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ARTICLES

INTRODUCTION TO TIME-VARYING MODELING WITH MACROECONOMIC AND FINANCIAL DATA

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1. INTRODUCTION

The dynamics of macroeconomic and financial series has evolved swiftly and asymmetrically since the end of the 1970s, and their statistical properties have also changed over time, suggesting complex relationships between economic and financial variables. The transformations can be explained by considerable changes in householder's behavior, market structures, and economic systems and by the alternation of exogenous shocks and financial crises that have affected the economic cycle, with significant evidence of time variation in the major economic variables. Hence, there is a need for new econometric protocols to take such changes into consideration. The introduction of ARMA (autoregressive moving average models) by Box and Jenkins (1970) led to the development of time-series econometrics, which had a major impact on the conceptual analysis of economic and financial data. This type of modeling offered a transition from a static setup to a new modeling process that reproduces the time-varying features of macroeconomic and financial series. However, the ARMA modeling system retains the constancy of the first and second moments, limits the phases of a cycle to symmetrical instances, and only reproduces the dynamics of stationary variables. It thus fails to adequately reproduce the nonstationary relationships between major economic and financial variables. Abrupt changes in economies and financial systems have given evidence of nonstationary series whose statistical properties are also time-varying, making it necessary to develop new econometric tools to capture the time variation of economic and financial series in the mean and in the variance, and to apprehend their dynamics in the short and long term. Among the most important and influential studies in the 1980s' econometrics literature were therefore those that dealt with the introduction of the ARCH (autoregressive conditional heteroskedasticity) model by Engle (1982) and the cointegration theory by Engle and

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Granger (1987). The ARCH model, which focuses on the time-varying features of volatility structure, was a major breakthrough, as it highlighted the importance of the second moment of time series, while the cointegration framework enabled the short- and long-term dynamics of nonstationary variables to be modeled.

Recently, however, increased use of quantitative economic and financial data, improvements in empirical techniques, and the development of databases have shown that these models are not always able to apprehend all the stylized factors in economic and financial time series satisfactorily. In particular, we noted that time variation in economic and financial series has become increasingly significant, and the relationships appear somewhat more persistent, abnormal, asymmetrical, and nonlinear. These properties may escape the linear cointegration framework. However, several nonlinear models have been developed to capture persistence, irregularity, and nonlinearity in economic and financial data.

This Introduction aims to briefly explain the time variation and irregularity characterizing key economic and financial data and to discuss the failure of linear modeling to capture the behavior of macroeconomic and financial variables. We also present and discuss several empirical studies that model the statistical properties of the economic and financial series under consideration in different ways, using diverse econometric tools. The analysis of their findings indicates significant contributions and results.

The introduction is organized as follows. First, Section 2 briefly discusses the importance of time variation and asymmetry in the data. In Section 3, we present the limitations of linear models for reproducing this asymmetry. Section 4 then provides a brief overview of time-varying models. Finally, we present the different contributions of this special issue.

2. TIME VARIATION AND ASYMMETRY IN MACROECONOMIC AND FINANCIAL DATA

The analysis of financial and macroeconomic data indicates that their dynamics evolve significantly over time. This time variation appears to be due to internal and external, microeconomic and macroeconomic, endogenous and exogenous factors. Indeed, in recent decades changes in corporate strategies and consumer behavior, evolution in market regulations and regimentation, increases in supply and demand, and new government regulations have had an impact on all economies and have led to considerable changes in all economic systems. Furthermore, the international infrastructure has also experienced considerable changes, with the recent and impressive growth in China and the emerging markets: the move toward financial capitalism, the adoption of the floating exchange system, the modernization of financial institutions, the development of financial innovation and a number of sophisticated new financial instruments and products, the increase in financial and economic integration, the use of new information and communication technologies, and the rapid evolution of international capital markets, financial globalization, and the rise in capital mobility. Such changes are

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not without consequences, as they generate complex dynamics and asymmetrical relationships between economic and financial variables, which exhibit different types of asymmetries and nonlinearities.

Granger et al. (2010) suggest that nonlinearity involves several economic variables and can be explained in different ways. When central banks set exchange rate boundaries, they generate nonlinearity between the exchange rate and its fundamentals. In labor markets, the behavior of firms employing workers may generate asymmetric and nonlinear fluctuations in employment. Additionally, when governments introduce new reforms and policies, this can lead to asymmetric variations in supply and demand. The presence of transaction costs in capital markets is an important source of nonlinearity. Overall, large fluctuations and variations in economic and financial series may occur. Moreover, their dynamics tend to evolve over time and their adjustment is likely to vary asymmetrically according to the phase of the economic cycle (economic growth, collapse). Investors and firms are in competition to make money quickly, for instance, and investors may often use arbitrage techniques and implement risky positions to this end, leading to rapid price increases and excessive volatility.

To model the dynamic evolution of economic and financial time series, previous studies have used different tools and techniques. Overall, they come to two major conclusions. First, linear modeling fails to reproduce such time-varying dynamics, as it does not enable the first and second moments to evolve over time. Second, the failure of linear modeling encouraged researchers to look for a suitable model that allows variable dynamics to be apprehended. Nonlinear models thus began to supplant the linear model to improve the modeling of the dynamics of economic and financial data.

3. LIMITATIONS OF LINEAR MODELING

Modeling economic and financial series is a difficult task, particularly when their properties display time-varying dynamics. When using linear modeling to model time series, econometricians often assume that series display normal distribution with constant variance. However, in a sample comparison using visual inspection with a time series generated by the standard normal distribution, we can show the limitations of this hypothesis for major economic and financial series. In several series, the variance is not constant, and a more general distribution would be more suitable to capture this change over time. Moreover, analyses of stylized factors in financial series often show dynamics that exhibit excess skewness and kurtosis compared to the normal distribution. However, these properties cannot be reproduced using linear modeling, as it cannot capture the properties of time-varying macroeconomic and financial series, and their implementation may lead to biases in the estimation.

Thus, linear modeling displays a number of limitations. First, ARMA models do not enable the asymmetry characterizing various economic and financial series to be reproduced. Second, these models do not allow for time variance,

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structural breaks, or switching regimes in the data. Third, ARMA modeling requires the normality hypothesis. Finally, linear models only require the first and second moments (average, variance), which implies underexploitation of the time-series information. These limitations can be overcome using nonlinear models, which can improve the study of time-varying properties in economic and financial data.

4. TIME-VARYING MODELING

Several models have been developed in the literature to capture the time-varying dynamics of economic and financial series. A number of these models have given rise to nonlinear models, which appear useful for reproducing economic relationships that evolve over time. The nonlinearity is in the mean equation and/or the variance equation, thus identifying nonlinear models in the mean and nonlinear models in the variance, respectively.[1]

Interestingly, with nonlinear models, the parameters can vary over time, allowing the dynamics of a series to evolve and to be different across the phases of the cycle. However, as in Granger et al. (2010), when we try to consider a nonlinear model to explain the variation in economic or financial time series, the presence of several models poses a problem: which model should be retained from the nonlinear models available? To select the best model, econometricians should check which one provides the best fit to the data. To this end, they need to build their model in different stages, checking its ability to apprehend the statistical properties of the data. Indeed, in the econometrics literature related to time-varying modeling, econometricians choose and build their models according to the hypotheses under consideration and the results of linearity tests, as illustrated by the different contributions in this special issue. They then develop new econometric tools and test their performance on real data.

5. PRESENTATION OF THE CONTRIBUTIONS

The papers in this special issue of *Macroeconomic Dynamics* were presented at the first International Symposium in Computational Economics and Finance (ISCEF) in Sousse, Tunisia 25–27 February 2010.[2] They were submitted for publication in this issue and, after several rounds of double-blind review, were recommended for publication. We will present the papers in the Introduction and briefly discuss their main findings and contributions. As we will see, these papers have greatly contributed to the current literature on time-varying modeling. They concern different countries, focus on different data, use different modeling tools, and yield strong evidence of time variation, persistence, asymmetry, and nonlinearity in macroeconomic and financial data.

The first paper, entitled "Business Environment, Start-Ups, and Productivity during Transition," by Zuzana Brixiová (African Development Bank, Development Research Department) and Balázs Égert (Organization for Economic

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Cooperation and Development, Economics Department),focuses on the study of business environments and productivity in Central European, Eastern European, and Baltic countries during transition. The authors note a significant increase in productivity, which they explain by the rapid reform and transformation of their business environments. This implies significant variation of productivity in these countries and a narrower productivity gap with advanced countries. The most important contribution of this paper is the development of a dynamic search model of company start-ups that reflects these trends. Their model shows that an enabling business climate contributes significantly to highly productive business start-ups at an earlier stage of transition, underscoring the importance of early reforms. This topic has been studied in several previous papers, but only from an empirical viewpoint. Thus, the present paper contributes to closing the research gap by extending the dynamic model of Brixiova and Kiyotaki (1997) for the role of the business climate. Their model helps to explain some of the diverging economic outcomes observed between the economies in Central and Eastern Europe and the Baltics (CEEB) and the Commonwealth of Independent States (CIS) by showing how an enabling business climate can stimulate an earlier shift to highly productive private firms and thus faster growth in the private sector, productivity, and employment. The authors point out that the CEEB's faster implementation of market reforms and more enabling business climate have helped stimulate an earlier structural shift to more productive private firms. Their model also illustrates the way this has contributed to faster and time-varying labor productivity growth and, consequently, to more rapid convergence with the income levels of advanced economies, thus confirming the importance of undertaking structural reforms and strengthening the business climate.

The second paper is by Michal Rubaszek (Economic Institute, National Bank of Poland and Econometric Institute, Warsaw School of Economics) and concerns "The Role of Two Interest Rates in the Intertemporal Current Account Model." The paper analyzes the role of the lending-deposit interest rate spread in the dynamics of the current account in developing countries. The author extends the standard perfect-foresight intertemporal model of the current account to the existence of interest rate spread. Applying this modeling to panel data for 60 developing countries, the author points to significant relationships between the current account and the interest rate spread. The paper contributes to the literature on intertemporal current accounts in several ways. Whereas previous studies often assumed that only one domestic interest rate existed for both deposits and loans, this paper differentiates between the two interest rates. Because of the existence of a spread between these two interest rates, it may be optimal for low-income, converging economies to run balanced current accounts. Also, while developing a perfect-foresight general equilibrium model with two interest rates and following several simulation exercises, the author shows that even a small change in interest rate spread can have a huge impact on the current account balance, especially if the interest rate spread is close to zero. The existence of interest rate spread can significantly change the implications of the standard intertemporal current account

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and may also imply significant variation in the dynamics of other macroeconomic variables.

Whereas the two first papers concern Central and Eastern European and Baltic countries and developing countries, respectively, the paper "Real Effects of Monetary Policy in Large Emerging Economies," by Sushanta K. Mallick(Queen Mary University of London) and Ricardo M. Sousa (University of Minho and London School of Economics) focuses on large emerging countries, notably the monetary policy transmission of five key emerging market economies: Brazil, Russia, India, China, and South Africa (BRICS). The authors justify the choice of this sample by the fact that they are the largest and fastest-growing emerging markets. Also using interest rates to define monetary policy shocks, the paper contributes to studies on the sources of time-varying economic fluctuations and provides evidence of monetary policy transmission for the major emerging market countries. The authors focus in particular on the real effects of monetary policy for the BRICS. The study enhances our understanding of the impact of monetary policy shocks in emerging market economies, while improving and extending the existing literature in several areas. First, it looks at the impact of monetary policy not only in terms of output and inflation, but also with regard to monetary growth rate, the exchange rate and stock price, thus shedding light on the role of monetary policy in terms of provision of liquidity, explaining the current account imbalances, and on its effects on the stability of the financial markets. Second, the authors identify the monetary policy shock using modern estimation techniques, namely, the Bayesian structural vector autoregressive (B-SVAR) and the sign-restrictions VAR, thereby accounting for the uncertainty regarding the impulse-response functions. Third, they use quarterly data for a longer time period (namely, 1990:1–2008:4) and are thus able to obtain more precise estimates. They show that a contractionary monetary policy has a strong and negative effect on output and that contractionary monetary policy shocks tend to stabilize inflation in these countries, while producing a strongly persistent negative effect on real equity prices. Their findings highlight the fact that a monetary policy contraction has a negative effect on output; leads to inflation stabilization with persistence in the aggregate price level, coinciding with the fall in commodity prices; produces a small liquidity effect; has a strong and negative impact on equity markets; and generates domestic currency appreciation.

Overall, the study indicates that an exogenous increase in the short-term interest rate tends to be followed by an immediate decline in prices and appreciation of the exchange rate, and has a significant negative impact on output and equity prices. However, although monetary policy has a very strong influence on economic activity, evidence regarding the transmission of short-term interest rates to inflation remains limited, indicating that the major focus of monetary policy for the five large emerging economies in the BRICS has been more on stabilizing output than on controlling inflation. This confirms the strong relationship between monetary policy and real macroeconomic variables, and may help to improve our understanding of time variation and the different changes characterizing the most important macroeconomic indicators.

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The paper "Modeling Nonlinear and Heterogeneous Dynamic Links in International Monetary Markets," written by Mohamed Arouri (EDHEC Business School), Fredj Jawadi (University of Evry & Amiens School of Management), and Duc Khuong Nguyen (ISC Paris School of Management), also focuses on monetary policies. However, it concerns three important developed markets: France, the United Kingdom, and the United States of America. The paper examines the dynamic linkages of international monetary markets over the period 2004–2009 using daily short-term interbank interest rates from three of the most advanced countries (France, the United Kingdom, and the United States). The authors apply vector error-correction models and smooth-transition error-correction models that enable them to examine the short-run dynamics and long-run relationships of the interest variables. These techniques also appear to be well suited for capturing several forms of potential asymmetry, nonlinearity, and structural changes in their adjustment dynamics. The empirical results offer strong evidence of nonlinear and heterogeneous causality between the three interest rates under consideration. They also show that the relationships between interest rates are asymmetrically and nonlinearly time-varying. Furthermore, the authors find that exogenous shifts in the U.S. short-term interest rate led those in France and in the United Kingdom within a horizon of one to two days. These findings have important implications regarding the actions of leading central banks (ECB, the Bank of England, and the U.S. Fed), because the behavior of short-term interest rates can be viewed as an indicator of the degree of interdependence in central banks' policy. Indeed, if we consider that short-term interest rate deviations reasonably reflect changes in target interest rates, the convergence of short-term interest rates toward a common equilibrium over recent years may be explained by the greater coordination between ECB, U.S., and U.K. central bankers in an effort to manage crisis issues together.

In the paper "Why Do Risk Premia Vary over Time? A Theoretical Investigation under Habit Formation", Bianca De Paoli (London School of Economics, Centre for Economic Performance, and Bank of England) and Pawel Zabczyk (London School of Economics and Bank of England) focus on the study of risk premium dynamics and analyze its main determinants. Using a model with external habit formation, the authors identify the time-varying character of risk premia. In particular, they show that because of changing recession risks, risk premia can be pro-cyclical. Their results also indicate that persistent habits, shocks, and features generating hump-shaped consumption responses are all likely to make premia countercyclical. The findings are interesting because they not only indicate the importance of the role of countercyclical recession risks, but also provide evidence that factors that help match activity data (i.e., allowing for consumption habits and persistent shocks) are also likely to influence the asset-pricing dimension. Indeed, changes in risk premia can substantially contribute to asset price volatility, so having a good understanding of the factors driving them is crucial for modeling asset prices.

In their paper "Persistent Deficit, Growth, and Indeterminacy," Alexandru Minea (CERDI—University of Auvergne) and Patrick Villieu (LEO—University

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of Orléans) focus on macroeconomic data and investigate the short- and long-run effects of fiscal deficits on economic growth using an endogenous growth model with productive public spending that is financed by public deficit and debt. The question under consideration is extremely interesting, notably because public deficits are increasing in all countries and economic growth is crucial for most of them. As in previous studies, the authors provide evidence of a multiplicity of long-run balanced growth paths as well as of possible indeterminacy of the transition path. In particular, they show that starting from the steady, high-growth state, a positive impulse in the deficit ratio exerts an adverse effect on economic growth in the long run after an initial rise. Starting from the low-growth steady state, however, the situation may be radically undetermined, and the effect of fiscal deficit impulses is subject to "optimistic" or "pessimistic" views of public debt sustainability.

Overall, this means that higher public deficit can generate a crowding-out effect on economic growth, but may also ensure the development of productive infrastructures that promote long-run growth. However, this would depend on the initial debt ratio and on self-fulfilling prophecies about government debt sustainability. Formally, the model under consideration exhibits some complex dynamics, allowing indeterminacy and nonlinear effects of fiscal policy. Overall, these findings indicate a significant relationship between fiscal policies and economic growth and, interestingly, show that the response of economic growth to fiscal deficits may exhibit time variation, asymmetry, irregularity, and nonlinearity.

Finally, the last paper in this issue by Pascal Seppecher (CEMAFI—University of Nice Sophia Antipolis), entitled "Flexibility of Wages and Macroeconomic Instability in an Agent-Based Computational Model with Endogenous Money," investigates the effects of a decrease in nominal wages on the level of unemployment, prices, and the equilibrium of the system as a whole. According to Keynes, one should not expect the effects of a fall in nominal wages to be limited to the labor market, because the level of effective demand may be modified. This paper presents a computational macroeconomic model that closely associates Keynesian thinking and an agent-based approach. To this end, the author presents a model of a dynamic and complex economy in which the creation and destruction of money result from interactions between multiple and heterogeneous agents. In particular, agent-based computational methods enable the modeling of complex systems populated with large numbers of autonomous and heterogeneous agents. Adopting this approach, the author built a computational model of a dynamic and complex economy in which the interactions between agents are real and monetary.

Interestingly, he shows on the one hand the emergence of macroeconomic stability due to the long-term stability of the distribution of total income, wages, and profits which can be explained by the fact that the model, in its basic version, contains a rigid labor market. On the other hand, when nominal wages are made more flexible, he shows that households become more flexible to the demands of employers, with no sustained reduction in the level of unemployment. These downward wage adjustments lead to weaker demand, inducing not only

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lower commodity prices but also lower production levels, with subsequent rises in unemployment. These findings illustrate and confirm Keynes's reasoning, whereby he asserts that a fall in nominal wages cannot guarantee full employment, and could even destabilize prices and the whole economic system. They also suggest the importance of time variation in real and monetary macroeconomic data.

NOTES

1. For more details about recent developments in nonlinear time-series models, see Granger et al. (2010), who work on an update of the book by Granger and Teräsvirta (1993). See Barnett and Jawadi (2010) for more different applications of nonlinear modeling.
2. For more details about the ISCEF, see the conference website: www.iscef.com.

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