to the present author Dr. Helge Sanner pointed out that the last may not be true - the competitors might also end the markets where local demand dropped to zero. Unfortunately the present author has not been able to locate any publication by Dr. Sanner to cite on this.

Further thought, however, indicates that this case would never happen. If one endpoint only extends to the point where demand vanishes, the competitor in question would always profit from moving its location until an endpoint of the fixed interval is reached. This is because greater spatial symmetry of the market resulting from this always increases profit.

It yet remains to formulate the entire model under elastic demand and to consider its global dynamics . To provide a basis for such is the exact purpose of this contribution. Further some interesting extensions of the model, such as different adjustment time scales for choices of mill price and location , the latter possibly connected to installed capital and its depreciation, and, of course, extension to the full two dimensions of geographical space will be indicated.

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# An Evolutionary Cournot Model with Heterogeneous Firms

Gian Italo Bischi*[1] Fabio Lamantia†[2] and Davide Radi‡[3]

* DESP, University of Urbino "Carlo Bo ", Urbino, Italy
† DESF, University of della Calabria, Rende, Italy
‡ Department of Management, Marche Polytechnic University, Ancona, Italy

## Abstract

In this paper we analyze a dynamic game of Cournot competition with heterogeneous firms choosing between different production strategies. The underling oligopoly structure is standard: $N$ firms produce homogeneous goods which are sold in a market characterized by a single representative consumer. The model is first considered with exogenously fixed fractions of firms in the two complementary groups. Then it is generalized by considering an endogenous evolutionary switching process between the two behavioral strategies based on profit-driven replicator dynamics. The role of the number of firms, information costs and inertia (or anchoring attitude) in production decisions is analyzed, as well as the influence of random noise in demand function and memory of past profits in the evolutionary process. Moreover, some global properties of the oligopoly with evolutionary pressure between behavioral rules are discussed, with particular respect to cases in which the Nash equilibrium is unstable.

JEL classification: C73, D83, L13.
Keywords: Oligopolies; Local Monopolistic Approximation; Evolutionary dynamics; Heterogeneous Strategies; Nonlinear phenomena.

*gian.bischi@uniurb.it
†lamantia@unical.it
‡d.radi@univpm.it

# Complexity and Behavioral Economics

Barkley Rosser Jr.

James Madision Univerisy

## Abstract

This paper will consider the relationship between complexity economics and behavioral economics. A crucial key to this is to understand that Herbert Simon was both the founder of explicitly behavioral economics as well as one of the early developers of complexity theory. Bounded rationality was essentially derived from Simon's view of the impossibility of full rationality on the part of economic agents. Modern complexity theory through such approaches as agent-based modeling offers an approach to understanding behavioral economics by allowing for specific behavioral responses to be assigned to agents who interact within this context, even without full rationality. Other parts of modern complexity theory are considered in terms of their relationships with behavioral economics. Fundamentally, complexity provides an ultimate foundation for bounded rationality and hence the need to use behavioral economics in a broader array of contexts than most economists have thought appropriate.

# The Generation of SAO and LAO in Kaldor Model under Stochastic Perturbation

Tatyana Ryazanova* and Lev Ryashko†

Ural Federal University (Russia)
* tatyana.r:yazanova@urfu.ru
† lev.r:yashko@urfu.ru

## Abstract

We consider the business cycle Kaldor model [1] forced by random noise

$$\dot{Y} = \alpha(I(Y,K) - S(Y,K)) + \epsilon_1 \dot{W}_1,$$
$$\dot{K} = I(Y,K) - \delta K + \epsilon_2 \dot{w}_2,$$

where $w_i$ are standard Wiener processes, and $\epsilon_i$ are noise intensities.

A full parametrical analysis of the deterministic system is carried out and zones of coexisting stable equilibrium and stable limit cycle are found. In these zones, noiseinduced transitions between these attractors are studied using stochastic sensitivity function technique and confidence domains method. Critical values of noise intensity corresponding to noise-induced transitions "equilibrium→cycle" and "cycle→equilibrium" are estimated. Dominants in combined stochastic regimes are discussed [2].

In zones with the only stable equilibrium, a phenomenon of the transition from small amplitude oscillations (SAO) to large amplitude oscillations (LAO) is discussed. Additionally, in the zones with the only one stable limit cycle, we show the phenomenon of suppression of LAO by random perturbations.

We study probabilistic properties of stochastic attractors using method of confidential domains based on the stochastic sensitivity functions technique [3] and numerical methods .

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# Chaos in Duopoly Pricing: A Reexamination with Time Delays

Luca Gori*, Luca Guerrini† and Mauro Sodini‡

## Abstract

This paper revisits the classical work of Puu (1991) by gathering two distinct aspects of the functioning of markets: production of goods requires time and it is subject to some gestation lags but exchanges take place continuously in the market. Therefore, the dynamics in our duopoly is characterised by a two-dimensional system of differential equations with discrete time delays. We show the existence of Hopf bifurcation and detect how time delays and inertia affect the stability of the system by using stability crossing curves. The study of oligopoly dynamics is the object of growing body of studies led by Puu (1991) and Bischi et al. (1998). Both works take into account discrete time repeated duopolies with quantity setting firms. They show that endogenous fluctuations and complex dynamics may emerge in a simple market with two firms that strategically interact between each other. The former paper actually represents a cornerstone in the related literature and it is characterised by the hypothesis of players with complete knowledge of the market (full information). They choose the quantity that should be produced in the subsequent period by following the best reply dynamics with static expectations. This means that every firm is profit maximiser and in each period, it expects that the rival will produce the quantity produced and sold in the previous period. The latter paper concentrates on the analysis of the behaviour of quantity-setting firms with limited information. Indeed, the efficient use of the set of available information of economic agents (firms, consumers and so on) does represent a strong assumption given the high costs related to that kind of behaviour. The main aim of that work then was to question the rational expectation paradigm by showing that fluctuations and dynamics that are more complex may emerge endogenously because of the existence of heterogeneous interacting agents that adopt some behavioural rules to overcome their informational lacunae and choose production period by period. Both works share the assumption that the timing of production coincides with the timing of trading in the market, and the discrete time framework may partially well capture the. However, it is reasonable to consider that actual oligopoly markets gather two distinct aspects of the functioning of this kind of economies: production of goods requires time and it is subject to some gestation lags but trading takes place continuously. In this work, we explicitly model this aspect.

Keywords Chaos; Cournot duopoly; Stability crossing curves; Time delays

JEL Codes C62; D43; L13

*Department of Law, University of Genoa, Via Balbi, 30/19, I-16126 Genoa (GE), Italy
e-mail: mailto:luca.gori@unige.it or mailto:dr.luca.gori@gmail.com
tel.: + 39 010 209 95 03 ; fax: + 39 010 209 55 36

†Department of Management, Marche Polytechnic University, Pia:zza Martelli 8, I-60121, Ancona (AN), Italy
e-mail: mailto:luca.guerrini@univpm.it
tel.: + 39 071 22 07 055.

‡Department of Economics and Management, University of Pisa, Via Cosimo Ridolfi, 10, I-56124 Pisa (PI ), Italy
e-mail: mailto:mauro.sodini@unipi.it
tel.: + 39 050 22 16 234; fax: + 39 050 22 10 603

# The multiplier-accelerator interaction and the financial system

Serena Sordi and Alessandro Vercelli

Department of Economics and Statistics University of Siena Siena, Italy

## Abstract

We develop a simple behavioural macrodynamic model in continuous time with the purpose of investigating possible channels of interaction between the real economy and the stock market. Our starting point is the model developed by Westerhoff (2012) where such an interaction is formalised in the simplest possible way by assuming, first, with regard to the real side of the model, that aggregate demand in the goods market depends both on national income and on the stock price and that there is a one-period time-lag between aggregate demand and production. Second, with regard to the financial side, that the dynamics of the stock price is determined by the behaviour of two heterogeneous groups of investors ('chartists' and 'fundamentalists') who share their perception about the fundamental value of the stock price which is expected to be proportional to national income. The two groups of investors however crucially differ in their expectations about the behaviour in time of the stock price, chartists believing in the persistence of 'bull and bear markets', fundamentalists in a return of the stock price toward its fundamental value. In addition, fundamentalists are assumed to use a nonlinear trading rule such that the larger the mispricing, the more they become aggressive. By using both analytical analysis and numerical simulations, Westerhoff shows that these assumptions are such as to generate complex dynamics of both national income and stock price. In the paper we rewrite the model in continuous time and show, as expected, that in this case the dynamics it generates are much simpler and not persistent. We then consider a more general version of the model which we obtain as a result of an attempt to enrich the specification of the real side of the model. First, as suggested by Westerhoff himself, we enrich the specification of aggregate demand by assuming that investment is determined by the accelerator principle. Second, we enrich the disequilibrium character of the model by assuming that the accelerator principle only determines the desired level of investment and that effective investment adjusts to it with a distributed time-lag. Third, we introduce into the model the nonlinear accelerator. The resulting highly nonlinear, first order 3x3 system is shown to generate various dynamic regimes, among which chaotic dynamics and the coexistence of periodic attractors with interesting economic implications.

# Dynamics of a Two-Country New Economic Geography Model with Four Regions with four regions

Iryna Sushko*,Pasquale Commendatore†,
Ingrid Kubin‡ and Pascal Mossay§

* lnstitute of Mathematics, NASU , Kyiv, Ukraine,
† University of Naples 'Federico II', Italy,
‡ Vienna University of Economics and Business Administration, Austria,
§ Newcastle University, UK, and CORE, Belgium

## Abstract

The NEG approach originates from Krugman's seminal contribution [1], where he put forward the well-known Core-Periphery (CP) model. This model describes an economy composed of two symmetric/identical regions and two productive sectors: agriculture and manufacturing. The footloose entrepreneurs (FE) model [2] is a variant of the CP model. Both CP and FE models were originally framed in continuous time. In [3] discrete time versions of the CP and FE models are presented, showing that while preserving many of the most interesting features of their continuous time counterparts they possess additional properties such as chaotic dynamics, multiple attractors, agglomeration via volatility, etc. One of possible directions of further research is related to a two-country four-region NEG model [4]. Basic ingredients of this model are the following. There are two countries (Home and Foreign) each of which has 2 regions. Each country comprises one border region and one interior region: Regions 1 and 2 compose Country 1 (Home) and Regions 3 and 4 compose Country 2 (Foreign). Both countries have the same number of mobile entrepreneurs $E = 2$; Each region is endowed in $L = 4$ unskilled labor. The interior regions only trade with the border region in the same country, whereas the border regions trade also with the border region in the other country. There are no direct links between the two interior regions (and also no indirect links via the two border regions). Entrepreneurs are only mobile within each country, but not internationally; mobility depends upon the indirect utility enjoyed in the region of location. In [4] we consider both countries as symmetric, i.e., interior trading costs are the same. In the present paper we extend this model in several directions, namely, we consider a non symmetric case (different interior trading costs), and we allow trade between any regions, as well as different migration speed in home and foreign countries. The model is defined by an 8-parameter family of two-dimensional piecewise smooth noninvertible maps. We investigate bifurcation structure of the parameter space and describe typical bifurcation sequences observed in the model under variation of some parameters. Various types of attractors (including attractors in Milnor's sense) and their basins are also discussed.

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# Nonlinear Cobweb Model with Production Delays*

Akio Matsumoto† and Frenc Szidarovszky‡

## Abstract

We study the effects of production delays on the local as well as on global dynamics of nonlinear Cobweb model in a continuous-time framework. After reviewing a single delay model, we proceed to two models with two delays. When the two delays are used to form an expected price or feedback for price adjustment, we have a winding stability switching curve and in consequence, obtain repetition of stability losses and gains via Hopf bifurcation. When the two delays are involved in two interrelated markets, we find that the stability switchings occur on straight lines and complicated dynamics can arise in unstable markets.

Keywords: Continuos-time Cobweb model, Nonlinear price dynamics, Production delay, Stability switching, Hopf bifurcation

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†Professor, Department of Economics: Senior Researcher: International Center for further Development of Dynamic Economic Research: Chuo University, 742-1, Higashi-Nakano, Hachioji. Tokyo, 192-0393, Japan: akiom@tamacc.chuo-u.ac.jp

‡tprofessor, Department of Applied Niathematics, University of Pees: Ifjusag, u. 6, H-7624, Pees, Hungary; szidarka@gmail.com

# Unbalanced Growth in A Neoclassical Two-sector Optimal Growth Model with Sector Specific Technical Progress: A Turnpike Approach

Harutaka Takahashi

Department of Economics Meiji Gakuin University

## Abstract

We will study the unbalanced growth in a neoclassical two-sector optimal growth model with sector specific technical progress and will demonstrate the existence and the saddle-point stability of the optimal steady state (OSS) in the efficiency-unit. By so doing the efficiency-unit OSS paths will exhibit the unbalanced growth in terms of the original-unit; each sector will grow at its own growth rate. Furthermore the growth rate of the aggregated output (GDP) will converges to the one of the sector with the higher technical progress. This result exhibits a sharp contrast to the well-known result by Baumol. (95 words)

JEL Classification:O14,O21,O24,O41

# The Optimum Quantity of Debt for Japan*

Tomoyuki Nakajimat† and Shuhei Takahashi‡

Preliminary and Incomplete

## Abstract

Japan's net government debt reached 130% of its GDP in 2013. This paper calculates the optimum amount of debt for Japan and the welfare loss that the current debt generates. We calibrate the model of Aiyagari and McGrattan (1998) to Japan's economy. We find that under the baseline parameterization, the welfare-maximizing level of debt is zero, i.e., 0% of GDP. The current level of debt incurs the average welfare cost that is 0.04% of the optimal consumption, whereas the cost is 0.6% for households with no wealth. However, if the interest rate increases by one percentage point from the baseline case, the optimal debt becomes -200% of GDP. The average welfare cost of the current debt increases to 0.9% of the optimal consumption, while the cost is 6.1% for households with zero wealth.

Keywords: Government debt, Japan, incomplete markets

JEL classification: E62 , H63

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†institute of Economic Research, Kyoto University, Yoshida-Honmachi, Sakyo-ku, Kyoto 606-8501, Japan.
‡Institute of Economic Research, Kyoto University, Yoshida-Honmachi, Sakyo-ku, Kyoto 606-8501, Japan.

# Two Time Lags in the Public Sector: Macroeconomic Stability and Complex Behavior

Eiji Tsuzuki

Chiba Keizai University, Chiba, Japan

## Abstract

Recently, many studies have examined the effects of time lags on macroeconomic stability using traditional Keynesian models. Asada and Yoshida (2001) introduce a fixed government expenditure lag into the Kaldorian model proposed by Chang and Smyth (1971). This study develops a Kaldorian model that considers two time lags in the public sector—a government expenditure lag and a tax collection lag—and examines the effects of these lags on local stability of the steady state. Sportelli, Cesare, and Binetti (2014) also propose a macrodynamic model with two time lags in the public sector, but they use the dynamic IS-LM model. In addition, we perform a stability analysis employing a mathematical method developed by Gu et al. (2005). This method enables us to present an exact figure of a stability crossing curve—a curve that separates stable and unstable regions on a parameter plane. Few studies have employed this method for economic analysis. We demonstrate that a tax collection lag can have a stabilizing effect on the steady state. We also develop an analysis of global dynamics to demonstrate that an increase in a tax collection lag can yield complex behaviors.

# Does High-Frequency Trading Improve Market Quality?

Ryuichi Yamamoto[a*]

[a] Department of Political Science and Economics, Waseda University, Tokyo 169-8050, Japan

## Abstract

Upon the advancement of computer technology, major stock exchanges have developed an automated order-matching platform that has facilitated order acceptance notices as well as information distribution of transaction prices and quotes to stock traders. In response to the introduction of the computerized platform, high-frequency (hereafter HF) trading has been popular in recent stock trading. HF traders conduct stock trading with its programmed computer system, which quickly implements trading decisions. On the other hand, we observed a considerable price drop by almost 10% within 15 minutes before rebounding in e-mini S&P 500 futures market on May 6, 2010, which is so-called the Flash Crash. Some claimed that HF traders liquidated their positions and exacerbated the downturn, and thus they are a new source of market fragility. The market crash with the growing and substantial use of HF trading has let researchers, regulators, and practitioners to hotly debate the impact of HF trading on the market quality. Does HF trading make stock markets more fragile or robust? Does it foster price discovery and liquidity of the market? How about the impact on welfare in the economy? If the HF trading has negative effects on the economy, what regulations the policy makers should impose on HF trading? This study provides possible answers on these questions by proposing a simple agent-based model with HF and non-HF traders. HF traders can revise the quotes of their limit orders at a faster rate than slower traders after the arrivals of fundamental news. Thus, HF traders can avoid a picking-off risk. Furthermore, HF traders have a chance to pick off limit orders placed by slower traders and make a profit, and thus slower traders may incur a loss from the picking-off risk. We evaluate benefits and costs of HF trading by investigating the impacts on price discovery, liquidity, volatility, and welfare. We demonstrate under which conditions HF trading benefits and costs the market. For a case that the HF trading negatively contributes to the market, we suggest that transaction tax, cancellation fee, and speed limit of routing orders are the possible policy choices for mitigating the negative impact.

*Email address: ryuichi@waseda.jp (R. Yamamoto)

# The Stability of Normal Equilibrium Point and the Existence of Limit Cycles in a Simple Macrodynamic Model of Monetary Policy

Rudolf Zimka and Toichiro Asada

## Abstract

In the contribution a two-dimensional model of monetary policy, describing the development of the nominal rate of interest and the expected rate of inflation is analyzed. In the first part of the contribution conditions for the existence of a normal equilibrium point of the model are found and its stability is investigated. In the second part of the contribution questions concerning the existence of limit cycles around the normal equilibrium point are studied. The bifurcation equation is derived. The formulae for the calculation of its coefficients are gained. An economic interpretation of the gained results is given. A numerical example is presented.

# List of Participants

## Presenting a paper

| NAME | AFFILIATION | E-MAIL ADDRESS |
|---|---|---|
| Ken-lchi, Akao | Waseda University, 1-6-1 Nishiwaseda Shinjuku Tokyo, 169-8050, Japan | akao@waseda.jp |
| Yoshiyuki, Arata | Research Institute of Economy, Trade and Industry(METI), 11th floor Chiyoda-ku, Tokyo, 100-8901, Japan | yoshiyuki0325@yahoo.co.jp |
| Gain-ltalo,Bischi | University of Urbina "Carlo Bo", via Saffi 42, Italy | gian.bischi@uniurb.it |
| Volker, Böhm | Bielefeld University, POB 100131, 33501 Bielefld, Germany | vboem@wiwi.uni-bielefled.de |
| Giovanni, Campisi | Marche Polytechnic University, Piazzale Martelli 8, Italy | giovannicampisi6@gmail.com |
| Gustav, Feichtinger | University of Technology, Vienna, Austria | gustav@eos.tuwien.ac.at |
| Alessandro, Fiori Maccioni | University of Sassari, Department of Economics & Business, Italy | alex.fiori.maccioni@gmail.com |
| Ryoji, Hiraguchi | Chiba University, 1-33, Yayoicho, Inage, Chiba, Japan | ryojih@chiba-u.jp |
| Cars, Hommes | University of Amsterdam, the Netherlands | C.H.Hommes@uva.nl |
| Daivd, Goldbaum | University of Technology Sydney, 15 Broadway, Utlimp NSW 2007, Australia | david.goldbaum@uts.edu.au |
| Luca, Gori | University of Genoa, Via Balbi, 30/19, Italy | luca.gori@unige.it |
| Xue-Zhong (Tony), He | University of Technology Sydney, Business school,POBOX 123, Broadway, Australia | tony.he1@uts.edu.au |
| Weihong, Huang | Nanyang Technological University, 14 Nanyang Drive, Singapore | awhhuang@ntu.edu.sg |
| Yosuke, Kimura | Graduate school of economics, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, Japan | y.kimura1009@gmail.com |
| Hiroshi, Kokubo | Kyoto University, Japan | kokubu@math.kyoto-u.ac.jp |
| Kai, Li | University of Technology, Sydney, POBOX 123 Broadway, NSW 2007, Australia | KAI.LI@uts.edu.au |
| Mariano, Matilla-Garcia | UNED, Paseo Senda del Rey, 11. Fac Economicas Empresariales, Spain | mmatilla@cee.uned.es |
| Ugo, Merlone | University of Torino, Italy | ugo.merlone@unito.it |
| Hiroki, Murakami | University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Japan | leafedclover@gmail.com |
| Franco, Nardini | Department of Mathematics, Piazza di Porta San Donato 5, Italy | franco.nardini@unibo.it |
| Kazuo, Nishimura | Research Institute for Economics and Business Administration Kobe University, 2-1, Rokkodai-cho, Nada-ku, Kobe, 657-8501, Japan | nishimura@rieb.kobe-u.ac.jp |
| Yasuo, Nonaka | College of Economics Kanto Gakuin University, 1-50-1 Mutsuura-Higashi, Kanazawa-Ku, Japan | nonaka@kanto-gakuin.ac.jp |
| Michiya, Nozaki | Gifu Economic University, Japan | michi post@kfx.biglobe.ne.jp |
| Tamotsu, Onozaki | Faculty of Economics Rissho University, Osaki 4-2-16, Shinagawa-ku, Japan | onozaki@ris.ac.jp |

| NAME | AFFILIATION | E-MAIL ADDRESS |
|---|---|---|
| Anastasiia, Panchuk | Institute of Mathematics, National Academy of Sciences, Ukraine, Tereshchenkivska str., 3 | anastasiia.panchuk@gmail.com |
| Nicolo, Pecora, | Catholic University, Via Emilia Parmense, 84, Piacenza, Italy | nicolo.pecora@unicatt.it |
| Marina, Pireddu | University of Milano-Bicocca, Dept. of Mathematics and Applications, U5 Building, Via Cozzi 55, 20125 Milano, Italy | marina.pireddu@unimib.it |
| Davide, Radi | Marche Polytechnic University, Piazzale Martelli, 8, Italy | d.radi@univpm.it |
| Barkley, Rosser | James Madison University, USA | rosserjb@jmu.edu |
| Manuel, Ruiz Marfn | Universidad Politecnica de Cartagena, Calle Real 3, Edificio Cim, Spain | manuel.ruiz@upct.es |
| Tatyana, Ryazanova | Ural Federal University, Russia, Ekaterinburg, Mira str, 19 | tatyana.ryazanova@urfu.ru |
| Mauro, Sodini | University of Pisa, Via Cosimo Ridolfi, 10, Italy | mauro.sodini@unipi.it |
| Serena, Sordi | Department of Economics and Statistics, University of Siena, Piazza San Francesco 7, 53100 Siena, Italy | serena.sordi@unisi.it |
| lryna, Sushko | Institute of Mathematics, National Academy of Sciences of Ukraine, 3, Tereshchenkivska st., Ukraine | sushko@imath.kiev.ua |
| Ferenc, Szidarovszky | University of Pees, Hungary | szidarka@gmail.com |
| Harutaka, Takahashi | Meiji Gakuin University, 1-2-37 Shirokanedai, Minato-ku, Tokyo, Japan | haru@eco.meijigakuin.ac.jp |
| Shuhei, Takahashi | Institute of Economic Research, Kyoto University, Yoshida Honmachi Sakyo-ku, Japan | takahasi@kier.kyoto-u.ac.jp |
| Eiji, Tsuzuki | Chiba Keizai University, 3-59-5 Todoroki-cho, Inage-ku, Chiba, Japan | tsuzukie5@gmail.com |
| Puu, Tönu | University of Umea, Sweden | tonu.puu@umu.se |
| RyuichiYamamoto | Waseda University, Department of Political Science and Economics, 1-6-1 Nishiwaseda, Shinjuku-ku, Japan | ryuichi@waseda.jp |
| Rudolf, Zimka | Faculty of Economics, Matej Bel University, Tajovskeho 10, 975 90, Banska Bystrica, Solovak Republic | rudolf.zimka@umb.sk |

# Participation Only

| NAME | AFFILIATION | E-MAIL ADDRESS |
|---|---|---|
| Toshio, lnaba | Waseda University, 1-6-1 Nishiwaseda Shinjuku-ku, Japan | inaba@waseda.jp |
| Miki, Kobayasi | Rissho University, Japan | miki@wpi-aimr.tohoku.ac.jp |
| Makoto, Okamura | Hirosima University | andrew-uf@galaxy.plala.or.jp |
| Yoshitaka, Saiki | Graduate School of Commerse and Management, Hitotsubashi University, Naka 2-1, Kunitachi, Tokyo, Japan | yoshi.saiki@hit-u.ac.jp |

# Local Organizers

| NAME | AFFILIATION | E-MAIL ADDRESS |
|---|---|---|
| Toichiro, Asada | Chuo University, Japan | asada@tamacc.chuo-u.ac.jp |
| Toshiharu, Ishikawa | Chuo University, Japan | ishiychuo2@aol.com |
| Masaaki, Kijima | Tokyo Metropolitan University | kijima@tmu.ac.jp |
| Akio, Matsumoto | Chuo University, Japan | akiom@tamacc.chuo-u.ac.jp |
| Hirokazu, Takizawa | Chuo University, Japan | hirokazu.takizawa@gmail.com |
| Masahiro, Yabuta | Chuo University, Japan | yabuta@tamacc.chuo-u.ac.jp |

# Snapshots

# from the Conference