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RISK PERCEPTIONS AND FUNDAMENTAL EFFECTS ON SOVEREIGN SPREADS

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Abstract

We examine the determinants of spreads based on views regarding sovereign riskiness. The empirical analysis relies on panel data estimation techniques for 30 sovereign bonds for the period of 2009Q1 to 2017Q1, with data in quarterly frequency. We find that indeed there is a wide asymmetry in the effects exercised by sovereign spreads' determinants, which is related to the riskiness of the sovereign. Low-risk spreads are found to be more sensitive to the prospects of higher growth rates and inflation; high-risk spreads are found to be more sensitive to idiosyncratic volatility and global volatility. Also, our results indicate that primary surpluses indeed lower spreads, but this reduction is not strong enough to 'shield' the sovereign against volatility; thus, policy makers should avoid 'noise' that may undermine investor confidence by increasing idiosyncratic volatility.

Keywords: sovereign spreads; credit ratings; quantile regressions; investor perceptions; fundamentals; volatility

JEL: F34; F45; G12; G15; H30

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1. Introduction

The euro-area debt crisis has showcased the importance of understanding the drivers of sovereign bond spreads, in order for policy makers to provide appropriate responses to potential distortions of the debt's refinancing. The criticality of understanding market signals extends to the designing of policies that aim to overcome or avoid crises. Thus, the correct reading, by policymakers, of the markets' diagnosis of a sovereign debt problem is crucial for restoring or sustaining market access.

Moreover, in case a crisis erupts, this may have sprouted up from several roots. In this regard, the response to a confidence crisis is different to that of an external balances crisis or a fiscal balances crisis; the latter are resolved with the implementation of fiscal or external balances' consolidation policies. However, in the case of a loss of investor confidence towards a sovereign entity, consolidation may be a necessary but not sufficient condition to restore or ease market access; on top of consolidation, policies that aim to lower idiosyncratic volatility and enhance market sentiment, such as guidance to investors and credible pledges, may be needed so that investors' confidence is restored.

All in all, the early diagnosis of the information content of markets' movements is crucial; as a result the literature on the determinants of sovereign spreads, i.e. the premia investors demand for any given sovereign issue due to risks, has grown in the years following the Global Financial Crisis of 2007-2009 and the euro-area debt crisis of 2010-12. Still, there is no unique answer to the crucial question "what drives spreads higher". In fact, the literature has all but been dichotomized between studies that argue that global risk aversion, and its resulting re-pricing of risks, after the Global Crisis, was the main driver of the jump witnessed in sovereign spreads and studies that see spreads reflecting country-specific macroeconomic and fiscal fundamentals, albeit with considerable lag.

In particular, on the one hand, at the early stages of the crisis country-specific imbalances were deemed to be the root-cause of the divergence of the costs of borrowing of euro-area member states from the bond markets (see, e.g., Bernoth and Erdoghan 2012, Gruber and Kamin 2012, Mink and de Haan 2013, Arghyrou and Kontonikas 2012, Ghosh *et al*. 2013a, Beirne and Fratzscher 2013). According to this literature, lower fiscal or external deficits (or higher surpluses) should lead to lower sovereign bond yield premia. So, this line of the literature has provided arguments for the need of consolidation towards the diminishing of fiscal or external imbalances; as Manganelli and Wolswijk (2009) argued, markets may impose fiscal discipline to divergent euro-area member-states by punishing the consistent violators of the Stability and Growth Pact.

However, this approach on the relationship between macroeconomic and fiscal fundamentals with spreads has relied on a 'rational expectations' foundation when modelling sovereign spreads. In particular, this point of view adopts the theoretical view that the market only prices-in risk premia after the fundamentals of the economy are misaligned to an objectively specified threshold (e.g. the existence of an optimal value of debt, as in Calvo 1988); under this point of view, the risk premia of sovereign bonds (i.e. spreads) can deviate from the level implied by the macroeconomic and fiscal fundamentals, only temporarily. However, this view cannot explain the spikes in sovereign risk premia, due to self-fulfilling expectations, as shown by de Grauwe and Ji (2013), and/or systemic market turbulence. In this regard, Favero (2013) argues that "[…] if markets can stay irrational longer than a country can stay solvent, then the role of yield spreads on national bonds as a fiscal discipline devise is considerably weakened […]".

On the other hand, other studies, based on the view that sovereign bonds are parts of portfolios consisting of broader market positions, argue that sovereign spreads are driven mainly by global risk aversion and that their pricing of risks is dependent on the broader regimes of the market (see, e.g., Longstaff et al., 2011, Ang and Longstaff 2013, Chiarella et al., 2015, Delatte et al., 2017). The policy-related arguments from this literature state that market dynamics are exogenous, associated to shifts in global risk aversion, and, thus, fiscal (and external) imbalances' consolidation may not be sufficient to address self-fulfilling market dynamics (see, e.g., De Grauwe and Ji 2013). The significant reduction of the euro-area sovereign spreads, after Mario Draghi's pledge that the ECB "will do whatever it takes", has been taken, by and large, as a confirmation of the view that market confidence (or the lack of it) is a crucial determinant of spreads' movements (see, e.g., Saka et al. 2015).

As a consequence, this strand of the literature argues for the need of a coordinated response to the re-pricing of sovereign risks in order to address the potentially destabilizing impact of global market dynamics on public finances (see, again, De Grauwe and Ji, 2013). The arguments developed by this point of view provide support for such policies as the central banks' asset purchases, outright monetary transactions or even common bond issuances in order to provide a euro-area wide safe asset by bundling sovereign risks in tranches (see, Brunnermeier et al., 2016 and ESRB 2018a and 2018b). So the need for coordinated actions, at the international level, has been based on the foundations built by lessons taught by the previous crisis (i.e. the 2007-2009 Global Crisis).

Still, this point of view does not provide the answer to the question what policy should be followed domestically, in order for sovereign states to rein in their cost of borrowing from the bond markets. There are various reasons to believe that sovereign bond spreads are affected differently by the same factors, according to their state of risk; for instance, the literature has already documented the different reaction of spreads to different states of the market.[1] What remains to be answered is whether spreads' reaction to fundamentals differ based on the perceived, by investors, state of risk of each sovereign; while the literature has already examined global regimes of risk aversion, or market conditions, the notion that investors perceive different risks across different categories of sovereigns, has not yet found its way to the empirical analyses of sovereign spreads.

So, in the present paper, we associate the effects exercised by (domestic and global) risk aversion and several fiscal and macroeconomic fundamentals on spreads with the level of risk of each sovereign, as viewed by investors. For this purpose, investors' views are linked to the assessment of sovereign risks by rating agencies and to the implicit market taxonomy to high- and low-yielders. Our findings indicate that the magnitude of the effects exercised on spreads by macroeconomic fundamentals and risk factors are dependent on investors' views of the riskiness of a sovereign.

In particular, we find that spreads of sovereigns considered riskier, either according to their ratings or their risk premia relative to the rest of countries in our sample, are reduced by consumer confidence, stronger economic and financial activity, domestically, as well as, primary fiscal surpluses, while being particularly prone to episodes of idiosyncratic and global market volatility. On the other hand, the most important 'challenge' for sovereigns considered safer, i.e. highly rated and low-yielding ones, seems to be inflation and, less so, global volatility, whereas

[1] For the euro-area periphery, Delatte et al. (2017) associate the regime shift in the pricing of sovereign bonds with the bank-sovereign loop. For a wider sample of countries, Malliaropulos and Migiakis (2016) find that the systemic re-pricing of sovereign risks was related to the rise in global risk aversion that followed the eruption of the Global Crisis.

idiosyncratic financial market volatility seems to lead their spreads lower, possibly as a reflection of a portfolio reallocation towards safer assets.

The rest of the paper is organized as follows. Section 2 discusses the issues that are usually addressed by empirical analyses of sovereign bond spreads and presents the model used herein in order to capture cross-section heterogeneities in sovereign spreads. Section 3 describes the data. Section 4 presents the results, when ratings are used to capture the state of sovereign risk, while in section 5 the heterogeneity in spreads is captured by quantile regressions that classify spreads to high-, median- and low-yielders. Finally, section 6 concludes.

2. Modeling sovereign spreads

2.1 Standard models of the effects of fundamentals on spreads

Sovereign bond spreads are specified as mean-reverting stationary, albeit highly persistent, processes, that are affected both by country-specific and global risk factors (see, Favero 2013). The following relationship illustrates the standard setup used in panel data analyses, in its general form:

$$(R_{it} - R_{0t}) = \alpha_i + \rho \cdot (R_{it-1} - R_{0t-1}) + \gamma \cdot f_{it} + d \cdot v_t + e_{it} \qquad (1)$$

In equation (1) R_{0t} stands for the sovereign bond yield of the benchmark country, at each point in time (t), whereas R_{it} stands for the yield of the bond, with similar term to maturity, of sovereign *i*. The difference between the two (i.e. $R_{it} - R_{0t}$) is the sovereign bond yield spread, also known as 'sovereign spread' or simply 'spread'.

In equation (1) above, a fixed effects constant (i.e. α_i) is added, as a standard way to capture country-specific, time-invariant, deterministic effects. Next, the inclusion of the spread's first lag is dictated by the property of high persistence and, as a result, of spurious inference of the coefficients of those determinants that are correlated to the spread's time path. Also, following the recent empirical literature on the effects of global risk aversion on sovereign spreads, the variable v_t is introduced in order to capture effects that stem from global financial volatility. Finally, country-specific fundamentals (f_{it} , stands for a vector of macroeconomic and fiscal fundamentals) are also taken into account, as indicators of the level of risk of the sovereign.

In this respect, in the extant literature on sovereign spreads the fiscal imbalances or the current account imbalances are introduced, in order to gauge the risks that stem from the external debt accumulation or the general public debt accumulation, due to the respective imbalances. These variables are expected to be significant if investors monitor fiscal or external imbalances, as well as the dynamics of debt, in order to form their views on a sovereign's ability to serve its debt and, as a consequence, on its risk to default.

On the other hand, other variables with information related to the streams of public revenues have been given little attention by the empirical literature. For example, economic activity, economic confidence, inflation and financial activity, are all variables that affect not only the revenue streams of the state but also the denominator of the debt-to-GDP ratio.[2] In the present paper we also examine for these variables' effects on spreads, while controlling for issues of collinearity between the various fundamentals.

2.2 Effects of fundamentals on spreads conditioned on investors' view of risk

An important aspect that still remains to be incorporated in the examinations of the effects of macro and fiscal fundamentals on spreads, is that at any given time at which investors form their expectations on macroeconomic and fiscal fundamentals they are not neutral towards the sovereign; they already have formed an opinion about its riskiness. Therefore, spreads' reaction to fundamentals, which reflects investors' portfolio allocation decisions, may differ with regards to (a) the sensitivity or (b) the direction of the effects, across sovereigns with different riskiness.

This can easily be understood if we consider that, for example, a given change in the fiscal balance or the growth rate of a sovereign whose revenues marginally cover its financial needs may lead to stressed borrowing, whereas this would not be the case for a sovereign that is not considered as risky. Also, it is very frequent to have reactions dictated by already formed opinions for a sovereign, either due to herd behaviors or due to 'prisms' that form investor perceptions, such as implicit or

[2] Still, these variables are taken into consideration by market participants, when assessing sovereign credit risk; for example, rating agencies assess the economic strength of the sovereigns by using, among others, GDP growth rates and GDP volatility (see, Moody's 2015, Standard and Poor's 2011 and Fitch 2010).

explicit taxonomy by market participants of the riskiness of sovereigns across spectrum.

Still, a large part of the extant literature, addresses the issue of effects stemming by macro and fiscal fundamental variables on spreads, i.e. a variable that is determined by highly-frequent trading, within a rational-expectations framework. Most prominently Calvo (1988) sets the theoretical framework for pricing the expected path of the general government debt in the interest rates of government bonds. According to Calvo's rational expectations model, sovereign bond spreads should incorporate risk premia only when a certain level of the debt-to-GDP, or some other measure of the level of indebtedness, is reached. So, by incorporating the notion of expectations of fundamentals, Equation (1) becomes:

$$\left(R_{it} - R_{0t}\right) = \alpha_i + \rho \cdot \left(R_{it-1} - R_{0t-1}\right) + g \cdot E_t(f_{it+h}|\Omega_t) + \gamma \cdot m_{it} + d \cdot v_t + \epsilon_{it} \quad (2)$$

In the equation above, $E_t(\cdot\,|\Omega_t)$ is the expectations operator for a set of fiscal variables (denoted by *f*), given the set of information (*Ω*) at the time of expectations formation, while *m* denotes the rest of the macroeconomic fundamentals, that relate to economic activity and inflation. In this setup, the information obtained at time t is adequate for investors to form expectations of the fiscal variables *h* periods ahead. Apart from accurately disentangling the component of spreads that is affected from fiscal fundamentals from that affected by all other factors, a difficulty in examining the rationality of investors' expectation formation, as reflected by spreads, is that there is no such value as a 'fair spread'. On the other hand, if the expected fiscal fundamentals' effects on spreads are conditional on investors' views on sovereign risk, this is indirect evidence that investors have already formed their perceptions of the riskiness of a given sovereign before pricing its bonds.

The notion that investors price sovereign risks based on a rational expectations setup, has already been put to trial during the Global Crisis as yields rose even for highly-rated sovereign bonds and this has been associated to the rise of global risk aversion (see, Ang and Longstaff 2013 and Malliaropulos and Migiakis 2016). As a result, the threshold level of debt, below which sovereign risk premia are negligible, cannot provide sufficient explanations for the abrupt movements of relatively risk-less sovereign bond yields. In this respect, empirical findings, such as the ones from a part of the literature mentioned in the previous section, that have highlighted the significance of market sentiment conditions, global risk aversion and regime-dependent sovereign risk pricing, consist deviations from a hypothetical process dictating that spreads are determined by decisions of investors that result to pricing fundamentals in an accurate and unbiased way. Most importantly, these findings shed light to the effects exercised on spreads by factors that may well affect the views of investors regarding the risk of any given sovereign, even if its fundamentals do not change.

So, herein we examine whether factors that relate to the formation of investors' views on the riskiness of the sovereign affect the effects exercised by its macro and fiscal fundamentals on its bond spreads, as well as the effects of global risk aversion and idiosyncratic volatility. Note, however, that a difficulty in the examination of the process of the formation of expectations is imposed by the fact that investors' views are not directly observable; on the other hand, there are various mechanisms that relate to the formation of the views of investors on the riskiness of the sovereign. As a result we may examine the interaction of such mechanisms with the effects of macro and fiscal fundamentals on spreads. Then, if the perceived riskiness of a sovereign significantly interacts with the pricing of its macro and fiscal fundamentals, there will be sufficient evidence that investors base their reaction to fiscal and macro fundamentals on predetermined criteria about sovereign risk.

In this respect, criteria used to gauge sovereign risk may lead to pricing fundamentals in clusters; that is, the effects of fundamentals on spreads may be similar for sovereigns belonging to a given category of riskiness, while being different across sovereigns that belong to other groups of sovereign risks. Econometrically, this can be examined if the effects of macro and fiscal fundamentals are interacting with investors' views on the level of sovereign risk. For this purpose we estimate the effects of fundamentals on sovereign spreads by allowing for cross-section variation of the effects, according to classifications of the sovereign's riskiness at each point in time. Equation (3), below illustrates this concept:

$$\left(R_{it} - R_{0t}\right) = \alpha_i + \rho_1 \cdot \left(R_{it-1} - R_{0t-1}\right) + g_1 \cdot E_t(f_{it+h}|\Omega_t) + \gamma_1 \cdot m_{it} + d_1 \cdot v_t + \rho_2 \cdot \left(R_{it-1} - R_{0t-1}\right) \cdot c_i + g_2 \cdot E_t(f_{it+h}|\Omega_t) \cdot c_i + \gamma_2 \cdot m_{it} \cdot c_i + d_2 \cdot v_t \cdot c_i + u_{it} \quad (3)$$

In Equation (3), the expected (fiscal) fundamentals are allowed to affect spreads according to existing views of investors about the riskiness of each sovereign, which are captured by c_i. This way we allow expectations on fiscal fundamentals to be based on the perceived, or real, level of sovereign risk; such a specification allows both for the rational formation of expectations and for the formation of expectations that deviate from the rationality paradigm. Whether perceptions of sovereign risk are rational or not, however, does not fall in the scope of the present study; we restrict on examining whether the pricing of sovereign risk, as reflected by sovereign spreads' movements, entails an interaction of expected fiscal fundamentals with variables that provide information about investors' views on sovereign risk.

Similarly, the effects that stem from the rest of the determinants of spreads, in Equation (3), are also allowed to depend on the riskiness of the sovereign. In particular, effects on spreads may be different from the cross-section average, for different levels of (perceived or real) sovereign risk. So, by examining whether views on the riskiness of a given sovereign affect the sensitivity of its spread to its (fiscal and macroeconomic) fundamentals, we may infer evidence of existence of a risk-based heterogeneity in the pricing of fundamentals. In this regard, this risk-based pricing may explain the documented heterogeneity of spreads' determinants (see, e.g. Georgoutsos and Migiakis, 2013 and Gibson *et al*. 2015); spreads may be affected differently by the same developments, according to the classification of the sovereign to higher- or lower-risk classes. To this end, the interaction of expected fiscal fundamentals ($E_t(f_{it+h}|\Omega_t)$), current (macroeconomic) fundamentals (m_{it}) and volatility variables ($\mathrm{v_t}$) with variables used to gauge investors' views on the riskiness of sovereigns, can be used to examine the effect of investors' views on sovereign risk for sovereign bonds' pricing.

2.3 Ratings- and markets-based classification of sovereign risk

The next question is which variable(s) can be used to gauge investors' views on sovereign risk, as denoted by c_i? First, we note that there are several measures that can be used in order to capture variations of the risk as viewed by investors; for example, on the one hand, global risk aversion variables may be used to provide information about investors risk tolerance towards the global financial system, while, on the other hand, idiosyncratic volatility may provide information on the risk tolerance towards specific entities. Our aim is to examine to what extent the pricing of fundamentals varies across categories of different levels of sovereign risk.

For the purpose of this examination the variables that reflect investors' views on sovereign risk should be country-specific. In this context, we capture views on sovereign risk either with the use of credit ratings or by following an inherent market classification of risks to high- and low-yielding sovereigns. Credit ratings reflect the rating agencies' views on the riskiness of the sovereign; the classification of spreads to low and high quantiles, at each point in time, serves for extracting bond market participants' views on the riskiness of the sovereign relative to other sovereign bonds.

First, credit ratings are assessments of the ability and willingness of an entity to respect its debt obligations in full. For the purpose of classifying the risk that a sovereign may default on its obligations, credit rating agencies assign alphanumeric values that inform investors on the riskiness of each sovereign, as perceived by the rating boards of the agencies. Sovereign risk is very often inferred, by market participants and policy makers, with the use of credit ratings. So, sovereign ratings may be used to reflect investors' perceptions of sovereign risk as they are both reflections of fundamentals and of the perceptions of experts on sovereign risk.

Importantly, ratings provide an assessment of the prospects of the sovereign, as seen by ratings' boards of experts, on top of the score assigned to each sovereign based on its present economic situation. In particular, the procedure of assigning ratings to sovereigns entails both an objective and a judgmental stage (see, Fitch 2010, Moody's 2015 and Standard and Poor's 2011). In the first stage, macro, fiscal, institutional and political factors are assessed (see, IMF 2010), while in the second, ratings committees input their views of the prospects of the economy. Thus, the assessment of sovereign risks, as reflected by ratings, has been found to deviate from the underlying level of risk implied by fundamentals.

The judgmental stage in assigning ratings has led to critiques for ratings' deviations from the levels implied by fundamentals. Lennkh and Moshammer (2018) have examined ratings provided by Moody's for 74 countries worldwide and find that its ratings deviate significantly from the level implied by fundamentals for several countries. The tendency to assign worse ratings to sovereigns considered riskier by markets, may relate to the impaired reputation of ratings in the aftermath of the Global Financial Crisis (see, De Vries and De Haan 2016 and Bedendo *et al.* 2018), thus resulting to a feedback loop of risk perceptions between markets and rating agencies. Despite this critique, however, several studies have documented the usefulness of ratings for the formation of investors' views about sovereign risks, by associating the pricing in bonds to credit ratings (e.g. Livingston *et* al. 2010, Aizenmann *et al.* 2013, de Santis 2012 and Malliaropulos and Migiakis 2016, Gibson *et al*. 2017).

For these reasons, we believe it is very interesting to examine whether ratings affect the impact of other determinants on spreads. To do so, we estimate equation (3), by using ratings for the classification of sovereigns to categories of riskiness (i.e. variable c). The estimation of equation (4), below, will provide the answer to whether ratings (a) are significant gauges of investors' perceptions of risks and (b) are linked to the heterogeneity of spreads' determinants.

$$\left(R_{it} - R_{0t}\right) = \alpha_i + \rho_1 \cdot \left(R_{it-1} - R_{0t-1}\right) + g_1 \cdot E_t(f_{it+h}|\Omega_t) + \gamma_1 \cdot m_{it} + d_1 \cdot v_t + \rho_2 \cdot \left(R_{it-1} - R_{0t-1}\right) \cdot c_{it} + g_2 \cdot E_t(f_{it+h}|\Omega_{it}) \cdot c_{it} + \gamma_2 \cdot m_{it} \cdot c_{it} + d_2 \cdot v_t \cdot c_{it} + u_{it} \quad (4)$$

In Equation (4), each sovereign does not belong to a predetermined class of risk for the entire sample, as would be the case if we split the section of the sample to specific groups of countries (e.g. emerging vs. advanced economies or core vs. periphery euro-area countries). This approach, although has provided valuable inference on the determinants of spreads for heterogeneous groups of countries, has the disadvantage of being static. In our case, in Equation (4), the variable used to classify sovereign risk (i.e. c_{it}) is allowed to vary over time, thus migrating from low to high risk groups and vice-versa, and it provides therefore a more realistic illustration of the way investors view each sovereign. So, in Equation (4) ratings are used for gauging investor perceptions on sovereign risk; the estimation of equation (4) provides an examination of the significance of ratings for the pricing of sovereign risk in bond markets.

Second, in light of the critique exercised on ratings, we also try to infer investors' views of sovereign riskiness by using a comparative, market-based, classification of the riskiness of sovereigns is useful. To serve this purpose the cross-section comparison of sovereign bond yields stands as the reflection of the inherent classification, by market participants, of the riskiness of sovereigns. In this way, we lift the dependence of investor perspectives on external assessments, such as ratings and examine whether the pricing of sovereign bonds depends on market-based beliefs about the riskiness of sovereigns.

The classification of sovereigns to those that belong to the upper quantile (e.g. the highest 25% quantile, or q=75%) and those belonging to lower quantile (the lowest 25% quantile, i.e. q=25%) or the median quantile (i.e. q=50%) provides an endogenous taxonomy of spreads, which may also reflect the views of investors for the riskiness of each sovereign, relative to the rest of the sample. In particular, this clustering technique reflects a taxonomy of sovereign bonds that is very often used by market participants; i.e. sovereigns are thus classified to low-, median- and high-yielders. This taxonomy, although being of similar information to ratings with regards to the classification of sovereign bonds to clusters of risk, relies on investors' views and allows for time variations of investors views.

For the purpose of reflecting time variations in the results we use a time-varying parameters approach; this allows us to disentangle spreads' movements due to global factors from those that are due to country-specific riskiness, as reflected in market pricing relative to other sovereigns. In this respect, when we allow for the comparison of the level of spreads across sovereigns to govern the specification, a time-varying parameters approach should be used in order to obtain cross-section classifications in quantiles of the dependent variable. So, we estimate the relationship:

$$\left((R_{it} - R_{0t})\middle|q_\tau\right) = \alpha_\tau(q_\tau) \quad + \rho_\tau \cdot \left((R_{it-1} - R_{0t-1})\middle|q_\tau\right) + g_\tau \cdot E_t\left(f_{i,t+h}\middle|q_\tau\right) + \gamma_\tau \cdot (m_{it}|q_\tau) \quad + d_\tau \cdot v_t + (\varepsilon_{it}|q_\tau) \qquad (5)$$

In Equation (5), q denotes the conditioning of the regression to quartiles; in particular we allow the data properties to classify spreads to the highest 25% (q=75%), the lowest 25% (q=25%) and to the median class (q=50%), for each sub-sample (τ). Also, the coefficients of the regression are, thus, estimated in a time-varying fashion, as for each window of observations used we re-estimate the sensitivities of spreads to their determinants. This technique entails the advantage that it addresses heterogeneity of the determinants of spreads across different clusters of risk of the sections. This is done by classifying spreads to higher and lower quartiles endogenously to the data properties, thus acquiring a classification that is meaningful for investors' views on sovereign risk. Since the classification is done dynamically, i.e. for each three-month sub-sample, we avoid having false classifications due, perhaps, to different monetary regimes in the full period of our sample.

3. Panel data analysis

3.1 Description of the data

Yields of ten-year sovereign bonds are used in quarterly frequency, for 30 sovereigns[3] from various regions of the world, while the period covered by our sample is from 2009Q1 to 2017Q1. The source of the bond yields data is Thomson Reuters Datastream. We incorporate sovereigns from various regions and with a wide dispersion in the underlying characteristics, as a central aim of the present paper is to reflect possible origins of the heterogeneities in the determinants of sovereign spreads. Spreads series are constructed by taking yields differentials between sovereign bonds and the ten-year United States Treasury bond, while the spread of the United States bond is calculated as the difference between the US Treasury yield and the swap-implied yield for the ten-year maturity segment.

Also, we use ratings, in notch levels, from the three largest credit rating agencies (CRAs), for the same period, which have been transformed from alphanumeric to numeric values[4], while the time of a rating change is noted by lifting (lowering) the value of the country-specific variable in case of a downgrade (upgrade), within the quarter that a CRA proceeding to such a change converged to an already existing rating of another CRA; this classification rule is followed by both regulation and international market practice. The source of the ratings data is Bloomberg.

The quarterly frequency is dictated by the (non-) availability of many macroeconomic and fiscal fundamental variables in higher frequencies. In particular, based on the findings of earlier studies, the variables used are: debt-to-GDP, primary balance-to-GDP (i.e. the difference between primary revenues and expenses as a ratio of GDP), annualized growth of real GDP, inflation (measured by the year-on-year changes of CPI), consumer confidence, the private debt-to-GDP ratio, volatility of domestic stock markets and the VIX. Thus, we may group these variables in three categories: variables related to fiscal strength (primary balance and debt-to-GDP), variables related to economic/ financial activity (real GDP growth, consumer confidence, private debt-to-GDP and inflation) and variables related to global or domestic risk aversion (VIX and volatility of domestic stock markets). The source of the spreads' determinants is Thomson Reuters Datastream.

[3] Austria, Australia, Belgium, Brazil, Canada, Chile, Czech Rep., Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, S. Korea, Mexico, New Zealand, the Netherlands, Norway, Poland, Portugal, Russia, Slovakia, Spain, Sweden, Turkey, United Kingdom and the United States.

[4] The transformation follows the rule: AAA=1, AA+/Aa1=2, AA/Aa2=3, AA-/Aa3=4, A+/A1=5, A/A2=6, A-/A3=7, BBB+/Baa1=8, BBB/Baa2=9, BBB-/Baa3=10, BB+/Ba1=11, BB/Ba2=12, BB-/Ba3=13, B+/B1=14, B/B2=15, B-/B3=15, CCC/Caa1 and lower =16.

Fiscal variables are at the epicenter of the examination of the effects of fundamentals on spreads. According to Calvo's (1988) framework, the expected values of the debt-to-GDP are the ones that should affect sovereign risk. However, there is no unique series for inferring the debt-to-GDP of a given sovereign, as expected by investors, let alone a series that would cover the entire horizon of the ten-year bonds that we use. As a result, we must rely on inference of investors' expectations. Assuming that investors have informational advantages, such as being able to proceed to formation of expectations based on econometric models, we make use of the standard government budget constraint (see, for example, Ghosh *et al.* 2013b):

$$E_t(d_{t+1}) = d_t + [(r_t - \pi_t) - g) \cdot d_t - s_{t+1} \quad (6)$$

In Equation (6), d_t is the level of debt (as a ratio to GDP) at time t, r is the cost of refinancing the debt, π is inflation rate, g is a constant marking the long-run real level of GDP growth and s_{t+1} is the primary balance-to-GDP which takes positive values in the case of a primary surplus or negative ones in the case of a deficit. We assume that the cost of refinancing follows the market process of pricing of sovereign debt; so, we use the ten-year sovereign bond yield as the variable reflecting the cost of borrowing from the markets and subtract a constant factor as a proxy for the long-run real GDP growth rate.

If we assume that investors base their expectations formation process on econometric modeling it is easy to infer the expected value of debt at time t+1, with standard estimation techniques. Similarly by simply rearranging the variables of equation (6) an additional forecast for the primary balance is obtained (i.e s_{t+1}). Thus, the expected primary surplus is gauged, as a function of realizations of the primary balance (s_t), real growth rate (g_t) and the change in debt in time *t*, as shown in equation (7):

$$E_t(s_{t+1}) = g_t - \Delta d_t + s_t \quad (7)$$

In this way, we may construct the variables that we use for gauging expectations of the debt-to-GDP and the primary balance-to-GDP. Note, however, that we have also examined alternative specifications of the expected variables; in particular, we find similar results to those presented in Sections 4 and 5, if alternative specifications of the expected debt and expected primary balance, in which we replace the 'econometrician's' view with 'perfect foresight' and ARIMA forecasts of fiscal fundamentals, are used.[5]

Theoretically a lower (higher) level of expected debt-to-GDP will be associated with lower (higher) sovereign risk premia, thus resulting to a positive sign in the coefficient(s) of the expected debt, while positive (negative) expected primary fiscal balances, i.e. expected primary surpluses (deficits), will be associated to lower (higher) premia, thus resulting to a negative sign of the respective coefficient(s). We use the expected values for debt and primary fiscal balance, from the respective estimations of equation (6), 4 quarters (1 year) ahead.

The use of macroeconomic fundamentals also bears challenges for the econometric modeling. In particular, variables that reflect economic activity, such as the real GDP growth, consumer confidence and private debt, are expected to co-vary, a feature that may result to inflated variances of their estimated coefficients if inserted together in the same estimation setup. However, while real GDP growth may suffice as a reflection of economic activity and the growth prospects of a given economy, consumer confidence and private debt have additional information that may be useful for modeling sovereign bond spreads. In particular, consumer confidence reflects the views of consumers both for the present and the near-term economic prospects, from the side of economic agents with information disadvantage. So, we choose to include all variables, after isolating the effects on economic activity that are due to consumer confidence and private debt-to-GDP, by taking the residuals from the regression of real GDP growth to consumer confidence and private debt-to-GDP. Also the consumer confidence variable has been made orthogonal to private debt-to-gdp.[6]

The private debt-to-GDP has been used in studies with a particular focus on emerging economies as a reflection of financial development of the economy that affects the sovereign's access to sovereign bond markets (see, Presbittero *et al*. 2015). Note that our variable also includes market financing of the private (non-financial) sector of the economy; as a result, both bank credit and bond issuances by the non-financial sector are taken into account. In this respect, the information obtained by the private debt-to-GDP variable better reflects the degree to which the financial sector of

[5] The effects of these variations of expected fiscal fundamentals on spreads are qualitatively similar to our approach and are available upon request.

[6] The results of the estimation of the fixed-effects panel data regression, that has been used to make real GDP growth orthogonal to consumer confidence and private debt-to-GDP, are available upon request to our readers.

each economy is developed, especially in the light of strong market financing in the aftermath of the Global Financial Crisis.

With regards to the expected sign of the coefficients, we expect that variables related to economic and financial activity may be either related with a negative or a positive sign to spreads. For example, on the one hand, higher real GDP growth rates in developed (and inherently less risky) economies may lead investors to form expectations for higher future short-term rates, thus resulting to a positive sign in the coefficient. On the other hand, for riskier sovereigns, i.e. ones with weak economic activity or structural weaknesses, a stronger real GDP growth rate may lead to receding investor concerns over the sovereign's ability to produce revenues and service its debt, thus resulting in negative signs in the coefficient. This makes the case of heterogeneity in the coefficients of variables related to economic activity significant; wide cross-section dispersion may result to spurious non-significance or a significant coefficient with either positive or negative sign that would not be representative of the effects exercised by economic activity on spreads for all groups of sovereigns. The expected sign of the private debt-to-GDP is ambiguous; expanding the financial sector as a ratio of GDP may result to lower sovereign risk premia, due to financial development, or to higher ones, if investors deem that the expansion of the financial sector comes in expense of financial stability.

Finally, volatility variables are used in order to reflect effects from both global and idiosyncratic, country-specific, volatility on sovereign bond spreads. On the one hand, the VIX index on implied volatility of the S&P500 share price index options is used in order to capture global volatility conditions, following previous literature (among others, Ang and Longstaff 2013, Arghyrou and Kontonikas 2012 and Afonso et al. 2015). On the other hand, the global risk factor that is captured by the VIX index does not count for episodes of increased volatility, related to idiosyncratic risks or country-specific risk aversion.

For this purpose we have also constructed country-specific volatility variables, by taking the 3-month rolling standard deviation of daily stock market returns of the main stock index for each sovereign.[7] After calculating the 3-month standard deviation of the daily returns, we have regressed each country-specific volatility series on the VIX, in order to remove the effects of the global volatility conditions and

[7] Standard deviations of daily stock market returns have been estimated with a three-month window, so that the resulting country-specific volatility series will match the quarterly frequency of the rest of the data.

isolate the country-specific information in the resulting volatility series; the regression took place by using standard GARCH-M techniques in time series environment for each one of the 30 countries of our sample.[8] As a result, we also count for idiosyncratic volatility in our specification.

3.2 Estimation techniques

First, we must choose the appropriate estimation techniques, which are conditional on the properties of our data and the constraints of our setup. On the one hand, the simple Feasible Generalized Least Squares fixed-effects estimators with cross-section weights for counting for heterogeneity (see, for example, Afonso *et al.* 2015), provides efficient estimators. On the other hand, working with high persistent data, such as spreads, raises the probability of errors being serially correlated with the regressors, if a lagged dependent variable is not included in the setup. This is better highlighted by the results obtained by standard fixed-effects estimation of our specification, if an autoregressive component of the dependent variable is not included:

[Insert Table 1, around here]

In Table 1, spreads, on the left hand side of the equation, are estimated in a standard FGLS setup with cross-section weights, with each determinant entering the equation, on the right side, separately in the specifications under the columns (1) to (8). Results under column (9) correspond to a specification that includes all determinants dictated by equation (1), except for the lagged spread. The lower lines of Table 1 report the statistic of the Hausman test for adequacy of the random-effects setup, vis-à-vis the fixed effects alternative; in setups (1) to (8) the random component seems to dominate the residuals, while in (9) the cross-section fixed-effects is found to better fit the data, indicating the existence of significant heterogeneity in the data.

The estimation of specifications (1) to (8) ends up with the theoretically desired results, in the sense that all variables, when considered as determinants of spreads, are found to be significant with the appropriate sign, except for equation (2) in which the significance of the debt-to-GDP for sovereign spreads is not confirmed. However, these specifications are over-simplistic as the underlying hypothesis is that spreads may be well specified by a random-effects parameter, a common intercept and one additional explanatory variable. In the complete setup, under column (9), the

[8] The results of these estimations are, also, available upon request.

explanatory power of the model improves mainly as a result of the cross-section fixed-effects.[9]

To this end, even if we disregarded the low adjusted R-squared coefficients, in specifications (1) to (8) we should take a deeper look at the serial correlation issue; this is highlighted by the extremely low Durbin-Watson statistics. Moreover, and more importantly, although specification (9) leads to higher adjusted R-squared, it is also associated with serially correlated residuals. Possibly, the 'history' of spreads, captured by the residuals, is reflected by some of the determinants we have used in the specifications of Table 1.

Thus, it seems necessary to include a first-order autoregressive parameter in the specification. The inclusion of lags of the dependent variable classifies our setup to that of a dynamic panel data model. So, in the process to choose the most appropriate dynamic panel data model estimation technique we recall the argument of Hsiao and Zhang (2013) that highlight the existence of a finite sample bias in GMM estimators of dynamic panel models and this bias increases along with the squared product of the number of sections times the number of points in time ($\sqrt{N \cdot T}$). As a result, the IV FGLS-estimator performs better than the dynamic panel GMM-estimators for large samples.

Since our aim is to estimate a setup as complete as possible, it seems better not to use instrumental variables, but to control for possible determinants in the main regression. Moreover, this is justified since our explanatory variables are orthogonal, by construction, to each other and, thus, endogeneity issues are not a cause of concern. As a result we use FGLS estimates, in which we also incorporate the first lag of the dependent variable. Table 2 presents the results

[Insert Table 2, around here]

To begin where we left the commentary of the results reported in Table 1, the new estimations that include a lagged spread seem to have much improved statistics for serial correlation of the residuals. In particular, the lower line of Table 2 informs us that, under all specifications (1) to (9), including the first autoregressive factor of the spread renders the residuals with the desired property, i.e. eliminates serial correlation. Furthermore, the goodness-of-fit is also improved, as expected. The lack

[9] The adjusted R-squared of the estimation of equation (9) with cross-section RE is around 27%.

of serial correlation of the residuals from specification (9) of Table 2, is also formally confirmed in Table 3.

[Insert Table 3, around here]

What is more interesting though, is the reduction of the coefficient of the expected debt-to-GDP variable. In particular, although the expected debt-to-GDP remains a significant determinant of the sovereign spreads and with the expected positive sign, in specification (9), its value has been reduced by 80% compared to its value in specification (9) of Table 1 (i.e. without a lagged spread in the same setup). Similarly, the level of the coefficient of the expected primary fiscal balance (in absolute terms) is reduced by ½ in comparison to specification (9) in Table 1. Furthermore, other variables, such as inflation, private debt-to-GDP and idiosyncratic volatility are found to have lower (absolute) values in their coefficients, in comparison to specification (9) of Table 1. Moreover, in the case of real GDP growth and consumer confidence the sign changes from negative to positive.

So, these findings constitute evidence that the effects exercised by the expected fiscal variables and macroeconomic fundamentals have already been discounted, to a large extent, in past values of spreads. Also these findings underline the necessity to always include a lagged spread, in order to avoid having spurious estimated coefficients that would inflate the significance of the effects exercised by the fiscal fundamentals. From an empirical finance point of view they just indicate that market participants have already discounted various possible future outcomes in the pricing process of sovereign bonds.

Still, there is reason to suspect that the heterogeneity of spreads is not adequately treated by some time-invariant fixed-effects components. In particular, the fixed-effects component inherently constrains the country-specific effects that it aims to capture, to be invariant through time or have any other deterministic information, apart from that of being specific to each section (i.e. sovereign). For example, the case in which sovereigns may be grouped, say according to the perceived level of their risk, while also possibly migrating from across groups cannot be captured by fixed-effects terms. So, we now turn to the specifications that aim to capture cross-section variations of the effects of spreads' determinants, based on measures of sovereign riskiness. Both the ratings- and the markets-based setups, that we use for this purpose, follow the specification (9) of Table 2.

4. Ratings-based specification

4.1 Estimation of the ratings-based specification

First, we examine whether there is heterogeneity of the effects exercised by the spreads' determinants and if it is associated with the rating of each sovereign; so, in the following lines we present the estimation of the setup shown in equation (4). The usefulness of estimating the effects on spreads in interaction with ratings, is that it enables to map the effects exercised by the determinants according to ratings. If rating-specific effects are significant, then this lifts some of the heterogeneity underlying the spreads' panel data, whereas if they are not, the effects of spreads' determinants will be the same across rating categories, indicating homogeneity. Table (4) reports the results:

[Insert Table 4, around here]

In Table 4, we again follow a stepwise approach; this time, based on specification (9) of Table 2, we insert the variables in interaction with the ratings variable one at a time in specifications (1) to (8), while all variables, rating-specific or across-the-board, are included in specification (9). The estimation method (fixed-effects FGLS) and cross-section weighting remain unchanged, so that there is direct comparability of the results between this setup and the one displayed in Table 2.

Interestingly, the results in Table 4 indicate that only the private debt-to-GDP and inflation exercise homogeneous effects on sovereign spreads. The negative sign on the private debt-to-GDP indicates that spreads are reduced with financial development. However, this is not related to the rating of the sovereigns; riskier and safer sovereign spreads are affected similarly by higher financial activity. Also, inflation raises spreads regardless of the rating of the sovereign; sovereign bonds are required to pay a premium to investors for higher inflation rates, across rating categories.

Economic activity, on the other hand, seems to affect spreads in a rating-specific manner; while the across-the-board coefficient carries a positive sign, i.e. spreads rise with higher real GDP growth, its effects are diminished according to the value of the ratings variable. Note that lower ratings are associated to higher numerical values, by construction. As a result, this finding indicates that spreads of low-rated sovereigns rise by less with stronger real GDP growth rates, or even fall if the rating of the sovereign is low enough. Similarly, the across-the-board effects exercised by consumer confidence on spreads follow a similar pattern; possibly for the same reasons, as well, since consumer confidence is usually seen as a 'soft indicator' of near-term economic activity, e.g. in DSGE models (see, e.g., Bańbura and Rünstler, 2011). In particular, these findings seem to point out that stronger economic activity in highly-rated economies gives room for pricing-in higher future short-term rates, while in low-rated sovereigns, i.e. ones viewed as more unlikely to repay their debts in full, the focus is on the generation of revenues. Therefore, a measurement indicating stronger economic activity helps to smooth investor worries and, consequently, risk premia in sovereign bonds.

Equally interesting are the findings with regards to the effects exercised by volatility variables. Effects exercised by idiosyncratic volatility on spreads are also found to be both asymmetrical and non-linear across rating categories. Specifically, idiosyncratic volatility is found to result to lower spreads, for highly rated sovereigns. This finding possibly constitutes evidence for flights-to-safety from stocks to low-risk sovereign bonds. On the other hand, the structure of the effects reverses for lower rated sovereigns, for which a rise in the idiosyncratic component of the domestic stock market volatility is associated with more acute investor concerns which is reflected in rises of sovereign spreads. Such non-linear effects may explain both the flight towards safer sovereign bonds and the episodes of idiosyncratic tensions, such as the ones that led euro-area sovereign spreads higher, as a result of investor beliefs (see, Chiarella *et al.* 2015) and self-fulfilling expectations (de Grauwe and Ji, 2013).

The VIX variable is also found to have asymmetrical effects across ratings; that is a rise of the US stock market volatility, which is largely associated to global volatility, exercises upwards (downward) pressure on sovereign spreads (prices). So, this finding sits well with previous literature (see, among others, Arghyrou and Kontonikas 2012, Ang and Longstaff 2013 and Afonso *et al*. 2015), while we also report that the effect of global volatility is stronger on lower-rated sovereign bonds.

Finally, the effects exercised by the fiscal fundamental variables are found to be more prone to including interactions with ratings in the same setup. In particular, the across-the-board coefficient of both the expected debt-to-GDP and the expected primary balance-to-GDP are found to be non-significant. On the other hand, while the interaction of the debt-to-GDP variable with ratings is also non-significant, the interaction of the primary balance-to-GDP with ratings indicates that it has significant effects on spreads, which become even more pronounced for lower rating categories. As a result, policy-wise, our findings confirm the policy intuition that fiscal consolidation, with the aim to reduce fiscal deficits, helps indeed to lower sovereign bond premia. On the other hand, the dispersion of the panel data that we use is the main reason for which the debt-to-GDP is not found to have significant effects on spreads; for instance in case we remove cross-section weights the interaction of this variable with ratings becomes significant, with a positive sign; however, estimating our setup with cross-section weights is crucial especially due to the heterogeneity of our panel setup.

4.2 Contributions of determinants to spreads' movements per rating category

What do these results imply about the impact on spreads that a change in each of their determinants would have? To answer the question of economic importance of the results from the estimation of the setup, we have calculated the impact on spreads that a rise of the explanatory variables would have. These results are illustrated in Figure 1, below:

[Insert Figure 1, around here]

Figure 1, describes the various parameters that affect sovereign spreads, as estimated in specification 9 of Table 4. These results are the quantification of the impact of a positive shock, equal to one standard deviation, in each of the determinants, by aggregating the across-the-board and the rating-specific effect. Thus, if we take into account that the ratings variable varies from 1 (for triple-A rated sovereigns) to 16 (for sovereigns rated below single-B) the effect that a given across-the-board coefficient will give, may be reversed if the ratings-based coefficient (a) carries an opposite sign and (b) has an absolute value sufficiently larger than the value of the across-the-board coefficient, so that its product with the value of the rating variable for B-rated sovereign results to a reversal of the effects compared to high-rated sovereign bonds.

This is the case, for example, of the idiosyncratic volatility; as the across-the-board coefficient is -0.232 and the coefficient of the idiosyncratic volatility, in interaction with ratings, is 0.029, the negative effect is reversed for sovereigns rated lowed than BBB+. So, while we find that a hike in idiosyncratic volatility, equal to one standard deviation, lowers triple-A sovereign bond spreads by around 30 basis points (bps), a rise in idiosyncratic volatility in stock markets of sovereigns rated below single-B results to a rise of their spreads by 30 (for B+ bonds) to 35 bps (for B- bonds). These findings indicate that (a) the impact of idiosyncratic volatility is economically, apart from statistically, significant for sovereign spreads and (b) a rise in idiosyncratic volatility results to lower spreads for highly rated sovereigns and higher spreads for low-rated ones. Coupled with the high persistence, that characterizes sovereign spreads, a hypothetical rise of idiosyncratic volatility would not only result to a sizeable rise of low-rated sovereign spreads but it would also be persistent.

Similarly, the effect of a rise in consumer confidence is non-linear, as the sign of the effects changes across rating categories. In particular, while a rise equal to one standard deviation in consumer confidence leads to a near 10 bps rise of triple-A sovereign bonds and to a 5 and 3 bps rise of bonds rated at AA+ and AA, it results to a sizeable reduction of the spreads of low-rated sovereigns. For example, the effect of consumer confidence turns negative for sovereigns rated AA- and below and it is magnified for low-rated sovereigns, as in the B+ to B- categories where it results to a fall of the spreads by 35 to 42 bps. This finding seems to confirm the intuition behind the pricing of sovereign fundamentals under the prism of the riskiness of the sovereign; a rise in consumer confidence is found to have positive effects for highly-rated, possibly pointing towards higher expectations for interest rates' rises, while it has a reduction effect on spreads of low-rated sovereigns, possibly relating to expectations for stronger revenue generation due to higher growth rates.

Apart from the change in sign, that produces non-linearities in the effects across rating categories, asymmetrical effects exist as well. For example, the global volatility episodes, captured by VIX, exercise effects that are also dependent on the riskiness of the sovereign; riskier sovereign bonds are found to be more sensitive to global volatility. In this regard, we find that the effect of a one standard deviation rise of the VIX index (which is equal to 6 bps) results to a rise in spreads from 13 to 19 bps for sovereign bonds rated in the range of triple-A to AA-, from 22 to 34 for bonds rated from A+ to BBB- and 37 to 49 for BB+ to -B. So, this finding may explain the disproportionate effects that the volatility episodes, after the eruption of the sovereign debt crisis in 2010, have had to lower-rated sovereign bonds, compared to higher-rated ones.

Additionally, the expected primary surplus lowers spreads of low-rated sovereigns more than those of highly rated ones. In particular, spreads on sovereign bonds rated between B+ and B- are reduced by 26 to 30 bps, by a primary surplus equal to 2%, while this effect ranges from 2 bps, for triple-A bonds, to 11 bps for single-A bonds (spreads on bonds rated from BBB+ to BB- would be reduced by 15 to 25 bps). On the other hand, it is easily understood, by comparing across the effects exercised by different spreads' determinants, that fiscal consolidation may not counterbalance the effects of volatility shocks; moreover, a 2% primary surplus is required to provide only partial relief from a hypothetical, but very frequent, 6-point rise in global volatility.

Finally, inflation and financial development are found to have effects that are significant across-the-board. A one standard deviation rise in the inflation rate, i.e. of about 1.5%, is found to add 16 bps across rating categories. Also, a rise of one standard deviation of the private debt-to-GDP, which is equal to 2.9%, is found to lower spreads by 8 bps, again across rating categories. So, this finding suggests that financial development, as captured by the activity of the private sector in capital markets or the volumes of bank lending, reduces moderately the spreads of sovereigns across rating categories; however, if we take into account the difference in the level of the yields of low-rated sovereign bonds vis-à-vis highly rated ones, it is easily understood that this reduction is near to negligible for low-rated sovereign bonds.

All in all, the analysis of the effects exercised on spreads, by determinants related to fiscal and macroeconomic fundamentals, as well as idiosyncratic and global volatility, indicate that while fiscal consolidation indeed leads the yields of low-rated sovereign bonds to lower levels, the effects of volatility episodes, both due to country-specific investor concerns and to global risk aversion conditions, have offsetting effects and may easily reverse the benefits from prudent economic policies. On the other hand, highly-rated sovereign bonds are net beneficiaries of idiosyncratic investor concerns; thus, it is indicated that in periods of increased idiosyncratic volatility a flight towards safer assets lowers the spreads of highly rated sovereign bonds. Interestingly, the findings reported in this section indicate that policies directed towards improving confidence to the prospects of the economy, coupled with policies that boost real growth rates, are better candidates to address the effects of the inherently higher effects of risk aversion on lower-rated sovereign bonds.

5. Market-based specification

5.1 Determinants of sovereign spreads of low- median- and high-yielders

We now turn to the inherent classification of the riskiness of any given sovereign according to market practice. The intuition behind this specification, which follows equation (5), is that sovereign bonds are not priced in an objective fashion, but rather relative to other sovereign bonds. Thus, there exists a market-based classification of sovereign bonds from the low- to the high-risky ones, as sovereign bonds considered of lower risk are expected to systematically yield a lower compensation than those considered riskier. If this is true then we can gauge market-based classifications of sovereign bonds, to low-, median- and high-risk ones, by the distribution of sovereign risk premia; the lower quartile (25%) of spreads is expected to reflect effects on spreads of bonds systematically considered of lower risk than those that will be associated to the higher quartile (75%). Table 5, below, reports the results of the quantile regression.

[Insert Table 5, around here]

First, we should note that the quantile regressions are estimated based on a similar setup to previous specifications, only this time the classification of the risk-specific effects exercised by each of the determinants of sovereign spreads, is captured by the different quantiles. Second, we observe that results reported in Table 5 by and large confirm the association of heterogeneity in sovereign spreads to the classification of sovereign riskiness. This time, apart from the differences in the effects of the determinants on spreads belonging to different quantiles, there is a considerably larger degree of persistence for spreads belonging to the high-yielders group (75% percentile), compared to lower quantiles (50% and 25%). As a result, this finding highlights that the econometric specifications should also be based on the particularities of the series under examination.

Next, we find that the quantile regressions indicate the existence of high heterogeneity of the effects exercised by both idiosyncratic and global volatility; additionally, the structure of the effects exercised by these two variables is very similar to the one taken with the estimation of the ratings-based specification. In particular, a non-linearity, across low- and high-risk quantiles, is again found to characterize the relationship of spreads with idiosyncratic volatility; while idiosyncratic volatility is found to lead to significant rises in the spreads of sovereign high-yielders, it does not affect, if it doesn't reduce, spreads of low-yielders. Also, the positive effects exercised by global volatility on high-yielding sovereigns is more than double, in terms of magnitude, the effects exercised on low-yielders and around 75% higher than the effects exercised on the median quantile. So, this provides evidence that the effects from episodes of spikes in global volatility, during the Global Crisis, have affected sovereign bonds considered riskier relatively more than the ones that belong to lower-yielding classes.

Additionally, a rise in the real GDP growth is found to result to stronger rises of the spreads of sovereign bonds belonging to the low-yielders quantile (i.e. 25%), while also a rise in inflation is found to result to stronger rises to the low- and median-quantiles than on the high-yielders quantile. Similarly to volatility, these results also sit well with the results reported earlier under the ratings-based specification. As a result, the interpretation of these results is similar; stronger economic activity and inflation may lead investors to price in higher future interest rates and this result is particularly stronger for sovereigns considered of lower risk. All in all these results indicate that risk-based classifications of spreads are critical to revealing the true information that lies behind their movements; movements of spreads considered riskier may reflect different factors or different sensitivities to the same factors than those of sovereign considered of lower risk. On the other hand, the results reported in Table 5 do not confirm previous evidence on primary fiscal balance, consumer confidence and financial development. In particular, it is indicated that the primary balance is only significant for the low-yielders quantile, as is private-debt-to-GDP, while consumer confidence is not found to be significant across the different quantiles.

To this end, there should be a note of caution when comparing the results obtained by the quantile regression estimation with those obtained by the estimating the ratings-based specification; while in the latter the classification of a sovereign's riskiness changes in each point in time, by the sovereign's migration to higher or lower rating categories, and, thus, the information provided by ratings is directly associated to the sovereign's riskiness, when using quantiles of sovereigns, such an automatic distinction across time, according to the dynamics of each sovereign, is not provided by static estimations. For example classifying the spreads to 25%, 50% and 75% percentiles according to their levels, may classify a given sovereign to the low-yielding category at one point in time, while the same sovereign may belong to a higher category, in another period, not because of higher risk but because of different market conditions (e.g. periods of accommodative monetary policies and low interest rates vis-à-vis periods of higher interest rates). Thus, there may be heterogeneity within the quantiles, as the groups of sovereigns whose spreads are classified as belonging to a given quantile each time may not be of similar riskiness. In order to treat this kind of heterogeneity we move to re-estimating quantile regressions by using rolling estimation techniques.

5.2 Estimation of rolling quantile regressions

In order to estimate the quantile-specific relationships, we expand the data sample, by also including observations from the period before the eruption of the Global Crisis; thus while the variables and their construction remains the same, as described in section 3, the sample begins from 2005Q1 and ends in 2017Q1. We have expanded the sample in order to (a) obtain estimation of the coefficients of equation (5), as they would have been estimated by an econometrician in the beginning of our sample and (b) have sufficient observations (and degrees of freedom) in order to infer results with sufficient certainty. As for (b), it should be noted that as one of the main purposes of the present paper is to reflect investors' point of view, the piecewise approach to our sample enables the classification of sovereigns to low-, median- and high-yielders for each point in time, thus diminishing any time-related shifts that could make difficult the clarification of the information of these groups.

The window we use for estimating the coefficients of the setup contains 16 time observations and 30 sections (total 320 observations) while the step is equal to one quarter; again we use data in quarterly frequency. For example, the first regression reports results from a fixed-effects panel data quantile regression for the period from

2005Q1 to 2009Q1, the second is from 2005Q2 to 2009Q2 and moving onwards, the last estimation is based on the sample period from 2014Q1 to 2017Q1. This way we may associate the low-, median- and high-yielders groups, at each point in time, with the cross-section comparison of sovereign riskiness, while the comparison of the coefficients of the spreads' determinants, over time may reflect changes in the spreads' sensitivities to their deterministic factors, both across different classes of riskiness and across different conditions prevailing in markets at each point in time. Figure 2, below, illustrates the level of the coefficients that have been estimated by using rolling quantile regressions:

[Insert Figure 2, around here]

The time-varying estimation of the specification under equation (5) reveals that spreads vary both across time and across the different quantiles. The latter observation, i.e. the existence of a time-dependent structure across quantiles, may be an indication that the information behind the quantile formation is clarified when we diminish the time dimension so as to rely mainly on the comparison across the level of spreads.

Under the time-varying coefficients specification there is evidence that indeed the 75% quantile reflects effects on riskier sovereign bonds; for example the coefficients of this quantile indicate a greater sensitivity to determinants positively related to sovereign or broader definitions of risk. This is the case, for example, of the idiosyncratic volatility, the VIX and the expected debt-to-GDP (albeit it remains statistically not significant). Also, note that while there seems to be a rise in the effects exercised by volatility, global and idiosyncratic, after the Global Crisis erupted, this does not affect the cross-section structure of the volatility effects; in every point-in-time included in our sample, the sensitivity of the high-yielders (75% percentile) is positive and higher than that of the low- and median-yielder sovereigns. Furthermore, the finding that idiosyncratic volatility has triggered a flight-to-safety for bonds considered low-risk, is confirmed, for almost the entire sample (this observation is reversed towards the end of the sample).

Interestingly, the effects exercised by global volatility have a more active time-varying component; they are shown to have peaked just after the Greek debt re-structuring of 2012, and decreased with the implementation of ECB's asset purchase programs in 2015. As a result, this finding may be indicating that the central banks' QE policies have had significant effects across the board of sovereign bonds, thus not being restricted only to bonds included in the various purchase programs; of course this examination is outside the scope of the present paper and interested readers should refer to the developing literature (e.g. Neely 2015; Rogers *et al.* 2016; Belke *et al*. 2017). Thus, these findings confirm volatility variables' effects are more pronounced for high-yielding sovereign bonds, which may also be considered riskier, in relative terms, to the ones belonging to the other two quantile groups.

Also, the time-varying quantile regressions indicate that there is, indeed, a considerable degree of heterogeneity in the effects exercised by the rest of the variables, which has not been reflected by the static quantile regressions. For example the effects stemming from consumer confidence are found to be negative for the 75% group, in most time periods, while they are positive for lower quantiles; this finding, apart from confirming the results from the ratings-specific estimation, confirms also the intuition that investors' focus is different for sovereigns perceived to bear different levels of risk. Riskier sovereign bonds may even benefit (in times when the coefficient is significant) from a rise in consumer confidence, while the same event (rise in consumer confidence) results to expectations for higher short-term rates, when it comes to sovereign bonds of lower risk. Similarly, the effects of inflation and real GDP growth seem to point towards the same direction as those of consumer confidence; the effects of a rise of inflation or the real growth rate are considerably stronger for the 25% group than they are or the 75% group. Also, note that these results are consistent with the time variation of these coefficients; in particular all three macroeconomic variables are shown to have considerable variation, across time, with regard to the effects they exercise on spreads, the cross-quantile structure remains.

The only variable that is found to have an unclear structure with regards to the effects exercised in different quantiles is the private debt-to-GDP. Figure 2 shows that the effects that stem from this variable do not have a specific structure across the groups of sovereigns captured by the different quantiles; still, it is interesting to note that these effects have become positive from negative gradually since 2014. This finding suggests that there may be a shift in how investors perceive the level of the private debt-to-GDP since 2014; while it may have been an indication of financial development that led sovereign spreads lower, from 2014 onwards it might be considered as an indication of financial vulnerability that drives spreads higher.

All in all the market-based classification of spreads to low-, median and high-yielders provides evidence that confirm the intuition for a risk-based pricing of sovereign bonds. Spreads' sensitivity on fiscal and macro fundamentals and, even more, on global and idiosyncratic volatility is found to depend on a cross-section comparison that classifies each sovereign to groups according to the level of its risk premia. Moreover, interesting results are provided by the time-varying coefficients framework; global volatility's effects on sovereign spreads are found to have peaked after the sovereign debt crisis in the euro area, while the effects of idiosyncratic volatility are on the rise. In any case high-yielders are particularly more affected by both global and idiosyncratic volatility, in any given period.

6. Conclusion

We have examined whether the relationship between sovereign spreads and their determinants depends on variables that reflect the views of external agencies and of investors on sovereign riskiness. For this purpose we use ratings and quantile techniques for classifying sovereign states to risk groups at each point in time. Both ratings and quantiles of the level of the spread, are used in order to gauge investors' views on sovereign riskiness. Thus, we allow investors to price-in such variables as global and idiosyncratic volatility, expected fiscal primary balance, expected debt, real growth, inflation, consumer confidence and financial development, based on their views for the riskiness of each sovereign.

We find that indeed there is a wide asymmetry in the effects exercised by sovereign spreads' determinants, which is related to the riskiness of the sovereign. In this regard, the focus of investors seems to be different for different levels of sovereign riskiness; for sovereign states considered safer, spreads are found to be more sensitive to the prospects of higher growth rates and inflation, while spreads of low-rated states are found to reflect investor concerns, captured by idiosyncratic volatility and global volatility, while stronger economic activity and primary surpluses lower spreads.

More importantly, these results underline the importance, both for the econometrician and the policy marker, to appropriately tackle the high degree of heterogeneity, in panel data analyses of sovereign bond spreads. If not, it is highly likely that a wrong reading of the movements of spreads, will lead to the wrong diagnosis and treatment, in the case of a sovereign debt crisis. For example, it is shown that while fiscal consolidation has been a necessary condition for addressing the rise in the cost of borrowing by sovereigns, in those cases that fiscal imbalances produced investor uncertainty, it has not been a sufficient one, in the cases where fiscal consolidation was accompanied by inappropriate communication schemes. So, fiscal consolidation should not be the only focus of policies aiming to ease financing conditions faced by sovereigns with problematic market access; unnecessary statements that could be taken as portents of higher sovereign risk premia should also be avoided.

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Table 1: Spreads specification without lagged dependent									
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Intercept	1.191* (0.484)	-1.049 (1.916)	0.584 (0.435)	1.542** (0.473)	1.550** (0.524)	2.395** (0.569)	0.417 (0.600)	1.514** (0.149)	-5.417** (1.477)
$E_t(Primary_{t+4})$	-0.194** (0.035)								-0.051 (0.027)
$E_t(Debt_{t+4})$		0.036 (0.028)							0.081** (0.019)
Inflation			0.456** (0.065)						0.241** (0.038)
Real GDP growth				-0.316** (0.053)					-0.101** (0.021)
Consumer Confidence					-0.036** (0.014)				-0.002 (0.008)
Private debt-to-gdp						-0.151** (0.027)			-0.029* (0.014)
VIX							0.058** (0.009)		0.028** (0.006)
Idiosyncratic Volatility								-0.163** (0.035)	-0.297** (0.060)
Control	Cross-section RE	Cross-section RE	Cross-section RE	Cross-section RE	Cross-section RE	Cross-section RE	Cross-section RE	Period RE	Cross-section FE
Obs	852	851	956	956	956	956	956	956	839
Adj. R-squared	0.056	0.016	0.127	0.199	0.026	0.057	0.051	0.135	0.895
D-W	0.417	0.390	0.417	0.421	0.372	0.389	0.394	0.383	0.586
Period RE test (Hausman)	0.001 [0.983]	0.001 [0.998]	0.006 [0.937]	0.114 [0.736]	0.447 [0.504]	-	-	2.711 [0.099]	65.408 [0.000]
Cross-section RE test (Hausman)	0.209 [0.647]	3.521 [0.061]	0.875 [0.349]	0.097 [0.755]	0.001 [0.985]	0.001 [0.994]	0.005 [0.942]	-	65.636 [0.000]

Note: Panel FGLS estimates with cross-section weights, for the period 2009Q1-2017Q1, for 30 sovereigns. Asterisks * and ** denote 5% and 1% significance, while figures in parentheses are standard errors and in brackets are p-values; the null hypothesis of the Hausman test is the RE specification.

Table 2: Spreads specification with lagged dependent

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intercept	0.099** (0.027)	0.169 (0.112)	-0.006 (0.026)	0.106** (0.028)	0.086** (0.027)	0.290** (0.038)	-0.247** (0.034)	0.101** (0.025)	-1.607** (0.434)
Spreads(-1)	0.864** (0.017)	0.886** (0.018)	0.874** (0.015)	0.905** (0.018)	0.918** (0.018)	0.884** (0.016)	0.845** (0.015)	0.908** (0.016)	0.760* (0.019)
$E_t(Primary_{t+4})$	-0.039** (0.007)								-0.025** (0.009)
$E_t(Debt_{t+4})$		-8.36×10^{-4} (4.49×10^{-4})							0.016** (0.006)
Inflation			0.076** (0.011)						0.132** (0.012)
Real GDP growth				-0.008 (0.006)					0.037** (0.008)
Consumer Confidence					-0.003* (0.001)				0.003* (0.001)
Private debt-to-gdp						-0.027** (0.004)			-0.019* (0.008)
VIX							0.022** (0.002)		0.024** (0.002)
Idiosyncratic Volatility								-0.079** (0.021)	-0.135** (0.039)
Cross-section FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	849	848	953	953	953	953	953	953	836
Adj. R-squared	0.943	0.943	0.946	0.944	0.942	0.943	0.948	0.944	0.954
Durbin-h	1.999	2.013	2.001	1.953	1.945	1.959	1.944	1.943	2.095

Note: Panel FGLS estimates with fixed effects and cross-section weights, for the period 2009Q1-2017Q1, for 30 sovereigns. Numbers in parentheses refer to standard errors. Asterisks * and ** denote 5% and 1% significance.

Table 3: Correlation of the residuals from specification 10 with the regressors

$E_t(Primary_{t+4})$	-3.69% [0.228]
$E_t(Debt_{t+4})$	-0.4% [0.906]
Inflation	0.99% [0.776]
Real GDP growth	-5.05% [0.146]
Consumer Confidence	-8.99% [0.099]
Private debt-to-gdp	-1.62% [0.641]
VIX	3.8% [0.273]
Idiosyncratic Volatility	2.61% [0.451]

Note: Figures in brackets are p-values.

Table 4: System-wide effects and interactions with ratings									
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Intercept	-1.129** (0.434)	-0.881* (0.447)	-1.466** (0.430)	-1.799** (0.427)	-1.008* (0.423)	-1.309** (0.446)	-1.583** (0.442)	-1.308** (0.436)	-0.929* (0.442)
Spreads(-1)	0.692** (0.029)	0.658** (0.029)	0.702** (0.029)	0.699** (0.029)	0.667** (0.028)	0.668** (0.029)	0.699** (0.029)	0.659** (0.029)	0.723** (0.029)
$E_t(Primary_{t+4})$	0.020 (0.011)	-0.037** (0.010)	-0.019* (0.009)	-0.020* (0.009)	-0.015 (0.009)	-0.031** (0.009)	-0.046** (0.009)	-0.023* (0.009)	-0.005 (0.013)
$E_t(Debt_{t+4})$	0.006 (0.006)	0.004 (0.006)	0.014* (0.005)	0.019** (0.005)	0.009 (0.005)	0.011 (0.006)	0.013* (0.006)	0.011* (0.005)	0.007 (0.006)
Inflation	0.128** (0.012)	0.153** (0.012)	0.088** (0.014)	0.120** (0.012)	0.138** (0.012)	0.143** (0.012)	0.123** (0.012)	0.148** (0.012)	0.109** (0.016)
Real GDP growth	0.034** (0.008)	0.025** (0.008)	0.038** (0.008)	0.062** (0.010)	0.033** (0.008)	0.029** (0.008)	0.029** (0.008)	0.030** (0.008)	0.056** (0.011)
Consumer Confidence	0.005* (0.002)	0.001 (0.002)	0.004* (0.002)	0.005* (0.002)	0.016** (0.003)	0.002 (0.002)	0.002 (0.002)	0.003 (0.002)	0.015** (0.003)
Private debt-to-gdp	-0.021** (0.008)	-0.015* (0.007)	-0.024** (0.008)	-0.024** (0.008)	-0.032** (0.008)	-0.025* (0.010)	-0.018* (0.008)	-0.024** (0.008)	-0.027* (0.011)
VIX	0.026** (0.002)	0.024** (0.002)	0.024** (0.002)	0.025** (0.002)	0.026** (0.002)	0.024** (0.002)	0.011** (0.003)	0.025** (0.002)	0.017** (0.003)
Idiosyncratic Volatility	-0.179** (0.039)	-0.172** (0.039)	-0.171** (0.039)	-0.181** (0.039)	-0.156** (0.038)	-0.160** (0.039)	-0.156** (0.039)	-0.201** (0.054)	-0.232** (0.055)
Spreads(-1) *ratings	0.001 (0.003)	0.010** (0.003)	0.005 (0.004)	0.005 (0.004)	0.008* (0.003)	0.011** (0.003)	0.005 (0.003)	0.012** (0.003)	-0.004 (0.004)
$E_t(Primary_{t+4})$ *ratings	-0.022** (0.003)								-0.009* (0.004)
$E_t(Debt_{t+4})$* ratings		$3.36x10^{-4}$ ($2.05x10^{-4}$)							$-4.67 x10^{-4}$ ($2.68x10^{-4}$)
Inflation *ratings			0.015** (0.004)						0.002 (0.004)
Real GDP growth *ratings				-0.009** (0.002)					-0.007* (0.003)
Consumer Confidence *ratings					-0.005** (0.001)				-0.004** ($8.48x10^{-4}$)
Private debt-to-gdp *ratings						0.003 (0.003)			0.002 (0.004)
VIX*ratings							0.005** (0.001)		0.004** (0.001)
Idiosyncratic Volatility *ratings								0.013* (0.006)	0.029* (0.013)
Cross section FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	836	836	836	836	836	836	836	836	836
Adj. R-squared	0.958	0.959	0.956	0.958	0.958	0.957	0.956	0.957	0.958
Durbin-h	2.108	2.097	2.073	2.066	2.140	2.096	2.101	2.111	2.189

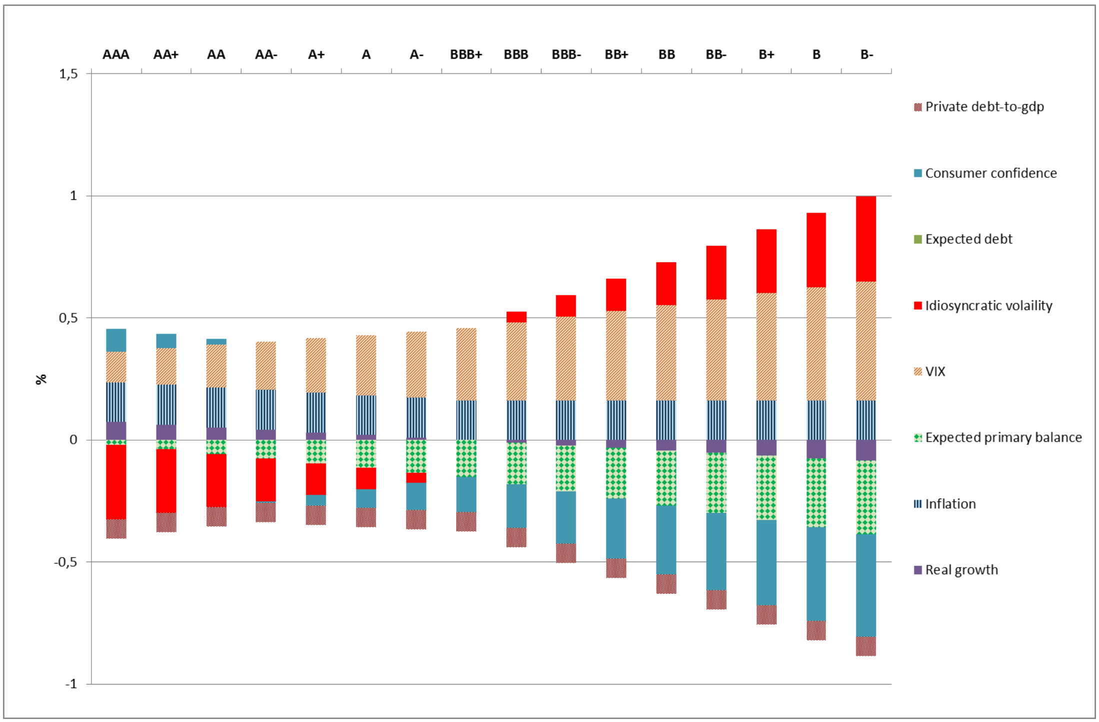
Note: Panel FGLS estimates with fixed effects and cross-section weights, for the period 2009Q1-2017Q1, for 30 sovereigns. Numbers in parentheses refer to standard errors. Asterisks * and ** denote 5% and 1% significance.

Table 5: Market-based classification of sovereign bonds to low, median- and high-yielders

	Low yielders (25% percentile)	**Median (50% percentile)**	**High yielders (75% percentile)**
Intercept	-0.539** (0.103)	-0.640** (0.094)	-0.717** (0.099)
Spreads(-1)	0.838** (0.015)	0.915** (0.026)	1.011** (0.028)
$E_t(Primary_{t+4})$	-0.014** (0.005)	-0.008 (0.005)	$-2.95x10^{-4}$ (0.004)
$E_t(Debt_{t+4})$	-0.001 (0.001)	$-3.12x10^{-4}$ (0.001)	$8.24x10^{-4}$ (0.001)
Inflation	0.117** (0.017)	0.114** (0.020)	0.085** (0.021)
Real GDP growth	0.032** (0.008)	0.034** (0.013)	0.029* (0.013)
Consumer confidence	$4.28x10^{-4}$ (0.003)	0.004 (0.003)	-0.003 (0.004)
Private debt-to-gdp	-0.035** (0.017)	-0.011 (0.013)	-0.0002 (0.013)
VIX	0.016** (0.003)	0.021** (0.003)	0.035** (0.003)
Idiosyncratic Volatility	-0.088 (0.058)	-0.002 (0.049)	0.131** (0.061)
Cross-section FE	Yes	Yes	Yes
Obs.	836	836	836
Adj. R-squared	0.725	0.776	0.819

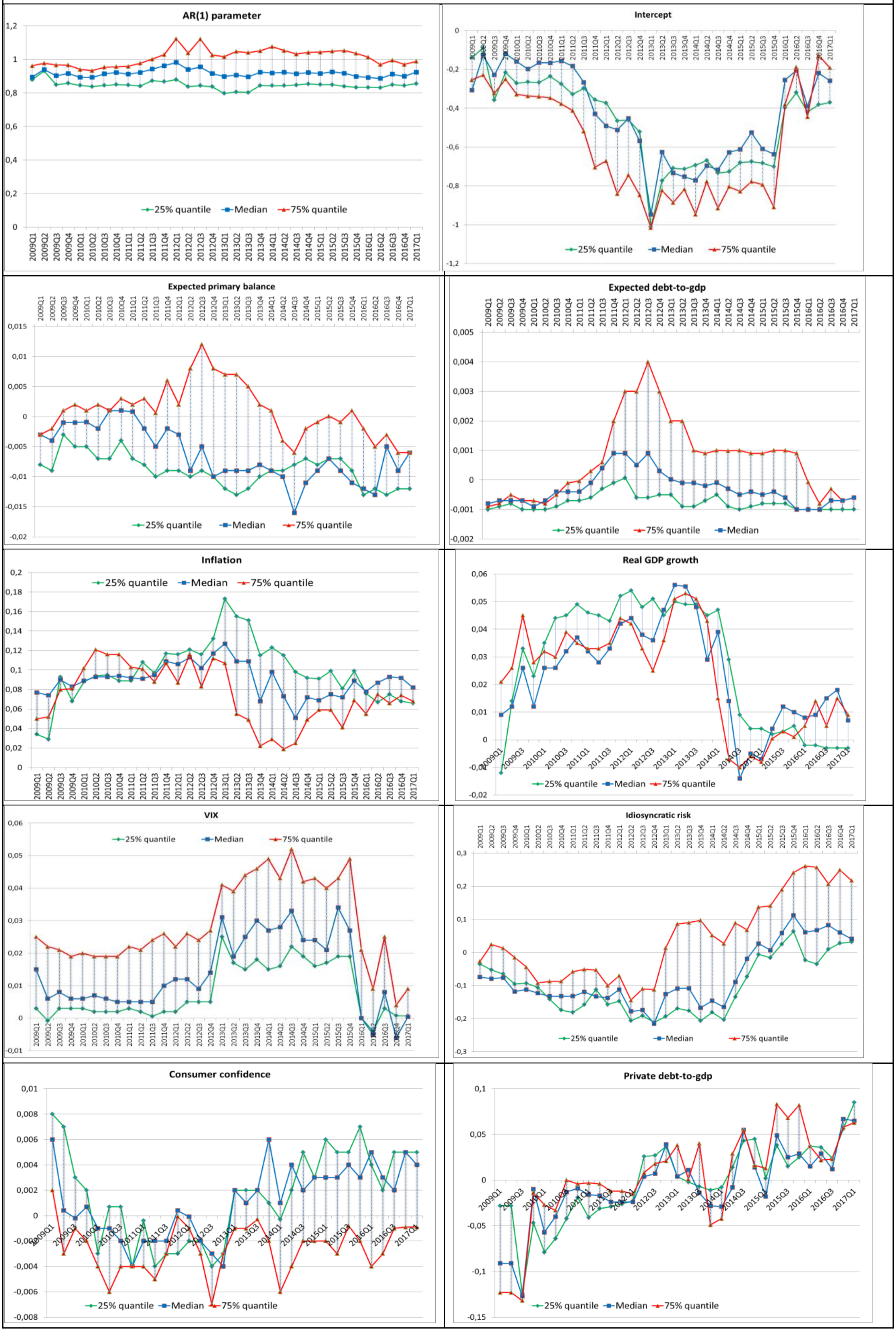
Note: Panel regression with fixed effects, for the period 2009Q1-2017Q1, for 30 sovereigns. Numbers in parentheses refer to standard errors. Asterisks * and ** denote 5% and 1% significance.

Figure 1: Contribution on spreads' movements



Note: The effects on spreads, depicted in Figure 1, are estimated under model9, in Table 4 and reflect the contribution of a rise equal to one standard deviation of the primary balance, consumer confidence, debt-to-GDP, real GDP growth, inflation, VIX and idiosyncratic volatility. Each variable reflects the aggregation of its across-the-board effects with the effects taken by these variables' interactions with ratings; only variables with significant coefficients are taken into account (i.e. the expected debt is excluded).

Figure 2: Time-varying and interquartile dispersion of the effects on spreads (FE estimation)



Note: The Figure illustrates the estimated coefficient for each determinant of spreads, according to equation (5). The size of the rolling windows is 16 quarters (4 years) and 30 sections, while a one quarter step is used for rolling the window, by removing one quarter from the beginning of each sample-window and adding a quarter at its end. The estimation also includes a fixed-effects constant.

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