How Do Sovereign Debt Yields Respond to Credit Rating Announcements

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Abstract

The concept of asymmetric information is probably best described by medieval idiom to buy a pig in a poke or to buy a cat in a sack, and is a long standing issue in a market economy. A solution to this predicament, is thought to be an objective third party certifier who would provide true information for the market participants. Credit Rating Agencies (CRAs) by all definitions act as such certifiers within financial markets and have been on the public spotlight for the last years. In both cases, the US subprime mortgage crisis and the EU sovereign debt crisis, the agencies were charged for miss-information on quality of financial products, that led to financial losses for the investors or debtors. Theoretical deduction suggest that certain market reaction to CRA announcements may indicate if markets perceive CRAs themselves as selling a cat in a sack to the investors. Event study approach is employed to investigate how do sovereign debt market react to CRA announcements. The results suggest that sovereign debt market reaction is more pronounced if three major CRAs issue clustered announcements, and more actively react to following announcements as opposed to the leading ones.

1 Introduction

Reflecting on subprime mortgage crisis that started in US in 2006, some academics (Benmelech and Dlugosz, 2009; Griffin and Tang, 20011) point out that Credit Rating Agencies (CRAs) had an important role in this episode. Namely, by overvaluing the creditworthiness of structured finance instruments, like Collateralized Debt Obligation (CDOs). At the same time, many investors had their investment decisions and risk assessment based on ratings issued by the CRAs. As general economic environment in US and worldwide deteriorated high ratings of many of these structured finance instruments suddenly collapsed.

CRAs have also been prominent figures during European sovereign debt crisis that became somewhat volatile in late 2009 and throughout 2010. Many European (as well as non-European) sovereign countries saw their credit ratings downgraded, and sovereign debt yields (Graph 1) and premiums on Credit Default Swaps (CDSs) mounting. Many European countries experienced upsurge of government deficits and levels of debt as a result of slowdown in economic activity and bailouts that were required by failing banking sectors. Probably the best-known examples were Ireland, Portugal, Spain, Italy and Greece, partly because these countries also are a part of the European Monetary Union (EMU) and do not have independent monetary system (which in concept could be used to address finan-
cial imbalances). In addition, reversing this status quo may prove technically very challenging, if possible. While Greece on several occasions have faced real danger of not being able to service its' debt, the problem was seen as general for the group of countries, as well as the EMU and EU itself. In many occasions politicians have argued that country rating downgrades were not deserved (and amplified the burden of debt servicing). Investors, however, may have seen this action as too little too late.

Graph 1. Sovereign debt yields 10-year constant maturity, monthly data, July 1993 - March 2012

In both cases, the subprime mortgage and sovereign debt crisis, CRAs were said to undervalue the risk of the debt (or instrument) issuer. This in turn led to incorrect risk assessment by investors, excessive borrowing and financial losses. If the later is true, this should mean that information supplied by CRAs and credit ratings may (or already have) become less important in investment decision-making. Therefore it is important to analyse the impact of CRAs' announcements. In this particular case, announcements on sovereign credit ratings is being analysed.

The aim of this paper is to attempt and analyse how sovereign debt markets react to CRA announcements. The results are evaluated while differentiating between announcements by particular CRAs, leading and following CRA announcements, impact of negative and positive information. Section 2 is aimed at presenting the role CRAs, as third party certifiers, have in the market (sub-sections 2.1 & 2.2). Sub-section 2.3 provides brief reasoning behind the factors influencing sovereign debt yields as well as sovereign debt ratings, how ratings are awarded, and why there should be a relation between credit ratings and debt yields.
Based on previous argumentation, 2.4 then details the motivation of the research and establishes objectives. Section 3 presents the event study method used to confirm sovereign debt yield responsiveness to announcements of credit ratings and data used for both of these variables.

2 Theoretical Motivation

2.1 Information Asymmetry

Perfect information is a widely used assumption throughout economics and finance theory. However the world, has learned that this is not necessarily the case a long time ago. German idiom describes information asymmetry as Die Katze im Sack Kaufen, Swedish - köpa grisen i säsken, French acheter dat en poche, in English that means buying cat in a sack or pig in a poke. Almost every nation of the world knows what it means. All these medieval idioms describe a situation when a buyer purchase something (likely of low value) without inspecting the good first. Researchers often mention information asymmetry or imperfection, as a cause of market imbalances, and financial markets are no exception. For example, debt issuer may be motivated to provide false information on its' financial status or investment opportunities in order to gain access to additional/cheaper funds. In a landmark paper The Market for Lemons Akerlof, 1970 utilized an example of used car market to discuss information asymmetry and adverse selection. In essence, a problem is shaped when one party, usually the seller, is better informed than the buyer. This lack of information then is translated into financial loss for the latter party. Empirical observation of financial markets also indicate that asymmetric information does have an impact on the markets (Tang, 2009; Chou and Cheng, 2012). Therefore investors tend to thoroughly investigate projects they invest in, shares they buy or subjects they borrow money to. In some cases this may prove to be a difficult task: data may be difficult to access, not available or analysis may require too high amount of resources and time. As a result the demand for third-party certifier arises. This impartial arbiter can act in a discrete way, employ economies of scale and deliver the product market demands - information on the quality of goods and services. Unfortunately, the third-party certifier may well be providing biased information or selling a cat in a sack, as further analysis suggests.
2.2 Certification

To start analysing and understanding the possible problem one must understand the process of certification and quality disclosure, that is, what is the role of the CRA in financial markets. In general quality can be disclosed either by the supplier of goods/services or by third party, both can be legally required or voluntary. If quality disclosure is not mandatory supplier may still chose to disclose information to differentiate from competitors in terms of quality. At the same time, low quality producer would prefer not to disclose quality related information and attempt to generate excessive gains while competing with high quality producers (in case of sovereign debt issuers, the product is the debt itself). However such position (of any producer) would be recognized as low quality by rational market participants and therefore such producer would automatically be deemed as "lowest quality" (Dranove and Jin, 2010). Ultimately, such process should force all competing producers to fall in line with certification, and in theory would provide better infrastructure for trading and more efficient pricing of goods and services, including financial products. However, the problem arises if we consider the possibility that the disclosed information can be influenced by the supplier or by the certifying third party.

Firstly, quality disclosure by the supplier poses obvious conflict of interest, also different suppliers may be providing non-homogeneous information which may be hard to compare. Quality disclosure by consumer reviews also poses some serious mitigations to the value of such disclosure as it may be easily manipulated (Glazer et al, 2008; Dranove and Jin, 2010). In result, third party quality disclosure is often considered as an alternative, however not without its' own flaws, also applicable to the former two methods of disclosure.

In everyday life consumers rely on quality disclose of the producer, whether it is voluntary or legally mandatory. For example, producers are obliged to state the ingredients of foods, car producers are required to conform with certain safety and technical standards, construction companies must adhere to legal and technical regulations related construction of buildings, many Central Banks impose minimum quality standards for commercial bank, all in order to assure consumer knows what one is paying for and support confidence within the market. At the same time it is very likely that any goods or services, that are not in line with legal or technical requirements for quality disclosure will not be very popular in the market, or may even be subject legal action against the producer.

Parallel to the abovementioned examples, sovereign (or other) debt issuer is effectively selling debt, for the price the investor is ready to pay for it. Just like any seller for the above-
mentioned reasons, sovereign is motivated to have its’ debt quality (or probability of default) examined and certified in order to have any hope at selling it on the financial market. Bosch and Steffen, 2011 research confirmed this by observing, that non-rated debt indeed has very low value in the market. In this set-up CRAs provide third party quality disclosure and provide the service of evaluating the capacity of borrower to service and repay the debt.

For the third party quality disclosure to be possible and to have any impact in the financial market, CRAs must hold at least some degree of credibility vis-à-vis investors (i.e. consumers). Imperatively this means CRAs must provide superior information on the quality of debt issuer. Therefore these two factors are directly linked. In real life this would mean that if, for any reason, markets perceive CRAs information provided on debt issuers as unreliable, this should instantly translate into lack of credibility and feeble response to credit rating announcements by the CRAs.

There may be several reasons, why a third-party certifier (and CRAs in particular) may not be providing the best information possible. In many cases researchers (White, 2010) suggest the reason is the fact that debt issuer is paying CRA for the rating it awards to the debt or other financial product. This obviously constitutes a conflict of interest for CRA, as it receiving payment from the same subject it is supposed to evaluate critically. While in theory, if CRA awards too high rating it would put its’ own credibility on the line and perhaps would resist any temptation of manipulating credit ratings or require payment so high that it would not be acceptable to the debt issuer. In reality this kind of motivation can be thinned by how a company operates, as in many cases lower level managers are required to generate revenues in short-run and possibly have less regard to long-term business prospects and rating agency’s future credibility with the investors. Competition between CRAs just like in any market may drive down the price of issuing and maintaining a credit rating and enhance quality of analysis and information that CRA is providing, and credit rating is representing (Dranove and Jin, 2010). Even if oligopoly competition is considered (with only three heavyweight agencies operating internationally), Bertand oligopoly competition model would still allow for efficiency of competitive markets. However, as Becker and Milbourn, 2011 research detected that an increase of competition amongst CRAs resulted in reduced quality of information credit ratings are providing. There may be a number of reasons for such findings, and not necessarily solely the lack of competition is to blame. Firstly, the probability of default that agencies may be using to assign credit ratings are not
fully disclosed. Therefore any rating issued or the accuracy of models can only be verified by the investors in only retrospective. Secondly, because the process by which debt issuer applies for a credit rating with different agencies is not public, this means that there is a possibility to "shop around" until one agency offers the best rating for the best price. For the abovementioned reasons this kind of option is also possible as far as CRA is concerned. This process can be encouraged further if debt issuer can choose if the credit rating is published. For example if it is below initial expectations, the debt issuer may chose to hide it from public. It is worth noting that the Dodd-Frank (Wall Street Reform and Consumer Protection) Act proposed by US Securities and Exchange Commission (SEC) and passed by US Congress in 19 May, 2011 was partially aimed at addressing these issues arising with credit ratings. Mathis and Rochet, 2009 research have suggested that the CRAs with large income fraction coming from rating of simple assets tend to act more disciplined, because market participants can inspect the robustness of the credit rating more easily. However, if CRA is operating in a market of more complex financial products, there is less motivation to tend to own credibility and more incentive to chase short-term profits, partially because it is less likely that market participants can reveal inaccuracy in a rating being assigned. Another reason for "biasness" could be insufficient information and/or it may be technically impossible to accurately evaluate associated risks. A less tangible source of biasness of CRAs can be excessive familiarity of debt issuer and CRA staff. Finally, another possibly very serious, source of biasness of information CRAs are providing could be informational cascades (also known as herding), as discussed by Dranove and Jin, 2010 and Bolton and Freixas, 2012. In such case any CRA with possession of information on deteriorating situation of a borrower would withhold its rating downgrade in fear that other CRAs would not follow and/or markets would perceive such step as badly informed on the part of that CRA. In result all CRAs' credit ratings would be influenced by iterated expectations' thus trying to "guess" what other agencies (and markets) believe the debtors situation is, instead of depending on own information based on fundamentals. The motivation for that is, that if a single CRA steps out of line this can hurt its credibility with both, the investors (consumers) as well as relations with subject CRA is rating. The result then is - loss of revenues. Such phenomenon would lead to overdue downgrades as economic difficulties

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1 When one market participant tries guessing other participants' moves in an attempt to capitalize short term gains or risk of loss rather than inferring on knowledge of fundamentals, also such expectations would be based on expectation of further expectation, as explained by Allen et al, 2006 and Becker and Todd, 2008.
progress. Empirical work by Becker and Milbourn, 2008 found evidence that reputation is of high concern to the CRAs, especially when considering pressures from competitors.

2.3 Drivers of Sovereign Bond Yields
A more precise picture and understanding of possible relation between sovereign debt yields (or simply yields) and their ratings, requires the understanding what are the drivers of sovereign bond yields.

Theoretically, sovereign debt yields ultimately reflect probability of default of the sovereign. The probability of default could be seen as a function of i) sovereign’s (tax) income and ii) funds required to maintain it debt. For empirical analysis researchers often used various proxies for these measures. The i) income from taxation itself is a function of size of its economy and the size of the aggregate tax rate as a fraction of the economy. The ii) funds required to maintain the debt is a function of the size of the debt and the risk premium required by the investors to buy the debt, the debt yield. Here it is worth noting, that in some cases debt yield can become an autoregressive function, where an increase in debt yields leads to further rise. In result, a sharp increase in debt yields can lead to inescapable or increasing burden of debt, especially if the size of debt is already on a hinge. Of course it is possible to continue indentifying further possible factors of influence that would have an effect on these first-round variables (such as economic slowdown, socio-political unrest, global economic and financial climate etc). Based on such reasoning many researchers (Alexopoulu et al, 2009; Afonso et al, 2011) use variables like GDP, CDS spreads, debt-to-GDP ratios, government deficit and other variables as proxies for these theoretical variables. Finally, given ever increasing interdependencies amongst countries, it is not unreasonable to assume that any economic, political or social situation could spread to neighbouring countries or simply have a significant effect on country ability to service its’ debt.

The trouble for an investor then is, to analyse all this information that may be non-homogeneous, difficult to interpret, aggregate and compare across different subjects, not neglecting the fact that information may not even be available publicly, especially if issuer of debt is a corporate. The solution then is the third party certification provided by the CRA.

It is no surprise that CRAs award sovereign debt ratings based on analysis of same or similar variables that drive sovereign debt yields (Standard & Poor’s, 2010; Moody’s Investor
Service, 1999; Fitch Sovereign Ratings, 2002). Although every CRA develop and apply
own risk models the variables they analyse are uniform in broad terms, at least in case of
the big three (Fitch Ratings, Standard & Poor's, Moody's Ratings). All three agencies name
economic risk analysis as the key factor in awarding sovereign credit rating. In practise
economic risk analysis involves macro-economic and fiscal policy evaluation (including
government debt and deficit, labour markets, balance of payments and other); tradable sec-
tors investigation with particular emphasis on current account, diversification (in terms of
geography and industry), Foreign Direct Investment (FDI) and other factors that may
strongly influence debtors' ability to service the debt. In addition, international and internal
political position risks are evaluated as these may influence sovereigns' ability and willing-
ness to repay the debt. It should then be a reasonable assumption investors would avoid
performing own analysis of fundamentals and infer on credit ratings, thus in effect making
use of economies of scale and scope that is acquired by CRA doing the analysis instead.

2.4 The Objectives of Research
If it is possible to conclude that sovereign government debt yields are a function of same
variables, that are analysed to award credit ratings by the CRAs, it should also be possible
to deduce that there should be at least correlation relation between debt yields and credit
ratings. However, if credit ratings indeed provide more quality information, which is more
easy to interpret, observe and is easier to access than macroeconomic data, investors would
inevitably choose the former as a criteria for investment decisions. As a result, credit rating
announcements would precede significant changes in sovereign debt yields or even trigger
them.

It is important to note that confirming this relation and dynamics at any point in time or
for any sample, confirms these relations only, and that markets do trade on any informa-
tion provided by the CRAs. Previous researches (Afonso et al., 2011, Gartner et al 2011)
have confirmed that government debt yields do respond to credit rating announcements.
However it is also important how this response is structured. Namely, it is crucial to ob-
serve the speed of adjustment of the markets in reaction to credit rating changes. Also, it is
essential to analyse if full price adjustment takes place after first announcement (for exam-
ple, first CRA downgrade) or if markets wait for confirmation on downgrades or an-
nouncement by other CRAs whose ratings may be applicable for the subject in question.
These, therefore, are the intended points of research of this paper.
In order to avoid any misinterpretation, it is crucial to point out that proving or disproving relation between CRAs announcements and sovereign debt yields only analyse that credit ratings and debt yields are functions of same variables, and that investors prefer (or not) third party certification to own analysis of fundamentals. Proving such relation does not necessarily mean that credit rating is providing the (in)correct information on the financial product investors are buying at the moment or vice-versa. However it does provide information on the perception of markets of credit ratings. This perception is most likely based on past observation of credit ratings and comparison to actual developments and defaults. For example, if such analysis would show that financial data (bond yields, CDO, CDS price, other) is less responsive at any time $T$ as compared to time $T-1$ this may indicate that CRAs have been providing low quality information on condition of these products in past time $T-1$. This, however, is not achievable by methods used in this paper.

2.5 The Big Three CRAs

Based on theoretical reasoning, further research is focused on three most influential CRAs: Moody's, Fitch and Standard & Poor's. Previous researches (Alsakka and Gwilym, 2010; Hill et al, 2010) have observed significant differences in CRAs' behaviour, therefore it is useful to consider the background of these companies. It is not unreasonable to assume, that different corporate structure and background to some extent may be the explanation for the (no) difference in information these companies provide for the investors. Theoretical deduction and event study assumptions also require that event-generating CRA must have strong credibility with the investors for the analysis to be possible.

Moody's Investor Service (referred to as Moody's) is the second largest of the big three (revenues of $1.8bn in 2009, posted by Moody's financial report, 2009). It is a subsidiary company of Moody's Corporation, which is also a parent company to Moody's Analytics. The Corporation is publicly traded company in the New York Stock Exchange (NYSE), with its' liabilities 11.96% in equity and 88.04% in debt. Major shareholders are Berkshire Hathaway Inc (12.77% of shares) and Capital World Investors (8.19%).

Moody's have been founded in US in 1909 for the purpose of publishing stock statistics manuals. In 1975 Moody's was certified as Nationally Recognized Statistical Ratings Organizations (NSROs) by the US Securities and Exchange Commission. In 2000 Rating business branch (Moody's Investor Service) was detached as a separate company, with Moody's Corporation as the owner.
A detailed of scheme credit ratings that Moody's Investor Service assign is presented in Annex I. As it was explained earlier, the nature of the task requires all three CRAs analyse the same variables. The choice of proxies for these variables are somewhat different however. Therefore do not and should not generate radically different results. The key difference of analysis for the purpose of assigning sovereign credit rating, as it was observed by Bhatia, 2002 is that Moody's analysis is based on expected loss as a function of probability of default and expected recovery rate once the default occurs. Thus the credit rating already incorporates both the probability of default, and expected recovery rate.

**Fitch Ratings** is the smallest of the big three. It is a part of Fitch Group (revenues of $782m in 2009, posted by FIMALAC financial report 2009), which is subsidiary of French FIMALAC (50%) and US Hearst Corp (50%) as of April 12, 2012. Both, FIMALAC and Hearst Corporation are privately owned.

Fitch was founded in 1913 as Fitch Publishing Company. In 1975 Fitch was recognized as an NSRO. In 1993 it merged with IBCA Ltd, in 2000 Fitch acquired Duff & Phelps Credit Ratings Company and Thompson Financial BankWatch.

A detailed of scheme credit ratings that Fitch Ratings assign is presented in Annex I. Fitch Ratings methodology of sovereign credit rating determination is based on probability of default only until the default happens (Bhatia, 2002). Once that happens the credit ratings are then differentiated based recovery rate.

**Standard & Poor's (S&P)** is considered to be the largest of the big three (revenues of $2.61Bn in 2009, posted by McGraw-Hill Companies financial report 2009). It is a subsidiary of McGraw-Hill Companies, which is publicly traded corporation on NYSE. It's liabilities consist of 55.73% in equity and 44.27% in debt. Major shareholders are Jana Partners LLC (17.19%) and Independent Franchise Partners LLP (8.70%).

S&P traces its roots back to 1860 with H. V. Poor's attempt to compile comprehensive financial information on railroad companies and established H. V. and H. W. Poor Company. In 1941 S&P was started by merger with Standard Statistics Bureau (founded in 1906). McGraw Hill Companies acquired the S&P in 1966.

A detailed of scheme credit ratings that S&P assign is presented in Annex I. Standard & Poor's methodology is based solely on the probability of default, and no analysis on the recovery rate. In this perspective S&P and Fitch approach is comparable until the default
event. The difference of analysis should then arise from the choice of proxy variables of choice and models of probability of default.

3 Empirical Method & Data

3.1 Event Study

The primary intention of the event study is to confirm yield - announcement relation predicted by theoretical deduction and previous researches (Afonso et al., 2011, Gartner et al 2011) and make inference (if any) on patterns of how sovereign debt yields react to CRA announcements.

The event study is based on several assumptions (Steiner and Heinke, 2001 presents event study in a rather systematic way). First assumption is that (i) efficient markets would instantly incorporate new information and this will be reflected in market prices. It is reasonable to assume, that rational investors would react to trustworthy information, as it was argued earlier. This assumption relates to CRAs having credibility with the investors, and that is the why The Big Three is being considered for the study. Secondly, (ii) the event is not foreseen in the market. In case of credit rating announcements, it is very plausible that there is some anticipation of the event. However, there is no reason why markets would know for certain the credit rating in advance. However, that may be a reason why an event study may not show significant results. The fact that a relatively short period of time is being observed means that there should still be a detectable market reaction to the announcement nonetheless. Finally, (iii) the event at question is indeed the only event that affects the market at the moment. This an important assumption which may not necessarily hold for every event, however credit rating announcement by one of the three agencies should be considered as dominant event. Even if there are overlapping important events, that does not mean that study results should be discarded without consideration, especially if these events are controlled and accounted.

The event study is set-up by first picking the CRA announcement (the event) which is associated to a particular point in time $T=0$ (see graph 2 for an illustration). Second, a period ($\alpha$) of 10 days prior the event is being used to estimate a benchmark value of debt yield. Here, a variant of mean method of the event study is being used. The best motivation for this choice is the assumption (iii), meaning that in absence of CRA announcement there
should be no significant change in sovereign debt yields, and the yields would fluctuate around their mean value. In addition, there is no reason why sovereign debt yields would have any deterministic or other trends. Next, a period (τ) of another 10 days is the post-event period or event window, over which yield movement is observed and the impact of credit rating announcement is tested. Ten-day period for α allows for accurate benchmark value calculation, while avoiding the risk of contamination, in case other significant information affects the market (the debt yields). Similar periods have been used by Afonso et al, 2011 and Gartner et al 2011. Similar argument applies for τ, however it is somewhat longer than used by previous studies. The reason for that is, that risk of contamination by alternative event is minimized due to the fact, that credit rating change can be seen as a major factor that, in theory, should permanently shift sovereign debt yields into a different level. At the same time it allows for more accurate testing of robustness of the change and allow sufficient time for markets to absorb the information.

The selection of variant of the event study is another important issue. Benchmark values, against which abnormal yields then would be estimated, can be calculated by using structural, autoregressive or other type of model. Such model could actually be used over relatively longer time horizon. The complication then is to develop an accurate and robust model that could then be used by an event study. For further discussion of complexity and limitations developing accurate model for debt yields, please see Annex II: Modelling Sovereign Yield Movement. Given the complexity of developing such model and the risk of error, for the purpose of this paper, it is more appropriate to concentrate on short term estimations, and apply more simple however less subject to error, the mean variant of event study, which is more transparent and is easier to evaluate.

The benchmark (here, expected value or mean) of the yield is then used to calculate the abnormal movement in yield, using formula

$$AY_{τ,c} = Y_{τ,c} - E\{Y_{α,c}\}$$

(eq 1)

where $AY_{τ,c}$ is the abnormal yield during post-event period $τ$, for country $C$; $Y_{τ,c}$ is the yield during post-event period $τ$, for country $C$; and $E\{Y_{α,c}\}$ is the expected value of yield for pre-event period $α$, for country $C$. Country notation that is used later to calculate the
results: $P$ for Portugal, $G$ for Greece, $IT$ for Italy, $IR$ for Ireland. T-test statics is calculated using formula

$$t = \frac{\bar{Y} - \Delta}{\sigma \sqrt{N}}$$

(eq 2)

where $\bar{Y}$ is mean value of estimated abnormal yields, $\Delta$ variable value tested (which is equal to 0 in this case), $\sigma$ standard error of the sample, and $N$ is sample size. In result $t$-value is used to test null hypothesis $H_0$: abnormal yield estimates are not different from 0.

For a more complete understanding of the process\(^2\), an example is illustrated by graph 2 and table 1. In the graph, yield curve marks sovereign debt yield daily movements, Event - the day of credit rating announcement, and $\pm 2\sigma$ is two standard deviations value around expected (benchmark) value, and is for illustrative purposes only. The graph on the left illustrates a case when there is no apparent impact of credit rating announcement on debt yields, during period $\tau$, as compared to period $\alpha$. An event study test (Table 1) confirms that. Using $t$-statics and p-value 0.4415, null hypothesis ($H_0$) cannot be reject. The conclusion therefore is that abnormal yield is a 0.

The graph on the right hand side illustrates an apparent positive event impact on yields. Event study and statistical test confirms that the expected value of abnormal yield 0.8193 is statistically significant. $H_0$ is rejected as p-value is <0.01, meaning the estimated value is significant at higher than 1% level.

Graph 2. An example of event study.

\(^2\) Papers by Steiner and Heinke, 2001 as well as Kothari and Warner, 2006 are also especially useful in understanding event study methods and variants.
Table 1. Corresponding statistics and tests for the example.

<table>
<thead>
<tr>
<th></th>
<th>Mean AY</th>
<th>Standard Error</th>
<th>t-static</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Impact (left)</td>
<td>-0.0023</td>
<td>0.03661</td>
<td>0.7984</td>
<td>0.4415</td>
</tr>
<tr>
<td>Positive Impact (right)</td>
<td>0.8193</td>
<td>0.3999</td>
<td>4.4987</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

3.2 Data

Data selection is not radically different from previous researches of similar character. Afonso et al, 2011, Larrain et al, 1997, Reisen and Maltzan, 1998 uses yield data and major rating announcements to test the relation between these two variables. In some case CDS data was also used, however such data is somewhat limited and market for CDS is relatively shallow as compared to sovereign debt markets.

Primary CRA announcement analysis (Section 4.1) takes a simple form of determination of stylized facts, data of three major credit rating agencies' (Standard & Poor's, Fitch Ratings and Moody's) announcements on credit rating changes is being analysed. The announcement of credit rating change data is on long term foreign currency denominated debt. There is no differentiation between the ratings assigned, only the fact of change in rating is considered. Sample time frame encompasses all credit rating change announcements between January 1980 and March 2012. Geographic dimension consists of most European Union member states: Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Portugal, Romania and Slovakia, Slovenia, Spain and Sweden. Some countries (Austria, France, Germany, Netherlands) implicitly are excluded because there were no credit rating changes associated with these sovereigns within the specified time frame. Data is publicly available from respective credit rating agencies.

The event study (Section 4.2), firstly is aimed at testing sovereign debt yield responsiveness to CRA announcements and the impact of upgrades as compared to downgrades As in previous part, data from Standard & Poor's, Fitch Ratings and Moody's is used, for time period from January 1980 and March 2012, for Greece, Ireland, Italy and Portugal. The motivation for picking of these particular countries is the particular fiscal troubles, and frequent credit rating changes over the sample period. Also the fact that these countries are characterized by high debt levels, indicate deeper markets for debt, and therefore more objective prices reflected by yields (Blundell-Wignall, 2012). The ratings that are analyzed are for long term foreign currency denominated debt. The exact value of the rating is not considered, only the fact that the rating has been changed is accounted. Based on previous data
examination, separate (non-clustered) events are selected. In order select as objective and diverse sample as possible, for every country an upgrade and downgrade event by every CRA is selected. However in some cases, such events were not available, namely Moody's downgrade for Portugal, and S&P upgrade for Italy. Although upgrade events are under-represented as compared to downgrades there is a significant amount of upgrade events that can be analysed.

Secondly, to test for the impact of ordinance of the announcements, only observations on clustered events is being considered. Events are considered as clustered if there is no larger than 2 month gap between any two events. Credit changes occurring within such period could be considered either as reaction to same changes variables or informational cascading. Larger period would pose risk that rating changes are related to different economic developments and thus undermine the attempt of assessing the impact of ordinance. However, a great number of these events are clustered within days. Country coverage, is same as for previous part of the analysis, namely Greece, Ireland, Italy and Portugal. All clustered downgrade events within time period and for sample countries where all three CRAs participated, for various country are selected. No significantly clustered upgrade events for the time period and country sample were recorded.

In both parts of the event study analysis daily data of constant 10-year maturity debt yield estimated by using third polynomial is utilized to proxy sovereign debt yields. Data is compiled and provided by Thomson Reuters DataStream.

4 Results

4.1 Stylized Facts
The primary examination of the data, over January 1980 and March 2012, of 314 events of credit rating changes shows that 96 out of 314 total events (31%) were clustered within two months, with majority of these events clustered within days. This observation is in line with the fact that the agencies use similar evaluation criteria, and does not contradict the possibility that there may be some informational cascades, especially in cases when only few days difference in considered. In these particular situations agencies in effect where providing similar information for the market participants.

The most active agency appeared to be Fitch Ratings, with 110 changes in sovereign credit ratings, and S&P and Moody's marginally less active with 100 and 104 changes respectively.
This observation broadly conforms with Afonso et al, 2011 analysis, that used different approach and sample however came to similar conclusion. In clustered events, Fitch Ratings also was most active: reacted first or second in 27 out of 32 clusters (84%) and was last to react in 5 out of 32 cases (16%). Moody's and S&P were more reserved, and only 19 out of 32 cases (60%) reacted first or second, and reacted last in 13 out of 43 cases (40%).

Rating agencies tended to lead clustered credit rating changes in certain countries (Table 1). For example, S&P consistently leaded rating changes for Bulgaria and Ireland, Fitch - for Greece, Moody's - for Hungary. This phenomenon could have a variety of interpretations. One of them could be, that some agencies actually have better access to information on some countries than others. Due to this fact one agency with the best information acts first, and others, assuming the first has more reliable information follow the leading change of credit rating.

Table 1. Countries and clustered events when specific CRAs were events in specific countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Event\Date</th>
<th>Fitch</th>
<th>Moody's</th>
<th>S&amp;P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hungary</td>
<td>30 Nov, 2000</td>
<td>A-</td>
<td>A3</td>
<td>A-</td>
</tr>
<tr>
<td></td>
<td>9 Nov, 2008</td>
<td>BBB</td>
<td>A3</td>
<td>BBB</td>
</tr>
<tr>
<td>Ireland</td>
<td>8 Apr, 2009</td>
<td>AA+</td>
<td>A1</td>
<td>AA+</td>
</tr>
<tr>
<td></td>
<td>6 Oct, 2010</td>
<td>A+</td>
<td>Baa1</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>9 Dec, 2009</td>
<td>BBB+</td>
<td>Baa3</td>
<td>A-</td>
</tr>
<tr>
<td>Greece</td>
<td>8 Dec, 2009</td>
<td>BBB+</td>
<td>A2</td>
<td>BB+</td>
</tr>
<tr>
<td></td>
<td>9 Apr, 2010</td>
<td>BBB-</td>
<td>A3</td>
<td>BB+</td>
</tr>
<tr>
<td></td>
<td>14 Jan, 2011</td>
<td>BBB+</td>
<td>B1</td>
<td>BB-</td>
</tr>
<tr>
<td></td>
<td>20 May, 2011</td>
<td>B+</td>
<td>Caa1</td>
<td>B</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>14 Jan, 2002</td>
<td>BB-</td>
<td>B1</td>
<td>BB-</td>
</tr>
<tr>
<td></td>
<td>24 Jul, 2003</td>
<td>BB+</td>
<td>Ba2</td>
<td>BB+</td>
</tr>
<tr>
<td></td>
<td>4 Aug, 2004</td>
<td>BBB-</td>
<td>Ba1</td>
<td>BBB-</td>
</tr>
</tbody>
</table>
4.2 Event Study Results

The event method described in section 3.1 is firstly used to test sovereign debt yield responsiveness to credit rating change announcements. The results of the event study are presented in table (2), abnormal yield estimates are acquired using equation (1) and t-statistic calculated using equation (2). The events are selected as to avoid analysis of multiple events within short time frame, thus respecting assumption (iii) of the event study, as discussed in section 3.1.

Table 2. Abnormal Yield change estimates, non-clustered events. The t-statistics is in parenthesis, Level of significance is denoted by asterisk: * at 10%, ** at 5% and *** at 1%, lower significance level or wrong sign estimates are not marked.

<table>
<thead>
<tr>
<th>Country</th>
<th>Event\Date</th>
<th>Upgrade</th>
<th>Downgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portugal</td>
<td>1 Jan, 1998</td>
<td>0.01</td>
<td>-0.02*</td>
</tr>
<tr>
<td></td>
<td>5 May, 1998</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15 Dec, 1998</td>
<td>-0.02*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.62]</td>
<td>[1.92]</td>
</tr>
<tr>
<td>Ireland</td>
<td>16 Dec, 1998</td>
<td>-0.02*</td>
<td>-0.03</td>
</tr>
<tr>
<td></td>
<td>04 May, 1998</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Oct, 2001</td>
<td>-0.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[2.20]</td>
<td>[13.47]</td>
</tr>
<tr>
<td>Greece</td>
<td>20 Jul, 2000</td>
<td>-0.06***</td>
<td>-0.05</td>
</tr>
<tr>
<td></td>
<td>14 Jul, 1999</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 Jun, 2003</td>
<td>-0.11***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[9.33]</td>
<td>[4.56]</td>
</tr>
<tr>
<td>Italy</td>
<td>17 Jun, 2002</td>
<td>-0.17***</td>
<td>0.04*</td>
</tr>
<tr>
<td></td>
<td>15 May, 2002</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[16.81]</td>
<td>[0.22]</td>
</tr>
<tr>
<td></td>
<td>02 March, 1993</td>
<td>-0.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[1.95]</td>
<td>[3.61]</td>
</tr>
</tbody>
</table>

The series of event studies aimed to test for sovereign debt yield responsiveness to the CRA announcements, suggest that these is some reaction of sovereign debt yield to CRA
announcements. However in some cases, considering separate events results fail to show the expected significant impact of CRA announcement (9 out of 22 events considered, table 2). There could be several reasons or a combination of them to explain such a result. Firstly, it is possible that in almost half of these cases markets did not believe that the information embodied in credit rating changes was correct, and therefore did not react. In result assumption (i) of the event study was not fulfilled: the new information was not reflected in the market. Secondly, in some cases they may have been strong anticipation of the change of the rating. In fact, 3 of the 9 events that the study failed to capture significant yield movements have been preceded by watch/outlook announcements. On the other hand this still leaves 6 cases with no clear indication of possible market anticipation. This would mean that in some cases the information of the credit ratings was already incorporated in the sovereign debt yields before the announcement.

Comparing positive and negative information impact, namely the upgrades and downgrades gives interesting result. The impact of an upgrade is generally smaller in size as compared to downgrades (table 2). The estimates of abnormal sovereign debt yields are larger in absolute value in case of downgrade, as compared to abnormal yield estimates in case of an upgrade. It would be premature to make any inference on over/under-reaction to positive or negative news, as specific situations and the true weight of new information were not taken into account (including the rating value, or possibility of rating failure). Yet, these results do not deny that possibility, and further research specifically aimed at analysing over/under-reaction might prove to be informative.

The abovementioned lack of expected responsiveness, may be explained by event study results considering clustered events (Table 3). The method described in section 3.1 is used to test sovereign debt yield responsiveness to clustered credit rating change announcements, as described in section 3.2. The abnormal yield estimates are acquired using equation (1) and t-statistic calculated using equation (2). Only events clustered within specified time frame are selected for this analysis, as it is observable in table 3. This kind of analysis is limited by the fact that several possibly significant events take place within short time frame, and may be interfering with each other. However, announcements of all three CRAs' announcements are considered and accounted for, therefore it is still possible to make inference on the results.
Table 3. Abnormal change in debt yields estimated using event study, clustered events. The t-statistics is in parenthesis.

<table>
<thead>
<tr>
<th>Country</th>
<th>Event\Date</th>
<th>Fitch</th>
<th>Moody's</th>
<th>S&amp;P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portugal</td>
<td>24 Mar, 2011</td>
<td>0.81***</td>
<td>0.20**</td>
<td>0.81***</td>
</tr>
<tr>
<td></td>
<td>0.81***</td>
<td>0.20**</td>
<td>0.81***</td>
<td></td>
</tr>
<tr>
<td>Ireland</td>
<td>2 Jul, 2009</td>
<td>-0.02</td>
<td>0.26***</td>
<td>-0.32</td>
</tr>
<tr>
<td></td>
<td>0.26***</td>
<td>-0.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Oct, 2010</td>
<td>-0.24</td>
<td>0.74***</td>
<td>0.46***</td>
</tr>
<tr>
<td></td>
<td>0.74***</td>
<td>0.46***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greece</td>
<td>8 Dec, 2009</td>
<td>0.69***</td>
<td>-0.02</td>
<td>0.44***</td>
</tr>
<tr>
<td></td>
<td>0.69***</td>
<td>-0.02</td>
<td>0.44***</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>27 Dec, 2011</td>
<td>0.1**</td>
<td>0.1**</td>
<td>0.52***</td>
</tr>
<tr>
<td></td>
<td>0.1**</td>
<td>0.1**</td>
<td>0.52***</td>
<td></td>
</tr>
</tbody>
</table>

Level of significance is denoted by asterisk: * at 10%, ** at 5% and *** at 1%

In this case, results are coherent with findings of previous researches: sovereign debt yields show strong and regular response to changes in credit rating. Therefore, there is solid evidence to suggest that markets do trade on information provided by CRA announcements on credit rating changes. However, some observations (Ireland downgrade by S&P, 30 March 2009, downgrade by Fitch, 6 October 2010 and other) suggest that markets do not respond to first (or sometimes even second) credit rating change announcement, and only show responsiveness to announcements that follow. In such case, it would mean that market participants wait for confirmation from other CRAs rather than reacting to the leading
announcement. Therefore it may mean that market participants differentiate between the agencies and information they are providing. If that is indeed the case, this may be an noteworthy reasons for informational cascades on the part of CRAs, as discussed in section 2.2. In instances (Greece downgrade by Fitch 20 May 2011; Ireland downgrade by Moody's 8 April 2009), when yields responded to the second announcements, there was no response to the last announcement, suggesting markets have already incorporated the new information, as it should be expected.

As it was mentioned beforehand, there are some limitations of using event study approach for such testing yield response in case tightly clustered events are analysed. It is difficult to determine if markets react to the leading announcement, following or both, because the event study of any one of the events would capture market reaction to either of these events, and not necessarily the one that is analyzed. Such case can be illustrated by graph 3 and table 4, using simulated data, where $\alpha_1$ and $\alpha_2$ are benchmark estimation periods for 1st and 2nd downgrades.

Graph 3. Illustrative example: debt yields react to first announcement, however, event study captures 1st and 2nd events as significant. However, for the 1st event abnormal yield estimates are higher due to lower benchmark value.

<table>
<thead>
<tr>
<th></th>
<th>Mean AY</th>
<th>Standard Error</th>
<th>t-static</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st downgrade</td>
<td>1.006</td>
<td>0.5410</td>
<td>6.17</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>2nd downgrade</td>
<td>0.9937</td>
<td>0.2126</td>
<td>15.50</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
Still it is possible to make some inference. Hypothetically, if markets reacted to the leading downgrade, benchmark yield for this event study would be lower than the benchmark yield of the following event, as it is illustrated by graph 4. This would result in a lower abnormal yield estimate for the following event. If markets reacted to the following downgrade, the reverse would happen, except that now benchmark yields would be similar, but abnormal yield estimate would be higher for the following downgrade because of higher yields. Notably, based on such reasoning, analysis of the estimation results again brings one to a conclusion, that markets tend to react to the second announcements in case of tightly clustered (within 10 days) credit rating changes (table 3). This observation is also consistent if compared to clustered credit rating announcements that are more spread out. In result, to some extent, analysis of clustered events explains previous observation of lack of yield response to leading announcements and lack of responsiveness to separate events.

5 Concluding Remark
This paper was an attempt to analyse sovereign debt markets reaction to CRA announcements on credit ratings using event study approach. Firstly theoretical background and motivation was provided, based on theoretical deduction and previous empirical observations. Particular emphasis was concentrated on confirming results of previous researches, and testing the impact of negative and positive rating announcements. Although approaches and data samples of previous researches varied, many previous researchers (Galil and Soffer, 2011; Griffin et al, 2011; Afonso et al, 2011; Gartner et al 2011) have found that there is a significant credit rating announcement-cost of sovereign borrowing relation. Additional analysis of clustered events was aimed at testing for the impact of announcement ordinance.

The event study approach analysing separate credit rating announcements indicate that there is some, however, irregular sovereign debt yields response to credit rating changes. The same analysis indicates that sovereign debt yield response to positive news was generally smaller in size, as compared negative announcements, which is consistent with previous research conclusions (Galil and Soffer, 2011; May, 2010). However, because the value of ratings or the weight of new information was not analysed, it would be difficult to make any definite statements (for example in favour or against the Expected Utility Theory or Prospectus Theory).
A follow up step, analysis of clustered credit rating events suggest that markets often fail to respond to leading announcements. This may partially explain previous irregularities in sovereign debt yield response to separate credit rating announcements. As it should be expected, once markets adjusted to one announcement, there was limited or no response to following announcements. In some cases, when announcements were clustered within days, event study approach have some limitations, that should be accounted for. In such instance, comparing the size of response of sovereign debt yields to announcement, also point that markets tend to linger and wait for confirmation from other agencies instead of reacting to leading announcements.

Galil and Soffer, 2011 observations could also explain the lack of responsiveness to single credit rating changes. Firstly, on watch or outlook announcements in many cases significantly affect markets, indicating that the change of credit rating is already anticipated when it takes place. Secondly, analysis of only un-clustered announcements underestimate the impact of an announcements on the markets.

Theory and deduction imply that there may be some imperfections of information that CRAs provide. However, the results of this research suggest that markets differ between the rating agencies, however do trade on whatever information CRA announcements provide, despite possible imperfections of information that is provided. In fact, it is possible that these imperfections are the reason for cautious market reaction to credit rating announcements. Some of these deficiencies, like informational cascades and iterated expectations, may actually be encouraged by wary markets, thus creating a self fulfilling circle. On the other hand, it seems that the presence of several large CRAs provide additional trust by the market. Therefore the present debt (or other financial products) certification system seems to have its’ flaws and support mechanisms that enable it to function as it does. These conclusions would be in line with previous analysis of duopoly of certification in market performed by Hirth, 2011, that yielded very similar observation.

The results of this analysis is that markets, in some instances, do not respond to credit rating announcements. Instead the response is more robust in case of several similar announcements by multiple CRAs. This may indicate that there is room for improvement for the CRAs. Still it is important to note, that any interpretation of results of this research should be considered along with limitations of an event study. Namely, the issues of market
anticipations of the event and that the event is indeed the only important factor that affects the markets within the event window.

The stability of financial markets depend on proper operation of CRAs to some extent. Based on results of this research and given that there may be a number of issues related to information CRAs are providing, it is reasonable to agree with some recommendations put forward by previous researchers. One of the most popular is: to abandon practice when debt issuer pays for the rating or at least significantly diversify the portion of CRAs income. This might even be seen as a silver bullet. A significant diversification of CRAs' income may mitigate risks related to shopping for credit ratings, managements' willingness to inflate ratings and reluctance to downgrade their client as situation develop. In fact, if the income is diversified towards subscribers, who actually base investments decisions on these ratings, it may even be an additional incentive for CRAs to provide most timely and quality information possible. However, perhaps, CRAs are in the best position and motivation to investigate, judge and make the necessary changes of the business.

This research did not prove or disprove certain market reactions (anticipation, over/under-reaction, impact of outlook announcements or other events), however did not contradict the possibility of such responses. Therefore further research, specifically aimed at testing these phenomena may be very much informative. Applying different methods, or investigating different time and country sample may be useful in evaluation of findings of this paper.

Acknowledgement

I would like to express my gratitude to Agostino Manduchi for initial support and very accurate advice in early development phases of this paper. Remarks and comments of my fellow students throughout the progress of my work are very much appreciated as well. Finally, Prof. Andreas Stephan deserves great credit for valuable guidance and instruction throughout the process of my work and beyond. Any and all errors that remain are my own.
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7 Annexes

7.1 Annex I: CRA Ratings Comparison

Table 1. CRAs' ratings awarded to long term sovereign debtors denominated in foreign currency.

<table>
<thead>
<tr>
<th>Interpretation</th>
<th>Moody's</th>
<th>Fitch</th>
<th>S&amp;P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment Grade</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extremely robust capacity to service debt</td>
<td>Aaa</td>
<td>AAA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aa1</td>
<td>AA+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aa2</td>
<td>AA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aa3</td>
<td>AA-</td>
<td></td>
</tr>
<tr>
<td>Strong capacity to service debt</td>
<td>A1</td>
<td>A+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A3</td>
<td>A-</td>
<td></td>
</tr>
<tr>
<td>Adequate capacity to service debt</td>
<td>Baa1</td>
<td>BBB+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baa2</td>
<td>BBB</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baa3</td>
<td>BBB-</td>
<td></td>
</tr>
<tr>
<td><strong>Speculative grade</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likely to fulfill obligation, yet ongoing uncertainty</td>
<td>Ba1</td>
<td>BB+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ba2</td>
<td>BB</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ba3</td>
<td>BB-</td>
<td></td>
</tr>
<tr>
<td>High probability of default, high-risk</td>
<td>B1</td>
<td>B+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B3</td>
<td>B-</td>
<td></td>
</tr>
</tbody>
</table>

Lower ratings indicate default or near default situation, and are difficult to compare as explained in Section 2.5.
7.2 Annex II: Modelling Sovereign Yield Movements

This short study is presented in order to demonstrate the complexity of accurately modelling sovereign yields. And provide additional motivation, why it may be preferable to use a simple variant of mean event study and concentrate on short term estimations, rather than using statistical model to predict debt yield movements and aiming for long term estimations.

Based on reasoning provided in earlier chapters of this paper, researchers (Alexopoulou et al 2009, Bellas et al 2010) often model government debt yields as function of external debt, fiscal balance, inflation, exchange rate, GDP-per-capita, GDP growth and other variables. Not surprisingly GDP growth and external debt variables prove to be statistically significant most often.

Therefore, for this attempt, quarterly nominal GDP growth (year-on-year) is used to proxy government tax revenues; size of general government debt as a share of GDP (compiled by EuroStat) is used to proxy burden of servicing the debt. In addition a term of one-period lagged size of debt is also included, as it is not unreasonable to assume that the price of government borrowing may actually depend of previous size of debt. Sovereign debt yield of constant 10-year maturity, compiled by European Central Bank (for measurement of convergence between member states) is used to proxy the price of government borrowing. Geographical coverage includes Portugal, Greece, Italy and Ireland.

Firstly, all three variables for every country are tested for unit root and stationarity using Augmented Dickey-Fuller test (table 1). Since test results indicate that all variables contain unit-root processes with stochastic trend and an intercept, first-differences of all variables are taken and re-tested for unit root using ADF test. The resulting ADF-statistic values are well below (more negative) than critical values of ADF-statistic, and corresponding P-values are <0.01, therefore it is possible confidently reject \( H_0 \): variable has a unit root, and conclude that now all of the variables are integrated to the zero order and can use for time-series analysis and modelling.

It is reasonable to believe that bond yield volatility changes and is clustering, that is, low volatility is followed by low and high volatility is followed by high. Primary analysis of structural sovereign debt yield models indicate significant heteroskedasticity effects which is confirmed by formal ARCH LM tests.
### Table 1. Augmented Dickey Fuller test results for unit root.

<table>
<thead>
<tr>
<th>Variable</th>
<th>in level</th>
<th>in first difference (Δ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ADF statistics</td>
<td>P-value</td>
</tr>
<tr>
<td>GRY</td>
<td>3.6246</td>
<td>1.0000</td>
</tr>
<tr>
<td>GRG</td>
<td>-2.0460</td>
<td>0.5590</td>
</tr>
<tr>
<td>GRD</td>
<td>0.7288</td>
<td>0.9995</td>
</tr>
<tr>
<td>ITY</td>
<td>-0.0823</td>
<td>0.9938</td>
</tr>
<tr>
<td>ITG</td>
<td>-3.4798</td>
<td>0.0547</td>
</tr>
<tr>
<td>ITD</td>
<td>-2.2400</td>
<td>0.4562</td>
</tr>
<tr>
<td>IRY</td>
<td>-0.7600</td>
<td>0.8210</td>
</tr>
<tr>
<td>IRG</td>
<td>-2.0981</td>
<td>0.2464</td>
</tr>
<tr>
<td>IRD</td>
<td>-1.4254</td>
<td>0.5609</td>
</tr>
<tr>
<td>PTY</td>
<td>2.7590</td>
<td>1.0000</td>
</tr>
<tr>
<td>PTG</td>
<td>-2.5885</td>
<td>0.2872</td>
</tr>
<tr>
<td>PTD</td>
<td>2.5735</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

*Data for Italy and Ireland debt test positive for unit root even in first difference, so taking second differences Δ² integrates data to the 0th order. Then ADF test is used to examine for unit root in this series, which gives for Italy debt ADF statistics -13.99278 and p-value of 0.0000, for Ireland -8.1533 and p-value 0.0000, allowing to reject H0 series has unit root. For these variable data in 2nd difference is therefore used for model estimation.

To account for arch effects and avoid non-negativity constrains IGARCH(1,1) method is the model of choice to explain the movements in yields. Such method of estimation is also in line with previous research attempts, including (Bierns et al, 2003).

The complexity comes due to the fact, that most economies, especially European, are interconnected by trade and financial flows, as well as political ties. Therefore developments in one country may well have strong impact on the economy of another. In order to account and compare the results, first, sovereign debt yields (Y) are modeled using IGARCH(1,1) model, with mean equation defined by size of debt (Dₜ), one-period lagged debt (Dₜ₋₁) and GDP growth (Gₜ). Second, to show the economic impact of fiscal troubles in Greece to other countries, Greek government debt yields (GRYₜ) are included as explanatory variables for Portugal, Ireland and Italian debt yields.

In result, first, for every country a model with mean equations defined as

\[
\Delta Y_t = \alpha_0 + \alpha_1 \Delta D_t + \alpha_2 \Delta D_{t-1} + \alpha_3 \Delta G + u_t
\]

(eq A)

---

3 Yields denoted as Y, GDP growth - G and Debt -D, and preceded by country specific prefix, for example. GRY - is Greek debt Yields, GRD - Greek government debt, GRG - Greece GDP growth; IT - for Italy, PT - Portugal.
is estimated. Secondly, model with mean equation including Greece debt yields, defined as

$$\Delta Y_t = \alpha_0 + \alpha_1 \Delta D_t + \alpha_2 \Delta D_{(t-1)} + \alpha_3 \Delta G + \alpha_4 \Delta GRY_t + u_t$$

(eq B)

is estimated. In both cases, IGARCH(1,1) variance equation is defined as:

$$u_t = v_t h_t$$

$$h_t = \sqrt{\alpha u_{t-1}^2 + \beta h_{t-1}}$$

$$\alpha + \beta = 1$$

Before interpretation of regression results, residual diagnostic tests for residual normal and homoskedastic distribution, and free of autocorrelation must be performed, to make sure that some basic assumptions required by the estimation method are met (table 2).

<table>
<thead>
<tr>
<th>Country</th>
<th>Yields</th>
<th>Jarque-Bera Normality Test</th>
<th>ARCH LM Heteroskedasticity Test</th>
<th>Residual SAC &amp; SPAC values, Q-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>JB-statistic</td>
<td>P-value</td>
<td>F-statistic</td>
</tr>
<tr>
<td>Greece</td>
<td>(eq 1A)</td>
<td>0.8292</td>
<td>0.6606</td>
<td>0.2818</td>
</tr>
<tr>
<td></td>
<td>(eq 2A)</td>
<td>1.4336</td>
<td>0.4883</td>
<td>1.0511</td>
</tr>
<tr>
<td></td>
<td>(eq 2B)</td>
<td>0.0274</td>
<td>0.6612</td>
<td>0.7529</td>
</tr>
<tr>
<td>Portugal</td>
<td>(eq 4A)</td>
<td>0.9653</td>
<td>0.6174</td>
<td>0.4444</td>
</tr>
<tr>
<td></td>
<td>(eq 4B)</td>
<td>1.6216</td>
<td>0.4445</td>
<td>0.8922</td>
</tr>
<tr>
<td>Ireland</td>
<td>(eq 5A)</td>
<td>1.5707</td>
<td>0.4556</td>
<td>0.5428</td>
</tr>
<tr>
<td></td>
<td>(eq 5B)</td>
<td>3.3970</td>
<td>0.1830</td>
<td>0.0596</td>
</tr>
</tbody>
</table>

To test for normality Jarque-Bera normality test is used, where $H_0$: residuals are normally distributed. As it observable in table 2, JB-statistic is above critical values and corresponding P-values are >0.05 therefore we cannot reject the $H_0$.

---

4 Equation numbers are attributed depending on country: 1 - Greece, 2 - Italy, 3 - Portugal, 4 - Ireland. The letter attached, refer to version of mean equation: A - for equation (A) and, B - for equation (B).
To test for heteroskedasticity ARCH LM test is used. F-statistics for all equations is lower than critical values at 5% significance level, P-values >0.05, therefore $H_0$: residuals are homoskedastic, is not rejected.

To test for autocorrelation Sample Auto-Correlation & Sample Partial Auto-Correlation values are examined, by analysing the corresponding Q-statistics and P-values for up to 3 lags. The Q-statistics for every equation & lag is lower than critical values at 5% significance level and P-values >0.05. Therefore the null hypothesis $H_0$: SAC & SPAC values are not significantly different from 0 is not rejected. The conclusion is: there is no autocorrelation in the residuals.

Since diagnostic testing provides positive results, indicating no significant problems that may be relevant to the estimates, it is possible to interpret the results of model estimations (table 3).

Table 3. Estimated coefficients, z-values in parenthesis, significance level marked by *, ** or *** - as explained below.

<table>
<thead>
<tr>
<th>Yields</th>
<th>Intercept $(\alpha_0)$</th>
<th>Debt $(\alpha_1)$</th>
<th>Debt (-1) $(\alpha_2)$</th>
<th>GDP growth $(\alpha_3)$</th>
<th>Greece Yield $(\alpha_4)$</th>
<th>ARCH $(\alpha)$</th>
<th>GARCH $(\beta)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
<td>(eq 1A) -0.0259</td>
<td>0.0137</td>
<td>0.0412**</td>
<td>-0.0003</td>
<td>0.2183***</td>
<td>0.7816***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-0.5330]</td>
<td>[0.8341]</td>
<td>[2.0471]</td>
<td>[-0.0116]</td>
<td>[0.3479]</td>
<td>[12.4525]</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>(eq 2A) 0.0350</td>
<td>-0.0066</td>
<td>0.0211*</td>
<td>-0.0160</td>
<td>0.0393</td>
<td>0.9607***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.8638]</td>
<td>[-0.3867]</td>
<td>[1.9182]</td>
<td>[-0.2854]</td>
<td>[0.4215]</td>
<td>[10.3004]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(eq 2B) -0.0321</td>
<td>0.0013</td>
<td>0.0199**</td>
<td>-0.0006</td>
<td>0.2233***</td>
<td>0.1710</td>
<td>0.8290***</td>
</tr>
<tr>
<td></td>
<td>[-1.1262]</td>
<td>[0.1092]</td>
<td>[2.5651]</td>
<td>[-0.0139]</td>
<td>[6.7497]</td>
<td>[1.6243]</td>
<td>[7.8771]</td>
</tr>
<tr>
<td>Portugal</td>
<td>(eq 3A) -0.0733*</td>
<td>0.0904***</td>
<td>-0.0070</td>
<td>0.1129***</td>
<td>0.2072*</td>
<td>0.7928***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[-1.8558]</td>
<td>[4.7787]</td>
<td>[-0.2953]</td>
<td>[4.1005]</td>
<td>[1.6821]</td>
<td>[6.4368]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(eq 3B) 0.0104</td>
<td>-0.045***</td>
<td>0.0134</td>
<td>0.0538***</td>
<td>0.1869**</td>
<td>0.8131***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.6452]</td>
<td>[-4.3061]</td>
<td>[1.3310]</td>
<td>[5.8848]</td>
<td>[2.1864]</td>
<td>[9.5097]</td>
<td></td>
</tr>
<tr>
<td>Ireland</td>
<td>(eq 4A) 0.0434</td>
<td>-0.0090</td>
<td>0.0666***</td>
<td>-0.040***</td>
<td>0.3608**</td>
<td>0.6392***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[1.7617]</td>
<td>[-0.5911]</td>
<td>[4.8507]</td>
<td>[-3.2732]</td>
<td>[1.9715]</td>
<td>[3.4923]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(eq 4B) 0.0009</td>
<td>-0.0052</td>
<td>0.0243</td>
<td>-0.0003</td>
<td>1.0050***</td>
<td>0.6458***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.1303]</td>
<td>[-1.2035]</td>
<td>[5.4746]</td>
<td>[-0.1412]</td>
<td>[59.8142]</td>
<td>[3.8045]</td>
<td>[2.0868]</td>
</tr>
</tbody>
</table>

***-significant at 1% level; **-at 5%; *-at 10%.

For Greece (table 3, equation 1A), only one-period lagged change in debt/GDP ratio appear to be statistically significant(p-value <0.05). In this case an increase of 1% debt/GDP ratio should lead to 0.0412% increase in government long-term debt yield. Significant ARCH and GARCH terms indicate there is indeed clustering of volatility of the yields.

For Italy (table 3, equation 2A) only one-period lagged change in debt/GDP ratio appear to be statistically significant (p-value <0.1), and appears to positively contribute to change
in government debt yields. If Greek debt yields are included (equation 2B) as explanatory variables this variable remains statistically significant, however, now, 1% in Greek government debt yields translates into +0.223% yield for Italy.

For Portugal (table 3, equation 3A) debt/GDP ratio appear to positively contribute to the debt yields, as expected. GDP growth seem to have positive impact on debt yields. Reason to that could be that growth may have been fuelled by credit and coincided with changes in debt and therefore should be investigated further. If Greek debt yield is included as an explanatory variable (equation 3B) it appears that 1% change in Greek debt yields leads to 0.6758% change in Portuguese debt yields. Significant ARCH and GARCH terms indicate there is clustering of volatility if the yields.

For Ireland (table 3, equation 4A) debt/GDP ratio of previous period seem to positively contribute to government debt yields, also GDP growth appear to negatively contribute to debt yields, as it should be expected. If Greek debt yield is included as an explanatory variable (4B) it appears that 1% change in Greek debt yields leads to 1.005% change in Irish debt yields. Significant ARCH and GARCH terms indicate there is indeed clustering of volatility if the yields.

Concluding Remark

The results of this short analysis show that accurate modelling of sovereign debt yields may prove to be very complicated. The model or method choice may be different, however the result of this example indicate, that estimates for different countries vary significantly, especially if additional important variables are introduced. The importance of the variables may well change depending on situation. This leads to conclusion that the development of an accurate model would then mean embarking on developing of a full scale probability of default model (one almost rivalling the ones used by CRAs). This, however is beyond the scope or resources available for development of this paper. On the other hand, using inaccurate model (and almost certainly introducing omitted variables bias) for the purpose of event study may be self-defeating and introduce unnecessary further risk of error, which in addition may be difficult to recognize, evaluate and account for.