



Financial risk distribution in European Union

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HIGHLIGHTS

- A methodology to forecast the inequality of financial risk in the EU.
- Markov chains and dynamic entropy measures applied to credit ratings and spread.
- The financial inequality is different depending on the rating agency.
- The Brexit should not change the inequality within European Union.
- Development of an open source software to apply the methodology.

ARTICLE INFO

Article history:

Received 6 November 2017
Received in revised form 1 March 2018
Available online 29 March 2018

JEL classification:

C61
C63
G17

Keywords:

Financial inequality
Markov chains
Sovereign credit ratings
Credit spreads
Dynamic Theil's entropy

ABSTRACT

A methodology based on Markov chains and dynamic entropy measures is proposed for measuring and forecasting the evolution of the inequality of financial risks in the European Union (EU). The proposed methodology requires knowledge of the past evolution of sovereign credit rating for the EU member states and historical data concerning harmonized interest rates of government bonds. The methodology is applied to real data from European countries for the three rating agencies Fitch, Moody's and Standard & Poor's. Obtained results show that, although these rating agencies share similar view on the rating assignment process, they have a different perception of the risk when expressed in terms of basis points and this fact determines divergences on the forecasted financial inequality in the EU. The development of an open source and user friendly (i.e. we implemented also a Graphical User Interface) software (<https://github.com/lstorchi/markovctheil>) will permit the replication of all the results both for the actual scenario in the EU and for possible future scenarios as the Brexit.

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1. Introduction

Changes of European Union's structure is of wide interest considering the economic and financial consequences for both the member states and the rest of the world. An important aspect, that should be deepened, is the financial risks related to each member state and to the EU as a whole. The aim of this work is the assessment of the inequality of the financial risk distribution among European countries in order to understand criticisms, if there exist, in the financial structure and to forecast future developments.

With the term financial risk we refer to the credit spread of government bonds paid by each country, whose evolution is influenced by credit rating events. This relationship has been studied for corporate bonds see, e.g. Ref. [1]. In their work the authors proposed a model for the mean evolution of the yield spread, considering the rating evaluation as the determinant of it. Rating migration has been widely studied. In particular, sovereign credit migration risk has become a major research

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topic in finance. In Ref. [2], the author investigated sovereign credit ratings, developing a multi-factor Markov chain model for rating migrations that is applicable both to sovereign and corporate debts. Furtés et al. [3] compared three estimators within a discrete and continuous time framework applied to a sample of sovereign credit rating data of 72 countries. More recently, Perilioglu and Tuysuz [4] proposed a factor model to estimate sovereign conditional transition probability matrices, extending the existing models on corporate debts. Emphasis has also been placed on the importance of rating assignment and on the differences among rating agencies. In their work, Alsakka and Gwilym [5] and Hill et al. [6] described the disagreement about credit quality assignment among the major credit rating agencies.

Information theory has been applied to economic and financial issues: as an example in Refs. [7,8] the regional wealth inequality is computed by comparing Theil's, Gini and Herndahl–Hirschman indices for the Italian case. Zunino et al. [9] and Bariviera et al. [10] proposed an information theory approach in order to assess risk linked to market informational efficiency applied both to sovereign and corporate bond markets. Furthermore, Oh et al. [11] analysed the uncertainty in the financial market using Shannon entropy, and Jizba et al. [12] investigated financial time series by means of Rényi's entropy. Income inequality is investigated in Refs. [13,14] where Theil's index is modified to face with stochastic processes.

Interestingly, the study of the financial risk inequality within a group of countries over a horizon time it has been never faced in the financial literature. In this paper we fill this gap with the main new contribution represented by the construction of a methodology for the assessment and forecasting of inequality distribution of financial risk in the EU. The methodology is based on the population dynamic Theil's entropy proposed by D'Amico et al. [14] as a measure of inequality given the credit rating migration historical data and the harmonized interest rates of government bonds. We notice that: the outputs are different depending on the rating agency and this is mainly due to the evolution of credit spreads which are significantly different among rating agencies; the historical entropy has decreased since 1998 as the risk has become gradually more equi-distributed; the known *Brexit* should not change dramatically the inequality within European Union, while removing the newest members (i.e. Bulgaria, Romania and Croatia) the dissimilarities are more pronounced.

Moreover, we develop an open source software (implemented in Python) to apply the methodology, and a GUI (graphical user interface) to make it easy to use for the reader (see [Appendix](#)).

The paper is organized as follows: Section 2 describes the data collected; Section 3 shows the methodology applied to the datasets, the results are instead shown in Section 4. The work ends with some conclusions and future developments. Finally some computational details illustrating the developed software are reported in the [Appendix](#).

2. Data

Since we are interested in forecasting the inequality of the financial risk distribution, our starting point is the study of the credit spread and its relationship with sovereign credit ratings.

We refer to credit spread as the basis points that each country should pay at a specific time, given the assessment of its creditworthiness. To estimate credit spreads due to rating occupancy we collected observed credit ratings and basis point values.

The first dataset has been built starting from the sovereign credit ratings assigned by the three major rating agencies: Moody's, Standard & Poor's and Fitch. It contains monthly long-term foreign-currency ratings of European Countries from January 1998 to November 2016¹ using a broad scale so that AAA (Aaa) = 1, AA (Aa) = 2, A(A) = 3, BBB (Baa) = 4, BB (Ba) = 5, B (B) = 6; CCC-CC-C (Caa-Ca-C) = 7 and SD/D = 8 for Standard & Poor's and Fitch (Moody's). The data are gathered from the *Tradingeconomics* web-site and verified through publications of each agency. Cyprus has been excluded because Fitch started ranking it only from February 2002.

Overall, there is a high proportion of sovereign of high credit quality (for S&P only 15% of the sample has rating between BB (Ba) and SD/D while for Fitch and Moody's the percentage is almost 12%) with infrequent changes. There are countries whose rating remained stable like Belgium, Germany and Luxembourg, while for the other countries the average time before new rating assignment is almost 6 years and it becomes smaller as the credit quality decreases. Furthermore, the entry in European Union of new members did not influence countries' credit quality in the sense that there were no crucial rating changes around those dates.

As stated by other studies (see Refs. [5,6]), the credit rating agencies often disagree about credit quality and this is partly due to differences in valuation criteria and thresholds. As a matter of fact, we found that S&P and Fitch show the highest rating volatility (both changed rating assignment 62 times, Moody's 53 times) while Moody's has the highest rating stability even if it tends to adjust sovereign ratings by more than one notch. In fact, according to [Fig. 1](#), which shows the observed rating trajectories for Greece and Ireland, Moody's agency downgraded Greece sovereign securities in June 2010 from A to Ba, while the transition for the other agencies was more gradual, with previous migration in rating class BBB. Similarly, Ireland experienced a downgrade of Moody's assignment from rating class Aa to Baa in December 2010. On the contrary, Fitch and S&P previously downgraded Ireland sovereign bonds from AA to A and then, in April 2011 from A to BBB.

S&P and Fitch behave quite similarly in terms of timing and assignment, whereas Moody's differs from the others because it lags in downgrades and, to a lesser extent, in upgrades, except for Slovenia and United Kingdom. However, only S&P rated sovereign bonds using SD (Selected Default) related to Greece in 2012. In general, rating transitions to a better/lower state

¹ Actually, the size of the dataset changes among the agencies: in fact, while Moody's ratings are available from January 1998, the samples composed by Fitch and Standard & Poor's start from June 1998 and November 1998 respectively.

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