



Nonlinear Economic Dynamics 2023

In memoriam J. Barkley Rosser Jr.

June 19-21, 2023

UiA, Kristiansand, Norway

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Nonlinear Economic Dynamics (NED)

The NED conference series aims at facilitating the interdisciplinary exchange among economists and mathematicians interested in current developments in nonlinear economic dynamics.

The *bi*-annual conference originated in Odense (Denmark, 2002, 2003). Subsequent venues included Tokyo (Japan, 2004), Urbino (Italy, 2005), Bielefeld (Germany, 2007), Jönköping (Sweden, 2009), Cartagena (Spain, 2011), Siena (Italy, 2013), Tokyo (Japan, 2015), Pisa (Italy, 2017), Kyiv (Ukraine, 2019), and Milano (Italy, 2021).

The main topics of the conference comprise complex processes in economics and finance modeled by nonlinear dynamical systems; evolutionary game theory; dynamics of systems with adaptive expectation, social interaction, learning mechanisms, heterogeneous agents; behavioral economic models, models of structural change and growth, models of new economic geography.

NED2023

This year's conference takes place at the University of Agder (UiA) in Kristiansand Norway. It specifically features the interaction between economic and environmental dynamics.

The conference is dedicated to the late **John Barkley Rosser Jr.**

Scientific committee

| | | |
|--------------------|--------------------|----------------|
| Gian Italo Bischi | Herbert Dawid | Laura Gardini |
| Luca Gori | Xuezhong (Tony) He | Cars Hommes |
| Jochen Jungeilges | Ingrid Kubin | Akio Matsumoto |
| Kiminori Matsuyama | Mauro Sodini | Serena Sordi |
| Iryna Sushko | Fabio Tramontana | |

Organizing committee

Jochen Jungeilges Tatyana Perevalova Trygve Kastberg Nilssen

Timetable

Sunday, 18th of June

19:00–21:30 "Meet & Greet" – Get-together at Scandic Hotel Bystranda (lobby)

PP: Physically Present, ON: Online

Monday, 19th of June

| | | | |
|-------------|----------------------------------|--|---|
| 8:00–8:45 | Registration | | |
| 8:45–9:10 | Conference opening | | |
| 9:10–10:30 | Session 1: Depletable Resources | | Chair: Jochen Jungeilges |
| 9:10–9:30 | PP | Alessandro Bellocchi Urbino, Italy | Shallow Lakes and Pollution Constraints (8) |
| 9:30–9:50 | ON | Gian Italo Bischi Urbino, Italy | Evolutionary dynamics in fishery exploitation (9) |
| 9:50–10:10 | PP | Andrea Carravagio Foggia, Italy | Optimal water tariffs for domestic, agricultural and industrial use (10) |
| 10:10–10:30 | ON | Giovanni Vilani Bari, Italy | Regulation and enforcement in the exploitation of the groundwater resource (11) |
| 10:30–10:50 | Coffee break | | |
| 10:50–12:10 | Session 2: Green monetary policy | | Chair: Thomas Zörner |
| 10:50–11:10 | PP | Andrea Bacchiocchi Urbino, Italy | The effects of a green monetary policy on firms financing costs (12) |
| 11:10–11:30 | PP | Allessia Cafferata Turin, Italy | Managing greenflation in an environmental DSGE model with heterogeneous expectations (13) |
| 11:30–11:50 | PP | Germana Giombini Urbino, Italy | Inflation, monetary policy and green transition in an environmental OLG growth model (14) |
| 11:50–12:10 | PP | Thomas Zörner Vienna, Austria | The Green and the Brown: Environmental effects in a credit cycle model (16) |
| 12:30–14:00 | Lunch break | | |
| 14:00–15:20 | Session 3: Carbon Dynamics | | Chair: Ivan Savin |
| 14:00–14:20 | PP | Luca Gori Pisa, Italy | The abatement game in a dynamic oligopoly: social welfare versus profits (18) |
| 14:20–14:40 | ON | Fabio Lamantia Calabria, Italy | Environmentally concerned firms and partial cooperation: an evolutionary analysis (19) |
| 14:40–15:00 | PP | Simone Marsiglio Pisa, Italy | Complexity and Uncertainty in Low-Carbon Transitions: a Policy Perspective (20) |
| 15:00–15:20 | PP | Ivan Savin Barcelona, Spain | An agent-based model of cultural change for a low-carbon transition (21) |
| 15:20–15:40 | Coffee break | | |

Tuesday, 20 of June

| | | | |
|-------------|---|--|--|
| 9:00–10:40 | Session 4: Industrial Organization | | Chair: Anastasiia Panchuk |
| 9:00–9:20 | PP | Sarah Mignot Bamberg, Germany | Complex dynamics in a nonlinear duopoly model with heuristic expectation formation and learning behavior (22) |
| 9:20–9:40 | PP | Vincenzo Valori Florence, Italy | Price and industry dynamics with a dominant firm, a competitive fringe and endogenous entry and exit (23) |
| 9:40–10:00 | PP | Pasquale Commendatore Naples, Italy | Environmental policy and the dynamics of industry location and residential choice (24) |
| 10:00–10:20 | PP | Elisabetta Michetti Macerata, Italy | Dimensional traps in evasion models and their effects on industrial structure (26) |
| 10:20–10:40 | PP | Anastasiia Panchuk Kyiv, Ukraine | Evolution of dishonest behavior in public procurement. The role of updating control (27) |
| 10:40–11:00 | Coffee break | | |
| 11:00–12:00 | Session 5: Learning | | Chair: Roberto Dieci |
| 11:00–11:20 | PP | Jan Wenzelburger Kaiserslautern, Germany | Perfect Foresight in Two-Sectoral Two-Period Lived OLG Models (28) |
| 11:20–11:40 | PP | Cars Hommes Amsterdam, Netherlands | Adaptive behavior in the laboratory (29) |
| 11:40–12:00 | PP | Xue-Zhong (Tony) He Jiaotong, China | Limit order book information and reinforcement learning (30) |
| 12:00–12:30 | Special Session: In memoriam John Barkley Rosser Jr. | | |
| 12:30–14:00 | Lunch break | | |
| 14:00–15:20 | Session 6: Capital market dynamics | | Chair: Davide Radi |
| 14:00–14:20 | ON | Fausto Cavalli Milano, Italy | A reappraisal of fundamentalists in heterogeneous agents economic modelling (31) |
| 14:20–14:40 | PP | Frank Westerhoff Bamberg, Germany | On boom-bust stock market dynamics, animal spirits and the destabilizing nature of temporarily attracting virtual fixed points (32) |
| 14:40–15:00 | PP | Iryna Sushko Kyiv, Ukraine | Dynamics of a 2D discontinuous piecewise linear stock market model (33) |
| 15:00–15:20 | PP | Davide Radi Milano, Italy | Exchange rate dynamics and central bank interventions: On the (de)stabilizing nature of targeting long-run fundamentals interventions (34) |
| 15:20–15:40 | Coffee break | | |
| 15:40–17:00 | Session 7: Macro dynamics | | Chair: Alessia Cafferata |
| 15:40–16:00 | PP | Paulo Medeiros Siena, Italy | Real-financial market interactions in dual-economies (35) |
| 16:00–16:20 | PP | Mauro Sodini Napoli, Italy | Debt dynamics and fiscal policy in a monetary union (36) |
| 16:20–16:40 | PP | Spiros Bougheas Nottingham, United Kingdom | On the Transmission and Synchronization of Endogenous Business Cycles (37) |
| 16:40–17:00 | PP | Daniele Ravasi Genoa, Italy | Intergenerational inequalities and endogenous growth: the role of informal job networks (38) |
| 18:30–22:00 | Conference Dinner at "Hos Oss" in Lillesand, Norway | | |

Wednesday, 21st of June

| | | | |
|-------------|---|--|--|
| 9:00–10:40 | Session 8: Cobweb markets | | Chair: Lorenzo Cerboni Baiardi |
| 9:00–9:20 | PP | Lorenzo Cerboni Baiardi Bologna, Italy | Evolutionary selection in cobweb markets with finitely many players (39) |
| 9:20–9:40 | PP | Roberto Dieci Bologna, Italy | Supply-side interactions and cobweb dynamics (40) |
| 9:40–10:00 | PP | Akio Matsumoto Chuo, Japan | Asymptotic Dynamics in a Multi-market Delayed Cobweb Model (41) |
| 10:00–10:20 | PP | Fabio Privileggi Torino, Italy | Variational Analysis with Respect to Fractal Probability Measures and Application to Stochastic Economic Growth (42) |
| 10:20–10:40 | PP | Trygve Kastberg Nilssen Kristiansand, Norway | Risk management for concession power in the Norwegian electricity market (44) |
| 10:40–11:00 | Coffee break | | |
| 11:00–12:20 | Session 9: Diverse | | Chair: Fabio Tramontana |
| 11:00–11:20 | ON | Daniela Visetti Milano, Italy | OLG model with economic and epidemiological interacting spheres (45) |
| 11:20–11:40 | PP | Marwil J. Davila-Fernandez Siena, Italy | Endogenous political cleavages and the social dimension of climate change (46) |
| 11:40–12:00 | PP | Fabio Tramontana Urbino, Italy | An evolutive model of boundedly rational consumer with changing preferences and reference group consumption (47) |
| 12:00–12:20 | ON | Makar Pavletsov Ekaterinburg, Russia | Sensitivity analysis for attractors in a 3-person consumption network (48) |
| 12:20–12:30 | Conference closing | | |
| 12:30–14:00 | Lunch break | | |
| 16:00–18:00 | Excursion: Boat trip through the inner coast water way near Kristiansand | | |



List of Abstracts – Talks

Shallow Lakes and Pollution Constraints

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Abstract

Ecological systems such as *shallow lakes* are typically non-linear and may exhibit discontinuities and hysteric behaviour. The economic analysis of these systems requires the solution of a non-standard *optimal control* problem. Shallow lakes with infinite time horizon have been extensively studied by the literature, which focused mainly on lake management through optimal taxation or improved soil management ([2], [1]). In this paper, we focus instead on a dynamic optimisation problem with a *finite time horizon* and the effects of an upper bound on the pollution growth rate (i.e., *environmental regulation*) [3]. Notably, the time and emission constraints crucially influence the expected effects of regulation and its actual ability to achieve the environmental objectives set by the legislator.

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Evolutionary dynamics in fishery exploitation

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Abstract

We provide an overview of some dynamic oligopoly models proposed in the literature to describe the exploitation of a common pool renewable natural resource (e.g. fisheries) when agents can switch between different harvesting strategies according to a switching mechanism denoted as exponential replicator. In the models considered the population of exploiters can employ different strategies for deciding their next-period harvest, and the basic idea is that the fraction of the exploiters' population which adopts the more profitable strategy in the current period will increase in the next period. This is a common situation when authorities adopt a "libertarian paternalism" approach, leaving the possibility to freely choose among a limited number of alternative harvesting strategies according to profit maximization considerations to the exploiters. Indeed, due to the particular form of cost functions used in the exploitation of fisheries, fish harvesting is generally less profitable when a fish stock is more depleted. This may imply that profit considerations naturally lead to the exploitation of more abundant fisheries, so that the depleted ones are preserved. The examples proposed include models that describe the creation of marine protected areas where fishing activity is limited, models where cooperative behaviors are suggested instead of individualistic and aggressive ones, models describing the possibility to harvest just one fish species according to profit maximization arguments. In all these cases we include a dynamic evolutionary component, by assuming that harvesting strategy choices can be repeated at discrete time periods, and players are allowed to change their mind, i.e. switching their strategy according to a profit-driven exponential replicator. As usual in the study of complex nonlinear systems, an interdisciplinary approach is proposed, involving competencies from economics, ecology, social sciences and, of course, mathematics involving a trade-off between analytical and numerical methods.

References

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Optimal water tariffs for domestic, agricultural and industrial use

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Abstract

In this paper, we propose a leader-follower finite-horizon differential game in which an agency (public or private) sells and distributes water to a group of users (domestic, agricultural, industrial) of a given territory. The seller has several goals: to maximize revenue, minimize costs, take into account the well-being of users, and preserve the necessary availability of the resource for the future. The seller determines the price to apply to each user. It can vary over time and depend on the availability of water. Heterogeneous users adjust their demand for water in response to its price and their current (also seasonal) needs. Users do not observe the water stock but only the price and therefore behave in a myopic way. The seller, on the other hand, is farsighted because she is also concerned with maintaining optimal water availability for the future. More specifically, this work addresses the following research questions: what is the water demand of different users in response to the tariffs applied; is the block pricing scheme preferable to the linear one? To this end we characterize, by means of the Hamilton-Jacobi-Bellman (HJB) equations, an internal leader-follower feedback equilibrium of the game. Furthermore, supported by a series of numerical simulations, we analyze the interesting properties of this solution. Finally, the problem of the possible depletion of the water resource and the impossibility of fully satisfying the demand for water is discussed. In this case, it is also necessary to study corner solutions. The latter analysis is limited to an essentially static version of the game.

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Regulation and enforcement in the exploitation of the groundwater resource

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Abstract

Sustainable pumping of water resource requires intervention by a public agency in order to avoid over-exploitation. For this reason, we study the evolution of compliance and regulation of groundwater resource when farmers can decide on whether to comply or not with pumping quotas in a differential game. The public agency sets the optimal quotas and the farmers can choose between compliance or violation. We investigate the policy of the public agency which may impose sanctions to discourage withdrawals that deviate from the optimal quota. Using numerical simulations we analyze the effects that parameters have on the equilibrium of the aquifer and on the farmers behavior.

References

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The effects of a green monetary policy on firms financing cost

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Abstract

The monetary policy operations of a Central Bank (CB) involve allocation decisions when purchasing assets and taking collateral. A green monetary policy aims to steer or tilt the allocation of assets and collateral towards low-carbon industries, to reduce the cost of capital for these sectors in comparison to high-carbon ones. Starting from a corporate bonds purchase program (e.g. CSPP) that follows a carbon-neutral monetary policy, we analyze how a shift in the CB portfolio allocation towards bonds issued by low-carbon companies can favor green firms in the market. Relying on optimal portfolio theory, we study how the CB might include the risk related to the environmental sustainability of firms in its balance sheet, so that the portfolio choice encompasses three objectives: maximizing returns, containing financial risks, and reducing firms' environmental footprint. In addition, we analyze the interactions between the neutral or green CB re-balancing policy and the evolutionary choice (i.e. by means of exponential replicator dynamics) of a population of firms that can decide to invest in a green or non-green technology according to bonds borrowing cost. We obtain some main findings. First, some scenarios are characterized by a strong path dependency: if a large share of firms employed non-green technology, no investment in green technology occurs in the long-run, even if the non-green investment equilibrium is inefficient. We define this equilibrium *technology trap* and show that the green CSPP helps the industry leave the *technology trap*. Second, green and non-green bond riskiness is a key factor that impacts borrowing costs: the larger the average financial risk of bonds, the lower the share of bonds in CB portfolio, and the higher firms' borrowing cost. Third, in the presence of imperfect competition and (or) a high degree of market imperfections the *technology trap* is more likely to happen and the green CSPP seems to foster the adoption of the green technology.

Managing greenflation in an environmental DSGE model with heterogeneous expectations

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Abstract

Climate change is one of the most challenging topics of our generation, with profound implications for society, politics and also economics. The debate regarding the role of central banks and financial regulators in addressing climate-related policies has notably gained importance in recent years. Although the majority of the population agrees on the necessity of fighting this phenomenon, there is still heterogeneity on the urgency with which agents want to act. This heterogeneity in ecological thinking affects households [1], firms [5], financial regulators and central banks [2]. In this respect, [3] develop a two-sector dynamic stochastic general equilibrium (DSGE) model to examine the optimal response of the interest rate to sector-specific price changes. Using a similar New Keynesian setup but departing from the rational expectations assumption, we introduce heterogeneous expectations in a model with green and brown firms. Following [4], we develop a framework in which expectations are heterogeneous with respect to their level of anchorage around the targets of the central bank, and where brown firms' expectations are less anchored due to the potential increase of costs derived from green policies. Our results show that central banks need to respond to changes in relative prices, and weak responses to shocks in the brown sector may lead to waves of greenflation.

References

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Inflation, monetary policy and green transition in an environmental OLG growth model

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Abstract

Central Banks have started to recognize that climate change is a major source of structural change impacting the economy and the stability of the financial system ([8]) through a physical risk and a transition risk channel ([6]). Thus, green monetary policies have recently become an important mechanism to foster the transition to green technologies. Indeed, the relatively large upfront costs incurred in these capital-intensive expenditures are particularly susceptible to changes in the cost of credit, and low and declining interest rates have measurably contributed to the fall in the “levelised cost of electricity”, or LCOE, of renewable energies ([9]). While price stability is a prerequisite for a sustainable transformation of economies, recent inflation dynamics threaten green transition. On the one side, to lower price dynamics, CB are tightening monetary policies and, as a consequence, financing conditions are becoming restrictive. Since fossil fuel-based power plants have comparably low upfront costs, a persistent rise in the cost of capital may discourage efforts to decarbonise our economies rapidly. On the other side, unless greenhouse gas emissions are cut rapidly, our economies will remain exposed to the risks of “climateflation” and “fossilflation” – that is, persistent inflationary pressures associated with more frequent natural disasters and a continued dependency on gas, oil and coal.

In this paper we model this recent dilemma by considering an OLG economy in which two assets coexist: capital and government bonds. Our study builds on John and Pecchenino’s seminal article [7] that develops an environmental OLG growth model (e.g. [1]; [3]). The present paper extends their framework in two different ways. First, it incorporates a damage function from GHG emission externalities to output (see [2]). Second, we compare the adoption of a simple inflation target rule with a green-augmented one in lines similar to [10]. In this way, we join recent efforts assessing the implications of including environmental goals into the monetary policy (for example [5], [4] proposed a climate-augmented monetary policy rule).

References

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The Green and the Brown: Environmental effects in a credit cycle model

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Abstract

We propose an augmented variant of the credit cycle model introduced by [3] to analyse the linkages between financial market dynamics and the environment subject to fiscal and financial regulation. The environmental quality of our economy depends on the pollution emitted by Brown investment projects and may be enhanced by an endogenously determined abatement technology financed by taxes.

In an overlapping generations setting, agents choose a utility maximising allocation of their net worth to Green or Brown projects, which ultimately differ in their general equilibrium effects and in their impact on the environment. While Green projects generate pecuniary spillovers to the next generation, Brown projects fail to do so. The latter are moreover subject to an environmental tax, which is used to finance abatement technologies that ultimately generate a positive environmental externality.

Following [1], the externality is modelled by a learning-by-producing abatement technology that (partially) offsets the emitted pollution. Green projects generate a certain return equal to the marginal product of capital without demand for external finance, while Brown projects are assumed to yield higher returns but need to be financed by credit and are subject to an environmental tax. Thus, agents who want to start Brown projects need to borrow from the competitive capital market and have to pledge their expected net return as collateral. The Browns' contribution and their exposure to environmental risks may diminish the value of the projects' return, such that the collateral is additionally subject to an *environmental haircut*.

In our setting, a regulator observes the environmental quality and sets the haircut as well as the environmental tax accordingly. Hence, we link the environmental quality to the financial market in twofold manner. First, the credit flow into Brown projects is regulated via the environmental haircut and thus reduces pollution by lower investments into emitting projects. Second, taxation reduces the profitability of Brown projects and simultaneously used to finance abatement technologies.

To establish a link between the economy and the environment, we employ a "pollution" function in the spirit of [2]. The specific functional form links the overall environmental damage to the pollution accumulation, the environmental absorption capacities, as well as the abatement technologies in a nonlinear fashion.

In general, the proposed model allows us to explore the general equilibrium effects and the dynamic impacts of an environmental regulation via financial markets, financing conditions and taxation. Moreover, as the setup enables us to trace the income of the respective generation, we are able to quantify the different social costs of the two environmental regulation possibilities. Due to the intergenerational and environmental spillovers generated by the heterogeneous investment projects and the potentially regulated credit flow, complex dynamics emerge and provide interesting insights of the stability and feedback loops of credit and environmental dynamics. The first results point towards

an ambiguous effect of financial restrictions of Brown projects for both the environmental quality and the aggregated output of the economy.

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The abatement game in a dynamic oligopoly: social welfare versus profits

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Abstract

This article departs from the (static) duopoly by [3], in which firms choose strategically to abate or not to abate pollution through an end-of-pipe technology and extends the analysis to an N -firm oligopoly. Then, it considers a dynamic setting in which the environmental regulator sets the tax rate to incentivise firms to undertake emission-reduction actions according to different hypotheses (ranging from the fixed rule to the optimal rule). The behaviour of the public authority sharply affects the firm's (individual) incentive to move towards the abatement activity over time. This indeed affects the number of (non)abating firms on the market and then the corresponding social welfare outcomes. The article pinpoints that the environmental policy may cause oscillations resulting in a coexistence of the two types of firms in the long term.

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Environmentally concerned firms and partial cooperation: an evolutionary analysis

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Abstract

In the context of evolutionary oligopoly models [2], we revisit the work in [1], which proposes an oligopoly framework to deal with partial cooperation and partial aggressiveness between firms. In particular, we here introduce the possibility for firms to internalize the environmental damage of their emissions and invest in emission reduction. The obtained model combines the oligopoly's industrial dynamic with pollution dynamics and firms' abatement decisions. We then explore the role of the regulator in imposing a tax on emissions in this industry.

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Complexity and Uncertainty in Low-Carbon Transitions: a Policy Perspective

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Abstract

We explore the uncertain and complex dimensions of energy systems analyzing whether and under which conditions low-carbon transitions can effectively take place. By accounting for social and environmental considerations, heterogenous single utility-maximizer agents optimally decide whether to adopt a green technology which reduces carbon emissions, allowing eventually for a green energy transition. We characterize the determinants of the success of such a transition, emphasizing that even if the favorable conditions are met the low-carbon transition may not result in long run environmental improvements due to the uncertainty associated with green technology adoption. Public policy may solve these issues by increasing the incentive for single individuals to adopt, ensuring thus the achievement of a permanent low-carbon state. By extending the analysis to a spatial network characterized by multiplexity due to the social and environmental interconnections, we show how these two separate complexity layers affect our conclusions.

An agent-based model of cultural change for a low-carbon transition

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Abstract

Meeting climate goals requires radical changes in the consumption behaviours of individuals. This necessitates an understanding of how the diffusion of low-carbon behaviours will occur. The speed and inter-dependency of these changes in behavioural choices may be modulated by individuals' culture. We develop an agent-based model to study how behavioural decarbonisation interacts with longer-term cultural change, composed of individuals with multiple behaviours that evolve due to imperfect social learning in a social network. Using the definition of culture as socially transmitted information, we represent individuals' environmental identity as an aggregation of attitudes towards multiple relevant behaviours. The strength of interaction between individuals is determined by the similarity in their environmental identity, leading to inter-behavioural dependency and spillovers in green attitudes. Our results show that the initial distribution of agent attitudes towards behaviours and asymmetries in social learning, such as confirmation bias, are the main drivers of model dynamics, helping to generate awareness of what roadblocks may appear to deep decarbonisation. To assess the impact of culture beyond a purely diffusive regime, we introduce green influencers as a minority of individuals who broadcast a green attitude. The greatest emissions reduction is achieved with the inclusion of culture, relative to a behavioural independence case, and with low confirmation bias. However, green influencers fail to achieve deep behavioural decarbonisation through solely voluntary action. We identify areas for further research regarding how culture, through inter-behavioural dependence, may be leveraged for climate policy.

Complex dynamics in a nonlinear duopoly model with heuristic expectation formation and learning behavior

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Abstract

We develop a nonlinear duopoly model in which the heuristic expectation formation and learning behavior of two boundedly rational firms may engender complex dynamics. Most importantly, we assume that the firms employ different forecasting models to predict the behavior of their opponent. Moreover, the firms learn by leaning more strongly on forecasting models that yield more precise predictions. An eight-dimensional nonlinear map drives the dynamics of our approach. We analytically derive the conditions under which its unique steady state is locally stable and numerically study its out-of-equilibrium behavior. In doing so, we detect multiple scenarios with coexisting attractors at which the firms' behavior yields distinctively different market outcomes.

Price and industry dynamics with a dominant firm, a competitive fringe and endogenous entry and exit

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Abstract

We study market dynamics and efficiency in a model in which a dominant firm and a large, endogenous number of small, not fully rational firms coexist. The dominant firm announces a target price, but the market price may deviate from this price: this is because the dominant firm exploits the limited rationality of marginal firms to pursue its objectives [1]. Small firms are subject to a credit constraint and can therefore go bankrupt. At the same time, when average profits are positive, there is an influx of new firms into the market [2]. This combination of facts leads to a change in the number and type of small firms in the market, with implications for the effectiveness of the dominant firm's strategies and for market efficiency. We simulate the model for a range of parameter values, following the evolution of prices, the number of active firms, profits and market surplus. We finally draw some policy implications.

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Environmental policy and the dynamics of industry location and residential choice

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Abstract

Pollution and environmental policy affect simultaneously and directly the utility of households and profits of firms. Household and firms may be induced to reconsider their resp. location choice. In order to study the interdependence of pollution, environmental policies, firms' and households' location choice, we use as comprehensive framework a new economic geography (NEG) model with the following characteristics. We differentiate two countries. Each country hosts a manufacturing sector with firms that can relocated between countries; manufacturing generates local pollution (that does not accumulate); it uses two types of labour input: unskilled workers that cannot migrate and work where they live; and high-skilled entrepreneurs that choose where to produce and where to live. Taking on board distance working, entrepreneurs can live in a different location from production. Both types of households enjoy utility from consuming all commodities (locally and imported variants) and suffer from local pollution.

In a previous paper, we studied this model without environmental policies. In this paper, we extend the model to account for environmental policies. In order to keep the analysis as tractable as possible, we focus on local policies and disregard transnational policies, and we do not consider strategic interaction between countries in policy setting.

Even with these simplifications, environmental policies can enter the model in different forms; in particular, they can aim at reducing emission or at reducing the impact/damage from pollution. In this paper, we focus on the latter. Examples for these policies are public facilities benefitting everybody living in a country (eg sewage or waste-water treatment) or private investments (eg. noise protection windows), which links our analysis to the discussion on self-protective expenditures. In both cases, we account for the resources required for producing these implements and the financing side: Public facilities are financed by taxes (on firm profits, or on income of high-skilled households, or on income of high- and low-skilled households); private investments are financed by private expenditures. The resulting model is of the footloose entrepreneur variant, but involves two dynamic processes: the standard one governing the residential choice of entrepreneurs, and another one governing where production is located. The residential choice of entrepreneurs is driven by utility, which depends on the percentage of locally available commodities and on local pollution. Industry location is driven by profits, which depend upon the extent of local demand and on the number of local competitors. Environmental policies affect both dynamic processes: Household utility changes because of the direct improvements of environmental quality and because of the financing required for the policies. Firms' profits directly change, if a profit tax is imposed, and indirectly, if a household tax is imposed, which alters local demand and thus the size of the local market. A circular process set

in, in which firm relocation affect household utility (and thus the mobility incentive) by changing the level of local pollution and of locally available commodities; and in which household mobility affect profits of firms (and thus their mobility incentive), because of changing the extent of local demand. On a more technical note, the model is set in discrete time and is defined by a two-dimensional piecewise smooth map with natural constraints 0 and 1 for the two main variables (which are the regional shares of mobile households population and of firms). We investigate the properties of the long run dynamics by using mathematical and simulation methods. In particular, we are interested in how environmental policies affect the long run regional distribution of firm and (high-skilled mobile) households as well as the wealth distribution between high-skilled mobile households and low-skilled immobile households.

Dimensional traps in evasion models and their effects on industrial structure.

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Abstract

In [2] we described how size-dependent tax enforcement may be a source of dimensional trap in a single-firm evasion model. In the present work, we move to a heterogeneous setting thus considering different industrial structures composed of many firms with different dimensions. Following [2] and [1] taking into account empirical evidences, we assume that the State monitoring efforts are positively related to firms' dimension, so that larger firms face a higher probability to be controlled. As a consequence, small firms can find it convenient not to invest all profits in order to guard a lower control level, thus falling into a dimensional trap that hinder growth. When many firms are considered, the consequence of such a trap on the industrial structure evolution over time must be studied by combining analytical findings and simulation results.

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Evolution of dishonest behavior in public procurement. The role of updating control

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Abstract

The process of public procurement includes many corruption risks due to certain advantages of dishonest behavior. Recent models are often based on an evolutionary process with honest and dishonest agents, which are allowed to change their attitude joining the opposite party. Following suggestions of some researchers, it is assumed that the agents are more inclined to honesty (the honesty propensity assumption). That is, a dishonest firm meeting an honest one will always change type if the honest behavior is more beneficial. However, not every honest firm meeting a dishonest one will change type even if a higher expected utility can be reached.

The present paper is a continuation of our earlier works, where we consider a two dimensional piecewise smooth map, describing the evolution of the dishonest firm fraction and of the monitoring level by the State, which is introduced endogenously in the model. In contrast to previous works, the current setup includes more sophisticated rule for changing the State's monitoring level, which leads to richer asymptotic dynamics.

Perfect Foresight in Two-Sectoral Two-Period Lived OLG Models

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Abstract

This article investigates the existence of perfect-foresight equilibria in two-sectoral two-period lived OLG Models. It extends the setting in [1] by allowing for partial depreciation of capital, factor-intensity reversals, and subjective erroneous beliefs of agents. The generalisation thus allows to include the important parameterisation of CES production functions which so far had to be ruled out. The analysis of temporary equilibria precedes the description of a well-defined intertemporal growth process. It is shown that, generically, perfect foresight is possible only locally in the sense that the economy may persistently assume states in which beliefs cannot be self-fulfilling.

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Adaptive behavior in the laboratory

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Abstract

In this paper we study the (in)stability in laboratory experiments with human subjects in systems with expectational feedback. Earlier experiments in one variable have shown that the sign and strength of this feedback is an important predictor of the market stability [1]. Here we generalize this result to a two dimensional system, where the expectations and realisations of two prices affect each other. We conduct a Learning to Forecast Experiment and show that eigenvalues can be used as predictors of stability in such a higher dimensional framework. We investigate eigenvalues of positive real part, and found that complex eigenvalues with a polar angle of $\pi/4$ lead to more stable dynamics than real eigenvalues with the same absolute value. For the real eigenvalues we find a change from stable to unstable dynamics inside the unit circle, which is in line with the findings from the one dimensional case. In order to reproduce the decisions being made in individual time steps, simple models like an adaptive rule are often sufficient. In order to reproduce long run dynamics, we develop a two dimensional Heuristic Switching Model. We use this model to predict the stability of systems with eigenvalues which we did not test experimentally.

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Limit order book information and reinforcement learning

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Abstract

How is rational expectations equilibrium (REE) achieved? This paper aims to answer this question in limit order markets. Because of high dimensionality in dynamic limit order book, it is very challenging to characterize dynamic REE model of information-based trade in which agents make choice of limit or market orders endogenously, particularly when agents have less incentive to trade in highly volatile market. In market practice, we have seen rapid rising and ubiquity and algorithmic trading based on bounded rational learning. Therefore, it is important to understand whether such bounded rational learning can be effective in achieving REE. This paper shows that REE can be achieved by simple payoff-based reinforcement learning (RL) in limit order markets. Benchmarked on REE models of [1] and [2], we demonstrate that RL can be very effective in learning market equilibrium, generating consistent information acquisition and trading behavior. More importantly, RL provides a more flexible framework to characterize strategic order choices, market liquidity, and price discovery. In particular, we show that, when fundamental is highly volatile, information asymmetry plays more important role than agents' trading incentive based on their private values, providing some insight to information channels of agents' trading behavior, market liquidity, and price discovery.

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A reappraisal of fundamentalists in heterogeneous agents economic modelling

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Abstract

We propose a class of agents to overcome the limits of fully rational agents and fundamentalists in economic contexts characterized by heterogeneous agents (see [1, 2, 3]). Fully rational expectations require the complete knowledge about both the market structure and agents' choices. On the other hand traditional fundamentalists ([3, Chapter 5.1.3]), have a precise knowledge just about the market fundamentals, while they act without considering that there are agents with non-rational expectations. Being the former information setting too unrealistic, the latter one may be too unsophisticated. We consider a class of fundamentalist agents that have perfect knowledge of the market demand/supply functions and are aware that the market is populated by heterogeneous agents. Moreover, they can obtain the distribution of agents that have adopted a certain type of expectation in the previous period. With these assumptions, our fundamentalists compute the price that would realize in such a market in the next period. Fractions are then updated in an evolutionary fashion based on net realized profits. We consider this new kind of agents in classic economic contexts and we study the resulting models from static and dynamical points of view.

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On boom-bust stock market dynamics, animal spirits and the destabilizing nature of temporarily attracting virtual fixed points

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Abstract

We propose a stock market model with chartists, fundamentalists and market makers. Chartists chase stock price trends, fundamentalists bet on mean reversion, and market makers adjust stock prices with respect to the current excess demand. Moreover, fundamentalists' perception of the stock market's true fundamental value is subject to animal spirits. They optimistically (pessimistically) believe in a high (low) fundamental value when the stock market increases (decreases) strongly. When the stock market is relatively stable, they are neutral and believe in an intermediate (normal) fundamental value. We show that animal spirits create temporarily attracting virtual fixed points, which, in turn, may engender boom-bust stock market dynamics that coevolve with waves of optimism and pessimism.

Dynamics of a 2D discontinuous piecewise linear stock market model

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Abstract

A stock market model with chartists, fundamentalists and sentiment traders is proposed. Its dynamics are defined on three partitions by a 2D piecewise linear discontinuous map for which we obtain in explicit form the boundaries of periodicity regions associated with different types of attracting cycles. Since these regions overlap with the stability domain of a fixed point and may overlap also with each other, we describe their basins of attraction. Our results contribute to the understanding of the excessively volatile boom-bust nature of stock markets, and also to the understanding of the bifurcation structures in discontinuous maps. The novelty of having three partitions where the map acts differently leads to new types of attracting cycles compared to those associated with a map on two partitions. In the parameter space of the map we show that two different periodicity regions are issuing from a point related to the center bifurcation of the fixed point with complex eigenvalues on the unit circle and a rational rotation number.

Exchange rate dynamics and central bank interventions: On the (de)stabilizing nature of targeting long-run fundamentals interventions

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Abstract

We develop a stylized model of the foreign exchange market in which the exchange rate is driven by interactions between internationally operating firms, heterogeneous speculators and a central bank. In particular, we are interested in the effects of so-called targeting long-run fundamentals interventions according to which the central bank starts to intervene in the foreign exchange market when the exchange rate leaves a predefined target zone. Since our model can be represented by a two-dimensional piecewise linear map with three branches, we are able to carry out a detailed analytical study of its main policy implications. One remarkable finding is that a too aggressive central bank can set persistent exchange rate dynamics in motion by repeatedly triggering destabilizing speculative orders.

Real-financial market interactions in dual-economies

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Abstract

Despite academics' growing interest in financial phenomena – driven mainly by the great financial crisis of 2008 - a strikingly overlooked point was the role of the informal sector. Informal firms account for up to half of economic activity in developing countries [3]. Those firms usually hire informal workers and have no access to financial markets. Countries representing a large part of the global economy, such as China, India, and Brazil, have a significant portion of their companies operating in the informal sector. Given that informal companies cannot access the formal credit market, the relationship between the real and the financial markets in those economies is likely to differ qualitatively, with major macroeconomic implications proportional to the size of the informal sector. The present paper provides an innovative, dynamic framework in discrete-time to study the role of the informal sector in changing qualitative aspects of the relationship between the financial and real sides of the economy.

It is shown analytically and through numerical simulations that even in a pure 2D financial economy, a rise in the share of the informal sector affects the equilibrium point and the qualitative dynamics of liquidity and solvency. The model is compatible with persistent endogenous fluctuations that follow Flip and Neimark-Sacker bifurcations. In the 3D version of the nonlinear dynamic system that introduces a production specification, the share of the informal sector will also affect the macroeconomy. The interaction of the deterministic skeleton of the model with a stochastic component generates time series with properties similar to those observed in actual data. Finally, we allow for different trading strategies in the financial sector using a discrete-choice approach [1]. In this way, we innovatively expand the results found by [2], showing the importance of specific analysis for countries with a large informal sector. Some final considerations follow on how the institutional legislation and macro-prudential policies in the global North may increase volatility and lower growth rates in the South.

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Debt dynamics and fiscal policy in a monetary union

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Abstract

A strand of the literature has extensively used a reduced form of the New Keynesian macroeconomic model to study the interaction between monetary and fiscal authorities within a monetary union [2]. In a static policy game, the agents usually act independently and simultaneously; as a result, a Cournot-Nash equilibrium emerges, which is stable in the sense that each authority achieves the best possible result by minimizing its objective function. Nevertheless, since it is a simultaneous game, it is not possible to analyse the convergence process towards the equilibrium; moreover, the literature has emphasised that the problem of debt stabilisation needs to be studied in the context of dynamic policy game [1].

These arguments motivate our choice to present a dynamic version of the reduced form of the New Keynesian macroeconomic model in order to analyse the issue of debt stabilisation within a monetary union. In particular we consider a model where two or more fiscal authorities choose the level primary government balance while the monetary authority sets the policy rate.

This paper shows that simple decision processes driven by the best response mechanism due to [3] does not guarantee convergence to steady-state equilibrium, defined as the target of the authorities. Instead, different attractors may emerge and/or persistent fluctuations in the level of macroeconomic variables and policy instruments can characterize the dynamics of the model.

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On the Transmission and Synchronization of Endogenous Business Cycles

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Abstract

We develop a two-country dynamic model to study the synchronization and transmission of endogenous business cycles following the liberation of international capital flows. Business cycles are endogenous and the mechanism that generates them is a simplified version of that in Matsuyama et al. (2016). Agents can invest in two types of projects. ‘Good’ projects are produced under a neo-classical CRS technology and their output can be either consumed or invested. ‘Bad’ projects offer a constant return and their output can only be consumed. Bad projects become gradually available only after the economy has reached a certain level of development. As the economy grows the return to physical capital declines offering incentives to agents to invest in bad projects. This mechanism can produce complicated dynamic paths including cycles. In a typical 2-period cycle the economy rotates between one where the initial capital stock is too low so that bad projects are not available and thus all savings are invested in good projects and another where now the initial capital stock is sufficiently high to allow for investment in bad projects thus restricting the following period’s capital stock. For the transmission of cycles we study two countries that in isolation both are following 2-period cycle paths but they are not synchronized. When we allow for capital to move across borders we find that the two cycles are indeed synchronized. This is in accord with empirical evidence that examines the effects of market integration on international business cycles. For the transmission of cycles we study two countries that differ in their total factor productivities and in isolation the less productive one is at a low steady-state equilibrium while the more productive one follows a 2-period cycle. When we allow for capital to move across borders we find that it moves from the less to the more productive one and that in the long-run even the less productive economy will follow a cyclical path. This prediction is also in accord with empirical evidence that shows the destabilizing effects of international capital flows for low-growth economies.

Intergenerational inequalities and endogenous growth: the role of informal job networks

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Abstract

We study the time evolution of the ratio of educated people in a classical growth model as in [3]. The choice of being educated is endogenized according to an adaptive decision process. Following the literature on the role of referrals and informal networks, see, e.g., [1] and [2], this adaptive process accommodates the frictions in the labor market, which can be reduced through personal connections. In particular, having educated parents reduces the risk of being educated and, at the same time, not being successful in finding a job. The investigation reveals how such a rigidity impacts on the rate of educated people and on the economic growth.

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Evolutionary selection in cobweb markets with finitely many players

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Abstract

An evolutionary cobweb market model is formulated with finite number of producers. Each agent exploits a certain predictor rule, chosen among a finite set of alternatives and implemented at a fixed cost, in order to forecast future average prices. “*On-average*” market equilibrium condition implicitly determines average price recurrence, given expected aggregate productions. The evolutionary side of the model accounts for the dynamics of predictors’ distribution among producers and it is carried out on the finite population by means of a profit-driven stochastic Moran process. Uniqueness of the equilibrium price and invariant distribution is ensured under mild assumptions. We highlight some interesting outcomes in the context of a linear cobweb and by assuming that rational and static rules are involved.

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Supply-side interactions and cobweb dynamics

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Abstract

This paper reconsiders a recent extension of the cobweb model, in which producers have the choice between two markets and tend to enter the one that was more profitable in the recent past, which results in time-varying supply schedules [1, 2]. Such interacting cobweb markets are investigated under fairly general demand and supply functions (possibly including risk aversion in supply decisions), while the number of producers in each market evolves through a discrete time replicator dynamics driven by realized profits, a switching mechanism involving imitative behavior. Analytical results and numerical investigations shed light on the way such supply-side interlinkages add to the fluctuations generated in each market by producers' price expectations and production delays.

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Asymptotic Dynamics in a Multi-market Delayed Cobweb Model

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Abstract

This study analyzes a two-market cobweb model involving production delays for agricultural products and information delays concerning the cross-market prices. A 2-D system of multi-delay differential equations describes its dynamics. It represents the linear stability conditions in parameter spaces containing the two production delays and the sum of the information delays. In the two-market model, the cross-influence from one market to the other has prominent features. First, it is confirmed that the two-market dynamics are similar to the one-market dynamics if the interdependency is one-way. It is, then, demonstrated that the unstable steady-state bifurcates various dynamics from a simple cycle to chaotic fluctuations if the interdependency is two-way.

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Variational Analysis with Respect to Fractal Probability Measures and Application to Stochastic Economic Growth

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Abstract

In this paper we are interested in proving optimality conditions for the calculus of variations problem:

$$\max_x \int_a^b f(t, x(t), D_\mu x(t)) d\mu \quad (1)$$

subject to $x(a) = x_a$ and $x(b) = x_b$ where μ is an abstract probability measure. When μ is a normalized Lebesgue measure this problem collapses to a classical formulation. The abstract probability measure allows to describe potential shocks by means of its support. The above formulation can also be interpreted as a variational problem on time scales. The derivative of x at the point t is calculated with respect to μ as follows:

$$D_\mu x(t) = \lim_{\epsilon \rightarrow 0^+} \frac{x(t + \epsilon) - x(t)}{\mu([0, \epsilon])} \quad (2)$$

We also discuss the case of fractal probability measures that are obtained as fixed points of Iterated Function Systems (IFS). We prove convergence results related to the sequence of minimizers that are calculated using pre-fractal measures. Finally we show an application to a Ramsey-type stochastic economic growth model.

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Risk management for concession power in the Norwegian electricity market

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Abstract

In this work we discuss risk management for municipalities selling concession power in Norway. The Norwegian Law of Concession Power (Konsesjonsloven) from 1917 states that a municipality that hosts hydroelectric power production has the right to buy up to 10% of the yearly electricity production at production cost. This energy may be used locally or traded. Most municipalities choose the latter.

The concession power from Agder, the county in the south of Norway, is traded from the inter-municipal company Konsesjonskraft IKS. It's risk strategy is to sell the energy on spot, and to hedge by using one-year-, two-year- and three-year financial future contracts. All energy and contracts are sold evenly and daily. The price dynamics is modelled by Ornstein–Uhlenbeck processes. The parameters of the processes are determined by maximum likelihood estimation.

At the start of each year Konsesjonskraft IKS estimates the Value at Risk of all its unsecured wealth over the next 4 years, which consists of the following 10 components: spot sold in year 0 through year 3, one-year contracts sold in year 0 through year 2, two-year contracts sold in year 0 through year 1, three-year contracts sold through year 0.

The unsecured energy wealth equals the sum of the averages of each component, A_k , weighted by its volume, V_k ,

$$W = \sum_{k=1}^{10} V_k A_k.$$

This portfolio of the unsecured wealth is analyzed. The Ornstein–Uhlenbeck nature of the prices is used to calculate the Value at Risk of the portfolio.

OLG model with economic and epidemiological interacting spheres

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Abstract

We propose and study the effects of interactions between the economic domain with the epidemiological sphere. The economic side is described by an OLG model with capital accumulation, while the epidemiological dynamics are driven by an SIS model. The transmission rate of epidemics θ negatively depends on the level of public expenditures, while in the OLG model household preferences are characterized by a psychological discount factor β positively depending on the number of susceptibles. Labor force consists of non infected people, which supply labor with a total factor productivity A , decreasing with the number of infected people. The resulting model is then described by the two dimensional discrete dynamical system

$$\begin{cases} s_{t+1} = s_t[1 - \theta(\tau A(s_t)s_t^{1-a}k_t^a)(1 - s_t)] + \gamma(1 - s_t) \\ k_{t+1} = \frac{\beta(s_{t+1})}{1 + \beta(s_{t+1})}(1 - \tau)(1 - a)A(s_t)s_t^{1-a}k_t^a \end{cases}$$

where the state variables s_t and k_t represent respectively the fraction of susceptible individuals and the capital per adult at each discrete time t , $\tau \in [0, 1]$ is the taxation rate, $\gamma \in (0, 1)$ is the recovery rate and a is the capital share to output.

We study the possible disease free and endemic steady states, focusing on the existence and coexistence of multiple endemic steady states. After analyzing comparative statics, we study steady state stability, focusing on possible dynamics arising when stability is lost, with the emergence of coexistence among attractors characterized by different complexity degrees.

Endogenous political cleavages and the social dimension of climate change

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Abstract

In the 1950s and 1960s, the vote for social-democratic, socialist and affiliated parties was associated with lower-educated and low-income voters. However, it has gradually changed so that, in the 2010s, higher educated citizens voted for the left while high-income voters continued to support the right. The apparent disconnection between income and education effects on voting could be understood as a change in structural parameters that shifted the unique equilibrium point of the socio-economic system. Alternatively, one could conceive a multi-stable system where critical events such as the fall of the Soviet Union and slow-motion processes, e.g. weakening of labour unions and deepening globalisation, altered the boundaries of the respective basins of attraction, leading to a transition between equilibria. The present paper favours this second perspective. Building on the discrete-choice approach with heterogeneous interacting agents, we develop a 3D nonlinear dynamic model that differentiates between two main political dimensions: economic-distributive and environmental. Conditional to the composition of the population in both spheres, policymakers choose the carbon tax and investments in education. The former influences the development of energy-saving production techniques, thus impacting output and emissions, which are feedback on political attitudes. On the other hand, human capital accumulation results in a wage differential that influences production and feeds inequality. We study analytically and numerically the conditions leading to the coexistence of stable equilibria and the possibility of endogenous political cycles, concluding with some considerations on the implications of such a result to fighting climate change.

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An evolutive model of boundedly rational consumer with changing preferences and reference group consumption

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Abstract

In this paper, two dynamic models, recently proposed to describe the adaptive repeated choices of a boundedly rational consumer, are joined together. One considers a consumer adjusting the consumption level of a given good over time according to the observed discrepancy between expected and realized utility gain and modifies the utility function according to past consumption experience, also including saturation effects when past consumption is excessive. The other one considers the same adjustment mechanism with constant preferences but with a behavioral effect that introduces a tendency (or bias) to imitate a reference group of consumers. Merging these two models a two-dimensional nonlinear dynamical system is obtained which describes consumers that decide their next period consumption of a given good by following two different (sometimes contrasting) criteria: their own utility maximization on one side and imitation of a reference group of consumers on the other side. This leads to a greater uncertainty with respect to the model without the behavioral bias. Such uncertainty is studied through a numerical exploration of the long run dynamics, guided by some global dynamical features of the nonlinear model, such as the folding action of the critical curves that characterize the behavior of the iterated noninvertible map and the singularities related to the presence of a vanishing denominator, namely focal points and prefocal curves. So, the aim of the paper is twofold: on one side it tries to contribute to the literature on economic theory of boundedly rational consumers represented by evolutionary and behavioral approaches; on the other side it tries to contribute to the recent literature about the global analysis of discrete dynamical systems characterized by contact bifurcations leading to the creation of complex topological structures of the attractors and their basins of attraction.

Sensitivity analysis for attractors in a 3-person consumption network

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Abstract

The dynamic model of interdependent consumer behavior [1] is generalized to a 2-commodities, n -person case, embedded in stochastic environment. In particular, we focus on the dynamics in the $n = 3$ person case. While individuals' own consumption experience plays only a weak role in the formation of their preferences, the past consumption of (a subset of) peers in the network strongly affects the choice of preferences. In this case, a 3-dimensional, non-linear, stochastic system describes the consumption dynamics evolving in the space of budget shares. We demonstrate the coexistence of attractors, characterize their stochastic sensitivity following [2] and analyze noise induced transitions.

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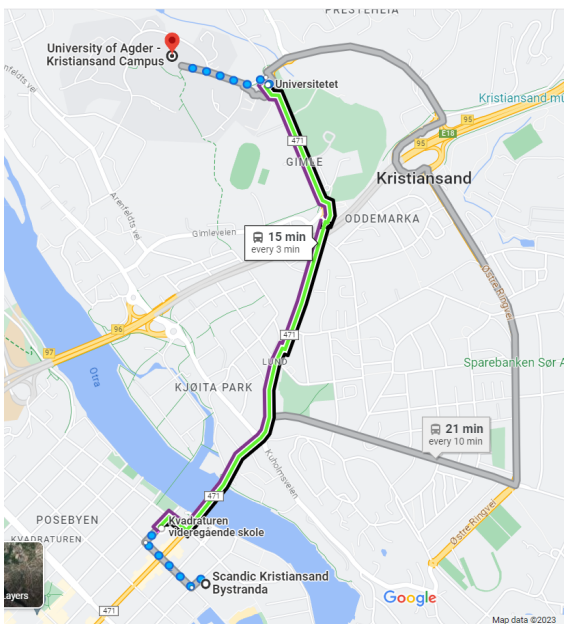
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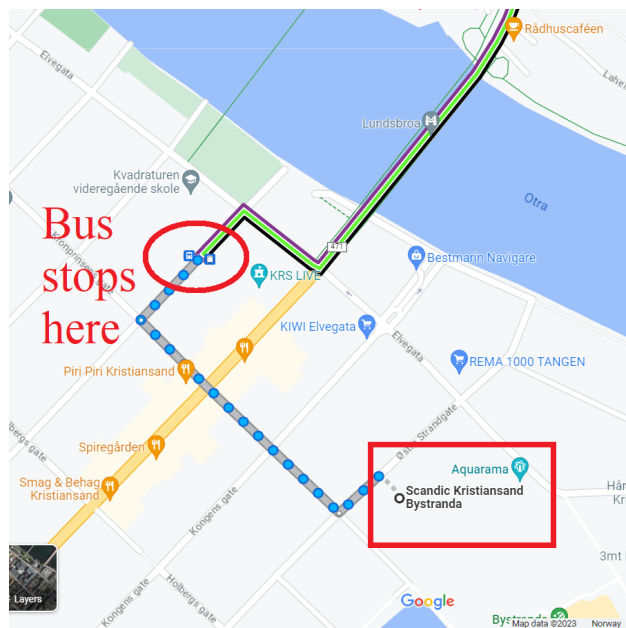
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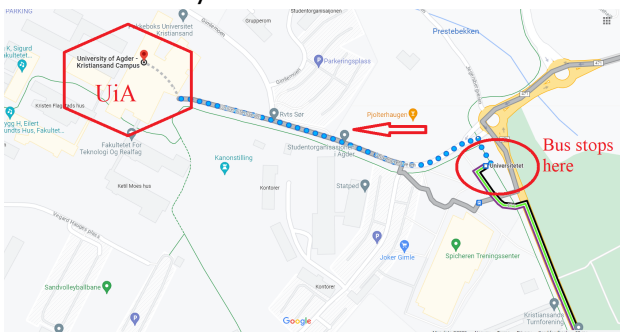
How to get to the UiA campus: walk from the Scandic Hotel to the stop "Kvadraturen Videregående Skole" (turn left out of hotel lobby, then right, and right again, 400m) take a bus to "Universitetet" (or "Spicheren"). Check buses and times on the AKT app (for web-based version see [here](#)). On Monday morning between 7:00 and 7:30, there are 10 travel options (buses) listed! The trip lasts 6 minutes. To get the cheapest ticket download the AKT app and utilize it for payment.



Overview from Scandic Kristiansand Bystranda to UiA



From Scandic Kristiansand Bystranda to bus stop, "Kvadraturen skolesenter"



From bus stop, "Universitetet" to UiA



UiA's main entrance

Talks will be held at room **B1-001**. This small auditorium is situated on the first floor of the main building (B-building).

Due to the data security measures in place at UiA, participants have to deliver their **presentations** on a **USB** stick.

Coffee breaks and lunches will take place in front of the auditorium and in the basement of the main building. Detailed directions will be given during the conference.

Internet access (Wi-Fi) will be available during the conference. Those who do not have global eduroam access will be offered a UiA guest account during registration.

The **conference dinner** will be held on Tuesday, June 20th, at the restaurant "Hos Oss" in Lillesand. We will travel to Lillesand by bus.

| time | event |
|-------|--|
| 17:30 | bus leaves UiA (in front of B-building) |
| 18:00 | walk through Lillesand guided by Theis Theisen |
| 18:30 | arrive at "Hos Oss" |
| 18:45 | dinner will be served |
| 22:15 | bus leaves Lillesand |
| 22:45 | bus arrives at the Scandic Hotel ByStranda |

The **boat trip** through the coastal waters of Kristiansand will take place on Wednesday, 21st of June, from 16:00 to 18:00. We will meet in front of the Scandic Hotel (Bystranda) at 15:30 to walk to the landing place of the boat "MS Maarten". Details about the location of the boat and the trip itself can be found [here](http://www.maarten.no) (www.maarten.no).

