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A technology-based countries-interaction dynamic model for the study of European growth and stability: Were there the conditions for convergence?

Bernardo Maggi

Department of Statistical Sciences, Faculty of Information Engineering, Informatics and Statistics, Sapienza University of Rome, Piazzale Aldo Moro, 5, 00185 Rome, Italy

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A B S T R A C T

In this research, we study a methodology for evaluating the dynamics of the European countries' growth. Our focus is on the analysis of the convergence conditions implied by the Lisbon strategy and founded on the interaction among technology diffusion, services for firms and production (the so-called "knowledge-based sustainable growth"). We estimate and analyse a differential equations system representing a disequilibrium model where business services assist the production process for the use of technology. To this aim, we develop a specific panel data estimation-procedure for continuous time nonlinear models. We find the offshoring activity, operated by foreign business services, essential for the countries' convergence to a stable growth path. Then, we perform a sensitivity analysis to assess the possible country's specific efforts necessary to gain stability. Further, we provide an evaluation of the convolution integral of our differential system to determine the initial conditions required to pursue a future target value for the endogenous variables.

1. Introduction

1.1. Aims and state of the art

In this research, we study a methodology for evaluating the dynamics of the European countries' growth path. Our focus is on the analysis of the convergence conditions implied by the Lisbon strategy of 2000 and following resolutions, whose kernel is the interaction among technology, services for firms – through a development of the internal market for services – and production, i.e., the so-called "knowledge-based sustainable growth". Such an interaction should have been at the basis of the European integration process. We aim at formalizing dynamically and testing econometrically the interaction between the three variables mentioned above at the time when the EU started up, in order to understand if these were the premises for the European countries' convergence to a stable growth path on the base of the strategy adopted. For this purpose, we develop a specific panel-data estimation procedure for continuous time nonlinear models. We estimate and analyse a disequilibrium differential equations system describing the diffusion of endogenous technology, employed in the production process thanks to business services.

From an economic point of view, the peculiarity of our approach consists in dealing with both transitional dynamics and technology diffusion in a structural endogenous growth model. Usually, the literature on endogenous growth with technology diffusion addresses only one of these two issues. In particular, Eaton and Kortum (1999) emphasize the difficulty of considering both these aspects together and concentrate on a detailed description of the innovation diffusion process. Actually, they provide a complete description of such a process by making use of the patents applications data from the cross-section WIPO database. Other literature focuses attention on the transitional dynamics but neglects the diffusion problems as in Jones (1995) and in the following strand of the New Economic Geography based on the seminal works of Krugman (1991a, 1991b), Venables (1996), Englmann and Walz (1995) and Walz (1996) in a two-regions framework. These works describe the interaction among countries by defining a proportion of a country variable on the total available for all the countries considered. Differently, the former class of models specifies the equations representing all the exchanges of inventions between countries – i.e. the structure of diffusion – but, in order to allow for a tractable problem, confines the analysis exclusively to the steady state. From the empirical side, though correct in principle, such an approach forces the estimation of a dynamic problem, as it is a growth one, by using only cross-sectional data as in Eaton and Kortum (1996, 1999, 2002). Not

E-mail address: bernardo.maggi@uniroma1.it.

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even the Dynamic Stochastic General Equilibrium approach applied to growth and innovation – as in Holden (2010) and The Anh (2011) – deals satisfactorily with both aspects since it neglects the transition phase and does not describe the diffusion process through specific functions referred to countries. Still, the estimation relies on the calibration of several parameters conferring a degree of arbitrariness to the empirical analysis. Another approach is that one a là Keller (2002), which considers a single equation. In such a case, lacking the structural equations of diffusion, broad definitional categories as proximity, languages etc. characterize the diffusion aspect.

We reckon that both the structure of the diffusion and the transitional dynamics are fundamental in order to assess the growth process. Our approach accounts for both of them by developing a continuous time structural disequilibrium model where the technology diffusion process is described in a country specific way. Then, we infer on the equilibrium, which may exist or not. We use, for such a specific problem, a panel data continuous-time econometric methodology, which has the advantage of estimating "exactly" the theoretical equations. The differential equations we estimate represents the disequilibrium of the system for studying the dynamics of growth, which is typically a continuous time problem for the straightforward interpretation of the rates of growth in terms of eigenvalues. The equilibrium condition therefore is just a possibility and furthermore, even if one may prove its existence by the estimated coefficients, its attainability may be complex. In this respect, we follow Schumpeter (1934) and Nelson and Winter (1982), who are agnostic a priori on the viability of the steady state and focus on the forces that drives the economy throughout the disequilibrium phase. Moreover, because of the nonlinearity, the approximation around the equilibrium, and consequently the evolution of the system, depend on time and countries, thus involving further qualifications to understand the feasibility of the equilibrium.

Another aspect often neglected in the literature of growth with diffusion is that of the stock of the innovations exchanged, which is crucial in describing the relations among both variables and countries, being a factor of the production function. The reason for this omission is that such a stock is an additional source of nonlinearity. In fact, the models under considerations are usually nonlinear and so the variables are typically transformed in logarithmic or exponential forms whilst, on the contrary, the stock of technology is the summation of the past and present contributions – coming from all countries – of flows of innovations not transformed. In order to circumvent such an aspect, the above mentioned literature resorts to a production function which focuses only on intermediates but, in so doing, omit to consider the contribution of technology to a country's production process coming from the other countries. Differently, we consider an endogenous stock of technology inside the production function and connect these two variables with business services, for their role of making usable technology by firms (Rubalcaba and Kox, 2007).

We consider both domestic and foreign business services in order to investigate if the offshoring process helps reach a country's stable growth path, which is an important empirical focus of this research.

From the policy implications point of view, we are concerned with planning and possibly controlling the occurrence of the variables' paths in a certain future period, with special emphasis on output. We do this by computing numerically the solution of our system and obtaining initial conditions coherent with our targets. We also compute the derivatives of the eigenvalues and eigenvectors with respect to the structural parameters of the model in order to study the changes in the stability conditions that may come from possible policy actions.

1.2. *Distinguishing features and structure of the paper*

Summing up, the main distinguishing features of this research are the following. a) An assessment of the convergence process related to the exchanges of new technologies between European and foreign countries – as implied by the Lisbon strategy for the European integration – and in particular the relevance in such a process of the offshoring activity. b) The definition of a modelling methodology that accounts for both the dynamics of growth and the structure of the technology diffusion in a country specific way. c) The adoption of a specific estimation procedure of continuous time nonlinear dynamic systems in an *exact* way for panel data — i.e., we estimate the solution of a differential system without approximating the continuous time model to a discrete one. d) The sensitivity analysis of the model eigenvalues and eigenvectors with respect to the model parameters. e) The analysis of the initial conditions necessary to obtain, according to the countries' interactions, a desired path for the variables of interest.

In the second section, we explain the relations between variables and the logic of the model. In the third section, we expound the methodology of continuous time econometrics for panel data. In the fourth section, we present the estimations. The fifth section shows the stability and sensitivity analyses. In the sixth section, we perform the policy analysis. The seventh section concludes. Appendix A shows the integration procedure adopted for the exogenous variables in order to obtain the final solution of the system to estimate. Appendices B and C report some algebra, which may be skipped in the main text, used for estimation and simulation, respectively.

2. Theoretical background

2.1. *Output, technology and business services*

The focus on the endogenous interaction among output, technology and business services is motivated by the interest that the European countries have in reaching a knowledge-based sustainable growth path assisted by business services since the beginning of the EU, as reported in the Lisbon Agenda devised in 2000 and its revised versions (European Commission, 2005a, 2005b). In this study, we intend to evaluate if the strategy for growth adopted by the European Union was effective as well as the policy actions, which might enhance growth.

The logic of this three-way interaction rests upon the basic concept that, as widely shown by Evangelista et al. (2013), firms exploit technology in the production process thanks to business services. In this sense, the role of business services is that of explaining the total factor productivity.[1] Accordingly, the desired business services are determined both by the level of output to produce and by technology. The technology necessities in their turn depend again on the level of output and on business services. This latter effect is due to the monopolistic competition market form of business services, which ask for new technologies to develop (Zagler, 2002). All other variables are exogenous.

We consider two models, an unrestricted and a restricted one. In the former are present several additional exogenous variables and an endogenous one, not contained in the latter. Crucially, the endogenous variable under question is the imported services in order that, from the comparison of these two models, it is possible to assess the importance of the offshoring activity in the convergence process. For convenience of exposition and to deal properly with the dynamic analysis (which needs to be based on the broader model for the major completeness in terms of explicative variables), we start describing the unrestricted model in that it comprises the restricted one.

As usual, in continuous time architecture the actual values of the endogenous variables adjust to their partial equilibrium – i.e., desired – functions, which depend on specific determinants – i.e., driving forces. The driving forces for output (Y) are the basic stocks of the production

[1] Marrewijk et al. (1997) argues that business services may have the role in the production function of representing the advanced capital such as the ICT one.