Introduction

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Abstract. This collected volume gives a concise account of the most relevant scientific results of the COST Action IS1104 "The EU in the new complex geography of economic systems: models, tools and policy evaluation", a four-year project supported by COST (European Cooperation in Science and Technology). It is divided into three parts reflecting the different perspectives under which complex spatial economic systems have been studied: (i) the Macro perspective looks at the interactions among international or regional trading partners; (ii) the Meso perspective considers the functioning of (financial, labour) markets as social network structures; and, finally, (iii) the Micro perspective focuses on the strategic choices of single firms and households. This Volume points also at open issues to be addressed in future research.

Keywords: COST Action IS114 · European Union · Economic Geography · Financial Markets · Strategic Decisions and Interactions · Complexity

1 The COST Action IS1104 "The EU in the New Complex Geography of Economic Systems: Models, Tools and Policy Evaluation"

Inspired by the New Economic Geography (NEG) approach, initiated by Paul Krugman and Masahita Fujita in the 1990s, the main objective of the COST Action 1104 "The EU in the new complex geography of economic systems:

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models, tools and policy evaluation (GeComplexity)" has been to approach the study of EU, more generally, economic systems from a multi-layered perspective featuring interconnected spatial structures. At each layer, different types of decisions and interactions take place: interactions among international or regional trading partners at the macro-level; the functioning of (financial, labour) markets as social network structures at the meso-level; and finally, the strategic choices of single firms and households at the micro-level. Within these structures, the spatial distribution of economic activities is evolving through time following complex patterns determined by economic, geographical, institutional and social factors. To study these structures, during its four years life time (March 2012–September 2016), the Action has built successfully an interdisciplinary approach. It has further developed advanced mathematical, computational and empirical methods and tools for analysing complex nonlinear systems, including macro and micro models, nonlinear dynamical systems, social networks, game theoretical models and agent based models.

This leads to the second objective of the Action: building multiregional models that integrate real world features; mapping the geography of the financial and banking networks; understanding firms' strategic choices on location and R&D cooperation and competition. More generally highlighting the pervasiveness of networks structures at the various levels of aggregation.

To achieve these objectives, several activities have been performed. Twenty-three meetings of which four major events – including a Final Conference – and several workshops have taken place. Researches from twenty-six European countries and across the world and from an EU Commission research institution (the Joint Research Centre, JRC, Seville) have contributed with an interdisciplinary expertise: economists, regional economists, applied economists, mathematicians, physicists. These activities lead to several scientific outcomes including more than 140 articles in leading journals, Special Issues (four published and two as an expected outcome of the Final Conference), three collected volumes, multiple book chapters and working papers.

The Action has evolved into a very active network not only through several meetings but also via more than eighty Short Term Scientific Missions (STSMs). A high percentage of STSMs have been allocated to Early Stage Researchers (ESRs). Moreover, three Training School have been specifically designed to build the capacity of PhD students and young scholars. Dissemination has been conducted also via the Action Website http://www.gecomplexity-cost.eu and a Discussion Paper Series edited by COST Members and indexed in REPEC.

This book gives a concise account of the most relevant scientific results of the GeComplexity Cost Action and points at open issues to be addressed in future projects. The Volume is divided into three parts reflecting the different perspectives under which complex spatial economic systems have been studied.

2 The Macro Perspective - Economic Geography

The chapter by **Commendatore, Hammer, Kubin and Petraglia** provides a non-technical overview of new economic geography models dealing with policy

issues. The Chapter begins by describing the main ingredients of the NEG approach and illustrating the basic mechanism at work centred on the interplay of agglomeration and dispersion forces. As suggested by Krugman (1991), trade integration leads to spatial concentration of economic activity altering the balance in favour of the agglomeration forces. The authors consider various policy measures including alternative categories of public expenditure, international tax competition, unilateral actions of protection/liberalisation, and trade agreements. The implications of public intervention in two-region NEG models are discussed by unfolding the impact of policy measures on agglomeration/dispersion forces. Results are described and contrasted to those obtained in standard non-NEG theoretical models. Paradigmatic examples are the non-neutrality of home-bias public procurement for the determination of a country's pattern of specialization; the presence of taxable agglomeration rents leading to a "race to the top" rather than a "race to the bottom" within a tax competition game between countries; the impossibility to exploit a potential comparative advantage to avoid deindustrialization in poorer countries when agglomeration effects are at work.

The high degree of abstraction limits the applicability of NEG models to real world policy issues. The authors discuss in some detail two extensions of NEG models to reduce this applicability gap: the cases of multi-regional frameworks and firm heterogeneity.

The applicability gap is addressed by **Commendatore, Kubin and Sushko** by studying a three-region economy in a NEG model. By using linear (and not iso-elastic) demand functions, the model is able to account for trade patterns between pairs of regions allowing for unilateral, bilateral and no trade regimes. Thus, the proposed framework is suitable to study how changes in parameters that are typical for NEG models, such as trade costs and regional market size, not only shape the regional distribution of economic activity, but also at the same time determine the emergence of trade links between regions.

To focus the analysis, the authors study in more detail three specific trade patterns frequently found in the EU trade network. First, they consider three autarkic regions belonging to an economy at its first stages of development. For this set-up, instances of coexisting stable long-run equilibria (multi-stability) are found, which cannot occur in a two-region framework, stressing the importance of initial advantage in the process of industry concentration; then following the improvement of transport infrastructures between two regions, the possibility that these regions trade with each other (but only with each other) is introduced. As trade costs fall, the region with a larger initial endowment of the mobile factor starts exporting to the closer region and attracts the industrial sector. However, in contrast to the two-region case, some of the industry locates in the more remote region, finding shelter from competition; and, finally, even the remote region closes its distance with one of the other two regions, which increases its centrality in the trade network. However, centrality does not necessarily translate into a locational advantage.

More generally, the authors find a surprising plethora of long-run equilibria each involving a specific regional distribution of economic activity and a specific pattern of trade links. This implies that a variation in trade costs shapes simultaneously industry location and the configuration of the trade network.

Basile and Mínguez propose a critical review of parametric and semiparametric spatial econometric models. They focus on the capability of each class of models to fit the main features of spatial data, namely spatial dependence (or weak cross sectional dependence, due to spatial spillover effects), strong cross-sectional dependence (due to unobserved common factors), spatial heterogeneity, nonlinearities, and time persistence. They also provide a brief discussion of the existent software developed to estimate most of the econometric models described in the chapter.

They start by summarizing the broad literature on parametric spatial autoregressive models, which is still the dominant paradigm in spatial econometrics. Within this literature, it is possible to distinguish between first-generation spatial econometric models (essentially developed to handle cross-sectional data) which focus on modeling spatial dependence through different alternative linear specifications, and second-generation spatial econometric models, developed during the last decade, more specifically, static and dynamic spatial panel data models which prove to be particularly useful to control for unobserved spatial heterogeneity and time persistence. A natural extension of the last class of models, proposed during the last few years, consists of the combination of spatial panel data models and common factor models in order to disentangle strong and weak (spatial) cross-section dependence.

In spite of these important advances in the literature, it is important to recognize that any parametric model is limited to specific forms of spatial variation of the parameters, while they are not able to capture more general forms of model mis-specifications, such as spatial parameter heterogeneity and nonlinearities. Thus, semiparametric spatial econometric models appear as more flexible estimation frameworks. The authors dedicate the second part of their Chapter to this category of models, distinguishing between (mixed)-GWR models based on kernel methods, and models based on penalized spline smoothers. Three recent contributions are of particular relevance in this context. First, combining kernel smoothing methods and standard spatial lag models, a new class of data generating processes (DGP) within the GWR literature (Mixed Geographically Weighted Regression Simultaneous AutoRegressive Models) provides an important framework to account for both spatial dependence and nonstationarity of the parameters. Second, combining penalized regression spline methods with standard cross-section spatial autoregressive models, another class of DGP allows the researchers to simultaneously control for spatial spillover effects, nonlinearities, spatially autocorrelated unobserved heterogeneity, and spatial nonstationarity of the parameters. Finally, semiparametric models for longitudinal data, which include a non-parametric spatio-temporal trend, a spatial lag of the dependent variable, and a time series autoregressive noise, represent a valid alternative to parametric methods aimed at disentangling strong and weak cross-sectional dependence. Natural directions in which these methods can be extended are specifications suitable for the analysis of dynamic frameworks.

The last chapter by **Commendatore and Kubin** concludes Part I of the Volume. The authors summarise the work carried out during the lifetime of the Action by the Working Group whose main task was to build multiregional NEG

models. The authors list the main results, point at the questions left open and suggest topics for future research. What emerges from the discussion is that the predictions of NEG models are highly sensitive to their specification: different assumptions concerning, for example, the geographical structure of the economy or even the functional form of consumer's preferences lead to different long-run spatial distributions.

3 The Meso Perpective - Financial Markets

Bougheas, Harvey and Kirman explore the relationship between systemic risk and the behavior of aggregate credit. The two most severe macroeconomic crises of the last 100 years, namely, the Great Depression of the 1930s and the Great Recession that commenced at the close of the first decade of the current century, were preceded by extreme events in financial markets in general and the banking system in particular. In a recent study, Schularick and Taylor (2012) have empirically identified a historical link between the level of aggregate credit in the economy and macroeconomic performance. They argue that aggregate credit can be a powerful predictor of economic crises, especially, rare catastrophic events.

Their aim is to provide a microfoundational explanation for the above relationship. In this work the focus in on the behavior of aggregate credit. In particular, the authors analyze the dynamics of aggregate bank credit in an economy where all financial transactions are intermediated through the banking system. Viewing the financial system as a network of banks that are connected through their financial obligations to each other, they examine how the impact of shocks on the asset side of the banking balance sheets may disrupt the supply of aggregate credit.

In their model, banks are unable to completely diversify their loan portfolios and thus they can become insolvent. This will be the case when the total loan repayments (from both entrepreneurs and other banks) are insufficient to cover their obligations to their depositors and other banks. In order to clear the banking system when some banks become insolvent the authors apply the method suggested by Eisenberg and Noe (2001). Insolvencies can propagate through the banking network. When one bank is unable to meet its obligations to another bank, the latter bank might itself become insolvent even if it would have remained solvent had its loans to the originally failed bank been repaid. The bankruptcy resolution process terminated when there are no insolvent banks left. The number of bank failures will depend on (a) the distribution of initial losses across the banking system, and (b) the structure of the financial network (see, for example, Acemoglu et al. 2015).

As long as the liquidation of assets held by insolvent institutions does not depress the market values of these assets the total systemic losses by the end of the resolution process will be equal to the initial losses due to the inability of entrepreneurs to repay their loans. However, as Shleifer and Vishny (1992) have argued during systemic episodes, exactly because there are many failing institutions, the market value (liquidation value) of the assets can drop below

their corresponding book values (fire sales). This drop in asset prices forces other institutions to reevaluate their own assets thus potentially causing new rounds of failures.

In the model, when the authors do not allow for fire sales, the value of aggregate credit provided by the banking network follows a random walk. This is because the capacity of the banking network to provide credit each period depends on the availability of reserves which in turn depends on the performance of aggregate loans the period before. Given that shocks are normally distributed each period it follows that aggregate lending activity follows a random walk. When they introduce fire sales, systemic losses can be much greater than initial losses thus introducing fat tails on the lower end of the distribution of aggregate credit. Under the supposition that aggregate credit is positively correlated with aggregate output their approach might be useful for explaining two features of business cycles: (a) the asymmetry in booms and busts (Acemoglu and Scott 1991), and (b) macroeconomic fat tails Acemoglu et al. 2017).

The chapter by **Schmitt, Tuinstra and Westerhoff** reviews the literature on market interactions and policy measures. In the wake of the financial crisis that hit the global economy almost ten years ago many economists and policy makers realized that the strong links between individual markets played an important role in allowing the crisis to spread globally, or may even have been at the core of the emergence of the crisis. This has spawned a literature that deals both with the effect that interactions between markets have on market stability, and with the policy measures that may be implemented to counter the instabilities that potentially arise from these interactions. In this chapter, the authors review a small part of that literature.

That individual markets may lead to instability has been recognized for some time already. Classic textbook examples are the cobweb model under naïve expectations (see Ezekiel 1938) or the Cournot oligopoly model under best reply dynamics (see Theocharis 1959). More recently the development of the theory of nonlinear dynamical systems has led to an increased attention for the possibility of market instability. Some early and important applications of this theory are Grandmont (1985) and Bullard (1994) on overlapping generations models, Chiarella (1998), Hommes (1994) and Brock and Hommes (1997) on cobweb markets, Day and Huang (1990), Lux (1995) and Brock and Hommes (1998) on financial markets and Puu (1991) and Kopel (1996) on Cournot duopoly models. Laboratory experiments with paid human subjects suggest that instability is indeed likely to occur in some of these market environments (see e.g. Hommes, Sonnemans, Tuinstra and van de Velden, 2005 and Heemeijer, Hommes, Sonnemans and Tuinstra 2009).

In the last decade, the interaction between markets has been identified as an additional route to market instability. Dieci and Westerhoff (2009, 2010), for example, find that two stable cobweb markets may become unstable when they are linked. Tuinstra, Wegener and Westerhoff (2014) show that this increased instability may result in counterintuitive policy prescriptions: increasing import tariffs between interacting markets may decrease allocative efficiency at the

steady state equilibrium, but may be welfare enhancing nevertheless. This is because they weaken the link between markets and thereby stabilize consumption and production patterns. Even in the absence of naïve price expectations and cobweb dynamics linking two markets may lead to instability, as demonstrated by Schmitt, Tuinstra and Westerhoff (2017a, 2017b). They study a stylized model of market interaction, where firms may migrate between two regions on the basis of profitability between these regions. If firms are sufficiently sensitive to these profit differences this may lead to unstable dynamics. Following the insights from Schmitt and Westerhoff (2015, 2017), the papers by Schmitt, Tuinstra and Westerhoff (2017a, 2017b) investigate how the introduction of profit taxes may dampen the profit differences between the two markets and thereby stabilize the dynamics. Schmitt, Tuinstra and Westerhoff (2017b) discuss the scenario where each region is overseen by an independent local government or regulatory authority. Optimally, these two regulators coordinate their profit taxes in such a way that markets are stable and total welfare is maximized. However, Schmitt, Tuinstra and Westerhoff (2017b) argue that, if regulators are only (or mainly) interested in welfare in their own region, each of them will may have the incentive to decrease the profit tax, which can destabilizes markets.

The last chapter of Part II by **Bougheas and Kirman** offers a number of suggestions for future research, first, for exploring the link between the network structure of the banking system and aggregate credit and, second, the relationship between systemic risk in financial markets and macroeconomic fat tails.

4 The Micro Perspective - Strategic Decisions and Interactions

Colombo and Dawid offer an innovative approach to the issue of location decisions and R&D spillovers and provides ample opportunity for further developments. The authors assume that firms are forward looking and base their location decisions on sophisticated (Markov) strategies that determine their R&D investments. In particular, the authors consider a differential game based on a standard Cournot model with three firms. Firms 2 and 3 are located in an industrial cluster and at $t = 0$, firm 1 has the choice to either co-locate in the cluster or instead locate in isolation. The difference between these two choices is that each firm in the cluster receives knowledge spillovers from all the other firms in the cluster whereas if located in isolation, firm 1 receives no spillovers but also does not need to worry about outgoing spillovers. The firms choose production quantities and their R&D investments that increase their knowledge stocks. In the model, absorptive capacity plays a crucial role: a firm's current knowledge stock determines its absorptive capacity which, in turn, determines how much of incoming spillovers the firm can absorb to increase its own knowledge stock. The firms located in the cluster face fixed costs of congestion each period and all firms try to maximize their discounted profits. The authors characterize Markov-Perfect Equilibria of this game for various scenarios. One of their insight is that the relation between firm 1's location choice and firm 1's initial knowledge stock

depends on the characteristics of absorptive capacity (exogenous and constant versus endogenous and proportional to knowledge stock). In case of a constant absorptive capacity, firm 1 prefers to locate in the cluster if its initial knowledge stock is small. However, if absorptive capacity is endogenous, then firm 1 locates in the cluster if its initial knowledge stock is large. As a consequence, the authors conclude that a deeper understanding of firms' location decisions requires a thorough investigation of the associated characteristics of the spillover mechanisms.

The chapter by **Kopel, Manasakis, and Petrakis** studies competition between a local firm that invests in corporate social responsibility (CSR) and a multinational firm that enters the foreign market either via exports or foreign direct investments. As a modeling framework the authors use a multi-stage game which is more standard in the International Business literature. In stage 1, the government of the foreign country sets the tariff; in stage 2, the multinational home firm decides whether to serve the foreign country's market through exports or FDI; finally, in stage 3, the local firm invests in CSR and the two firms set their quantities for the markets. The game is solved by backward induction and the solution concept is Subgame Perfect Nash. The authors derive results on the interaction between the optimal mode of entry of the (multinational) enterprise and the local firm's investment in CSR. They further look at the effects on consumer welfare, firm profits, and total welfare. This paper brings together two important topics, namely the role of multinational enterprises in globalized markets and the impact of firms' corporate social responsibility. With the introduction of Directive 2014/95/EU on the disclosure of non-financial and diversity information, the European Commission expressed its view on CSR as an extended corporate governance policy. The Directive introduces enhanced reporting requirements on social, environmental and governance issues. During the process of the development of Directive 2014/95/EU, concerns were raised that due to this regulation European firms will have a competitive disadvantage against their international rivals. An important issue is, therefore, if CSR enhances or diminishes the competitiveness of European firms against their international rivals. This is particularly crucial, since the field of international trade and CSR policies is still under-researched (e.g. Kitzmuller and Shimshack 2012).

Bischi, Kopel, Lamantia, and Radi work within an evolutionary setting which is rarely used in the literature on location decisions of multinational firms. The authors study a population of firms that can either manufacture in their home country or off-shore production to a foreign country. The two locations are structurally different as the home country has higher unit production costs but higher internal knowledge spillovers whereas the foreign country has lower unit costs but also smaller internal knowledge spillovers. Additionally, (i) technology know-how developed in one country can potentially be transferred to the other country and be used for reducing costs, and (ii) firms located in the foreign country face congestion costs that are increasing in the manufacturing activity occurring in this country. The firms' location decisions are based on a simple (myopic) comparison of unit production costs taking into account current within-country spillovers, cross-border spillovers, and congestion costs. An evolutionary

choice mechanism based on an exponential replicator equation determines the share of firms that switch from one location to the other. From a modeling point of view, this chapter differs from the approaches taken in the previous two chapters of this section of the book since location strategies are spread in a population of firms via an evolutionary mechanism that captures some myopic decision rule instead of forward-looking rational decision calculus. The authors present a variety of scenarios and characterize long run location patterns for off-shoring and on-shoring and how these activities depend on spillovers and congestion costs. Such a framework can be used to generate robust predictions which can then be tested empirically.

Lastly, **Bischi and Kopel** briefly reviews the research activity carried out by the Working Group on 'Social and Industrial Interactions'. The main focus of this group has been on the behaviour of economic agents at the micro-level. Concerning firms locational choices, and especially referring to multinationals, the authors notice that the trend that has lead many firms to off-shoring their main activities is, recently, reversing. Moreover, the authors stress that environmental, social and governance dimensions are becoming more and more relevant issues. Finally, they suggest as main avenues for future research the study on corporate social responsibility strategies of multinational enterprises and their global value chains.

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