PRIN: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE – Bando 2015

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PART A

1 - Research Project Title

Financial cycles, credit networks and macroeconomic fluctuations: multi-scale stochastic models and wavelet analysis

2 - Duration (months)

36 months

3 - Main ERC field

SH - Social Sciences and Humanities

4 - Possible other ERC field

PE - Physical Sciences and Engineering

5 - ERC subfields

1. SH1_1 Macroeconomics; development economics; economic growth
2. SH1_3 Financial economics; monetary economics
3. SH1_6 Econometrics; operations research

6 - Key Words

1. FINANCIAL ECONOMICS
2. BUSINESS CYCLES
3. WAVELETS
4. FINANCIAL MATHEMATICS
5. SOCIAL NETWORK ANALYSIS

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7 - Principal Investigator

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8 - List of the Research Units

nº	Associated Investigator	Category	University/Research Institution	E-mail address
1.	RECCHIONI Maria Cristina	Professore Associato confermato	Università Politecnica delle MARCHE	mcrecch@tin.it (adesione completata il 13/01/2016)
2.	GAFFEO Edoardo	Professore Associato confermato	Università degli Studi di TRENTO	edoardo.gaffeo@unitn.it (adesione completata il 09/01/2016)
3.	CLEMENTI Fabio	Ricercatore confermato	Università degli Studi di MACERATA	fabio.clementi@unimc.it (adesione completata il 08/01/2016)

9 - Research project abstract

This project focuses on the macroeconomics of financial cycles. Usually defined in terms of self-reinforcing interactions between perceptions of value and risk, attitudes towards risk and financing constraints, which translate into booms followed by bust, the recent empirical literature has recurred to two approaches – turning point analysis and frequency-based filters – applied to measures of credit and asset prices to pose a number of stylized facts. First, financial cycles tend to display a greater amplitude and a lower frequency in comparison to business cycles, with peaks associated with systemic crises. Second, financial cycles depend on policy regimes and on the pace of financial innovations, leading to a wide cross-country heterogeneity and a time-varying degree of global synchronization. The latter point is clearly related to the structural transformations occurred in financial systems over the last three decades, like the cumulative integration of traditional banking with capital market developments and the increasing degree of interconnections among financial institutions. However, to date very little is known about determinants and mechanisms behind financial cycles, and on how they interact with business cycles and medium-to-long-run macroeconomic performance. In this project we plan to research along three dimensions: i) measurement issues, in order to provide a comprehensive assessment of the evolution of co-movements between financial and real variables across a sample of financial developed countries, both over time and at different frequencies; ii) theoretical issues, aimed at exploring under what circumstances the network of interconnections among financial intermediaries and between intermediaries and non-financial borrowers might evolve cyclically, contributing this way to regulate the incentives agents have in taking risks, and to set the importance of credit and financial frictions in accounting for time-varying misallocations of resources; iii) policy issues, given the role assigned by international supervisory bodies to a proper characterization and knowledge of the financial cycle as a prerequisite for the macro-prudential regulation of banks, and the scope of monetary policy in promoting financial stability in addition to the typical mandate of price stability.
Our task requires the employment of a new approach to macroeconomic analysis, diverse analytical tools and one unifying economic principle. As regards the latter, our focal point is the notion of risk externalities, across financial institutions and between the financial sector and the real economy. The set of tools we plan to employ spans from wavelets methods to multi-scale models in continuous time, and from strategic network formation to agent-based computational techniques. All these tools are instrumental in building and estimating macroeconomic models characterized by interrelated markets operating at different time scales.

10 - Total cost of the research project, per single item

Associated Investigator	item A.1	item A.2.1	item B	item C	item D	item E	item F	Total
RECCHIONI Maria Cristina	40.803 €	23.463 €	38.560 €	6.500 €	2.500 €	14.000 €	35.135 €	**160.961 €**
GAFFEO Edoardo	14.460 €	23.463 €	22.754 €	3.500 €	1.000 €	4.000 €	€	**69.177 €**
CLEMENTI Fabio	23.553 €	0 €	14.132 €	5.000 €	2.000 €	5.000 €	€	**49.685 €**
Total	**78.816 €**	**46.926 €**	**75.446 €**	**15.000 €**	**5.500 €**	**23.000 €**	**35.135 €**	**279.823 €**

- item A.1: enhancement of months/person of permanent employees
- item A.2.1: cost of contracts of non-employees, specifically to recruit

- item B: Overheads (flat rate equal to 60% of the total cost of staff, A.1 + A.2.1, for each research unit)
- item C: cost of equipment, instruments and software
- item D: cost of consulting services and similar
- item E: other operating costs
- item F: prize (to take advantage of the prize it is mandatory to attach to the project a declaration signed by the Rector of the university, according to the outline of section B2.7)

PART B

B.1

1 - State of the art

The role of financial factors for business fluctuations has been extensively analyzed in the economic literature well before the recent financial crisis of 2007-08. In the financial accelerator framework (see Bernanke and Gertler, 1989) financial frictions due to agency problems amplify and propagate the conventional transmission mechanism of real and monetary shocks through the endogenous emergence of limits on the available quantity of external finance. These limits can be loosened by a higher net worth or by higher values of the collateral pledged to the lender. Recent work on this front has proceeded by augmenting standard DSGE models with financial market imperfections (Bernanke et al., 1999), and by analyzing the role of the balance sheets of financial intermediaries in explaining movements in credit, leverage and asset prices (Gertler and Kiyotaki, 2010).
Other strands of the literature
have exploited the possibility to experience coordination failures among heterogeneous lenders behaving strategically, whenever their actions give rise to spillovers and strategic complementarities.
Aikman et al. (2015) model a credit market in which bank managers are concerned with their reputation.
When the state of the world is good, each manager has an incentive to relax credit standards and finance increasingly risky projects given that, in such a scenario, low profits would end up to signal a low ability. The announcement of high profits from a bank then encourages others to try to do the same, forcing them to choose projects with an increasing amount of risk. The strategic complementarity produces multiple equilibria: in a good state banks coordinate on risky projects (credit boom), in a bad one they coordinate on stringent credit standards (credit crunch). Interestingly enough, the strategic complementarity approach to financial frictions is very close in spirit to Minsky's financial instability hypothesis. According to Minsky (1982), capitalist economies with financially developed institutions are subject to endogenous shifts of the degree of financial fragility due to the unstable nature of the evolving patterns of financing arrangements reflected in the agents' balance sheets. As borrowers gradually shift from hedge to speculative and ultra-speculative positions, corporate balance sheets face either reduced liquidity or higher debt-equity ratios and the financial structure shifts from robustness to fragility (and vice-versa).
The theoretical literature we have just summarized predicts that financial markets should be characterized by procyclicality, boom-and-bust dynamics in prices and quantities, and time-varying attitudes towards risk. In fact, a recent strand of empirical research has provided robust cross-country evidence on the presence of financial cycles, whose features can be captured by three stylized facts: i) the financial cycle - usually defined by reference to fluctuations in the amount of total credit to the economy and the price of real assets (eg, equity and housing) - has a higher amplitude and a lower frequency than the business cycle; ii) the peaks of the financial cycle are closely associated with the onset of financial crises; iii) during the peak of the financial cycle a significant part of the growth of total credit is due to loans among intermediaries, i.e. an increase in the degree of interconnectedness within the financial system.
The awareness that global crisis episodes in developed countries are (rare) events (operating at a lower frequency than real fluctuations) has favored a renewed interest in the long run view of macroeconomic history (Schularick and Taylor, 2012). The main findings in this strand of the empirical literature are that a rapid increase of credit tends to precede financial crisis and that excessive credit growth has played a larger role than any other variable in predicting episodes of financial instability in advanced economies since late 18th century (Taylor, 2012).

References
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2 – Detailed description of the project: methodology, targets and results that the project aims to achieve and their significance in terms of advancement of knowledge

In this project we aim to shed light on the relationship between the financial cycle and output fluctuations. To do this we will first characterize the distinguishing features of the financial and business cycle fluctuations in terms of their characteristic frequency and amplitude. Then we will analyze the interactions and the relationships between financial and business cycles by taking into account that these two processes operate at different time scales. Finally, moving from the recognition that the fluctuations of financial variables are closely associated to fluctuations in the degree of interconnectedness of financial institutions, we will analyze the role of time-varying financial network relationships for understanding the evolution of financial and business cycles and systemic risk.

The motivating idea of our proposal is that the dynamics of financial aggregates - such as credit, property and equity prices -

plays a key role in the performance of real economies by reflecting the time-varying evolution of perceptions and attitudes towards risks of economic agents. As emphasized by Drehmann et al. (2012), it is nowadays apparent that "regardless of the specific approach, any future work to model financial factors requires a better understanding of the stylized empirical regularities of the financial cycle, with its booms and busts possibly leading to serious financial and macroeconomic strains". Several empirical contributions have combined a range of key financial aggregates covering quantities and prices to build synthetic measures of country-specific financial cycles, and to analyze their relationship with the real activity. Three stylized features emerge from this literature: i) the financial cycle and the business cycle operate on different frequencies: the first is a medium-term cycle with fluctuations between 8 and 30 years, the latter a short-term cycle with fluctuations between 2 and 8 years; ii) peaks in the financial cycle are likely to coincide with financial crises; iii) financial and business cycles are closely related, as recessions occurring during the downward phase of a financial cycle tend to be longer and deeper than other recessions (Borio, 2012).

Since financial cycles are not directly observable, they must be inferred. So far, two methodologies to extract the financial cycle can be reckoned as representative: i) a spectral-based analysis, with cyclical components at pre-defined frequencies extracted from raw data through band-pass filters; ii) the identification of turning points as local minima and maxima in the level of a series of interest. Both methodologies require specific assumptions on the hypothetical average cycle, for example in terms of minimum phase duration and frequency range. Furthermore, financial imbalances, as well as the perception and pricing of risk, are likely to evolve with different frequencies and amplitude in different market segments, with time-varying contributions to systemic risk. We argue that an additional methodology – wavelets - could sensibly increase our capability to characterize financial cycles by addressing both issues and to explore the nature of the relationships between financial and business cycles.
Even if widely used in scientific fields ranging from climatology to medical sciences, wavelet analysis is relatively new in social sciences. In fact, the number of applications in economics, finance and statistics using wavelet methods is gaining pace, given the usefulness and appropriateness of wavelet multiresolution decomposition analysis in dealing with scale-dependent decisions processes such as those distinguishing economics and finance. Wavelets are mathematical functions that allows the decomposition of a signal into its different frequency components and to study the dynamics of each of these components separately. The wavelet transform uses a basis function that is dilated or compressed (through a scale or dilation factor) and shifted (through a translation or location parameter) along the signal so as to provide a time-frequency representation where all the information is associated with specific time horizons and locations in time. Hence, a wavelet is similar to a sine and cosine function in that it also oscillates around zero, but differ because, as wavelets are constructed over finite intervals of time, they are well-localized both in the time and the frequency domain. The good frequency and time localization properties of the wavelet transform, by allowing to handle with non-stationary and complex signals and study features of the signal locally with a detail matched to their scale, make wavelets a powerful tool for detecting the presence of (highly localized) patterns, possibly only at certain scales, and of dominant scales of variation in the data, like characteristic scales.

The research on the empirical features of financial and business cycles we plan to carry out will start by using wavelet methods to assess whether financial and business cycles are processes operating at different time scales. These techniques include both continuous and discrete wavelet transform tools, respectively the wavelet power spectrum and the energy decomposition analysis. The first measures the contribution to the total energy of a signal and provides the temporal evolution of its frequency content, since the power is the absolute-value-squared of the wavelet coefficients, each representing the amplitude of the wavelet function at a specific position and scale. The latter, being the representation of the variability of stochastic processes on a scale-by-scale basis, allows the decomposition of the total energy of a series into the energy associated to each frequency-based component, so as to detect which cyclical components contribute substantially more to the overall energy of the process relative to the others. Both methodologies allow us to investigate the underlying pattern of the data by detecting characteristic features such as (highly localized) patterns, possibly only at certain scales, and potentially interesting structures like characteristic scales and dominant scales of variation. Therefore, after identifying a measure of the financial cycle through a composite indicator approach using information from credit, property and asset prices, we will determine whether the financial cycle and the business cycle are operating over different time scales by examining which cyclical components provide the most significant contribution in terms of their overall variance. Then, we will explore the linkages between the financial and business cycles by examining the behavior of the two cyclical components at turning points, especially at the peaks of the financial cycle, and their co-movements.

Admittedly, the literature stimulated by the Great Recession has devoted more attention to analyzing the dynamics of macroeconomic and financial variables in the typical run-up to a crisis and to developing methods for predicting crises, rather to developing formal models to understand the role of the financial cycle in output fluctuations when they interact by operating at different frequencies. In other terms, the existing theoretical literature has made no attempt, so far, to line up cycles in economic processes operating on diverse time scales. In fact, this issue might prove to be crucial, as it gives researchers a better idea of the "cyclical" information contained in each frequency scale for different phenomena.
Wavelets are an appropriate tool for taking into account the time-scale aspect of financial and business cycles interactions, and for estimating functional (time-varying) parameters in models characterizing such scale dependent decision processes. In particular, the combined use of wavelets and multiscale time continuous stochastic models may result in an efficient tool for investigating the link between financial and business cycles. In fact, multifactor stochastic volatility models have been used in finance to capture volatility smile and smirk (Fatone et al., 2009) as well as interest rate fluctuations (Recchioni and Sun, 2016) and spiky prices (Fatone et al. 2013). These models capture behavior in different time scales by using two or more stochastic factors which are described by mean reverting processes. As shown in the papers mentioned above, a suitable calibration procedure (by solving filtering problems) permits the efficient estimation of the model parameters. Moreover, analyzing the behavior of some estimated model parameters over time (i.e. the volatility of volatility and the speed of mean reversions of the stochastic factors) one may anticipate abrupt changes in the observed dynamics. In fact, in a "calm" economic climate the model parameters behave very differently than in a "turbulent" one. Specifically, the model parameters display significant fluctuations preceding a period of economic turbulence. This machinery can be easily and fruitfully applied to extend stochastic continuous time general equilibrium models recently appeared in the macro-finance literature (Brunnermeier and Sannikov, 2014), allowing us to take into account the interactions of sectorial dynamics evolving at different frequencies.

The theoretical underpinning from which we plan to move lies in the financial fragility hypothesis put forth by Minsky (1986), where the role of financial factors for the stability of the economic system is examined by looking at changes taking place over long-swing expansions and contractions. Long-term swings in financial variables reflect endogenous risk-shifting systemic changes in the financial structure of the economy occurring during the expansion phase of a long swing, giving rise to a destabilizing credit boom. In this sense, financial crisis are the result of the failure of institutions and policy interventions to limit the inherent tendency of market economies to instability. During long expansions, agents are induced to take riskier

financial positions and more speculative financial arrangements, thus causing an initially robust financial system to endogenously evolve into a fragile one. Minsky's financial instability hypothesis can thus be interpreted as an evolutionary approach characterized by an endogenous mechanism where financial long waves are generated by cumulative changes taking place over long-swing expansions and contractions, with periodic financial crises occurring as extreme outcomes following periods of aggregate tranquility . The findings recently reported in the field of macro-financial history (Jordà et al., 2013) and the analysis of the Great Moderation (Bean, 2011) provide support to the financial instability hypothesis, in that an increase in financial instability is mainly caused by an expansion of credit and leverage of banks' balance sheets during periods of low volatility.

Interestingly enough, the narrative on the financial instability hypothesis is fully consistent with models including market frictions originating from strategic complementarities in risk-taking among financial intermediaries, due for instance to anticipated bail-outs, endogenously chosen correlation of returns on assets, concerns for reputation by bank managers paying attention to their relative performance, or cumulative feedbacks between credit expansions and systemic risk-shifting. It is well known that in this class of models, coordination failures among financial intermediaries can generate collective sub-optimal credit provision and asset growth dynamics, leading to swings between periods of excessive lending, bubbling asset prices and increasing risk, and periods characterized by credit crunches, fire sales and liquidity spirals.
Increases in systemic risk due to leverage and excessive asset growth are typically mirrored in a surge of interconnectedness among intermediaries. Far from being independent, the time series (evolution of risk due to financial imbalances over time) and cross-section (distribution of risk at a point in time due to direct or indirect interconnections among financial firms) dimensions of financial instability co-evolve. We therefore plan to extend the literature dealing with the relationship between connectivity and systemic instability in financial networks (Glasserman and Young, 2015) by explicitly analyzing how the topological structure of the financial system evolve in time. This will be done along two complementary lines. First, we will exploit the features of game-based network formation models with strategic complementarities to provide a unifying theoretical explanation of co-evolution of the time-series and cross-section dimensions of systemic risk. Second, we will recur to agent-based techniques to build computational models in which a financial network and a production network interact.

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3 - Project development, with identification of the role of each research unit and research organizations involved, with regards to expected targets, and related modalities of integration and collaboration

The project will be developed in a multi-disciplinary cooperative framework by taking advantage of the expertise developed by the team of researchers along their research history in the main subjects of the proposal, that is: i) business cycle analysis (Delli Gatti et al. 2013, Clementi et al. 2015), ii) wavelet multiresolution decomposition analysis (Gallegati et al. 2011, Ramsey and Gallegati, 2013, Gallegati and Semmler, 2014), iii) multiscale continuous time stochastic models (Fatone et al. 2009, 2013, Recchioni and Sun, 2016) and iv) credit network analysis (Gaffeo and Molinari, 2015, 2016).
The first goal of the project, that is characterizing the main features and the nexus between financial and business cycles, will be jointly developed by the Polytechnic University of Marche and the University of Macerata research units. The two research units will be jointly involved in the construction of a multivariate measure of the financial cycle for the main Euroepan countries (France, Germany, Italy, Spain and the UK) and the Euro area as a whole. Due to the lack of a commonly accepted medium-term financial cycle measure, in constructing the composite indicator that will support our analysis we will exploit different methodologies recently proposed in the financial cycle literature and identify the potentially best measure by means of graphical and statistical assessment techniques. As indicators, we will employ series typically used in the growing body of literature to capture the financial cycle, which are total credit and measures for different asset markets (residential property prices and equity prices). To contrast financial cycle with cyclical movements in the real economy (business cycle), we will characterize the latter by applying the same multivariate approach, i.e. by examining a set of business cycle indicators like economic output, unemployment rate and consumer price inflation. Relevant data will be extracted from the main dissemination databases deployed by statistics producers such as the Bank for International Settlements (BIS), the Organisation for Economic Co-operation and Development (OECD), the Eurostat and the European Central Bank (ECB). After deriving the best measure for approximating empirically the financial cycle, The Polytechnic of Marche research unit will be responsible for the analysis of the relative importance of different cyclical components of the financial and business cycles by using wavelet continuous and discrete tools of analysis, that is wavelet power spectrum and energy decomposition analysis. The University of Macerata research unit, in turn, will be responsible for the analysis of the links between the financial and the business cycle and their relationships with financial crisis episodes from both a national and a cross-country perspective.
The second goal of the project is to investigate the link between financial and business cycles using wavelets and model reduction by time-scale separation. It will be developed by the Polytechnic University of Marche research unit. The interdisciplinary nature of the research team structure and their specialization in the applications of wavelet methods in economics and finance and in multiscale models in stochastic continuous time is well suited for modelling and understanding the dynamics of complex economic systems such as those that involve processes acting on different time-scales. Specifically, the research team aims at combining the efficiency of the multiscale models with suitable bases of wavelet functions to get

wavelet expansions of the model parameters that can provide useful insights into future economic scenarios. To fulfill this goal we plan to estimate the model parameters by formulating a calibration problem as a suitable nonlinear optimization problem which takes advantage of the analytical tractability of the model. Moreover, due to the huge number of these parameters, we will develop an ad hoc optimization method to get accurate estimates of them from real data. This optimization method will be developed in order to find the solutions of the calibration problem as limit points of trajectories which are solutions of a suitable system of ordinary differential equations each starting from a different initial point (see Recchioni 2003). The performance of the optimization procedure will be improved by computing thousands of trajectories whose initial points are uniformly distributed in the feasible region of the parameters. The main advantage of this path following technique is that it is suitable for parallel implementation. In fact, each processor can compute a given number of trajectories without communicating with the others. The model calibration phase will provide historical series of the model parameters. These will allow us to measure the different time scales in the observed financial/economic variables as well as to define wavelet expansions capable of capturing the main features of the cycles of interest. We will use wavelet bases which perform well in terms of accuracy and computational cost. As shown in Recchioni and Zirilli (2003) these bases of functions can be efficiently implemented using parallel computation. Thus, the contribution of the research team to this second goal is substantially twofold. On the one hand, the team will develop a multiscale model which integrates the wavelet methodology to get formulas to describe the financial and business cycles. On the other hand we will develop a highly parallelizable algorithm to estimate the model parameters which are used to describe the financial and business cycles. The codes, implemented on very efficient parallel computers, allow us to efficiently estimate the model parameters. In fact, having cpu time at a powerful computing center, such as the ENEA Research Centre, we can develop and test ad hoc parallel implementations of path following optimization methods (Recchioni, 2003) to get an efficient tool for estimating the multiscale model parameters even from "big" data.
The third goal of the project, that is credit networks and system-wide financial conditions, will be jointly developed by the University of Trento and Polytechnic University of Marche research units. The research team aims at analyzing both short-term and long-term dynamics of financial networks over the financial cycle. On the one hand, the goal is to verify if the agents' heterogeneity implies a more severe trade-off between the stabilizing effect of risk diversification and the destabilizing effect of bankruptcy cascades in financial markets. On the other hand, the goal is to extend the results of previous works to more complex market settings. In particular, we aim to verify if the destabilizing effects of interdependence and trend reinforcement may be exacerbated by allowing for trading in derivative credit contracts. Last but not least, the research team want to better investigate the properties of credit networks when lending decisions happen in the presence of strategic complementarities. In fact, the stability of an interconnected system depends directly from the configuration of its connections. It is well known, for example, that core-periphery networks are vulnerable to targeted attacks and epidemic diffusion, requiring targeted immunization strategies of systemically important nodes. The analysis should provide a natural bridge between the time-series and the cross-section dimensions of systemic risk. Taking advantage of previous works on this subject, the goal is to devise tools to characterize the topology of real credit networks and to detect the systemically important nodes through the identification of subsets of highly connected nodes. We will adopt both a game-based network formation approach, and agent-based computational techniques.

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4 – Possibile application potentialities and scientific and/or technological and/or social and/or economic impact of the project

The project results are expected to improve the current state of the art in the analysis of the relationship between the cyclical behavior of financial aggregates and business cycle fluctuations and to provide a better understanding of the dynamic interaction between processes operating at different frequency ranges. Moreover, the decoupling of the dynamics of the financial and the business cycles may have interesting implications for the efficiency of policymakers in achieving the goal of financial stability.
Wavelet analysis has proven to be an efficient method to separate economic and financial data into their frequency components with respect to several approximations of the ideal band pass filter commonly used for extracting business cycle components, especially at the longest scales (Gallegati et al., 2016). While the optimizing criteria adopted by band-pass filter approximations implicitly define the specific class of models for which the approximating filter is optimal, the application of the wavelet transform does not require a commitment to any particular class of model. Therefore the nonparametric methodology applied in this project allows us to detect the fundamental characteristics of the financial cycle and to conduct a better assessment on the existence and importance of cycles at different frequencies with respect to band-pass filter approximation methods since wavelet-based results do not rely on the specific properties of the series to be analyzed. Moreover, with wavelet exploratory data analysis we can refrain from formulating a priori assumptions about different frequency ranges for financial and business cycles and obtain a complete characterization of these processes in the time-frequency domain.
From the perspective of economic theory our contribution improves the tools currently available to economists by introducing a mathematical technique for the analysis of complex systems that involves processes acting on different time scales. In fact, we plan to formulate an analytically tractable multi-scale stochastic volatility model to describe the joint dynamics of

variables which significantly affect the financial and business cycles. The model parameters will affect specific features of the cycles and will be used to develop efficient wavelet expansions of these cycles as well as indicators (possibly "early warning" indicators) of economic fluctuations.
The wavelet-based results obtained in this manner are "hybrid", in that they are not completely "assumption free", since they are related to a suitable multi-scale model for the financial/economic variables. The comparison of the assumption-free and hybrid results gives us a measure of the reliability of these results. A user friendly software package will be implemented and made available online for those interested in utilizing it. The package output will consist of graphic windows and text files. The graphic windows will show the parameter values and the early warning indicators as functions of time while the text files will contain the data plotted in the windows (i.e. the historical series of the model parameters). Furthermore, a parallel implementation of a code which integrates numerically the calibrated model will be used to analyze the financial and economic fluctuations.
Finally, the failure to recognize that the financial and the business cycles are operating over different time-scales may have important policy implications in terms of the appropriate design of policy tools aimed at achieving the goal of systemic financial stability. In fact, while a consensus on the opportunity that macroprudential tools (like countercyclical capital requirements and liquidity buffers) and monetary policy instruments (interest rates and central bank balance sheet changes) should be treated as complementary and mutually reinforcing in contributing to financial stability has emerged, it has also become apparent that conflicts could arise in the presence of misalignments between business and financial cycles (Svensson, 2016). Our research is expected to provide a better understanding of the dynamic interactions between the time-series and cross-section dimensions of systemic risk, in that helping policymakers to address how the vulnerability of the financial system evolves over the financial cycle. Such a knowledge is instrumental in calibrating policy interventions capable to contemporaneously target medium-to-low frequency movements of financial variables when setting macroprudential requirements and to adjust leaning-against-the-wind monetary policies.

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5 – Costs and fundings, for each research unit (automatically calculated)

nº	Associated or principal investigator	Total cost	Co-funding (item A.1)	MIUR funding (other items)
1.	RECCHIONI Maria Cristina	160.961 €	40.803 €	120.158 €
2.	GAFFEO Edoardo	69.177 €	14.460 €	54.717 €
3.	CLEMENTI Fabio	49.685 €	23.553 €	26.132 €
	Total	**279.823 €**	**78.816 €**	**201.007 €**

B.2

1 – Scientific curriculum of PI (highlighting, for LS and PE fields, of bibliometric indicators related to publications and citations, and, for SH field, of the quality and impact of publications; awards and other honors; degree of success in Italian or international previous projects)

RECCHIONI Maria Cristina

Maria Cristina Recchioni received her master's degree in Mathematics (mark: 110/110 cum laude) in 1987 and was Assistant Professor of Numerical Analysis from July 1990 to October 2001. Since November 2001 she has been Associate Professor of Mathematics for Economic and Financial Applications at Università Politecnica delle Marche.
In February 2014 she obtained the National Scientific Qualification to function as Full Professor of Mathematics for Economic and Financial Applications (competitive sector 13/D4 and disciplinary-scientific sector SECS-S/06) in Italian Universities.
She is associate editor for the journal, Accounting and Finance Research (http://www.sciedu.ca/journal/index.php/afr) ISSN 1927-5986 (Print) ISSN 1927-5994 (Online). She is on the editorial board of Journal of Research in Applied Sciences (JRAS) http://jrasjournal.com. ISSN 2148-6662.
She is a reviewer for the following scientific journals: Journal of Global Optimization since 1999, Journal of Optimization Theory and Applications since 1999, Optimization Letters since 2007, Journal of Futures Markets since 2009, Journal of Economic Dynamics and Control since 2008, European Journal of Operational Research since 2009, Quantitative Finance since 2011,Insurance: Mathematics and Economics since 2014, Plos One since 2015.
She has collaborated with several research institutes and companies among which:
- Banca d'Italia, Roma since 2012 - "Servizio Gestione dei Rischi" - "Divisione Gestione dei Rischi Finanziari" - coworker Elena Tiranti;
- ENEA (Ente per le Nuove tecnologie l'Energia e l'Ambiente) since 2000. The collaboration took place within

the CRESCO (Centro Computazionale di Ricerca sui Sistemi Complessi) Project;
- CASPUR (Consorzio interuniversitario per le Applicazioni di Supercalcolo per Università e Ricerca), Roma from 1999 to 2001;
Selex Sistemi Integrati S.p.A. Roma from 2009 to 2012 to study the traffic congestion phenomenon in complex networks;
- QuantLib Project (http://quantlib.org/index.shtml) from 2007 to 2009. QuantLib is a free/open-source software library for quantitative finance. This collaboration produced two QuantLib engines that implement option pricing formulae. These engines are available at the following websites:
http://quantlib.org/reference/class-quant-lib-1-1-perturbative-barrier-option-engine.html
http://quantlib.org/reference/class-quant-lib-1-1-integral-heston-variance-option-engine.html
Platform Computing Inc., Toronto, Canada, (http://www.platform.com) from 2007 to 2009 to develop a software package implementing formulae to price options;
- Banca Akros S.p.A.,Milano from 2008 to 2010 to develop mathematical models of hedge fund indices;
CINECA (Consorzio interuniversitario dell'Italia NordEst per il Calcolo Automatico) from 1999 to 2001;
- Italsiel S.p.A. Roma - Società Italiana Sistemi Informativi Elettronici S.p.A., Roma - from 1988 to 1989 during the fellowship Indam-Italsiel, to develop software testing.
She took part in the following projects European Project (2014-2016) FinMaP, Financial Distortions & Macroeconomic Performance (grant agreement № SSH.2013.1.3-2-612955); Research Project (2007): ``AEMCSSO - Acoustic and ElectroMagnetic Cross Sections of Smart Obstacles" granted to CERI-Università di Roma ``La Sapienza" by the European Union in its FPG-Research Infrastructure Project (EU FP6 project RI-031513 and the FP7 project RI-222919); Research Grant (2007): ``The impact of population ageing on financial markets, intermediaries and financial stability", by MIUR – Ministry of University & Research; Research Project (2007) ``Multiscale stochastic volatility models in finance and insurance", granted to the Università di Roma ``La Sapienza" by CASPUR (Supercomputing center) Roma, Italy.
She is author of over 80 scientific publications most of them published in international journals.
Her bibliometric indicators are:
Web of Science: papers = 48, Hirsch-index=9 citation=220.
Scopus papers = 54, Hirsch-index=10 citation=238
Her research interests include mathematical finance with special attention to the analytical treatment of stochastic volatility models and their multi-scale generalizations as well as estimating model parameters. This is done using both the maximum likelihood approach and other approaches involving filtering techniques and option pricing. Another interest is linear and nonlinear programming and multi-objective programming where she has developed new path following methods for nonlinear constrained multi-objective optimization. Finally, she has researched spectrum analysis using specific basis of wavelet functions and their applications to scattering and optimal control.

2 - Scientific curriculum of associated investigators (highlighting, for LS and PE fields, of bibliometric indicators related to publications and citations, and, for SH field, of the quality and impact of publications; awards and other honors)

1. **GAFFEO Edoardo**

   Edoardo Gaffeo is Associate Professor of Economics in the Department of Economics and Management of the University of Trento. He received a Ph.D. in economics from the Polytechnic University of Marche in 1997, a M.A. in economics from the University of Reading in 1995 and a B.A. in economics from the University of Bologna in 1992. His areas of specialization are macroeconomics, financial economics, computational agent-based modeling and applied econometrics. He has over 50 scientific publications which appeared in finance and economics academic journals including the Journal of Monetary Economics, Journal of Economic Behavior and Organization, Macroeconomic Dynamics, Economics Letters, Journal of Evolutionary Economics, Quantitative Finance. His refereed papers has been cited over 320 times in ISI indexed journals with an h-index of 10. He is a co-author of two books, Emergent Macroeconomics and Macroeconomics from the Bottom Up, both published by Springer. Prof. Gaffeo is a fellow of the Euro Area Business Cycle Network (EABCN). He has been recipient of the "Elsevier Economics & Finance Journals Most Cited Articles 2005-2009 Award" (2010) and of the "International Research in Philanthropy Award" (2013). He has been Visiting Research Associate at the University of California Santa Cruz and Visiting Professor at the Hebrew University, and currently he is a member of the Supervisory Board of Intesa Sanpaolo SpA.

2. **CLEMENTI Fabio**

   Fabio Clementi received his degree in Political Sciences (2002) and Ph.D. in Economics (2006) from the University of Rome "La Sapienza". From 2006 to 2010 he worked as post-doctoral fellow in the Economics Department of the Polytechnic University of Marche (Ancona). He visited the Research School of Physical Sciences and Engineering (Department of Applied Mathematics) of the Australian National University twice, the first time as a Ph.D. student (four months in 2005) and then as Visiting Fellow (from November 2006 to February 2007). From 2007 to 2009 he held courses on Public Economics and Fiscal and Monetary Policy at the Faculty of Law, University of Teramo. He is currently Assistant Professor of Economics in the Department of Political Sciences, Communication and International Relations of the University of Macerata, where he teaches Economics. In December 2014 he obtained the National Scientific Qualification to function as Associate Professor of Economic Statistics (competitive sector 13/D2 and disciplinary-scientific sector

SECS-S/03) in Italian Universities.

His main research interests focus on the size distribution of income and wealth, the business cycle analysis and the empirical validation of agent-based economic models with real-world data. He is author or co-author of more than 20 papers in peer-reviewed international journals and book chapters on topics related to his scientific and research activity, and served as referee for some project proposals and various international journals - including, among others, "Empirical Economics", "International Review of Economics", "Journal of Economics", "Physica A: Statistical Mechanics and its Applications", "Review of Income and Wealth" and "The European Physical Journal B". His bibliometric indicators are: H-index = 9 (Google Scholar); I10-index = 9 (Google Scholar). He has been involved in a number of national and international research projects in the field of agent-based computational economics, namely:

- the Italian project "Financial Fragility and Technical progress with Heterogeneous Agents and Social Interaction: Models, Simulations, Empirical Analysis" (PRIN 2004, http://cercauniversita.cineca.it/php5/prin/cerca.php?codice=2004133370);

- the European project "Evaluation of the Catallaxy Paradigm for Decentralized Operation of Dynamic Application Networks" (CATNETS, http://cordis.europa.eu/project/rcn/72296_en.html);

- the European project "An Agent-based Software Platform for European Economic Policy Design with Heterogeneous Interacting Agents: New Insights from a Bottom-Up Approach to Economic Modeling and Simulation" (EURACE, http://cordis.europa.eu/project/rcn/79429_en.html);

- the European project "Monetary, Fiscal and Structural Policies with Heterogeneous Agents" (POLHIA, http://cordis.europa.eu/project/rcn/89951_en.html).

He presented communications in many international meetings, also as an invited speaker, and contributed as a member of the scientific and/or organizing committee of some international conferences, among which:

- the "Econophysics Colloquium and Beyond", held at the Polytechnic University of Marche (Ancona) in 27-29 September 2007;

- the XVIIIth AISSEC Scientific Conference "Re-starting Growth: Protectionism versus International Governance", held at the University of Macerata in 23-25 June 2011 (http://www.unimc.it/aissec_conf/edizione-2011/organizing-committee);

- the AISSEC Workshop "Global Powers and Nation-States" (http://www.unimc.it/aissec_conf/edizione-2012/workshop-aissec-2012-new), held in Sirolo (Ancona) in 7-8 June 2012;

- the XIXth AISSEC Scientific Conference "Overcoming the Crisis: Inequality and Unemployment in Advanced and Emerging Countries" (http://www.aissec.org/aissec_conference_2014.htm), held at the University of Macerata in 26-27 June 2014.

In 2008, he served as Guest Editor for a Topical Section on Econophysics of "Advances in Complex Systems" (http://www.worldscientific.com/doi/abs/10.1142/S0219525908002008?journalCode=acs), and from June 2011 to June 2014 he was appointed as Executive Secretary of the Italian Association for the Study of Comparative Economic Systems (AISSEC, http://www.aissec.org). Since September 2014, he is the scientific coordinator of the Working Paper Series of the former Department of Studies on Economic Development (University of Macerata, http://ideas.repec.org/s/mcr/wpaper.html). Most recently, he has also acted as consultant for the World Bank on matters related to income distribution and inequality.

3 – Principal scientific publications of PI

1. Recchioni M.C., Sun Y. (2016). An explicitly solvable Heston model with stochastic interest rate. EUROPEAN JOURNAL OF OPERATIONAL RESEARCH, vol. 249, p. 359-377, ISSN: 0377-2217, doi: 10.1016/j.ejor.2015.09.035 - **Articolo in rivista**
2. Mancino Maria Elvira, Recchioni Maria Cristina (2015). Fourier Spot Volatility Estimator: Asymptotic Normality and Efficiency with Liquid and Illiquid High-Frequency Data. PLOS ONE, vol. 10, ISSN: 1932-6203, doi: 10.1371/journal.pone.0139041 - **Articolo in rivista**
3. Recchioni Maria Cristina, Tedeschi Gabriele, Gallegati Mauro (2015). A calibration procedure for analyzing stock price dynamics in an agent-based framework. JOURNAL OF ECONOMIC DYNAMICS & CONTROL, vol. 60, p. 1-25, ISSN: 0165-1889, doi: 10.1016/j.jedc.2015.08.003 - **Articolo in rivista**
4. M.C. Recchioni, A. Scoccia (2014). An Analytically Tractable Multi-asset Stochastic Volatility Model. APPLIED MATHEMATICAL SCIENCES, vol. 8, p. 1339-1355, ISSN: 1312-885X, doi: 10.12988/ams - **Articolo in rivista**
5. M.C. Recchioni, F. Screpante (2014). A hybrid method to evaluate pure endowment policies: Crédit

Agricole and ERGO Index linked policies. INSURANCE MATHEMATICS & ECONOMICS, vol. 57, p. 114-124, ISSN: 0167-6687, doi: 10.1016/j.insmatheco.2014.05.006 - **Articolo in rivista**

6. Lorella Fatone, Francesca Mariani, Maria Cristina Recchioni, Francesco Zirilli (2013). The Analysis of Real Data Using a Multiscale Stochastic Volatility Model. EUROPEAN FINANCIAL MANAGEMENT, vol. 19, p. 153-179, ISSN: 1354-7798, doi: 10.1111/j.1468-036X.2010.00584.x - **Articolo in rivista**
7. Lorella Fatone, Francesca Mariani, Maria Cristina Recchioni, Francesco Zirilli (2013). The use of statistical tests to calibrate the normal SABR model. JOURNAL OF INVERSE AND ILL-POSED PROBLEMS, vol. 21, p. 59-84, ISSN: 0928-0219, doi: 10.1515/jip-2012-0093 - **Articolo in rivista**
8. Lorella Fatone, Marco Giacinti, Francesca Mariani, Maria Cristina Recchioni, Francesco Zirilli (2012). Parallel option pricing on GPU: barrier options and realized variance options. THE JOURNAL OF SUPERCOMPUTING, vol. 62, p. 1480-1501, ISSN: 0920-8542, doi: 10.1007/s11227-012-0813-7 - **Articolo in rivista**
9. Fatone L., Recchioni M.C., Zirilli F. (2011). Acoustic scattering cross sections of smart obstacles: a case study. COMMUNICATIONS IN COMPUTATIONAL PHYSICS, vol. 10, p. 672-694, ISSN: 1815-2406, doi: 10.4208/cicp.120310.261110 - **Articolo in rivista**
10. Migliori S., Bracco G., Fatone L., Recchioni M.C., Zirilli F. (2011). A parallel code for time dependent acoustic scattering involving passive or smart obstacles. INTERNATIONAL JOURNAL OF HIGH PERFORMANCE COMPUTING APPLICATIONS, vol. 25, p. 70-92, ISSN: 1094-3420, doi: 10.1177/1094342010372819 - **Articolo in rivista**
11. CAPELLI P, MARIANI F, M. RECCHIONI, SPINELLI F, ZIRILLI F (2010). Determining a stable relationship between hedge fund index HFRI-Equity and S&P 500 behaviour,using filtering and maximum likelihood. INVERSE PROBLEMS IN SCIENCE & ENGINEERING, vol. 18, p. 83-109, ISSN: 1741-5977, doi: 10.1080/17415970903234398 - **Articolo in rivista**
12. FATONE L, MARIANI F, M. RECCHIONI, ZIRILLI F (2009). An explicitly solvable multi-scale stochastic volatility model: option pricing and calibration problems. JOURNAL OF FUTURES MARKETS, vol. 29, p. 862-893, ISSN: 0270-7314 - **Articolo in rivista**
13. MIGLIERINA E, MOLHO E, M. RECCHIONI (2008). Box-constrained multiobjective optimization: a gradient-like method without "a priori" scalarization. EUROPEAN JOURNAL OF OPERATIONAL RESEARCH, vol. 188, p. 662-682, ISSN: 0377-2217, doi: 10.1016/j.ejor.2007.05.015 - **Articolo in rivista**
14. G. FUSAI, M. RECCHIONI (2007). Analysis of quadrature methods for pricing discrete barrier options. JOURNAL OF ECONOMIC DYNAMICS & CONTROL, vol. 31, p. 826-860, ISSN: 0165-1889, doi: 10.1016/j.jedc.2006.03.002 - **Articolo in rivista**
15. L. FATONE, G. RAO, M. RECCHIONI, F. ZIRILLI (2007). High performance algorithms based on a new wavelet expansion for time dependent acoustic obstacle scattering. COMMUNICATIONS IN COMPUTATIONAL PHYSICS, vol. 2, p. 1139-1173, ISSN: 1815-2406 - **Articolo in rivista**
16. L.FATONE, F. MARIANI, M. RECCHIONI, F.ZIRILLI (2007). Pricing realized variance options using integrated stochastic variance options in the Heston stochastic volatility model. DISCRETE AND CONTINUOUS DYNAMICAL SYSTEMS, vol. Supplement 2007, p. 354-363, ISSN: 1078-0947 - **Articolo in rivista**
17. Malliavin Paul, Mancino Maria Elvira, Recchioni Maria Cristina (2007). A non-parametric calibration of the HJM geometry: an application of Itô calculus to financial statistics. JAPANESE JOURNAL OF MATHEMATICS. NEW SERIES, vol. 2, p. 55-77, ISSN: 0289-2316, doi: 10.1007/s11537-007-0666-7 - **Articolo in rivista**
18. M. RECCHIONI, ZIRILLI F. (2003). A new formalism for time dependent electromagnetic scattering from bounded obstacle. JOURNAL OF ENGINEERING MATHEMATICS, vol. 47, p. 17-43, ISSN: 0022-0833, doi: 10.1023/A:1025570924371 - **Articolo in rivista**
19. M. RECCHIONI, SCOCCIA A. (2000). A stochastic algorithm for constrained global optimization. JOURNAL OF GLOBAL OPTIMIZATION, vol. 16, p. 257-270, ISSN: 0925-5001, doi: 10.1023/A:1008357925133 - **Articolo in rivista**
20. PACELLI G., M. RECCHIONI (2000). A Monotonic variable metric algorithm for linearly constrained nonlinear programming. JOURNAL OF OPTIMIZATION THEORY AND APPLICATIONS, vol. 104, p. 255-279, ISSN: 0022-3239, doi: 10.1023/A:1004645328197 - **Articolo in rivista**

4 - Principal scientific publications of associated investigators

1. **GAFFEO Edoardo**

    1. Gaffeo E, Molinari M. (2015). Interbank contagion and resolution procedures: inspecting the mechanism. QUANTITATIVE FINANCE, vol. 15, p. 637-652, ISSN: 1469-7688, doi: 10.1080/14697688.2014.968196 - **Articolo in rivista**
    2. Gaffeo E., Molinari M (2015). Macroprudential consolidation policy in interbank networks. JOURNAL OF EVOLUTIONARY ECONOMICS, ISSN: 0936-9937, doi: 10.1007/s00191-015-0419-3 - **Articolo in rivista**
    3. Gaffeo Edoardo, Gallegati Mauro, Gostoli Umberto (2015). An agent-based "proof of principle" for Walrasian macroeconomic theory. COMPUTATIONAL AND MATHEMATICAL ORGANIZATION THEORY, vol. 21, p. 150-183, ISSN: 1381-298X, doi: 10.1007/s10588-014-9180-7 - **Articolo in rivista**

4. E. Gaffeo, P. Garalova (2014). On the finance-growth nexus: additional evidence from Central and Eastern Europe countries. ECONOMIC CHANGE AND RESTRUCTURING, vol. 2014 - Vol. 47, p. 89-115, ISSN: 1573-9414, doi: 10.1007/s10644-013-9143-x - **Articolo in rivista**
5. E. Santoro, I. Petrella, D. Pfajfar, E. Gaffeo (2014). Loss aversion and the asymmetric transmission of monetary policy. JOURNAL OF MONETARY ECONOMICS, vol. 2014 Volume 68, p. 19-36, ISSN: 0304-3932 - **Articolo in rivista**
6. V. Feroldi, E. Gaffeo (2014). At the Core of the International Financial System. GLOBAL ECONOMY JOURNAL, vol. 2014 Volume 14, p. 163-188, ISSN: 1553-5304, doi: 10.1515/gej-2014-0006 - **Articolo in rivista**
7. C. Canzian, E. Gaffeo (2011). The psichology of inflation, monetary policy and macroeconomic instability. JOURNAL OF SOCIO-ECONOMICS, vol. 2011, p. 660-670, ISSN: 1053-5357 - **Articolo in rivista**
8. E. Gaffeo (2011). The distribution of sectoral TFP growth rates: international evidence. ECONOMICS LETTERS, vol. 2011, p. 252-255, ISSN: 0165-1765 - **Articolo in rivista**
9. E. Gaffeo, D. Delli Gatti, M. Gallegati (2010). Complex agent-based macroeconomics: a manifesto for a new paradigm. JOURNAL OF ECONOMIC INTERACTION AND COORDINATION, vol. 2010, p. 111-135, ISSN: 1860-711X - **Articolo in rivista**
10. E. Gaffeo, E. Santoro (2009). Business failures, macroeconomic risk and the effect of recessions on long-run growth: a panel cointegration approach. JOURNAL OF ECONOMICS AND BUSINESS, vol. , p. 435-452, ISSN: 0148-6195 - **Articolo in rivista**
11. E. Gaffeo (2008). Lévy-stable Productivity Shocks. MACROECONOMIC DYNAMICS, p. 425-443, ISSN: 1365-1005 - **Articolo in rivista**
12. E. Gaffeo, A. E. Scorcu, L. Vici (2008). Demand Distribution Dynamics in Creative Industries: the Market for Books. INFORMATION ECONOMICS AND POLICY, vol. v.20, p. 257-268, ISSN: 0167-6245 - **Articolo in rivista**
13. E. Gaffeo, D. Delli Gatti, S. Desiderio, M. Gallegati (2008). Adaptive microfoundations for emergent macroeconomics. EASTERN ECONOMIC JOURNAL, vol. v. 34, p. 441-463, ISSN: 0094-5056 - **Articolo in rivista**
14. E. Gaffeo, A. Russo, M. Catalano, M. Gallegati, M. Napoletano (2007). Industrial Dynamics, Fiscal Policy and R&D: Evidence from a Computational Experiment. JOURNAL OF ECONOMIC BEHAVIOR & ORGANIZATION, p. 426-447, ISSN: 0167-2681 - **Articolo in rivista**
15. D. Delli Gatti, C. Di Guilmi, E. Gaffeo, G. Giulioni, M. Gallegati, A. Palestrini (2005). A new approach to business fluctuations: heterogeneous interacting agents, scaling laws and financial fragility. JOURNAL OF ECONOMIC BEHAVIOR & ORGANIZATION, vol. 56, p. 489-512, ISSN: 0167-2681 - **Articolo in rivista**
16. E. Gaffeo (2005). Inflation regimes and price-setting interactions. INTERNATIONAL JOURNAL OF THEORETICAL AND APPLIED FINANCE, p. 339-355, ISSN: 0219-0249 - **Articolo in rivista**
17. E. Gaffeo, D. Delli Gatti, M. Gallegati, A. Palestrini (2005). The apprentice wizard: monetary policy, complexity and learning. NEW MATHEMATICS AND NATURAL COMPUTATION (NMNC), vol. 1, p. 109-128, ISSN: 1793-0057 - **Articolo in rivista**
18. E. Gaffeo, M. Gallegati, M. Gallegati (2005). Requiem for the unit root in real per capita GDP? Additional evidence from historical data. EMPIRICAL ECONOMICS, vol. 30, p. 37-63, ISSN: 0377-7332 - **Articolo in rivista**
19. D. Delli Gatti, E. Gaffeo, M. Gallegati, S. Desiderio, P. Cirillo. (2011). Macroeconomics from the bottom-up.. BERLIN:Springer, ISBN: 9788847019706 - **Monografia o trattato scientifico**
20. E. Gaffeo, D. Delli Gatti, M. Gallegati, G. Giulioni, A. Palestrini (2008). Emergent Macroeconomics. An Agent-Based Approach to Business Fluctuations. BERLIN, NEW YORK:Springer, ISBN: 9788847007246 - **Monografia o trattato scientifico**

2. **CLEMENTI Fabio**

1. Clementi Fabio, Dabalen Andrew L., Molini Vasco, Schettino Francesco (in stampa). When the centre cannot hold: patterns of polarization in Nigeria. THE REVIEW OF INCOME AND WEALTH, vol. n/d, p. 1-25, ISSN: 1475-4991, doi: 10.1111/roiw.12212 - **Articolo in rivista**
2. Clementi Fabio, Schettino Francesco (2015). Declining inequality in Brazil in the 2000s: what is hidden behind?. JOURNAL OF INTERNATIONAL DEVELOPMENT, vol. 27, p. 929-952, ISSN: 1099-1328, doi: 10.1002/jid.3076 - **Articolo in rivista**
3. F. Clementi, M. Gallegati, M. Gallegati (2015). Growth and cycles of the Italian economy since 1861: the new evidence. ITALIAN ECONOMIC JOURNAL, vol. 1, p. 25-59, ISSN: 2199-322X, doi: 10.1007/s40797-014-0005-0 - **Articolo in rivista**
4. F. Clementi, M. Giammatteo (2014). The labour market and the distribution of earnings: an empirical analysis for Italy. INTERNATIONAL REVIEW OF APPLIED ECONOMICS, vol. 28, p. 154-180, ISSN: 0269-2171, doi: 10.1080/02692171.2013.838544 - **Articolo in rivista**
5. F. Clementi, F. Schettino (2013). Income polarization in Brazil, 2001-2011: a distributional analysis using PNAD data. ECONOMICS BULLETIN, vol. 33, p. 1796-1815, ISSN: 1545-2921 - **Articolo in rivista**
6. F. Clementi, M. Gallegati, G. Kaniadakis (2012). A generalized statistical model for the size distribution of wealth. JOURNAL OF STATISTICAL MECHANICS: THEORY AND EXPERIMENT, vol. 2012, p. 1-25, ISSN: 1742-5468, doi: 10.1088/1742-5468/2012/12/P12006 - **Articolo in rivista**
7. F. Clementi, M. Gallegati, G. Kaniadakis (2012). A new model of income distribution: the k-generalized distribution. JOURNAL OF ECONOMICS, vol. 105, p. 63-91, ISSN: 0931-8658, doi:

10.1007/s00712-011-0221-0 - **Articolo in rivista**
8. F. CLEMENTI, GALLEGATI M, KANIADAKIS G (2010). A model of personal income distribution with application to Italian data. EMPIRICAL ECONOMICS, vol. 39, p. 559-591, ISSN: 0377-7332, doi: 10.1007/s00181-009-0318-2 - **Articolo in rivista**
9. F. CLEMENTI, GALLEGATI M, PALESTRINI A (2010). A Big Mac test of price dynamics and dispersion across euro area. ECONOMICS BULLETIN, vol. 30, p. 2037-2053, ISSN: 1545-2921 - **Articolo in rivista**
10. F. CLEMENTI, GALLEGATI M, KANIADAKIS G (2009). A k-generalized statistical mechanics approach to income analysis. JOURNAL OF STATISTICAL MECHANICS: THEORY AND EXPERIMENT, vol. 2009, p. 1-13, ISSN: 1742-5468, doi: 10.1088/1742-5468/2009/02/P02037 - **Articolo in rivista**
11. DI GUILMI C, F. CLEMENTI, DI MATTEO T, GALLEGATI M (2008). Social networks and labour productivity in Europe: An empirical investigation. JOURNAL OF ECONOMIC INTERACTION AND COORDINATION, vol. 3, p. 43-57, ISSN: 1860-711X, doi: 10.1007/s11403-008-0034-6 - **Articolo in rivista**
12. F. CLEMENTI (2008). Editorial. ADVANCES IN COMPLEX SYSTEM, vol. 11, p. 653-654, ISSN: 0219-5259, doi: 10.1142/S0219525908002008 - **Articolo in rivista**
13. F. CLEMENTI, DI MATTEO T, GALLEGATI M, KANIADAKIS G (2008). The k-generalized distribution: A new descriptive model for the size distribution of incomes. PHYSICA. A, vol. 387, p. 3201-3208, ISSN: 0378-4371, doi: 10.1016/j.physa.2008.01.109 - **Articolo in rivista**
14. F. CLEMENTI, GALLEGATI M, KANIADAKIS, G (2007). k-generalized statistics in personal income distribution. THE EUROPEAN PHYSICAL JOURNAL. B, CONDENSED MATTER PHYSICS, vol. 57, p. 187-193, ISSN: 1434-6028, doi: 10.1140/epjb/e2007-00120-9 - **Articolo in rivista**
15. GAFFEO E, CATALANO M, F. CLEMENTI, DELLI GATTI D, GALLEGATI M, RUSSO A (2007). Reflections on modern macroeconomics: Can we travel along a safer road?. PHYSICA. A, vol. 382, p. 89-97, ISSN: 0378-4371, doi: 10.1016/j.physa.2007.02.011 - **Articolo in rivista**
16. F. CLEMENTI, DI MATTEO, T, GALLEGATI, M (2006). The power-law tail exponent of income distributions. PHYSICA. A, vol. 370, p. 49-53, ISSN: 0378-4371, doi: 10.1016/j.physa.2006.04.027 - **Articolo in rivista**
17. F. CLEMENTI, GALLEGATI M (2005). Power law tails in the Italian personal income distribution. PHYSICA. A, vol. 350, p. 427-438, ISSN: 0378-4371, doi: 10.1016/j.physa.2004.11.038 - **Articolo in rivista**
18. F. Clementi, M. Gallegati, M. Gallegati (2012). Crescita e fluttuazioni economiche: un'analisi di lungo periodo dell'Italia postunitaria, 1861-2009. In: Sviluppo economico e benessere. Saggi in ricordo di Giorgio Fuà. p. 187-223, Napoli:E.S.I. (Edizioni Scientifiche Italiane), ISBN: 9788849524284, Ancona, 5-6 Novembre, 2010 - **Contributo in Atti di convegno**
19. F. Clementi, M. Gallegati (2011). Una rilettura della crescita ciclica in Italia tra il 1861 e il 2009. In: M. Ciaschini G. C. Romagnoli. L'economia italiana: metodi di analisi, misurazione e nodi strutturali. Studi per Guido M. Rey. p. 265-294, MILANO:FrancoAngeli, ISBN: 9788856836554 - **Contributo in volume (Capitolo o Saggio)**
20. Clementi Fabio, Gallegati Mauro (2016). The distribution of income and wealth: parametric modeling with the κ-generalized family. p. 1-177, berlino:springer, ISBN: 9783319274089, doi: 10.1007/978-3-319-27410-2 - **Monografia o trattato scientifico**

5 – Main staff involved, highlighting the time commitment expected

List of the Research Units

Unit 1 - RECCHIONI Maria Cristina

Personnel of the research unit

nº	Surname Name	Category	University/Research Institution	E-mail address	Months/person expected
1.	RECCHIONI Maria Cristina	Professore Associato confermato	Università Politecnica delle MARCHE	mcrecch@tin.it (adesione completata il 13/01/2016)	4,0
2.	GALLEGATI Marco	Professore Associato confermato	Università Politecnica delle MARCHE	marco.gallegati@univpm.it (adesione completata il 13/01/2016)	3,0
3.	PALESTRINI Antonio	Professore Associato (L. 240/10)	Università Politecnica delle MARCHE	ants.pal@gmail.com (adesione completata il 13/01/2016)	1,0
4.	TEDESCHI Gabriele	Assegnista	Università Politecnica delle MARCHE	gabriele.tedeschi@googlemail.com (adesione completata il 13/01/2016)	1,0

Possible sub-unit

Surname	Name	Category	E-mail address	Months/person expected

Unit 2 - GAFFEO Edoardo

Personnel of the research unit

nº	Surname Name	Category	University/Research Institution	E-mail address	Months/person expected
1.	GAFFEO Edoardo	Professore Associato confermato	Università degli Studi di TRENTO	edoardo.gaffeo@unitn.it (adesione completata il 09/01/2016)	4,0

Unit 3 - CLEMENTI Fabio

Personnel of the research unit

nº	Surname Name	Category	University/Research Institution	E-mail address	Months/person expected
1.	CLEMENTI Fabio	Ricercatore confermato	Università degli Studi di MACERATA	fabio.clementi@unimc.it (adesione completata il 08/01/2016)	4,0
2.	CROCI ANGELINI Elisabetta	Professore Ordinario	Università degli Studi di MACERATA	croci@unimc.it (adesione completata il 13/01/2016)	1,0
3.	VALENTINI Enzo	Ricercatore a t.d. (art. 24 c.3-b L. 240/10)	Università degli Studi di MACERATA	enzo.valentini@unimc.it (adesione completata il 13/01/2016)	2,0

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6 - Major new contracts for staff specifically to recruit

nº	Associated or principal investigator	Number of contracts RTD expected	Number of research grants expected	Number of PhD expected	Predictable overall time commitment (months)
1.	RECCHIONI Maria Cristina	0	1	0	12
2.	GAFFEO Edoardo	0	1	0	12
3.	CLEMENTI Fabio	0	0	0	0
	Total	**0**	**2**	**0**	**24**

7 - Declaration Upload

- RECCHIONI Maria Cristina.pdf

"I dati contenuti nella domanda di finanziamento sono trattati esclusivamente per lo svolgimento delle funzioni istituzionali del MIUR. Incaricato del trattamento è il CINECA- Dipartimento Servizi per il MIUR. La consultazione è altresì riservata agli atenei e agli enti di ricerca (ciascuno per le parti di propria competenza), al MIUR - D.G. per il Coordinamento e lo Sviluppo della Ricerca - Ufficio V, al CNGR e ai CdS. Il MIUR potrà anche procedere alla diffusione dei principali dati economici e scientifici relativi ai progetti finanziati".

Date 14/01/2016 ore 10:56