A Measure of Redenomination Risk

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Abstract

Euro redenomination risk is the risk that a euro asset will be redenominated into a devalued legacy currency. We propose a time-varying, country-specific market perception of intra-euro area redenomination risk measure, defined as the quanto CDS of a member country relative to the quanto CDS of a benchmark member country. Focusing on Italy, Spain and France and using Germany as benchmark, we show that the redenomination risk shocks, defined as the unexplained component of the market perception of redenomination risk orthogonal to exchange rate, global, regional and liquidity risks, significantly affect sovereign yield spreads, with Italy and Spain being the countries most adversely affected, followed by France. Finally, foreign redenomination risk shocks spillover and above local redenomination risk shocks, corroborating the fact that this risk is systemic.

Keywords: Redenomination risk, sovereign credit spreads, systemic risk, euro.

JEL classification: C32, F36, G12, G15

Non-Technical Executive Summary

On 24 July 2012, the sovereign yield spreads of Italian and Spanish sovereign bonds - as measured by sovereign yield relative to the overnight index swap (OIS) rate - a risk-free rate proxy - reached record highs. The same spreads had been about 200 basis points lower only few months earlier in March 2012. On 26 July 2012, Mario Draghi, President of the European Central Bank (ECB), in a speech at an investment conference in London said that a "convertibility risk" explained this phenomenon, preventing the smooth functioning of the ECB's monetary policy across national borders inside the euro area and acknowledging that financial markets were pricing the risk of break-up. Therefore, he pledged to do "whatever it takes" to protect the euro area from collapse.

Can we measure currency redenomination risk, that is the compensation demanded by market participants for the risk that a euro asset is being redenominated into a devalued legacy currency?

In this paper, we employ US dollar and euro denominated CDS spreads, which are typically very liquid. Specifically, we use quanto CDS, namely the difference between the CDS quotes in US dollar and euros. The differential between US dollar and euro denominated CDS spreads is expected to be positive for Italian and Spanish sovereign contracts in the course of the first half of 2012, because getting paid off in euro-denominated credit event protection seemed increasingly less attractive. Should for example Italy declare a credit event, euro 10 million worth of protection on an Italian credit event would be worth much less after the event as a consequence of the devaluation of the euro or, if the euro would no longer exist, as a result of the devaluation of the "new" currency. This led to a major drop in demand for EUR-denominated Italian (and other European) protection.

A credit event does not automatically imply the break-up of the euro area, as in the Greek case in March 2012. Therefore, the quanto CDS, which measures the risk associated with the depreciation against the US dollar and not the intra-euro area currency risk, is not a sufficient measure. We argue that the difference between the quanto CDS for Italy/Spain and that for Germany - the benchmark euro area sovereign debt market - is the key measure of redenomination risk associated with the break-up of the euro area as perceived by the market. The use of countries' quanto CDS relative to Germany rests on the idea that such spread would be close to zero if market perceptions of break-up risks of the euro area were minor. Moreover, such measure is less prone to issues of whether the liquidity of sovereign CDS contracts is the

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same across the currency spectrum, because it is defined as a spread across countries' quanto CDS. Finally, the value of such measure is that it is directly observable, as it is based on traded contracts and, therefore, it provides the market perception of redenomination risk.

Focusing on Italy, Spain and France and using Germany as benchmark, the proposed measure of currency redenomination risk as perceived by the market reached a peak for both Italy and Spain just before the speech by President Draghi on 26 July 2012. Thereafter, it declined and since the end of 2012 it has remained contained. We then show that the redenomination risk shocks, defined as the unexplained component of the market perception of redenomination risk orthogonal to global, regional and domestic liquidity risks, significantly affect sovereign yield spreads, with Italy and Spain being the countries most adversely affected, followed by France. According to our estimates, at the time of its maximum impact in the first quarter of 2012, a decomposition of sovereign yield spreads suggests that about 30%, 40% and 50% of the respective French, Italian and Spanish sovereign yield spreads (respectively 35, 200 and 275 basis points) could be explained by redenomination risk shocks.

Finally, we test for the spillover effects, defined as the transmission of the foreign redenomination risk shocks to domestic markets over and above the domestic shocks. The results suggest that Italy and Spain are relatively less affected from redenomination risk spillovers, while France is also affected by foreign redenomination risk shocks. Given that the foreign redenomination risk shocks spill over and above the local redenomination risk shocks, we can argue that this risk is systemic for the euro area.

1 Introduction

In the first half of 2012, there were market concerns of a euro break-up. Euro area sovereign bond yields relative to the overnight index swap (OIS) rate - a risk-free rate proxy - reached record highs, with Italian and Spanish 5-year sovereign yield spreads (i.e. the difference between the sovereign yield and the OIS rate at 5-year maturity) rising in a few weeks from 200 basis points in March to 500-600 basis points in July (see Figure 1). It seemed that such developments were the results of self-fulfilling speculation and multiple equilibria (Calvo, 1988; Kehoe and Cole, 2000; Corsetti and Dedola, 2014), as many papers find evidence that a significant part of the surge in the euro area sovereign yield spreads over the 2010-2012 period was disconnected from underlying fiscal fundamentals (De Grauwe and Ji, 2012; Di Cesare et al., 2012; Favero, 2013; De Santis, 2014; Dewacher, et al. 2014).

On 26 July 2012, Mario Draghi, President of the European Central Bank (ECB), in a speech at an investment conference in London said that a "convertibility risk" explained this phenomenon, preventing the smooth functioning of the ECB's monetary policy across national borders inside the euro area, and acknowledged that financial markets were pricing the risk of break-up. He pledged to do "whatever it takes" to protect the euro area from collapse.

After the "whatever it takes" speech, the ECB launched the Eurosystem's Outright Monetary Transactions (OMTs) in secondary sovereign bond markets. Spain and Italy's sovereign yields and CDS spreads fell by about 250-350 basis points compared to the peak in July and they declined steadily during the course of 2012. It is generally accepted by academics, bankers, investors and policymakers that in launching the OMTs the ECB aimed at eliminating the financial risk premium caused by redenomination (or break-up) risk, which can be defined as the compensation demanded by market participants for the risk that a euro asset will be redenominated into a devalued legacy currency.

[Insert Figure 1, here]

Redenomination is a process whereby a country currency is recalibrated (i) due to significant inflation and currency devaluation, (ii) when a currency union is formed, (iii) when a currency union breaks up. The determinants of redenomination risk are very different depending upon the process under consideration.

Redenomination of the first kind has a long history. In the 19th century, recoinage of

gold or silver coins happened in various occasions (Helleiner, 2003); after the end of Bretton Woods system in 1973, many developing and transition nations redenominated their currencies, typically removing one of the zeros from the old currency (for instance, Turkey replaced in January 2005 its currency (the Lira) with the "New Turkish Lira" and Romania in July 2005 introduced a new "heavy" version of its currency, the leu, with four fewer zeros). In these cases, redenomination of individual currencies occurred after hyperinflation and sharp currency devaluations and governments adopted this policy aiming at anchoring inflation expectations. Redenomination risk in these cases is driven by expected inflation, which clearly is not a plausible explanation in the current context as euro area inflation has been rather muted.

Redenomination of the second kind has also its own tradition. Rose (2007) provides the list of currency union members after the second world war. Among the largest currency areas, one can list the West and the Central African CFA franc (50 million people), which were created in 1945 with the currency pegged to the French franc and since 1999 to the euro, and the European and Economic Monetary Union (EMU), which was formed in January 1999 and has a population of 330 million people. In the specific case of the EMU, the Maastricht Treaty in 1992 set out the ground rules for the introduction of the single currency. These conditions are known as the 'convergence criteria' (or 'Maastricht criteria') and include low and stable inflation, exchange rate stability and sound public finances. Therefore, the redenomination risk in the context of entry in the EMU is expected to be linked to the convergence criteria.

Redenomination of the third kind has also plenty of examples. Over the period 1949-1994, Rose (2007) counted 68 departure from currency unions and found remarkably little macroeconomic volatility around the time of currency union dissolutions. This is because the historical examples counted for many developing countries and, more in general, for countries with less than 0.5% of world GDP and much less in terms of financial market size. It is generally shared that the consequences of the euro area breaking up are unknown because the euro area plays an important role globally in terms of its economy and financial markets: the euro area accounts for about 20% of world GDP, 35% of global bank assets and liabilities and EUR 20 trillion of euro denominated contracts in existence outside the euro area jurisdiction, which would be very hard to redenominate efficiently in case the euro ceases to exist. The consequences of the euro area break-up would be severe; hence, one can assume that only extraordinary developments, such a sovereign credit event, could trigger it. In fact, the market concerns of a euro break-up are discussed in the context of the euro area sovereign debt crisis.

Can we measure the intra-euro area redenomination risk?

Currency risk was an important theme of academic research and political debate in, for example, the wake of the European Monetary System currency crisis in 1992, the Mexican financial crisis of 1994-1995, the Asian financial crisis of 1997, the Argentina's financial crisis in 1998-2002, or the break-up of the Ruble currency area between 1991 and 1995 and of the Czechoslovakian currency union in 1993. However, this debate is not helpful in the context of euro area because intra-euro area redenomination risk is a joint risk of the probability of a sovereign credit event and the depreciation of the new legal currencies.

In this paper, we propose a time-varying, country-specific measure of intra-euro area redenomination risk as perceived by the market, investigate its role in pricing sovereign yield spreads and assess its systemic effect by estimating the impact of foreign spillovers. The probability and size distribution of macroeconomic disasters are difficult to quantify empirically because the relevant events are rare and possibly absent in short samples (Barro , 2006 and 2009; Barro and Ursua, 2008; Barro and Jin, 2011; Barro, et al., 2013). The key advantage of the proposed measured is that it is observable daily.

There are five main approaches suggested implicitly by the literature to study the phenomenon. The first approach relies on using currency option prices to measure a severe exchange rate crisis, including the EUR/USD volatility skew.[1] However, this approach, while offering useful information about the volatility of the EUR/USD exchange rate and the expected depreciation of the currency by the market, does not uniquely identify market perception of intra-euro area redenomination risk, as a multiplicity of factors can affect expectations of EUR/USD changes and the key exchange rate of interest is the new legal currency against the euro. Moreover, the EUR/USD option price does not provide a country-specific measure and, therefore, cannot indicate the source of the crisis and its potential systemic risk. A second approach relies on an indicator from market Intrade, a platform that has ceased to exist, which suggested that the probability that at least one country using the euro will leave the euro area by the end of 2013 was about 65% in November 2011, 40% in March 2012 and 60% in August 2012 (Shambaugh, 2012; Klose and Weigert, 2012). Similarly to the first approach, the indicator from market Intrade, which is no longer available, cannot indicate the source of the crisis and its potential systemic risk. A third approach focuses on the estimation of equilibrium values of sovereign

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[1]See Campa and Chang (1996), Carr and Wu (1997), Farhi et al. (2009), Burnside et al. (2011), Hui and Chung (2011) and Jurek (2014).

yields and the distance from the actual value is the non-fundamental driven sovereign spread (Dewacher, et al. 2014). The disadvantage of this approach is that all non-fundamental factors including market perception of redenomination risk play a significant role and, therefore, one cannot clearly isolate redenomination risk. A fourth approach computes the expected currency depreciation upon exit using open economy New Keynesian general equilibrium models. Kriwoluzky et al. (2014) have calibrated a small-open economy model to Greece. The disadvantage of this approach is that one has to rely upon a specific theoretical model and key calibrated parameters. A fifth approach compares the yields of bonds issued in different currencies, with the intuition that the spread should reflect expected exchange rate movements. Krishnamurthy, et al. (2014) have considered the difference between the euro and the US dollar denominated sovereign yield spreads under the hypothesis that euro denominated sovereign yields should price redenomination risk as perceived by the market. They found that the redenomination risk channel is operative mainly for Spain and Portugal, but not for Italy. However, the US dollar market for euro area sovereign bonds is much less liquid, as only less than 0.5% of sovereign bonds of the largest euro area players, such as Germany, France, Italy and Spain, is issued in foreign currency. The resulting liquidity premium in the US dollar market might offset the redenomination risk premium emanating from the euro denominated bond market.

In this paper, we follow this fifth approach, but employ US dollar and euro denominated CDS spreads, which are used by investors to hedge against sovereign credit risk (Duffie, 1999) and are typically very liquid (Bongaerts, et al., 2011; Longstaff, et al., 2011). It could be argued that given the original contract it may be irrelevant whether the country declaring a credit event introduces a new currency. Financial letters and newspapers in 2012 asked (i) whether the sovereign bonds issued in the leaving country would still be repaid in euro or redenominated in the new currency; (ii) who would decide; (iii) in which courts would jurisdiction reside and (iv) whether outside courts would have any jurisdiction over a sovereign government. This is just a sample of the issues involved. The slim probability of such event combined with the severe implications forced financial managers to deal with such an important issue, sometimes using products to hedge against it. Although a credit event of a member country does not automatically imply the break-up of the euro area or the obligation payments in a new devalued currency, it certainly increases the market perception of risk of redenomination of sovereign assets in a new depreciated legal currency.

We use quanto CDS, namely the difference between the CDS quotes in US dollar and euros.

The differential between USD- and euro-denominated CDS spreads is expected to be positive for Italian and Spanish sovereign contracts in the course of the first half of 2012, because an euro-denominated credit event protection seemed increasingly less attractive. Should for example Italy declare a credit event, euro 10 million worth of protection on an Italian credit event would be worth much less after a credit event as a consequence of the devaluation of the euro or, if the euro would no longer exist, as a result of the devaluation of the "new" currency. This led to a major drop in demand for EUR-denominated Italian (and other European) protection. It is important to emphasise that the USD-denominated CDS market for euro area sovereigns is relatively bigger and if a liquidity premium existed in the EUR-denominated CDS market, the compensation for illiquid assets on top of the compensation for credit risk would be earned by the credit protection seller (Bongaerts, et. al. 2011). This implies that the quanto CDS is rather a conservative measure.

A credit event does not automatically imply the break-up of the euro area, as in the Greek case in March 2012. Therefore, the quanto CDS, which measures the risk associated with the depreciation against the US dollar and not the intra-euro area currency risk, is not a sufficient measure. We argue that the difference between the quanto CDS for Italy/Spain and that for Germany - the benchmark euro area sovereign debt market - is the key measure of redenomination risk associated with the break-up of the euro area as perceived by the market. The use of countries' quanto CDS relative to Germany rests on the idea that such spread would be close to zero if market perceptions of break-up risks of the euro area were minor. Moreover, such measure is less prone to issues of whether the liquidity of sovereign CDS contracts is the same across the currency spectrum, because it is defined as a spread across countries' quanto CDS. Finally, the value of such measure is that it is directly observable, as it is based on traded contracts and, therefore, it provides the market perception of redenomination risk.

We make use of a new source of data on euro-denominated CDS contracts, which are available for few largest euro area sovereign debt markets. Focusing on Italy, Spain and France and using Germany as benchmark, the proposed measures of currency redenomination risk reached a peak for both Italy and Spain just before the speech by President Draghi on 26 July 2012. Thereafter, they declined and since the end of 2012 they remained contained.

It is expected that the higher the redenomination risk premium demanded by investors the higher the sovereign yield spreads. The empirical analysis based on both single country vector autoregression (VAR) models and a factor-augmented vector autoregressive (FAVAR) approach

supports the link between market perception of redenomination risk and sovereign yield spreads. We show that the redenomination risk shocks, defined as the unexplained component of the market perception of redenomination risk orthogonal to exchange rate, global, regional and liquidity risks, significantly affect sovereign credit spreads, with Italy and Spain being the countries most adversely affected, followed by France. The proposed measure of market perception of redenomination risk captures an important component of overall sovereign risk, in the sense that it explains a significant share of the sovereign yield spreads of Italy, Spain and France.

We perform an extensive series of robustness checks that support our results. Based on a VAR decomposition, redenomination risk shocks during the peak in July 2012 accounted for about 165 basis points (= 28%) of the Italian 5-year sovereign yield spread, 275 basis points (= 39%) of the Spanish 5-year sovereign yield spread and 13 basis points (= 28%) of the French 5-year sovereign yield spread. At its maximum impact in the first quarter of 2012, a decomposition of sovereign yield spreads suggests that about 30%, 40% and 50% of the respective French, Italian and Spanish sovereign spreads is explained by redenomination risk shocks. These estimates are larger than those obtained by Kriwoluzky et al. (2014), who develop a New Keynesian model applied to Greece, where currency risk accounts for about 10% of the rise in sovereign yield spreads. However, these results are not necessarily contradictory given the greater role played by credit risk in the Greek crisis.

Finally, we test for the spillover effects, defined as the transmission of the foreign redenomination risk shocks to domestic markets over and above the domestic shocks. The results suggest that Italy and Spain are relatively less affected from redenomination risk spillovers, while France is also affected by foreign redenomination risk shocks. Therefore, we can argue that this risk is systemic for the euro area. It is important to stress that these results are obtained controlling for a large number of financial variables, including the level or skew of daily currency option prices, which are often used as a measure of currency risk.

The remaining sections of the paper are structured as follows: Section 2 shows the derivation of the market perception of redenomination risk. Section 3 presents briefly the underlying econometric specifications, discusses the main risk factors used as controls and summarises the key results. Section 4 concludes.

2 An observable measure of redenomination premium

2.1 The concept

Duffie (1999), Longstaff, et al. (2005 and 2011), Pan and Singleton (2008) and others have explained the sovereign CDS contract being an insurance contract against a credit event on sovereign debt. The CDS buyer pays a fee in regular intervals. Upon a credit event, the buyer receives the difference between the par value and the recovery value of the bonds.[2] Selling protection through a CDS contract replicates a leveraged long position in bonds of the underlying reference entity, exposing protection sellers to risks similar to those of a creditor. Conversely, buying protection through CDS replicates a short position on bonds of the underlying reference entity (with proceeds reinvested at the riskless rate).[3] All in all, CDS spreads are market premia used primarily to manage credit risk on debt and fixed-income positions and the premium payments are paid on the face value of the protection.

Using the reduced-form model notation proposed by Doshi, el al. (2013),[4] the yearly CDS spread $S_t^{c,h}$ for a h-year sovereign c CDS contract can be computed as the rate which equates the present value of the payments (premium leg) to the present value of the expected payout (loss leg),

$$
\overbrace{\mathbf{E}_t\left[S_t^{c,h}\sum_{j=1}^{h}q_{t+j}^c A_{t+j}\left(t+j\right)\right]}^{\text{premium leg}} = \overbrace{\mathbf{E}_t\left[\sum_{j=1}^{h}\left(1-R^c\right)\left(q_{t+j-1}^c - q_{t+j}^c\right)A\left(t+j\right)\right]}^{\text{loss leg}}, \qquad (1)
$$

where R^c is the recovery rate (as a proportion of the face value of the protection), q_{t+j}^c is the survival probability at time $t+j$, $q_{t+j-1}^c - q_{t+j}^c$ is the probability that the credit event occurs

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[2] Also private sector involvement (PSI) constitutes a credit event. On 9 March 2012, the International Swaps and Derivatives Association (ISDA) ruled that the activation by the Greek Government of the collective action clauses (CACs) constituted a 'restructuring credit event' for CDS referencing Greek sovereign debt. A CAC allows a supermajority of bondholders to agree to a debt restructuring that is legally binding on all holders of the bond, including those who vote against the restructuring. 96.9 per cent of private sector bondholders participated in the exchange of their Greek government bonds for short-term European Financial Stability (EFSF) notes and new long-term Greek government bonds, which equated to a reduction of 53.5 per cent in nominal values and around 75 per cent in net present value terms. As the debt swap deal caused significant economic losses to private creditors, Fitch downgraded Greece's sovereign debt rating from "C" to "RD" (Restricted Default) and the ISDA declared a credit event. An auction held by 14 banks set a price of 21.5 per cent of par and a market-wide pay-out of USD 2.5 billion, or 78.5 per cent of the USD 3.2 billion of net outstanding CDS as of March 9, when the credit event was declared by ISDA, the industry body that rules on pay-outs. The pay-out was considered fair value by many strategists and investors (http://www.ft.com/intl/cms/s/0/0997e7f4-71c4-11e1-b853-00144feab49a.html).

[3] For changes and trends in the CDS markets as well as a survey of the literature about the trading, pricing and clearing of CDS see the International Organization of Securities Commissions (2012).

[4] The only difference vis-à-vis Doshi, et al (2013) is that they use an indicator function, we use in our notation the survival probability.

during the interval $(t + j - 1, t + j)$ and $A(t + j)$ is the riskless discount rate $\exp\left(-\sum_{j=0}^{h-1} r_{t+j}\right)$ with r_{t+j} being the risk free rate. In terms of notation, $(1 - R^c)$ is the loss given default, $\lambda_{t+j}^c = (1 - R^c)\left(q_{t+j-1}^c - q_{t+j}^c\right)$ and $\mathbf{E}_t \sum_{j=1}^{h} \lambda_{t+j}^c A(t + j)$ is the present value of the expected loss as a percentage of exposure after a credit event.

From the point of view of an international investor based for example in the United States, if the contract has a face value of the protection denominated in US dollars (\$), $N_t^{c,USD}$, using (1) then

$$
\begin{aligned}
S_t^{c,h,USD} &= \frac{\mathbf{E}_t\left[N_t^{c,USD} \sum_{j=1}^{h} \lambda_{t+j}^c A(t + j)\right]}{\mathbf{E}_t\left[N_t^{c,USD} \sum_{j=1}^{h} q_{t+j}^c A(t + j)\right]} \\
&= \frac{\mathbf{E}_t\left[\sum_{j=1}^{h} \lambda_{t+j}^c A(t + j)\right]}{\mathbf{E}_t\left[\sum_{j=1}^{h} q_{t+j}^c A(t + j)\right]},
\end{aligned}
\tag{2}
$$

if instead the contract has a face value of the protection denominated in euro, $N_t^{c,EUR}$, then

$$
\begin{aligned}
S_t^{c,h,EUR} &= \frac{\mathbf{E}_t\left[\sum_{j=1}^{h} N_t^{c,EUR} X_{t+j}^{L,c} \lambda_{t+j}^c A(t + j)\right]}{\mathbf{E}_t\left[\sum_{j=1}^{h} N_t^{c,EUR} X_{t+j}^{P,c} q_{t+j}^c A(t + j)\right]} \\
&= \frac{\mathbf{E}_t\left[\sum_{j=1}^{h} X_{t+j}^{L,c} \lambda_{t+j}^c A(t + j)\right]}{\mathbf{E}_t\left[\sum_{j=1}^{h} X_{t+j}^{P,c} q_{t+j}^c A(t + j)\right]},
\end{aligned}
\tag{3}
$$

where $X_{t+j}^{P,c}$ is the USD/EUR exchange rate contingent upon a credit event not having occurred, $X_{t+j}^{L,c}$ is the USD/EUR exchange rate contingent upon a credit event having occurred over the period $t + h$ and $A(t + j)$ is the riskless discount rate prevailing in the US dollar money market.

Divide numerator and denominator by the current USD/EUR exchange rate, $X_t^{P,c}$, then

$$
S_t^{c,h,EUR} = \frac{\mathbf{E}_t\left[\sum_{j=1}^{h} \left(1 + x_{t+j}^{L,c}\right) \lambda_{t+j}^c A(t + j)\right]}{\mathbf{E}_t\left[\sum_{j=1}^{h} \left(1 + x_{t+j}^{P,c}\right) q_{t+j}^c A(t + j)\right]},
\tag{4}
$$

where $x_{t+j}^{P,c} = X_{t+j}^{P,c}/X_t^{P,c} - 1$ is the USD/EUR exchange rate appreciation contingent upon a credit event not having occurred and $x_{t+j}^{L,c} = X_{t+j}^{L,c}/X_t^{P,c} - 1$ is the USD/EUR exchange rate appreciation contingent upon a credit event having occurred.

Assume that in the absence of a credit event the exchange rate follows a random walk, $X_{t+j}^{P,c} = X_t^{P,c} + \varepsilon_t^c$ where ε_t^c is a white noise, then $\mathbf{E}_t \sum_{j=1}^{h} \left(1 + x_{t+j}^{P,c}\right) q_{t+j}^c A(t + j) = \mathbf{E}_t \sum_{j=1}^{h} q_{t+j}^c A(t + j)$

and (4) can be written as

$$S_t^{c,h,EUR} = \frac{\mathbf{E}_t\left[\sum_{j=1}^h \left(1 + x_{t+j}^{L,c}\right)\lambda_{t+j}^c A\left(t+j\right)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^c A\left(t+j\right)\right]}. \tag{5}$$

This implies that the quanto CDS, that is the difference between the USD- and the EUR-denominated CDS spreads, can be computed subtracting (5) from (2)

$$Q_t^{c,h} = \frac{\mathbf{E}_t\left[\sum_{j=1}^h \lambda_{t+j}^c A\left(t+j\right)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^c A\left(t+j\right)\right]} - \frac{\mathbf{E}_t\left[\sum_{j=1}^h \left(1 + x_{t+j}^{L,c}\right)\lambda_{t+j}^c A\left(t+j\right)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^c A\left(t+j\right)\right]}, \tag{6}$$

which can be rewritten as

$$Q_t^{c,h} = \overbrace{\frac{\mathbf{E}_t\left[\sum_{j=1}^h \lambda_{t+j}^c A\left(t+j\right)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^c A\left(t+j\right)\right]} - \frac{\mathbf{E}_t\left[\sum_{j=1}^h \lambda_{t+j}^c A\left(t+j\right)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^c A\left(t+j\right)\right]}}^{\text{Credit risk }(=0)}$$

$$\overbrace{- \frac{\mathbf{E}_t\left[\sum_{j=1}^h \lambda_{t+j}^c A\left(t+j\right)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^c A\left(t+j\right)\right]} \mathbf{E}_t\left[\sum_{j=1}^h x_{t+j}^{L,c}\right]}^{\text{Credit event probability-weighted expected currency depreciation }(+)} \tag{7}$$

$$\overbrace{- \frac{\mathbf{COV}_t\left[\sum_{j=1}^h x_{t+j}^{L,c}, \sum_{j=1}^h \lambda_{t+j}^c A\left(t+j\right)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^c A\left(t+j\right)\right]}}^{\text{currency risk associated with expected loss }(+)},$$

By subtracting the EUR-denominated CDS from the USD-denominated CDS, the credit risk component becomes nil and what is left is the expected depreciation and the currency risk component. Given that in case of a credit event among euro area countries the US dollar is expected to appreciate, then $X_{t+i}^{L,c} < X_t^{P,c}$ and $x_{t+i}^{L,c} = X_{t+i}^{L,c}/X_t^{P,c} - 1 < 0$. Therefore, the second component of (7), namely the credit event probability-weighted country c's expected currency depreciation against the US dollar, is positive. Moreover, the larger the expected loss, the larger the expected depreciation; hence the third component of (7), namely the currency risk associated with the expected loss, is also positive: $-\mathbf{COV}_t\left[\sum_{j=1}^h x_{t+j}^{L,c}, \sum_{j=1}^h \lambda_{t+j}^c A\left(t+j\right)\right] >$

0. Therefore,

$$Q_t^{c,h} = -S_t^{c,h,USD}\mathbf{E}_t\left[\sum_{j=1}^h x_{t+j}^{L,c}\right] - \frac{\mathbf{COV}_t\left[\sum_{j=1}^h x_{t+j}^{L,c}, \sum_{j=1}^h \lambda_{t+j}^c A(t+j)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^c A(t+j)\right]} > 0. \qquad (8)$$

$Q_t^{c,h}$ measures the compensation demanded by market participants for the risk associated in holding euro-denominated assets that the US dollar appreciates against the euro or the new legacy currency after a credit event.

Intra-euro area redenomination risk is the compensation demanded by market participants for the risk that a new legal currency devalues against the euro or the new benchmark legacy currency. Therefore, the market perception of intra-euro area redenomination (or convertibility) risk premium, $I_t^{c,b,h}$, is defined by subtracting from (8) an euro area benchmark country b' quanto CDS:

$$I_t^{c,b,h} = Q_t^{c,h} - Q_t^{b,h}. \qquad (9)$$

$I_t^{c,b,h}$ is the credit event probability-weighted expected depreciation of the new country c' currency versus the new country b's currency plus the difference of the currency risk associated with the expected loss across the two countries. Redenomination risk is therefore positively correlated with the expected depreciation of the new country c' currency, its probability of default and expected loss given default.

$I_t^{c,b,h}$ has the additional advantage that is less prone to issues of whether the liquidity or institutional characteristics of sovereign CDS contracts is the same across the currency spectrum, because it is defined as a spread across countries' quanto CDS. Nevertheless, it should be pointed out that if a liquidity premium existed in the EUR-denominated CDS market, the illiquidity compensation on top of the compensation for credit risk would be earned by the credit protection seller (Bongaerts, et. al. 2011). This implies that $I_t^{c,b,h}$ would be rather a conservative measure.

Assume that market participants perceive the euro to be irreversible: $I_t^{c,b,h}\big|_{\lambda_t^{c,h}>\lambda_t^{b,h}} = 0$. This implies that $Q_t^{c,h} = Q_t^{b,h}$ and, rearranging (8),

$$S_t^{c,h,USD} - S_t^{b,h,USD} = -\frac{\frac{\mathbf{COV}_t\left[\sum_{j=1}^h x_{t+j}^{USD/EUR}, \sum_{j=1}^h \lambda_{t+j}^c A(t+j)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^c A(t+j)\right]} - \frac{\mathbf{COV}_t\left[\sum_{j=1}^h x_{t+j}^{USD/EUR}, \sum_{j=1}^h \lambda_{t+j}^b A(t+j)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^b A(t+j)\right]}}{\mathbf{E}_t\left[\sum_{j=1}^h x_{t+j}^{USD/EUR}\right]}.$$

Given that in case of a credit event in the euro area the euro is expected to depreciate (i.e. $\mathbf{E}_t\left[\sum_{j=1}^h x_{t+j}^{USD/EUR}\right] < 0$), then the USD-denominated CDS spreads of sovereign country c vis-à-vis the benchmark country remain positive, $S_t^{c,h,USD} - S_t^{b,h,USD} > 0$, if, and only

if, $\dfrac{-\mathbf{COV}_t\left[\sum_{j=1}^h x_{t+j}^{USD/EUR},\sum_{j=1}^h \lambda_{t+j}^c A(t+j)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^c A(t+j)\right]} < \dfrac{-\mathbf{COV}_t\left[\sum_{j=1}^h x_{t+j}^{USD/EUR},\sum_{j=1}^h \lambda_{t+j}^b A(t+j)\right]}{\mathbf{E}_t\left[\sum_{j=1}^h q_{t+j}^b A(t+j)\right]}$; if, in other words, the USD/EUR currency risk associated with the expected loss is higher in the case of a credit event in the benchmark country, which is not implausible given the disaster event.

If also the currency risks are of the same magnitude across countries, then $S_t^{c,h,USD} - S_t^{b,h,USD} = 0$. This suggests that if market participants perceive small the risk of euro area break-up, then CDS spreads across euro area countries will tend to be relatively minor. To make this point clear, the case of Greece is illustrative. In March 2012, when the Greek government declared the credit event, the 10-year Greek sovereign yield hit record high 40%. When it became clear to investors that Greece would have remained in the euro area, the 10-yr Greek sovereign yield started a steady decline reaching 5% in the summer 2014.

Given that the expected probability of a credit event in the benchmark country is negligible, we expect

$$I_t^{c,b,h}\bigg|_{\lambda_t^{c,h} > \lambda_t^{b,h}} \geq 0. \tag{10}$$

The propositions that $Q_t^{c,h} > 0$ and $I_t^{c,b,h}\big|_{\lambda_t^{c,h} > \lambda_t^{b,h}} \geq 0$ are key features that should characterise the data.

2.2 The empirical measure

The USD- and EUR-denominated CDS spreads are plotted in Figure 2 for Italian, Spanish, French and German sovereigns at 3- and 5-year maturity. They are only reliable from September 2011, as they move with prolonged constant shifts in 2010 and in the earlier part of 2011.[5] However, this is not a big issue because the emergence of the risk of redenomination as perceived by the market was witnessed from the second half of 2011.[6] As shown in Figures 1 and 2, the most critical period for Italy, Spain and France is the sample period we are able to study. The CDS spreads were relatively large until the Draghi' speech on redenomination risk. Subsequently, both USD- and EUR-denominated CDS spreads started to decline (see Figure 2).

The quanto CDS at 3- and 5-year maturities are always positive in accordance with expression (8) with a size that is larger for Spain and Italy and smaller for France and Germany (see Figure 3), as one would expect given that the joint probability of a sovereign credit event and

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[5] We have chosen the 13th of September 2011 as the beginning of our sample, because Thomson Reuters constructed USD- and EUR denominated sovereign par yields using CDS data considered of high quality starting from this date.

[6] See speech by by Mario Draghi, President of the ECB, "The euro, monetary policy and reforms", Rome, 6 May 2013 (http://www.ecb.europa.eu/press/key/date/2013/html/sp130506.en.html).

the depreciation of the new legal currency has been higher for Italian and Spanish sovereign markets.

[Insert Figure 2, here]

[Insert Figure 3, here]

Germany is identified as the benchmark country for three main reasons: (i) the expected probability of a credit event in Germany has been so far considered negligible, as its debt is accredited with the top-notch triple-A rating,[7] (ii) the financial situation of the country is solid, (iii) the country is relatively large playing a central role in the euro area. This explains why the German Bund yield comoves with the euro OIS (risk-free) rate (see Figure 1), being even lower during the euro area sovereign debt crisis due to flight-to-liquidity (De Santis, 2014). All in all, by setting Germany as the benchmark country, the hypothesis that $\lambda_t^{c,h} > \lambda_t^{b,h}$ should hold particularly for Italy and Spain over the sample period.

The empirical measure of market perception of redenomination risk for Italian, Spanish and French sovereigns is plotted in Figure 4 (left panel). The redenomination risk premia are positive in accordance with expression (10), except for few calendar days for France at 3-year maturity in September 2011.[8] The market perception of redenomination risk premium at 3- and 5-year maturity for Italy and Spain fluctuated around 30 and 40 basis points up to mid-February 2012. Thereafter, it increased, reaching in May 2012 in the specific case of Spanish contracts about 110 basis points at 3-year maturity and 95 basis points at 5-year maturity. After a sharp fluctuation in June and July, since the London's speech by Draghi on 26 July 2012, the market perception of redenomination risk premium at 3-year maturity started a steady decline for both Italy and Spain. The market perception of redenomination risk measured at 5-year maturity started to decline only after the September ECB Governing Council meeting, which announced the technical implementation of the OMTs. Since end of 2012, the redenomination premium has been fairly constant, fluctuating at a level of around 20-30 basis points for both maturities. The market perception of the redenomination risk premium for France was also relatively large in the first half of 2012 and has been quite stable after the September ECB Governing Council meeting, being very close to zero at 3-year maturity.

The market perception of the redenomination risk premium comoves only partly with the

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[7] The only other euro area countries, which enjoy the best possible credit ratings, are Finland and Luxembourg.

[8] The sovereign bonds of France and Germany in 2011 and 2012 were considered relatively safe by investors and these assets were rated triple-A by the credit rating agencies. This explains why redenomination risk for France is minor and for few days in 2011 also turned negative.

EUR/USD volatility skew as measured by the 10-delta USD/EUR option implied volatility (see right panel of Figure 4). The unconditional correlations based on the daily first differences are close to zero for Italy and France and amount to 11.9% for Spain (see Table 1). The advantage of the suggested market perception of the redenomination risk premium is that it is country-specific and conditioned to credit events, which could indeed lead to the break-up of the euro area. It is function of the currency risk within the euro area (i.e. intra-currency risk), while the 10-delta USD/EUR option implied volatility is a measure of extra-currency risk; thereby, it does not uniquely identify redenomination risk, as a multiplicity of factors can affect expectations of the USD/EUR exchange rate.

[Insert Figure 4, here]

[Insert Table 1, here]

3 The determinants of sovereign yield spreads

A key question is investigating whether the country-specific redenomination risk premia as perceived by the market are statistically significant in explaining the dynamics of sovereign yield spreads. To address this important issue we have employed VAR methodology relying on daily asset price data and a large number of variables to disentangle the redenomination shock from other common shocks embodied in asset prices. We estimate three single country VAR, one per country (Italy, Spain and France). It could be argued that this approach is inconsistent given that we estimate three different dynamics for the variables that are common to the models (these are the so-called regional and global variables). Therefore, in addition, a FAVAR a la Bernanke, *et al* (2005) including all sovereign yield spreads and market perception of redenomination risk premia with the principal components of a sub-set variables is estimated. The first subsection describes briefly the method, the second subsection presents the explanatory variables and the third subsection discusses the econometric results.

3.1 The VAR

The VAR takes the following form:

$$\mathbf{A}_0 \mathbf{Y}_t = \phi + \sum_{j=1}^{p} \mathbf{A}_j \mathbf{Y}_{t-j} + \varepsilon_t, \tag{11}$$

where $\mathbf{Y}_t$ is the $k \times 1$ vector of variables observed at time t in the single country VAR and the $k \times 1$ vector of observed variables and principal components at time t in the FAVAR,[9] p is the lag length and ε_t is a $k \times 1$ vector of structural shocks, defined as being uncorrelated with one another. $\mathbf{A}_0$ is the impact matrix. Restrictions must be imposed on $\mathbf{A}_0$ to uniquely recover the structural form. Given the large set of financial variable employed, the identification restrictions imposed on $\mathbf{A}_0$ is recursive (Sims, 1980), which is equivalent to a Cholesky factor of the variance-covariance matrix of the reduced form white noise innovations with the redenomination risk shocks ordered last just before the local stock market and sovereign credit spreads. This assumption is very conservative, as we assume that all common contemporaneous shocks that could affect global variables, exchange rate variables, regional variables and liquidity variables are not classified as redenomination risk shocks, as the former variables do not depend contemporaneously on market perception of redenomination risk which is ordered after. Yet, the recursive approach is not linked to economic theory. However, if the residuals of the redenomination risk equation are mildly correlated with the residuals of the control variables of the system (i.e. global and exchange rate variables, regional variables and liquidity variables), then the results based on the Cholesky factorization would be much more general. A mild correlation matrix of the residuals of the VAR and similar impulse response functions of the redenomination risk shocks based on alternative ordering of the variables are important features to validate the use of the recursive approach.

The structural VAR associated with this equation can be represented by its vector moving average form,

$$\mathbf{Y}_t = \mu + \mathbf{C}\left(L\right)\varepsilon_t, \tag{12}$$

where L is the lag operator, $\mathbf{C}\left(L\right) = \left(\mathbf{A}_0 - \sum_{j=1}^{\infty} \mathbf{A}_j L^j\right)^{-1}$ and the constant k-vector $\mu = \left(\mathbf{A}_0 - \sum_{j=1}^{\infty} \mathbf{A}_j L^j\right)^{-1}\phi$. As suggested by equation (12), the variations of the endogenous variables can only be explained by variations in current and past structural shocks. Note that the endogenous variables depend on an infinite number of past structural shocks. Given the finite sample, the effect of all shocks that are realised previous to the sample is captured by the initial values of the endogenous variables. Therefore, equation (12) can be re-written as the sum of the time-varying deterministic component, $\mathbf{Y}_t^d$, and its stochastic component, $\mathbf{Y}_t^s$. The stability condition of a VAR requires that $\mathbf{Y}_t^d \longrightarrow \mu$ when t increases, because the shocks that are too

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[9]We consider a two-step estimation method, in which the factors are estimated by principal components prior to the estimation of the FAVAR.

far in the past have no effect in the current value of the variables. $\mathbf{Y}_t^d$, which is a function of the initial values and of the parameters of the reduced form model, is often referred to as the reference value of the historical decomposition of shocks.

Given our short sample size $T+p$, we first estimate $\mathbf{Y}_t^d$ and the contribution to the i-th variable of each regressor. To conduct this exercise, we define $\mathbf{Z}_t = [\mathbf{Y}_t - \mu, \ \mathbf{Y}_{t-1} - \mu, \ ..., \ \mathbf{Y}_{t-p+1} - \mu]$ and we rewrite model (11) more compactly in companion matrix form as a VAR(1)

$$\mathbf{Z}_t = \Lambda \mathbf{Z}_{t-1} + \mathbf{A}_0^{-1} \mathbf{v}_t, \tag{13}$$

$$\Lambda = \begin{pmatrix} \mathbf{A}_0^{-1}\mathbf{A}_1 & \mathbf{A}_0^{-1}\mathbf{A}_2 & \cdots & \cdots & \mathbf{A}_0^{-1}\mathbf{A}_p \\ I & 0 & 0 & \cdots & 0 \\ 0 & I & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & \cdots & \cdots & I & 0 \end{pmatrix}, \qquad \mathbf{v}_t = \begin{pmatrix} \varepsilon_t \\ \mathbf{0} \\ \mathbf{0} \\ \vdots \\ \mathbf{0} \end{pmatrix}$$

Then, by recursive substitution

$$\mathbf{Z}_t = \Lambda^{T+1}\mathbf{Z}_{t-(T+1)} + \sum_{s=0}^{T} \Lambda^s \mathbf{A}_0^{-1} \mathbf{v}_{t-s}, \qquad s = 0, \cdots T. \tag{14}$$

where $\mathbf{Z}_t^d = \Lambda^{T+1}\mathbf{Z}_{t-(T+1)}$ is the deterministic component and $\mathbf{Z}_t^s = \sum_{s=0}^{T} \Lambda^s \mathbf{A}_0^{-1} \mathbf{v}_{t-s}$ is the stochastic component.

Let $e(R)$ be a selection row vector of dimension $1 \times pk$, with a one in the place of the redenomination risk variables and zeros elsewhere. Then, the deterministic contribution to the CDS spreads or sovereign yield spread of market perception of redenomination risk is calculated as follows $e(R)\mathbf{Z}_t^d = e(R)\Lambda^{T+1}\mathbf{Z}_{t-(T+1)}$ under the hypothesis that $\mu(R) = \mathbf{0}$.

After having computed the contribution of redenomination risk owing to the initial values of the VAR, we compute two alternative counterfactuals both based on the hypothesis that market perception of redenomination risk is zero. The benchmark model is provided by the dynamics of the model in the absence of shocks, $\mathbf{Z}_t^d$.

The first counterfactual is obtained by conditioning the VAR to a zero path of the redenomination risk measures. As pointed out by Waggoner and Zha (1999, eq. 6 - pg. 640) and Jarocinski (2010, eq. 7 - pg. 258), this implies that an agnostic linear combination of all shocks

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$\mathbf{v}_t^1$ exists to explain the assumed paths. Then, the counterfactual requires

$$e(R)\Lambda^{T+1}\mathbf{Z}_{t-(T+1)} + \sum_{s=0}^{T} e(R)\Lambda^s \mathbf{A}_0^{-1}\mathbf{v}_{t-s}^1 = 0. \tag{15}$$

Differently form Waggoner and Zha (1999) and Jarocinski (2010), given the regional focus of the sovereign debt crisis, we assume that global shocks are not the source of the zero path for market perception of redenomination risk. Global shocks are identified using all global variables and the three variables associated to the foreign exchange rate. This counterfactual is performed under the restriction that market perception of redenomination risk is conditional to a zero path owing to any combination of regional and local shocks, which are orthogonal to global shocks. The aggregate combination of shocks can be calculated recursively as follows

$$e(R)\mathbf{A}_0^{-1}(C)\mathbf{v}_t^1(C) = -\left[e(R)\Lambda^{T+1}\mathbf{Z}_{t-(T+1)}(R) + \sum_{s=1}^{T} e(R)\Lambda^s \mathbf{A}_0^{-1}(C)\mathbf{v}_{t-s}^1(C) \right] \tag{16}$$

where C is the position indicator for all regional and local shocks.

All remaining variables are endogenously determined. The difference between the baseline and the counterfactual provides the thought experiment of holding market perception of redenomination risk fixed at zero due to the stochastic component: $\mathbf{Z}_t^d - \mathbf{Z}_t^1 = -\sum_{s=0}^{T} \Lambda^s \mathbf{A}_0^{-1}(C)\mathbf{v}_{t-s}^1(C)$, where $\mathbf{Z}_t^1$ is the vector of variables obtained under the counterfactual.

The second alternative counterfactual is obtained by making endogenous only a sequence of the structural redenomination risk shocks $\mathbf{v}_t^2(R)$, such that the redenomination risk variables are held at zero:

$$e(R)\Lambda^{T+1}\mathbf{Z}_{t-(T+1)}(R) + \sum_{s=0}^{T} e(R)\Lambda^s \mathbf{A}_0^{-1}(R)\mathbf{v}_{t-s}^2(R) = 0. \tag{17}$$

The required values of subsequent shocks can be calculated recursively as follows

$$\mathbf{v}_t^2(R) = -\frac{\left[e(R)\Lambda^{T+1}\mathbf{Z}_{t-(T+1)}(R) + \sum_{s=1}^{T} e(R)\Lambda^s \mathbf{A}_0^{-1}(R)\mathbf{v}_{t-s}^2(R) \right]}{e(R)\mathbf{A}_0^{-1}(R)} \tag{18}$$

and all variables are endogenously determined.[10] The difference between the baseline and the counterfactual provides the thought experiment of holding market perception of redenomination risk fixed at zero due to the stochastic component: $\mathbf{Z}_t^d - \mathbf{Z}_t^2 = -\sum_{s=0}^{T} \Lambda^s \mathbf{A}_0^{-1}(R)\mathbf{v}_{t-s}^2(R)$, where

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[10]Bachmann and Sims (2012) applied a similar methodology when studying the impact of a government spending shock "shutting down" the confidence channel.

$\mathbf{Z}_t^2$ is the vector of variables obtained under the second counterfactual.

3.2 The variables

We aim at explaining the developments of sovereign yield spreads in Italy and Spain, which have been under a tremendous pressure during the euro area sovereign debt crisis; specifically, we evaluate the role of market perception of redenomination risk over and above the EUR/USD volatility skew often used as a measure of currency risk. We also consider the case of France, which is an important euro area country that has lost the triple-A rating in 2013.

Elton, et al. (2001), Chen, et al. (2007) and Longstaff, et al. (2005, 2011) find that corporate credit spreads and sovereign credit spreads are not fully explained by credit risk determinants. Liquidity premia and market-wide factors are important additional components. Therefore, the selection of the variables has been carried out following the study conducted by Longstaff, et al. (2011) and expanding it given the specificity of the euro area. Given that we use daily data, we focus primarily on market-determined variables since they should aggregate expectations of economic agents, which is relevant to investors in the sovereign credit markets. Details about the definitions, timing, and sources of the data for the variables used in this study are provided in Appendix A.[11]

3.2.1 Global and foreign exchange variables

Given the key role of market perception of redenomination risk in this paper, we control for the actual percentage changes in the euro exchange rate against the US dollar, the expected percentage changes based on the covered interest parity condition and, most importantly, the EUR/USD implied volatility using currency options out-of-the-money (10-delta) (Carr and Wu, 1997; Hui and Chung, 2011; Jurek, 2014).

Italy, Spain and France have extensive economic relationships with the rest of the world. Therefore, we include a number of measures from the US equity and fixed income markets, first because shocks to the US financial markets are transmitted globally and second because the US economy is the largest global financial centre. As the equity variable, we include the US stock

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[11]Longstaff, et al. (2011) employ regression analysis in first difference and study the monthly changes in the sovereign CDS spreads on a large set of explanatory variables. However, this approach is correct only if regressors are exogenous. In our context, sovereign credit spreads, redenomination risk and many financial variables could be jointly determined; therefore, we prefer to use a VAR. Nevertheless, the results of the model in first difference, where we regress the daily changes in both the sovereign CDS spreads and sovereign yield spreads on the daily changes of the redenomination risk controlling for a large set of domestic, regional and global variables are reported and discussed in Appendix B.

market price and the volatility risk premium, measured as the difference between implied and realised volatility (Britten Jones and Neuberger, 2000; Pan, 2002). Specifically, we estimate a GARCH(1,1) on the US stock returns to estimate the realised volatility. These measures are also used in the literature to control for global risk premia such as jump-to-credit risk, recovery risk and distress risk (Longstaff, et. al, 2011). As the fixed income variable, we include the US Treasury yield at 5-year maturity and the US investment-grade corporate bond spread.

3.2.2 Regional variables

Italy, Spain and France have extensive economic relationships with all other euro area countries. Given the monetary union, the ability of one of these sovereigns to repay its debt depends not only on local variables, but also on the aggregate state of the euro area. Furthermore, shifts in the relative liquidity of markets over time and particularly during the sovereign debt crisis, as shocks induce investors to reallocate capital across different asset classes, could create correlation between asset classes even in the absence of correlated fundamentals.

To capture broad changes in the state of the euro area and/or shifts in the relative performance of different asset classes, we include a number of measures, such as (1) the German CDS to proxy for the common credit risk component, (2) the break-even inflation rate to proxy for the common inflation risk component, (3) the EONIA Overnight Interest rate Swap (OIS) to proxy for the common monetary policy or funding risk component, (4) the KfW-Bund spread to proxy for the regional flight-to liquidity risk component (De Santis, 2014; Monfort and Renne, 2014), (5) the Greek sovereign spreads to proxy for the Greek sovereign spillover risk component and, finally, (6) the spread of euro area investment grade corporate bonds and (7) the euro area implied stock market volatility to proxy for the regional risk aversion component. The first four variables of this subsection have a 5-year maturity matching the maturity of the endogenous variables. The Greek sovereign spreads is calculated based on 10-year maturity given that only the 10-year yield on Greek sovereign was traded after the escalation of the sovereign debt crisis.

3.2.3 Local variables

The state of the local economy is one important driving force of credit risk in one nation. Therefore, we consider the local stock market price and the country-specific market perception of redenomination risk. Given the strong correlation between the 3- and 5-year maturity measures amounting to 60% for Italy, 80% for Spain and 90% for France and given that the OMTs focus

on euro area government bonds with a maturity of between one and three years, we employ market perception of redenomination risk at 3-year maturities in the main analysis and carry out robustness check analysis based on the 5-year maturity measure. To capture information about liquidity risk, we include the specific bid-ask spread of the specific asset (Beber, et al., 2009). Finally, persistency is modelled with an autoregressive process.

3.2.4 Principal components

We extract and use the first principal component of:

1) US government bond yield at 5-year maturity, the US stock market index, US volatility premium and US investment grade;

2) EUR depreciation versus USD 5-year forward, EUR depreciation versus USD and EUR/USD implied volatility using currency options out-of-the-money (10-delta);

3) break-even inflation rate 5-yr forward and the 5-yr euro area OIS rate;

4) euro area stock market volatility, euro area investment grade and KfW-Bund spread;

5) Italian, Spanish and French CDS bid-ask spread;

6) Italian, Spanish and French sovereign yield bid-ask spread;

7) Italian, Spanish and French domestic stock markets;

As robustness check we also use the two principal components extracted from all global and exchange rate variables and the two principal components extracted from all regional variables.

3.3 The empirical results

The variables used in the VAR are the main 18 variables reported in Appendix A: the panel A describes the variables entering in the single country VAR; the panel B describes the variables and the principal components entering in the FAVAR. The lag length of each VAR and FAVAR is 2 based on Akaike information criterion (AIC), suggesting that the dynamic structure are similar across assets prices.

The unconditional correlation between each individual variable and the redenomination risk variables is documented in Table 1. The correlation between the country-specific market perception of redenomination risk and the sovereign yield spreads amounts to 9.2% for Italy, 43.2% for Spain and -4.2% for France highlighted in grey, yellow and blue, respectively.

The correlation among the market perception of redenomination risk premia is reported in the last three columns (see X9-X11): 22.2% between Spain and France, 36% between Spain and

Italy and 39.2% between Italy and France. The correlation between the EUR/USD volatility skew and the redenomination risk premia is statistically significant only for Spain. It is also interesting the strong positive correlation between the Italian and Spanish redenomination risk premia with the euro area corporate spreads, which could be affected also by the degree of investors' risk aversion and aggregate uncertainty particularly important during the euro area sovereign debt crisis.

The residuals of each VAR equation of the control variables (i.e. global variables, exchange rate variables, regional variables and liquidity variables) are mildly correlated with the residuals of the redenomination risk equation (see Table 2). This bodes well with the simple Cholesky factorization. At the same time, it is useful to point out that the correlation is positive and statistically significant between the residuals of the redenomination risk equation and the residuals of the sovereign yield spreads equation (see RES_X18) for Italy and Spain. Also the correlation with the residuals of the EUR/USD volatility skew equation (see RES_X7) for Spain is positive and strongly statistically significant in line with the correlations described in Table 1.

Similarly for the FAVAR model, the residuals of the redenomination risk variables are, as expected, highly correlated among themselves (see RES_X9-RES_X11 in the last three columns) as well vis-à-vis the residuals of the sovereign yield spreads (see RES_X16-RES_X18), but mildly correlated with the residuals of each VAR equation of the control variables. We place the market perception of domestic redenomination risk before the foreign redenomination risks in the Cholesky ordering. This is to say that if the foreign redenomination risk shocks exist than it is over and above the domestic shocks. All in all, the conditional correlations between the redenomination risk residuals and the residuals of the other control variables of the VAR are relatively small.

[Insert Table 2, here]

3.3.1 The impact of redenomination risk

To isolate the redenomination risk shocks we assume that $\mathbf{A}_0$ is recursive with the market perception of redenomination risk ordered last just before the local stock market and the sovereign credit spreads. This implies that we first identify the global and exchange rate shocks including the EUR/USD volatility skew, second we identify the regional and the liquidity shocks, and finally the redenomination risk shocks. As said this assumption is very conservative, as we assume that all common contemporaneous shocks that could affect global variables, exchange

rate variables, regional variables and liquidity variables are not classified as redenomination risk shocks. For example, most likely the EUR/USD volatility skew increases, the euro depreciates against the US dollar and other premia rise with the intensification of the break-up risk. The redenomination risk shocks measure developments that are over and above those measured by standard variables.

The impulse response functions (IRFs) of such shock on sovereign yield spreads is reported in Figure 5 for the four different models: three single-country VAR in the first three rows and one FAVAR in the last three rows. The redenomination risk shocks estimated using the single country VAR and the FAVAR are very similar. This suggests that the results are robust to model specification. The size of the redenomination risk shock is very similar across countries amounting to a standard deviation of 2-3 basis points at impact, but is much more persistent in the case of Italy and Spain. As for the transmission of such shock, the impact is almost twice as large in Spain relative to Italy and relatively smaller in France. The results are very similar when changing the ordering of the variables or using generalized impulse response functions (GIRFs) (see Figure 6). This implies that the results are robust to the ordering of the variables in the VAR. It is important to emphasise that the IRFs and GIRFs are statistically significant, despite the skew of the currency option-implied volatility is ordered first relative to the market perception of redenomination risk.

[Insert Figures 5 and 6, here]

In order to estimate the historical decomposition of the redenomination risk shocks, we rely upon a counterfactual analysis, which assumes that the path for market perception of redenomination risk is zero.[12] The results estimated with the single-country VAR are described in Figure 7, while those estimated with the FAVAR are described in Figure 8.

Focusing on the single-country VAR, under the hypothesis that the redenomination risk shocks are endogenously set to deliver a zero path for market perception of redenomination risk, the key results on sovereign yield spreads are the following (see 'Redenomination risk shock (b)' in Figures 7):

- The contribution of market perception of redenomination risk to the deterministic component of the sovereign yield spreads is marginal across all asset classes.

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[12] The counterfactual analysis is needed because the redenomination risk baseline is biased upward, given that the sample covers the most heightened sovereign crisis period.

- The impact through the stochastic component is relatively large reaching the peak for sovereign yield spreads in January 2012 in Italy and France and April 2012 in Spain at 200 basis points for Italy, 275 basis points for Spain and 35 basis points for France. This implies that during the first quarter of 2012 about 30%, 40% and 50% of the respective French, Italian and Spanish sovereign credit spreads could be explained by redenomination risk shocks.

- During the peak of the crisis in July 2012, redenomination risk shocks accounted for about 165 basis points (= 28%) of the Italian 5-year sovereign yield spread, 270 basis points (= 39%) of the Spanish 5-year sovereign yield spread and 13 basis points (= 28%) of the French 5-year sovereign yield spread.

- After President Draghi's speech in July 2012, the role of redenomination risk as perceived by the market has become gradually and steadily smaller and by end of 2013 we estimate that it has contributed to the size of sovereign yield spreads amounting to 110 basis points in Italy, 160 basis points in Spain and 2 basis points in France.

With the exclusion of global and exchange rate shocks, if all other shocks are endogenously set to deliver a zero path for market perception of redenomination risk, then the results (see 'Combination of all shocks (a)' in Figures 7 are very similar for Spain and France, while the impact is about 50 basis points smaller for Italian sovereign yield spreads.

[Insert Figure 7, here]

The results of the FAVAR (see Figure 8) are not dissimilar from those already presented:

- The contribution of market perception of redenomination risk to the deterministic component of the sovereign yield spreads is marginal across all asset classes. Therefore, they are not reported for the FAVAR.

- The impact through the stochastic component is relatively large reaching the peak for sovereign yield spreads in the first quarter of 2012 in Italy (190 basis points), Spain (250 basis points) and France (22 basis points). This confirms that during the first quarter of 2012 about 30% of French, 40% of Italian and 50% of Spanish sovereign yield spreads could be explained by redenomination risk shocks.

- During the peak of the crisis in July 2012, redenomination risk shocks accounted for about 170 basis points (= 29%) of the Italian 5-year sovereign yield spread, 235 basis points (= 33%) of the Spanish 5-year sovereign yield spread and 9 basis points (= 18%) of the French 5-year sovereign yield spread.

- After President Draghi's speech in July 2012, the role of redenomination risk shocks have become gradually and steadily smaller and by end of 2013 we estimate that it has contributed to the size of sovereign yield spreads amounting to 90 basis points in Italy and 130 basis points in Spain. The contribution of redenomination risk on the French sovereign yield spread was nil by end of 2013.

All in all, market perception of redenomination risk has played a vital role in describing the developments in sovereign yield spreads in Italy, Spain and France over the entire 2011-2013 sample period, supporting Mr. Draghi's worries that investors have been pricing what is an unfounded and undesirable break-up risk. Moreover, the results suggest that the euro area sovereign debt crisis remained an issue for policymakers also in 2013.

[Insert Figure 8, here]

3.3.2 The spillover effect

The final question we address in this paper is whether redenomination risk shocks in other countries have spilled over at home. To test this hypothesis we use the market perception of foreign redenomination risks of the FAVAR placed after the local redenomination risk in the Cholesky ordering. This is to say that if the foreign redenomination risk shocks exist than it is over and above the domestic shocks. The historical decomposition of the spillover (blue solid line) is derived as a difference between a counterfactual in which we assume that both the domestic and the foreign redenomination risk shocks are endogenously set to deliver a zero path for both redenomination risk variables (black dotted line) and a counterfactual in which we assume that only the domestic redenomination risk shocks are endogenously set to deliver a zero path for market perception of domestic redenomination risk (red solid line).

The results reported in Figure 8 suggest that Italy and Spain seem to be less affected from spillover effects, while France is particularly affected by foreign redenomination risk shocks. At peak in April 2012, the spillover effects to French sovereign yield spreads amount to 30 basis

points. At peak, the aggregate (domestic plus foreign) redenomination risk shock account for 40 basis points for French sovereign spreads (about 50% of the actual developments).

The spillover effects of the foreign redenomination risk shocks described in Figure 8 suggest that these measurable new financial risk premia are a source of systemic risk.

3.3.3 Robustness check

The robustness check of the results is carried out including additional information such as the skew of the currency option-implied volatility at 1-year maturity, the EUR/USD 1-month delta-neutral implied volatility, the US price-earnings ratio to proxy for global equity risk premium, the net flows (inflows minus outflows) into mutual funds investing primarily in bonds and equity, the US CDS spread, the credit spreads of other sovereign in particular the average credit spread for all the other euro area countries, the local expected budget deficit to GDP ratio computed using the consensus forecast, the German sovereign spread, commodity prices. Finally, we also employ market perception of redenomination risk at 5-year maturity. All the results shown in this paper remain broadly similar.

The results also do not change if the same variables are included in the FAVAR or if the first two principle components are extracted from the global and exchange rate variables or from the regional variables. Finally, also the results of the model in first difference discussed in Appendix B should be treated as a robustness check exercise suggesting that the redenomination risk measures do price significantly and instantaneously sovereign yield spreads.

4   Conclusions

Redenomination risk is one of the key factors behind the pricing of sovereign credit spreads, particularly of Italian and Spanish sovereigns in 2012. We have addressed this issue empirically by proposing a measure of country-specific redenomination risk based on CDS contracted in US dollar and euro. Specifically, we argue that the difference between the quanto CDS of one of euro area sovereign (i.e. Italy, Spain and France) and the German quanto CDS can act as a good observable measure of market perception of intra-euro area redenomination risk, which behaves according to expectations, namely rising in the first half of 2012 and declining after the speech by Draghi in July 2012. More specifically, after the speech, market perception of redenomination risk fluctuated around zero for France and around 20 basis points for Italy and

Spain, while it was positive and large in the first half of 2012.

The probability of a credit event with the break-up of the euro area was considered to be a possibility by the financial markets and investors must have been considering their risk management options hedging against the risk of some changes in the structure of the euro area. This is the reason why the euro area countries' quanto CDS relative to Germany is a valuable, observable redenomination risk measure as perceived by the market.

We study whether this measure prices sovereign yield spreads. The results show clearly that this is the case with the countries most adversely affected being Italy and Spain. At the time of its maximum impact in the first quarter of 2012, a decomposition of both CDS and sovereign yield spreads suggests that about 30%, 40% and 50% of the respective French, Italian and Spanish sovereign credit spreads was due to redenomination risk shocks.

Finally, we test the spillover effects defined as the transmission of the foreign redenomination risk shocks to domestic markets over and above the domestic effects. The results suggest that Italy and Spain are less affected from spillovers, while France are also affected by foreign redenomination risk shocks. Given the economic significance of both domestic redenomination risk shocks and its spillover effect, then this risk is systemic for the euro area.

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Figure 1. Sovereign Bond Yields and Spreads at 5-Year Maturity in Italy, Spain, France and Germany *(Basis points, sample period: 1 Jan. 2008 – 12 Nov. 2013)*

Sovereign yields
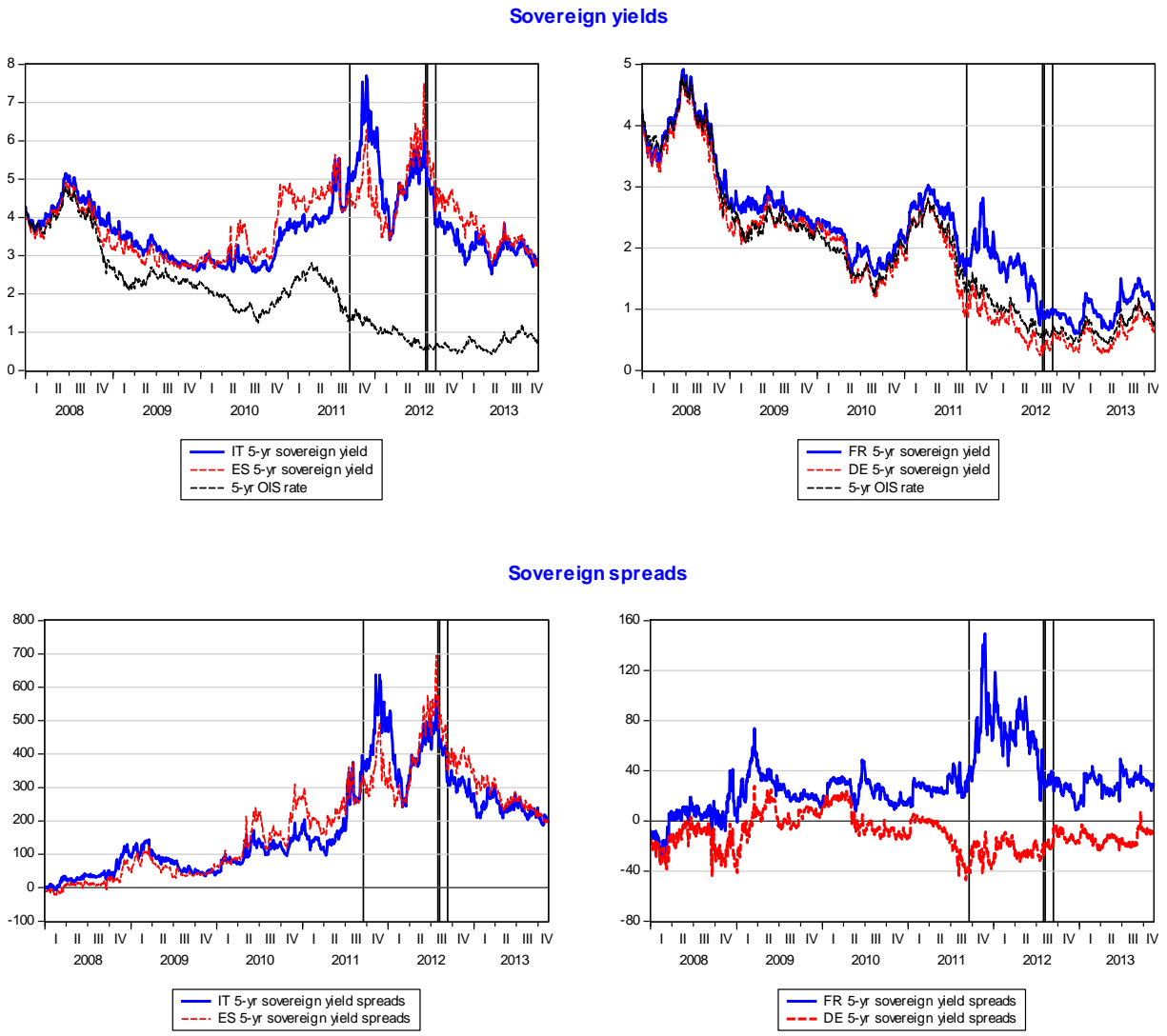
Sovereign spreads

Sources: Bloomberg and Thomson Reuters.
Note: The sovereign yield spread at 5-year maturity is the difference between the benchmark bond yield and the Euro Overnight Interest Rate Swaps (OIS) rate at 5-year maturity. The CDS spread is US dollar denominated. The four vertical bars denote the beginning of the sample of this study on 13 September 2011, the day of Mr. Draghi's speech in London on 26 July 2012 and the days of the ECB press conference on 2 August 2012 and 6 September 2012, respectively.

Figure 2. USD- and EUR-denominated CDS spreads at 3- and 5-Year Maturity in Italy, Spain, France and Germany *(Basis points, sample period: 1 Sept. 2011 – 12 Nov. 2013)*
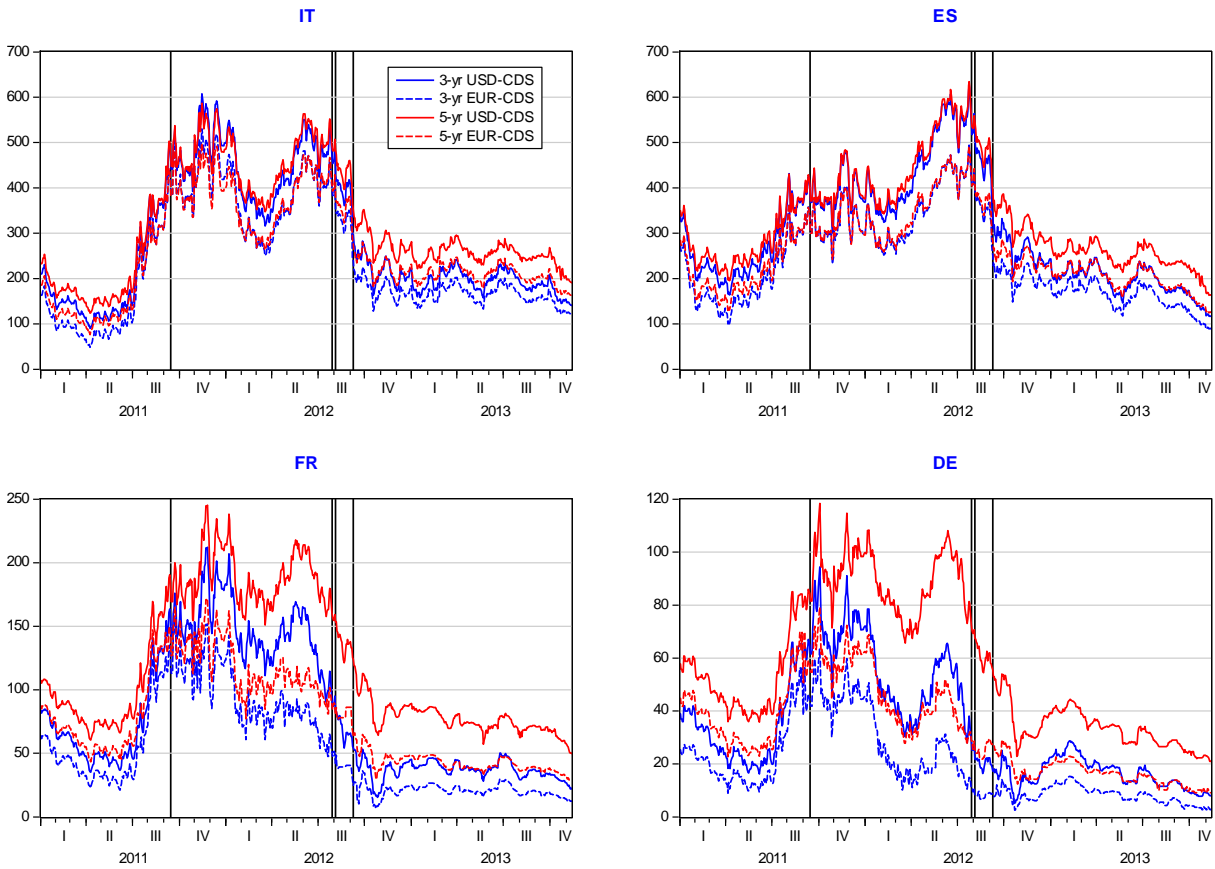
Sources: Thomson Reuters.
Notes: The Figure provides the USD- and EUR denominated CDS spreads at 3- and 5-year maturity for Italian, Spanish, French and German sovereign contracts. The quanto CDS is the difference between the USD- and EUR-denominated CDS spread. The four vertical bars denote the beginning of the sample of this study on 13 September 2011, the day of Mr. Draghi's speech in London on 26 July 2012 and the days of the ECB press conference on 2 August 2012 and 6 September 2012, respectively.
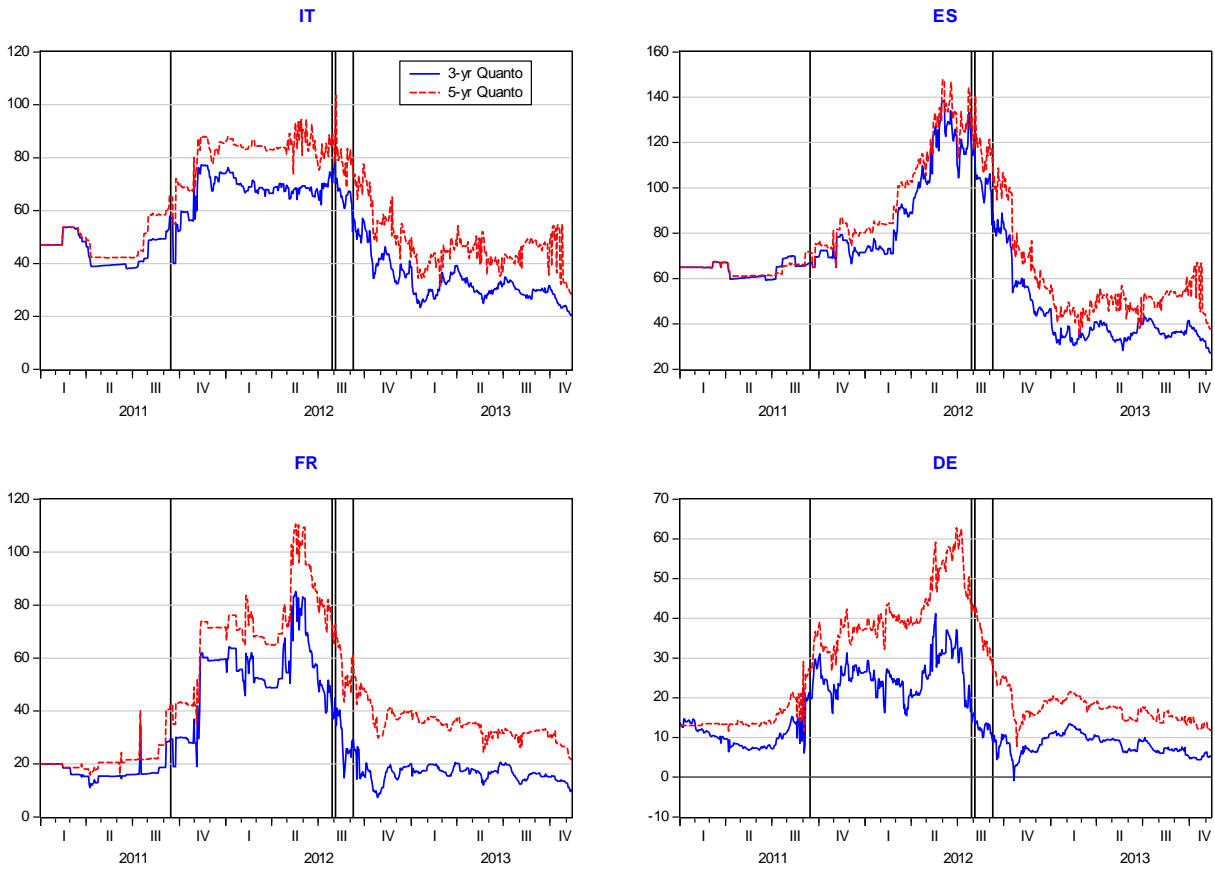
Figure 3. Quanto CDS at 3- and 5-Year Maturity in Italy, Spain, France and Germany
(Basis points, sample period: 1 Sept. 2011 – 12 Nov. 2013)

Figure 4. The redenomination risk premium at 3- and 5-Year Maturity in Italy, Spain and France
(Basis points, sample period: 1 Sept. 2011 – 12 Nov. 2013)
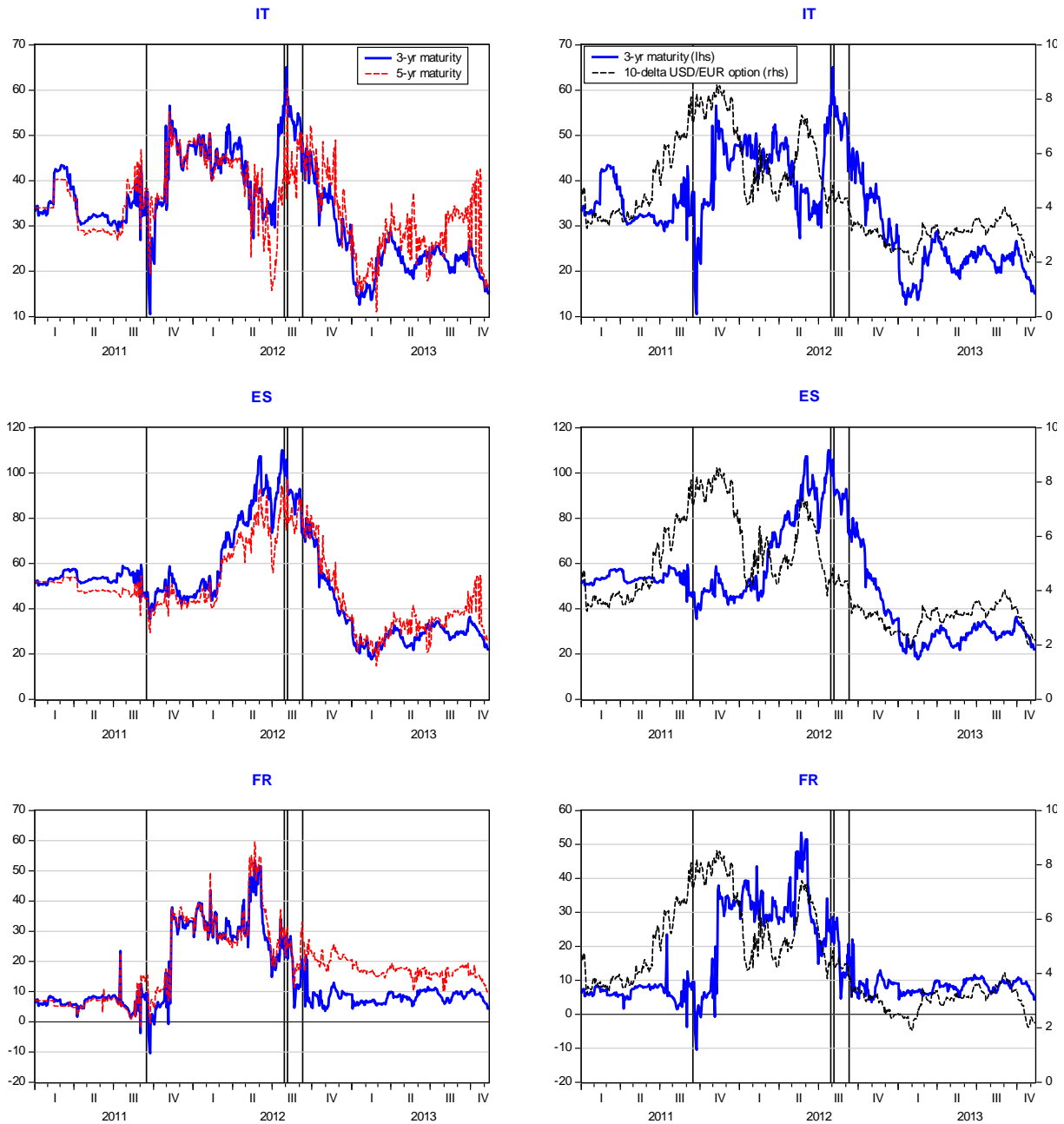
Sources: Thomson Reuters and own calculations.
Notes: The redenomination risk at 3(5)-year maturity is the difference between the quanto CDS for Italian, Spanish and French sovereign and the quanto CDS for German sovereign at 3(5)-year maturity. The 10-delta USD/EUR option measured to the right scale is the 10-delta dollar-euro option implied volatility either at 1-year maturity. The four vertical bars denote the beginning of the sample of this study on 13 September 2011, the day of Mr. Draghi's speech in London on 26 July 2012 and the days of the ECB press conference on 2 August 2012 and 6 September 2012, respectively.
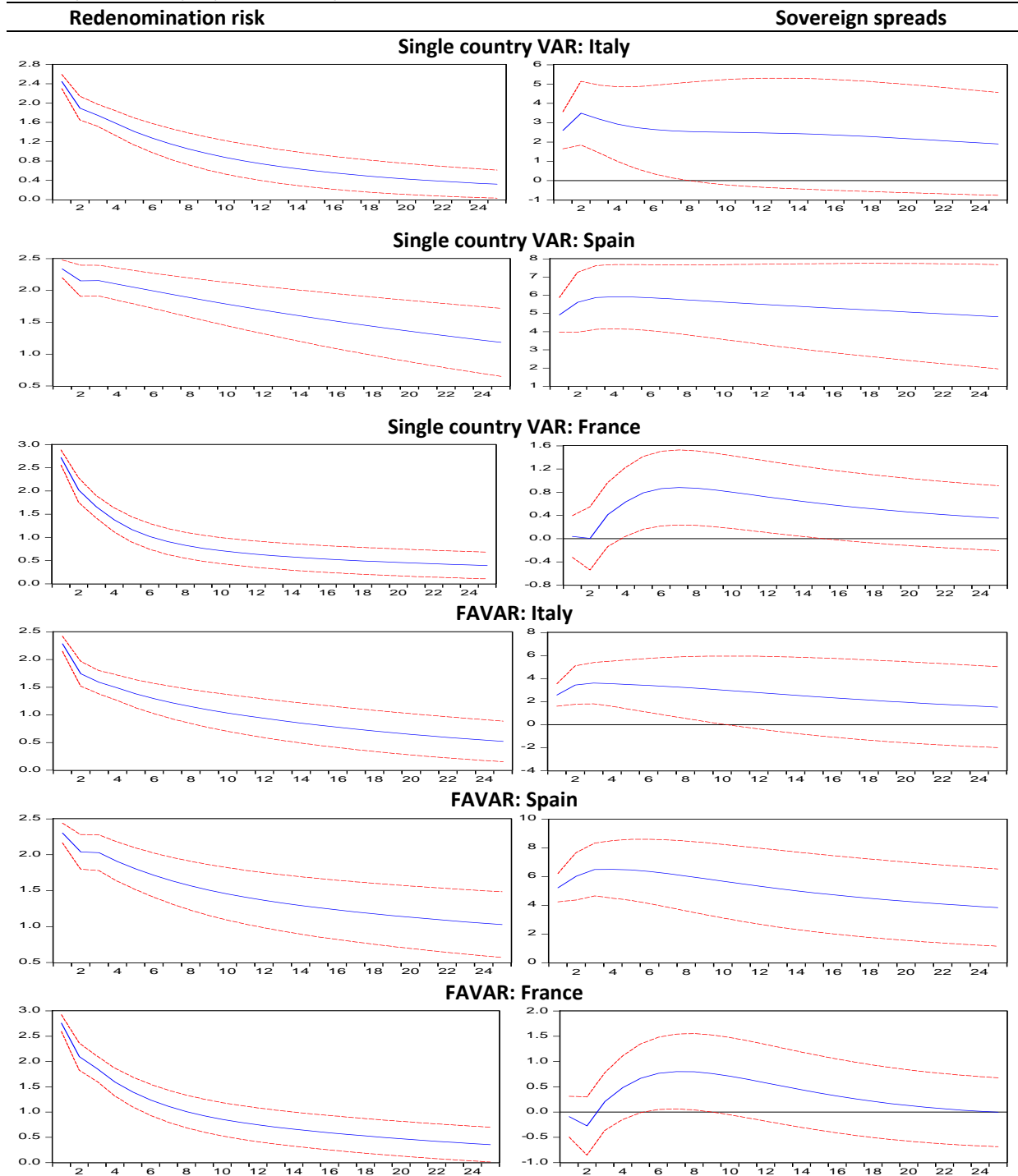
Figure 5. Impact of 1 Standard Deviation Redenomination Risk Shock (IRF) on Sovereign Yield Spreads at 5-Year Maturity in Italy, Spain and France

(Basis points, sample period: 13 Sept. 2011 – 12 Nov. 2013)

Notes: This figure reports the impulse response functions of one standard deviation redenomination risk shock. The shock is identified using the recursive approach after estimation of a VAR. The single country VAR orders the variable as follows: X1 = US government bond yield at 5-year maturity, X2 = the US stock market index, X3 = US volatility premium, X4 = US investment grade, X5 = EUR depreciation versus USD 5-year forward, X6 = EUR depreciation versus USD, X7 = 10 delta EUR/USD implied volatility, X8 = Break even inflation rate 5-yr forward, X9 = German 5-yr CDS, X10 = EA 5-yr OIS, X11 = euro area stock market volatility, X12 = euro area investment grade, X13. KfW-Bund spread, X14 = Greek sovereign spread, X15 = CDS or Sovereign yield bid-ask spread, X16 = Redenomination risk, X17 = Domestic stock market, X18 = CDS or Sovereign yield spreads. The FAVAR orders the variable with the following order: X1 = US 1st PC, X2 = FX 1st PC, X3 = EA 1st PC, X4 = German 5-yr CDS, X5 = EA risk 1st PC, X6 = Greek sovereign spread, X7 = CDS bid-ask spread 1st PC, X8 = Sovereign yield bid-ask spread 1st PC, X9-11 = FR/IT/ES Redenomination risk, X12 = Domestic stock market 1st PC, X13-X15 = FR/IT/ES CDS spreads, X16-X18 = FR/IT/ES Sovereign yield spreads. The variables are described in Appendix A.

Figure 6. Impact of 1 Standard Deviation Redenomination Risk Shock (GIRF) on Sovereign Yield Spreads at 5-Year Maturity in Italy, Spain and France

(Basis points, sample period: 13 Sept. 2011 – 12 Nov. 2013)
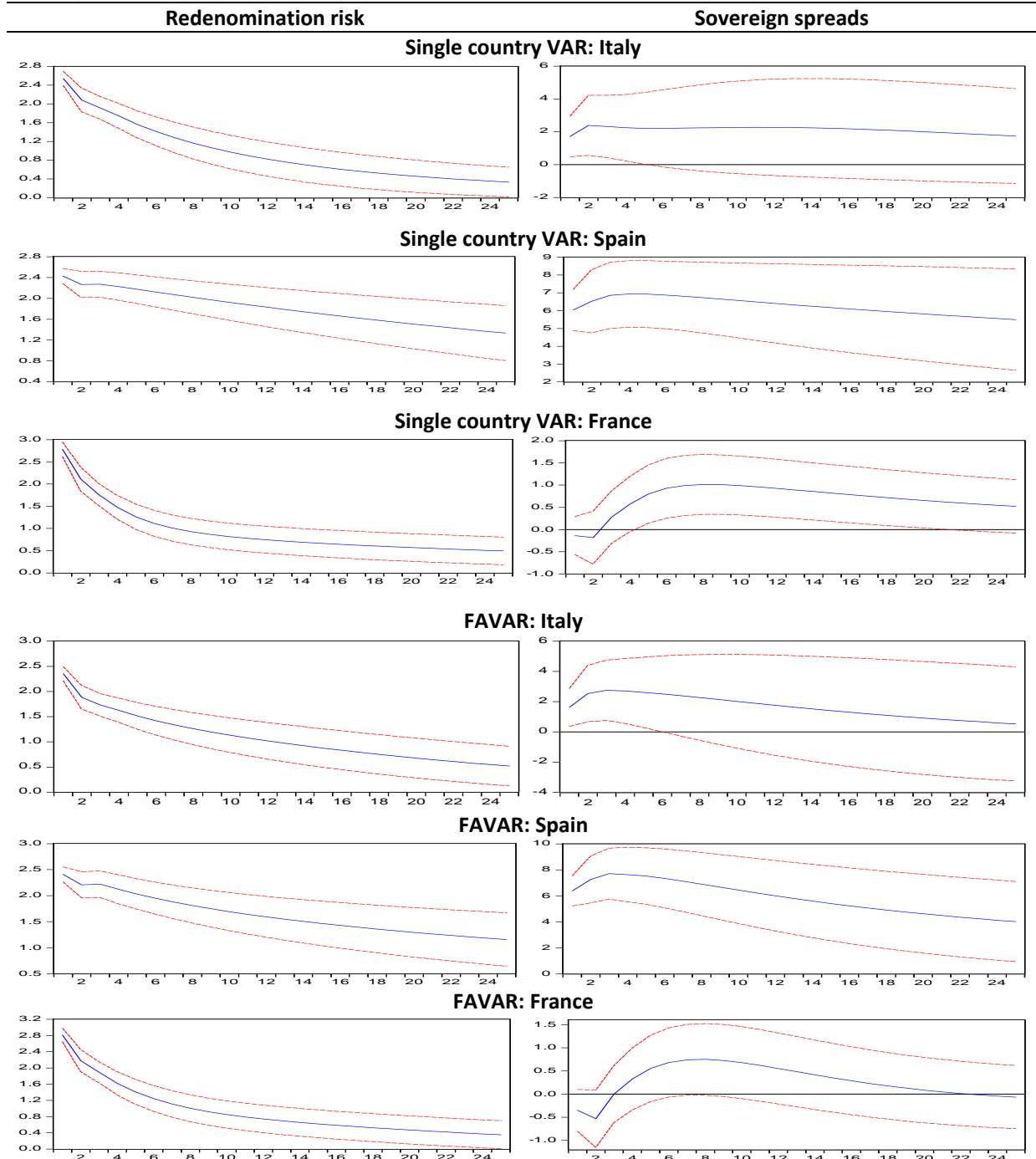
Notes: This figure reports the generalized impulse response functions of one standard deviation redenomination risk shock. The shock is identified using the recursive approach after estimation of a VAR. The single country VAR orders the variable as follows: X1 = US government bond yield at 5-year maturity, X2 = the US stock market index, X3 = US volatility premium, X4 = US investment grade, X5 = EUR depreciation versus USD 5-year forward, X6 = EUR depreciation versus USD, X7 = 10 delta EUR/USD implied volatility, X8 = Break even inflation rate 5-yr forward, X9 = German 5-yr CDS, X10 = EA 5-yr OIS, X11 = euro area stock market volatility, X12 = euro area investment grade, X13. KfW-Bund spread, X14 = Greek sovereign spread, X15 = CDS or Sovereign yield bid-ask spread, X16 = Redenomination risk, X17 = Domestic stock market, X18 = CDS or Sovereign yield spreads. The FAVAR orders the variable with the following order: X1 = US 1st PC, X2 = FX 1st PC, X3 = EA 1st PC, X4 = German 5-yr CDS, X5 = EA risk 1st PC, X6 = Greek sovereign spread, X7 = CDS bid-ask spread 1st PC, X8 = Sovereign yield bid-ask spread 1st PC, X9-11 = FR/IT/ES Redenomination risk, X12 = Domestic stock market 1st PC, X13-X15 = FR/IT/ES CDS spreads, X16-X18 = FR/IT/ES Sovereign yield spreads. The variables are described in Appendix A.

Figure 7. Impact of Domestic Redenomination Risk on Sovereign Yield Spreads at 5-Year Maturity in Italy, Spain and France: Historical Decomposition of the Shock from single country VAR

(Basis points, sample period: 13 Sept. 2011 – 12 Nov. 2013)

Panel A: Observed and counterfactual levels of sovereign yield spreads	*Panel B: Stochastic and deterministic components*
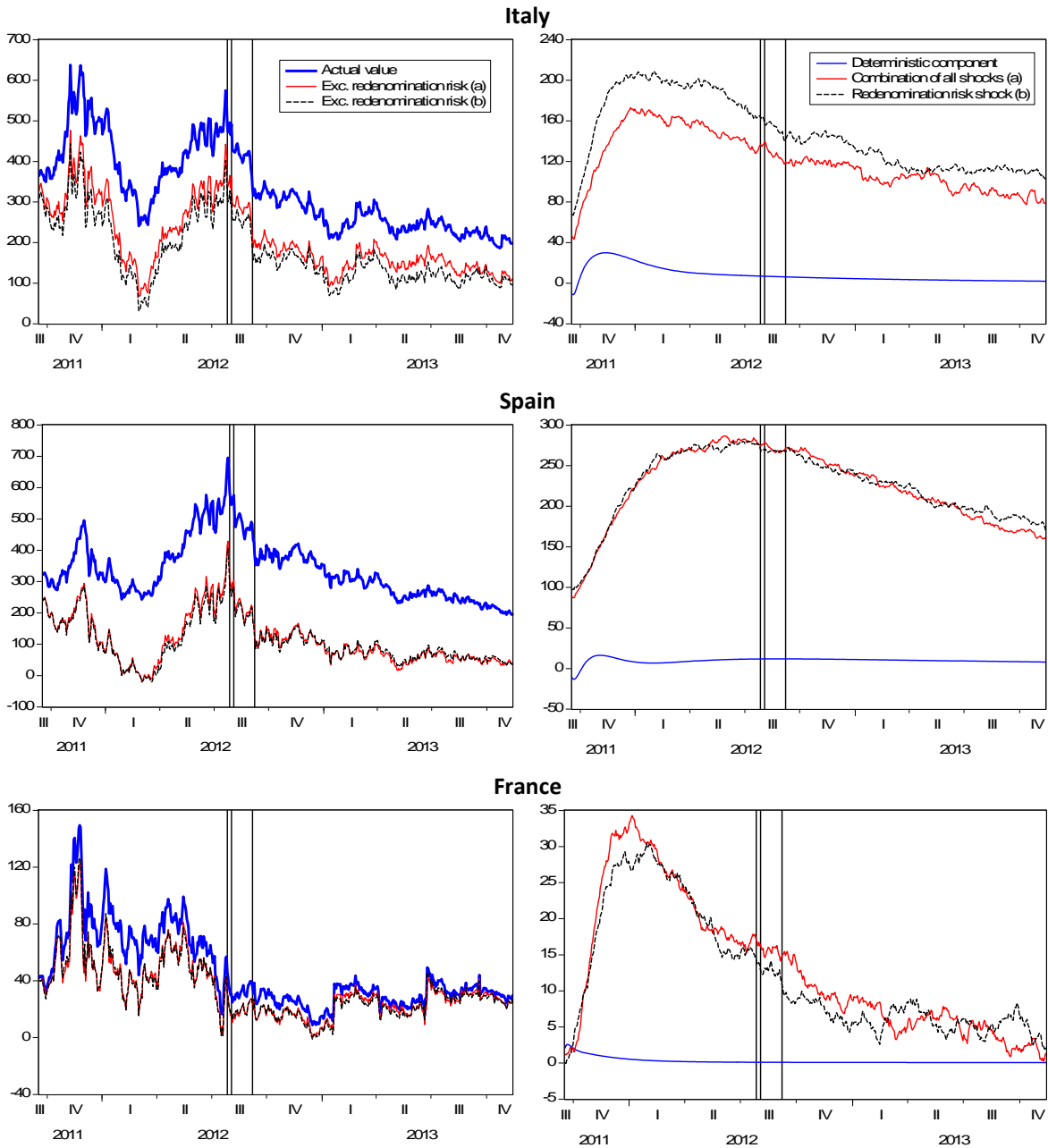
Notes: This figure reports the impact of the redenomination risk through counterfactual simulations as described in equations 16 and 18. Panel A shows the sovereign yield spread and its counterfactual when the redenomination risk is set to zero. Panel B shows the impact of the redenomination risk on the sovereign yield spread decomposing the deterministic component from the stochastic component. The counterfactuals are obtained under the hypothesis that the redenomination risk is zero. An agnostic linear combination of all shocks is employed to compute the counterfactual dubbed "combination of all shocks (a)". The redenomination risk shock is endogenously determined to compute the counterfactual dubbed "redenomination risk shock (b)". The variables are described in Appendix A. The three vertical bars denote the day of Mr. Draghi's speech in London on 26 July 2012 and the days of the ECB press conference on 2 August 2012 and 6 September 2012, respectively.

Figure 8. Impact of Domestic and Foreign Redenomination Risk on Sovereign Yield Spreads at 5-Year Maturity in Italy, Spain and France: Historical Decomposition of the Shock from FAVAR
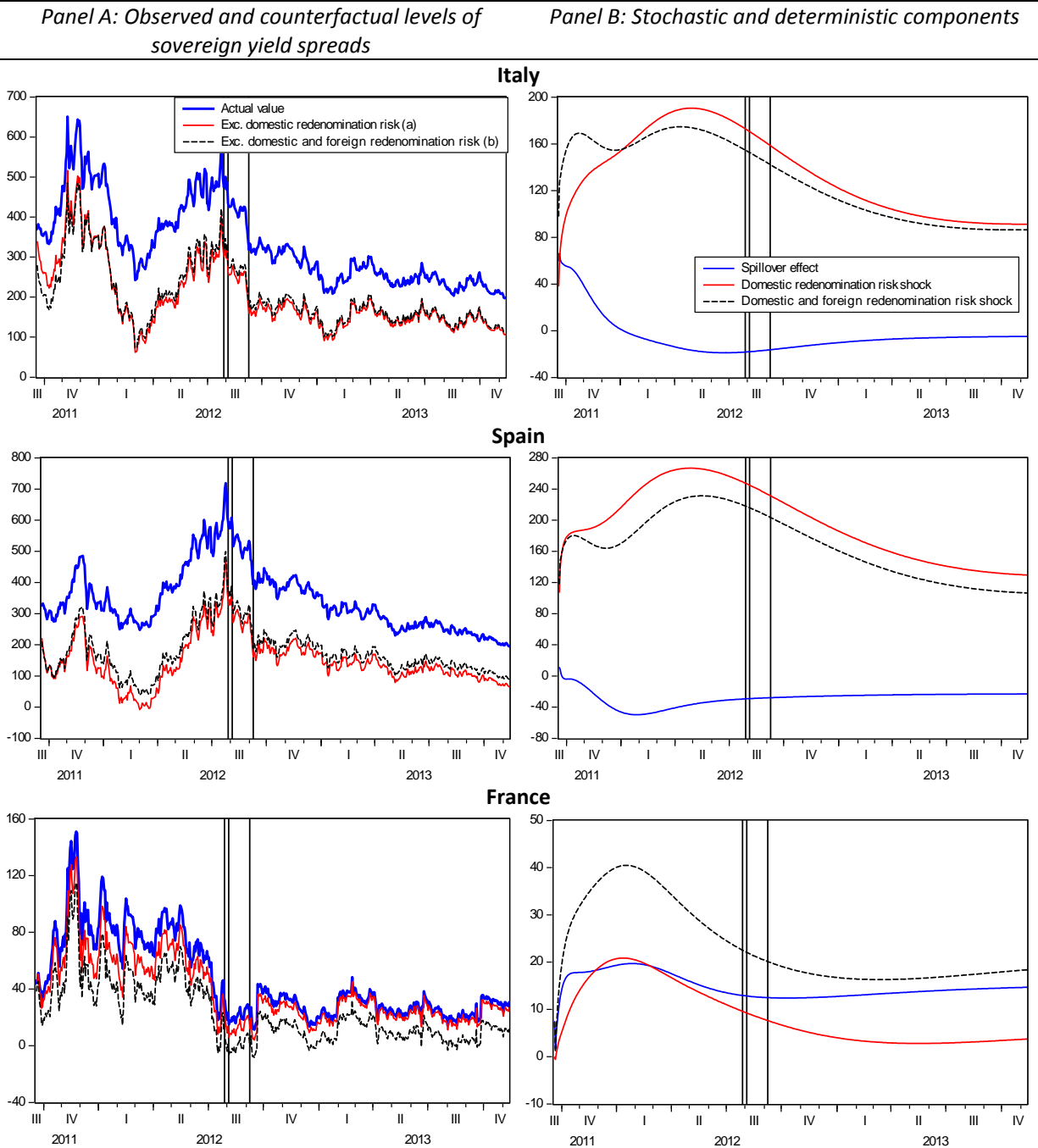*(Basis points, sample period: 13 Sept. 2011 – 12 Nov. 2013)*

Panel A: Observed and counterfactual levels of sovereign yield spreads

Panel B: Stochastic and deterministic components

Notes: This figure reports the impact of the redenomination risk through counterfactual simulations as described in equation 18. Panel A shows the sovereign yield spread and its counterfactual when the redenomination risk is set to zero. Panel B shows the impact of the redenomination risk on the sovereign yield spread decomposing the stochastic component into the domestic component and the foreign spillover component. The counterfactual "domestic redenomination risk shock" is obtained under the hypothesis that the domestic redenomination risk is zero and the domestic redenomination risk shock is endogenously determined. The counterfactual "domestic and foreign redenomination risk shock" is obtained under the hypothesis that both the domestic redenomination risks are zero and the domestic and foreign redenomination risk shocks are endogenously determined. The historical decomposition of the spillover (blue solid line) is derived as a difference between the two counterfactuals. The variables are described in Appendix A. The three vertical bars denote the day of Mr. Draghi's speech in London on 26 July 2012 and the days of the ECB press conference on 2 August 2012 and 6 September 2012, respectively.

Table 1. Unconditional Correlations of the Variables vis-à-vis Redenomination Risk
(Sample period: 13 Sept. 2011 – 12 Nov. 2013)

	Single country VAR			FAVAR		
	Italy	**Spain**	**France**	**IT**	**ES**	**FR**
X1	-0.062	-0.153***	-0.012	0.044	0.104**	-0.033
X2	0.065	-0.129*	0.049	-0.075*	0.081*	-0.095*
X3	-0.030	0.053	-0.011	-0.005	-0.04	0.012
X4	0.008	0.093**	-0.001	-0.178***	0.025	-0.116***
X5	-0.001	0.013	0.019	0.017	0.149***	-0.013
X6	0.01	0.086**	0.04	0.01	0.018	-0.047
X7	-0.043	0.119***	0.021	-0.051	-0.025	-0.089**
X8	0.032	-0.075*	-0.026	0.024	0.119***	-0.056
X9	-0.179***	0.054	-0.112***	**0.392*****	**0.222*****	**1.000**
X10	-0.037	-0.109**	0.028	**1.000**	**0.360*****	**0.392*****
X11	-0.065	0.122***	-0.049	**0.360*****	**1.000**	**0.222*****
X12	0.112***	0.11***	-0.004	-0.067*	-0.092**	-0.015
X13	-0.038	0.148***	0.04	-0.087**	0.102**	-0.073*
X14	0.003	0.095**	-0.047	0.024	0.263***	-0.077*
X15	-0.021	0.054	-0.017	0.031	0.327***	-0.028
X16	1.000	1.000	1.000	-0.004	0.066*	-0.039
X17	0.006	-0.31***	0.024	0.109***	0.255***	-0.052
X18	0.092**	0.432***	-0.042	0.121***	0.393***	0.021

Notes: This table reports the unconditional correlation coefficients of the variables in first difference vis-à-vis the redenomination risk.

The variables of the single country VAR are: X1 = US government bond yield at 5-year maturity, X2 = the US stock market index, X3 = US volatility premium, X4 = US investment grade, X5 = EUR depreciation versus USD 5-year forward, X6 = EUR depreciation versus USD, X7 = 10 delta EUR/USD implied volatility, X8 = Break even inflation rate 5-yr forward, X9 = German 5-yr CDS, X10 = EA 5-yr OIS, X11 = euro area stock market volatility, X12 = euro area investment grade, X13. KfW-Bund spread, X14 = Greek sovereign spread, X15 = Sovereign yield bid-ask spread, X16 = Redenomination risk, X17 = Domestic stock market, X18 = Sovereign yield spreads.

The variables of the FAVAR are: X1 = US 1st PC, X2 = FX 1st PC, X3 = EA 1st PC, X4 = German 5-yr CDS, X5 = EA risk 1st PC, X6 = Greek sovereign spread, X7 = CDS bid-ask spread 1st PC, X8 = Sovereign yield bid-ask spread 1st PC, X9-11 = FR/IT/ES Redenomination risk, X12 = Domestic stock market 1st PC, X13-X15 = FR/IT/ES CDS spreads, X16-X18 = FR/IT/ES Sovereign yield spreads.

The variables are described in Appendix A. *, **, *** denotes statistical significance at 10%, 5% and 1% level, respectively.

Table 2. Correlation Analysis of the VAR Residuals of the 5-year CDS and Sovereign Yield Spread vis-à-vis the Residuals of the Redenomination Risk Equations

(Sample period: 13 Sept. 2011 – 12 Nov. 2013)

	Single country VAR			FAVAR		
	Italy	**Spain**	**France**	**Italy**	**Spain**	**France**
RES_X1	-0.050	-0.155***	-0.028	0.072*	0.130***	-0.043
RES_X2	0.079*	-0.133***	0.045	-0.063	0.085**	-0.093**
RES_X3	0.013	0.055	0.002	-0.038	-0.057	0.002
RES_X4	0.034	0.09**	0.003	-0.157***	0.010	-0.134***
RES_X5	-0.039	-0.028	-0.025	0.04	0.139***	0.029
RES_X6	-0.075*	0.075*	-0.046	0.022	0.034	-0.032
RES_X7	-0.044	0.11**	0.002	0.048	-0.017	0.098**
RES_X8	-0.005	-0.078*	-0.044	0.079	0.120***	-0.018
RES_X9	-0.172***	0.045	-0.089**	**1.000**	**0.414*****	**0.382*****
RES_X10	-0.055	-0.145***	-0.016	**0.414*****	**1.000**	**0.239*****
RES_X11	-0.069	0.125***	-0.015	**0.382*****	**0.239******	**1.000**
RES_X12	0.136***	0.098**	-0.032	-0.059	-0.223***	0.008
RES_X13	-0.025	0.165***	0.091**	0.098**	0.247***	-0.043
RES_X14	0.005	0.087**	0.049	0.100**	0.308***	0.007
RES_X15	-0.025	0.051	-0.017	-0.033	0.1**	-0.066
RES_X16	1.000	1.000	1.000	0.163***	0.242***	-0.078*
RES_X17	0.013	-0.288***	0.01	0.098**	0.220***	-0.037
RES_X18	0.092**	0.419***	-0.027	-0.002	-0.002	-0.073*

Notes: This table reports the correlation coefficients of the residuals of the VAR vis-à-vis the residuals of the redenomination risk equations.

The variables of the single country VAR are: X1 = US government bond yield at 5-year maturity, X2 = the US stock market index, X3 = US volatility premium, X4 = US investment grade, X5 = EUR depreciation versus USD 5-year forward, X6 = EUR depreciation versus USD, X7 = 10 delta EUR/USD implied volatility, X8 = Break even inflation rate 5-yr forward, X9 = German 5-yr CDS, X10 = EA 5-yr OIS, X11 = euro area stock market volatility, X12 = euro area investment grade, X13. KfW-Bund spread, X14 = Greek sovereign spread, X15 = Sovereign yield bid-ask spread, X16 = Redenomination risk, X17 = Domestic stock market, X18 = Sovereign yield spreads.

The variables of the FAVAR are: X1 = US 1st PC, X2 = FX 1st PC, X3 = EA 1st PC, X4 = German 5-yr CDS, X5 = EA risk 1st PC, X6 = Greek sovereign spread, X7 = CDS bid-ask spread 1st PC, X8 = Sovereign yield bid-ask spread 1st PC, X9-11 = FR/IT/ES Redenomination risk, X12 = Domestic stock market 1st PC, X13-X15 = FR/IT/ES CDS spreads, X16-X18 = FR/IT/ES Sovereign yield spreads.

The variables are described in Appendix A. *, **, *** denotes statistical significance at 10%, 5% and 1% level, respectively.

APPENDIX A: The Data Set

This appendix provides additional details about the definition, sources and timing of the data used in the study.

Panel A: Main Variables of the single country VAR

X1 = US government bond yield at 5-year maturity.
The US government bond yield at 5-year maturity is United States 5-year government benchmark bond yield in US dollar provided by Bloomberg.

X2 = the US stock market index.
The US stock market is the Thomson DataStream Global Equity Index for the United States provided by Thomson Reuters.

X3 = US volatility premium.
The US volatility premium is calculated as the difference between the VIX index (obtained from Thomson Reuters) and a measure of realised volatility for the US stock market obtained as a GARCH(1,1) on the daily US stock market returns.

X4 = US investment grade.
The US investment grade is the spread between the United States corporate BBB and AAA 7-10-year (USD) Merrill Lynch Bond Index provided by Thomson Reuters.

X5 = EUR depreciation versus USD 5-year forward.
The euro depreciation versus USD 5-year forward is computed using the covered interest rate parity condition as a difference between the euro area and the US OIS risk free rates at 5-year maturity. The Euro and USD Overnight Interest Swaps (OIS) rate at 5-year maturity are provided by Bloomberg.

X6 = EUR depreciation versus USD.
The exchange rate is expressed as units of euro per US dollar and is obtained from the ECB.

X7 = 10-delta EUR/USD implied volatility.
The 10-delta dollar-euro option implied volatility is the difference in the US Dollar/Euro 1-month or 1-year Black-Scholes implied volatilities of an out-of-the-money 10-delta call option and an out-of-the-money 10-delta put option for OTC currency option markets provided by Bloomberg. A dollar-euro put (call) option is a European option of selling (buying) euro at the contractual option strike price in an exchange of US dollars at the option maturity.

X8 = Break-even inflation rate 5-yr forward.
The break-even inflation rate 5-yr forward is the five-year forward break-even inflation rate five years ahead provided by the ECB.

X9 = German 5-yr CDS.
The German CDS spreads are obtained from Bloomberg. They are midmarket indicative prices for five-year sovereign CDS contracts.

X10 = EA 5-yr OIS.
The EA 5-yr OIS is the Euro OIS rate at 5-year maturity provided by Bloomberg.
X11 = Euro area stock market volatility.
The euro area stock market volatility is the realised volatility for the euro area stock market obtained as a GARCH(1,1) on the daily euro area stock market returns provided by Thomson DataStream.

X12 = Euro area investment grade.
The euro area investment grade is the spread between the European Monetary Union corporate BBB and AAA 7-10-year (Euro) Merrill Lynch Bond Index provided by Thomson DataStream.

X13 = KfW-Bund spread.
The KfW-Bund spread is the difference between the 5-year KfW (`Kreditanstalt für Wiederaufbau') bond and the German sovereign bond (i.e. Bund). They are both guaranteed by the German government and, therefore, carry the same default risk. Any differences between agency and government bond yields should reflect international investors' preference for assets with the lowest liquidity risk.

X14 = Greek sovereign spread.
The Greek sovereign spread is the difference between the 10-year Greek sovereign bond and the 10-year Euro OIS provided by Bloomberg.

X15 = Sovereign yield bid-ask spread.
The sovereign bid-ask spread is the difference between the 5-year bid and ask EUR-denominated sovereign yield provided by Bloomberg.

X16 = Market perception of redenomination risk.
Market perception of redenomination risk is defined as a difference between the quanto CDS of Italy, Spain or France and the quanto CDS of Germany. The USD- and EUR-denominated CDS at 3-year maturity are provided by Thomson Reuters.

X17 = Domestic stock market.
The domestic stock market is the Thomson DataStream Global Equity Index for the country provided by Thomson Reuters.

X18 = Sovereign yield spreads.
The sovereign yield spreads are the difference between the 5-year EUR-denominated sovereign bond of Italy, Spain and France and the 5-year Euro OIS rate provided by Bloomberg. They are midmarket prices for five-year sovereigns.

Panel B: Main Variables of the FAVAR

X1 = US 1st PC
US 1st PC is the first principal component of US government bond yield at 5-year maturity, the US stock market index, US volatility premium and US investment grade.

X2 = FX 1st PC
FX 1st PC is the first principal component of EUR depreciation versus USD 5-year forward, EUR depreciation versus USD, EUR/USD implied volatility or 10-delta EUR/USD implied volatility.

X3 = EA 1st PC is the first principal component of break-even inflation rate 5-yr forward and the EA 5-yr OIS.

X4 = German 5-yr CDS
The German CDS spreads are midmarket indicative prices for five-year sovereign CDS contracts.

X5 = EA risk 1st PC
EA risk 1st PC is the first principal component of euro area stock market volatility, euro area investment grade and KfW-Bund spread.

X6 = Greek sovereign spread
The Greek sovereign spread is the difference between the 10-year Greek sovereign bond and the 10-year Euro OIS rate.

X7 = CDS bid-ask spread 1st PC
CDS bid-ask spread 1st PC is the first principal component of Italian, Spanish and French CDS bid-ask spread.

X8 = Sovereign yield bid-ask spread 1st PC
Sovereign yield bid-ask spread 1st PC is the first principal component of Italian, Spanish and French sovereign yield bid-ask spread.

X9-11 = IT/ES/FR Market Perception of Redenomination risk
Market perception of redenomination risk is defined as a difference between the quanto CDS of Italy, Spain or France and the quanto CDS of Germany at 3-year maturity.

X12 = Domestic stock market 1st PC
Domestic stock market 1st PC is the first principal component of Italian, Spanish and French domestic stock markets

X13-X15 = IT/ES/FR CDS spreads
The CDS spreads for Italy, Spain and France are midmarket indicative prices for five-year USD-denominated sovereign CDS contracts.

X16-X18 = IT/ES/FR Sovereign yield spreads.
The sovereign yield spreads are the difference between the 5-year EUR-denominated sovereign bond of Italy, Spain and France and the 5-year Euro OIS rate. They are midmarket prices for five-year sovereigns.

Variables used as robustness check:
• The US price-earnings ratio is based on the Thomson DataStream Global Equity Index for the United States provided by Thomson Reuters.
• The net flows (inflows minus outflows) into mutual funds are obtained from EPFR Global.
• The CDS spreads for the United States are provided by Bloomberg. They are midmarket indicative prices for five-year CDS contracts. The CDS contract references the sovereign.
• The credit spreads of other sovereigns is computed as an average of CDS spreads all the other euro area countries.
• The EUR/USD implied volatility, namely the US Dollar/Euro 1-month delta-neutral straddle Black-Scholes implied volatility for OTC currency option markets provided by Bloomberg.
• The 10-delta dollar-euro option 1-year implied volatility provided by Bloomberg.
• The local expected budget deficit to GDP ratio is computed as a ratio between the expected budget balance and the expected nominal GDP; the latter in turn computed using expected inflation and GDP growth. The data provider is consensus forecast. The observations are monthly.
• The German sovereign spread is the difference between the 5-year Bund and the 5-year Euro OIS rate provided by Bloomberg. They are midmarket prices for five-year sovereigns.
• The commodity prices are gold and oil provided by Thomson Reuters.
• The redenomination risk at 5-year maturity is defined as a difference between the quanto CDS of Italy, Spain or France and the quanto CDS of Germany at 5-year maturity. The USD- and EUR-denominated CDS at 5-year maturity are provided by Thomson Reuters.
• The first two principle components extracted from the global and exchange rate variables specifically for the FAVAR.
• The first two principle components extracted from the regional variables specifically for the FAVAR.

Appendix B: Regression analysis using first differences

Following Longstaff, et al. (2011), who regress the monthly changes in the sovereign CDS spreads on a large set of explanatory variables, we regress the daily changes in the 5-year sovereign yield spreads on the daily changes of the redenomination risk controlling for a large set of domestic, regional and global variables described in Appendix A. Table B1 reports the coefficients and the standard errors based on Newey-West heteroskedasticity- and autocorrelation-consistent estimates of the covariance matrix and adjusted R^2 for each of the six regressions.

Focusing on the redenomination risk, the change in local quanto CDS relative to Germany is strongly statistically significant (at 1 percent level) for Italian and Spanish sovereigns with coefficients amounting to 0.9 and 1.9, respectively. This variable is not statistically significant in explaining French sovereign spreads instantaneously. This implies that an increase in the break-up risk measured by the identified variable is clearly priced in the Italian and Spanish sovereign debt markets. Conversely, the EUR/USD volatility skew is not statistically significant.

Local stock market returns are also strongly statistically significant for all sovereigns (at 1 percent level) and with the negative sign, indicating that good news for the local stock market is also good news for sovereign yield spreads.

The German CDS spread is likewise very important in explain variations in sovereign credit risk. All the coefficients are statistically significant (at 1 percent level) acting as a common factor for euro area credit spreads as well as sovereign yield spreads. On the contrary the US variables including the US CDS spread (here not reported) are generally not statistically significant, except for the US stock market returns on Spanish sovereign yield spreads. This suggests that regional forces in the euro area are at play to explain sovereign spreads.

Another variable which is statistically significant particularly for the sovereign debt market is the euro area investment grade spreads. The coefficients are negative being potentially the result of substitution effects between sovereign and corporate bonds during the sample period, as shocks induce investors to reallocate capital across different asset classes.

Interesting is also the negative coefficient on the OIS rate, which suggest that the pass-through of monetary policy on sovereign yields is not complete at least instantaneously.

Finally, the changes in sovereign yield spreads are persistent for Italy and Spain.

Given the daily frequency of the sample size, the adjusted R^2 are fairly high. The adjusted R^2 ranges between 25 and 50 percent.

Table B1. The Determinants of Sovereign Yields Spreads at 5-Year Maturity in Italy, Spain and France: OLS Regression in First Difference *(Sample period: 13 Sept. 2011 – 12 Nov. 2013)*

	Italy	Spain	France
Local variables			
Lagged dependent variable	0.123**	0.088***	0.000
s.e.	(0.041)	(0.035)	(0.061)
Redenomination risk	0.899***	1.867***	-0.031
s.e.	(0.236)	(0.341)	(0.117)
Domestic stock market	-4.788***	-2.613***	-0.435***
s.e.	(0.571)	(0.449)	(0.285)
Bid-ask spread	0.139	0.671**	1.239**
s.e.	(0.594)	(0.305)	(0.507)
Regional variables			
Greek sovereign spread	-0.002	-0.006	0.000
s.e.	(0.006)	(0.005)	(0.003)
KfW-Bund spread	0.171	-0.046	-0.084
s.e.	(0.157)	(0.191)	(0.096)
EA investment grade	-0.293**	-0.151	-0.291***
s.e.	(0.122)	(0.108)	(0.075)
EA implied volatility	0.060	0.857	-0.016
s.e.	(0.535)	(0.521)	(0.202)
EA 5-yr OIS	-0.45**	-0.792**	-0.33***
s.e.	(0.208)	(0.227)	(0.127)
German 5-yr CDS	1.52***	1.548***	0.792***
s.e.	(0.334)	(0.277)	(0.175)
Break even inflation rate 5-yr FWD	0.097	-0.012	0.064
s.e.	(0.148)	(0.12)	(0.073)
Exchange rate and global variables			
10 delta EUR/USD implied volatility	2.002	0.338	0.370
s.e.	(2.631)	(2.814)	(1.471)
EUR depreciation versus USD	-0.444	-0.017	-0.399
s.e.	(0.629)	(0.649)	(0.291)
EUR depreciation versus USD FWD	-0.118	0.195	0.157
s.e.	(0.195)	(0.161)	(0.097)
US investment grade	-0.163	-0.028	0.272*
s.e.	(0.256)	(0.232)	(0.158)
US volatility premium	1.069	0.699	-0.342
s.e.	(1.455)	(1.418)	(0.519)
US stock market	1.087	1.566**	0.082
s.e.	(0.873)	(0.825)	(0.345)
US Treasury market	-0.205	0.118	-0.013
s.e.	(0.184)	(0.187)	(0.102)
Adjusted R^2	47.7	46.2	25.6
Number of obs.	573	573	573

Notes: This table reports the coefficients and the Newey-West HAC standard errors for the indicated regression explanatory variables. The variables are described in Appendix A.