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Determinants of the Expected Euro Depreciation upon a Sovereign Default

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Résumé

Ce mémoire analyse l'espérance de la dépréciation de l'euro en cas d'un défaut souverain dans l'Eurozone. Nous obtenons à l'aide d'un modèle de non-arbitrage et de couvertures de défaillance (CDS) exprimés en dollar (USD) et en euro une estimation du marché de cette dépréciation attendue. Nous mesurons ainsi que le marché attendait une dépréciation de l'euro de l'ordre de 32,1% par rapport à l'USD en moyenne en cas d'un défaut souverain. Un CDS en USD protège l'investisseur contre le risque de dépréciation et apparait donc plus onéreux que son équivalent en euro. Nous notons que l'espérance de dépréciation conditionnelle à un défaut varie fortement avec le temps et selon les pays étudiés. Notre analyse met en évidence qu'elle augmente lorsque le risque de crédit souverain diminue, lorsque le financement de la liquidité sur le marché s'assèche, et lorsque l'euro s'est déprécié par rapport à l'USD.

Mots-clés : Dépréciation implicite; Défaut souverain; CDS; Couverture de défaillance; Taux de change ; euro; Déterminants; Eurozone; Devise.

Abstract

This paper analyzes the expected depreciation of the Euro in the case of a sovereign default in Europe. Using an arbitrage-free model and country-level sovereign credit default swap (CDS) rates denominated in both USD and Euro, we obtain a market-based estimate of the expected Euro depreciation. We find that the Euro is expected to decline by 32.1%, on average, relative to the USD upon a country's default. A CDS in USD protects investors against depreciation risk and thus trades at a significant premium relative to its Euro counterpart. Notably, the expected Euro depreciation greatly varies across countries and over time. Our analysis shows that it increases with a country's sovereign credit risk, when funding market liquidity dries out, and when the Euro performs poorly.

Key-words: Implied Depreciation ; Sovereign Default ; SCDS ; Exchange Rate ; Currency; Determinants ; Euro ; Eurozone

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CDS: Couverture de défaillance (Credit Default Swap)

CDSQD: Différence entre les taux de SCDS en USD et Euro (Spread difference of SCDS denominated in USD and in Euro)

IMF: Fonds Monétaire International (International Monetary Fund)

ISDA: Association Internationale des Swaps et Dérivés (International Swaps and Derivatives Association)

SCDS: Couverture de défaillance de gouvernement (Sovereign Credit Default Swap)

USD: Dollar américain (US Dollar)

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Notes aux lecteurs

La section 2 du mémoire est constituée de l’article: “Determinants of the Expected Euro Depreciation upon a Sovereign Default”.

Toutes les sections de l’étude sont l’œuvre de l’auteur de ce mémoire, sous la direction d’Alexandre Jeanneret.

Chapitre 1 :
Introduction générale

1. Introduction

Les investisseurs rencontrent deux difficultés particulières lorsqu'ils investissent dans des actifs étrangers libellés en devise locale: ils doivent faire face au risque de devise, c'est-à-dire au danger que la monnaie locale se déprécie, et ils doivent évaluer le risque pays, à savoir la menace que la situation économique de l'État étranger se détériore. De récents travaux académiques ont démontré que ces deux risques interagissent. En particulier, un défaut souverain est vraisemblablement associé à une dépréciation forte de la monnaie locale, conduisant par conséquent à une très importante perte de valeur des actifs étrangers mesurés dans la devise de l'investisseur (Frankel et Rose, 1996; Reinhart, 2002; Herz et Tong, 2008; Mano, 2013; Popov et Wiczer, 2014). Tandis qu'il existe une littérature abondante concernant la compréhension du risque de défaut souverain,[1] nous avons aujourd'hui une connaissance limitée de cette dépréciation espérée de la devise locale associée à un défaut souverain. Ainsi, l'estimation prévisionnelle de ce risque apparait pertinente dans la prise de décision des acteurs sur les marchés financiers et des dirigeants d'entreprises.

Cet article estime la dépréciation attendue du taux de change local en cas de défaut souverain. L'analyse de ce risque de dépréciation se concentre particulièrement sur l'un des cours de change les plus échangés, celui de l'euro avec le dollar (USD). Dans cette étude, notre objectif consiste dans un premier temps à comprendre le niveau de cette espérance de dépréciation conditionnelle à un défaut, aussi bien que ses variations à travers le temps et selon les pays membres de l'Eurozone. Dans un deuxième temps, nous visons à déterminer les principaux facteurs influençant cette mesure.

Nous dérivons cette dépréciation attendue en cas de défaut en s'appuyant sur des couvertures de défaillance (CDS) écrites dans différentes devises. Les taux des couvertures de défaillance souveraines (SCDS) d'une même maturité sont en effet normalement cotés pour le même pays dans différentes devises. Par exemple, le 2 janvier 2012, les taux SCDS de l'Espagne étaient de 3,78 % en USD contre 2,90 % pour ceux cotés en euro. Puisque nous pouvons nous attendre à une dépréciation de l'euro en cas

[1] Voir Augustin, Subrahmanyam, Tang, et Wang (2014) pour une récente revue de littérature concernant les couvertures de défaillances (CDS).

d'un défaut, une position acheteuse dans un SCDS en euro protège un investisseur du risque de crédit, mais l'expose à un risque de devise. Ce dernier risque peut être évité si l'investisseur a directement une position acheteuse dans un SCDS en USD. L'écart de taux entre SCDS coté en USD et en euro semble donc incorporer de l'information pertinente sur le risque de dépréciation en cas d'un défaut souverain.

En comparaison, jauger directement l'impact de la dépréciation implicite du taux de change avec des obligations d'État apparait difficile : Il requiert de tirer l'information à partir des titres de créances de même maturité, portant sur une même entité et dans au moins deux devises différentes. Les obligations d'États respectant ces contraintes sont difficiles à trouver, surtout dans les pays industrialisés qui tendent à émettre leur dette dans leur propre devise. Une méthode alternative consisterait à utiliser la technique de Du et Schreger (2015). Pour calculer la dépréciation implicite de pays émergents, ils mesurent les composantes du risque de crédit des taux souverains libellés en monnaie locale et en USD en créant artificiellement un taux sans risque local, à l'aide des bons du Trésor américain, des taux LIBOR locaux et américains, et de swaps de devises. Cependant, une stratégie plus naturelle serait d'employer directement des taux de SCDS comme nous le proposons dans cet article. Effectivement cette dernière méthode évite des calculs et des hypothèses supplémentaires, puisque les taux de SCDS mesurent directement le risque de crédit, et qu'ils sont disponibles pour le même État dans différentes devises et avec la même maturité.

En utilisant les taux de SCDS et une méthode de non-arbitrage, nous dérivons la dépréciation attendue du taux de change en cas de défaut, qui est appelée par la suite « dépréciation implicite ». À l'aide d'un panel de 8 pays membres de la zone euro, nous estimons que le marché anticipait une baisse de l'euro de l'ordre de 32,1 % en moyenne entre 2010 et 2013, en cas d'un défaut d'un pays de l'Eurozone. De plus, il apparait que cette dévalorisation attendue augmente avec la maturité de la couverture. Cette mesure moyenne cache évidemment une importante hétérogénéité entre les dépréciations implicites estimées pour chaque pays membre, appelant à une analyse plus précise des facteurs qui l'influencent à travers le temps et selon les pays.

Nous étudions ainsi empiriquement les déterminants de la dépréciation implicite de l'euro. Nous mettons en évidence que la dépréciation implicite dépend fortement du niveau actuel du risque souverain : une augmentation de la probabilité de défaut décroit la dépréciation espérée du taux de change en cas de défaut. Cette relation est convexe, ce qui signifie que l'effet du niveau du risque de crédit est plus prononcé lorsque le risque souverain est faible. Ce résultat est cohérent avec l'idée que le marché prend en compte l'augmentation de la probabilité de défaut en vendant l'euro par rapport à l'USD : lorsque le défaut est très probable, le marché n'attend plus une dépréciation très forte de l'euro. À l'autre extrême, lorsque le défaut est très improbable, un évènement de crédit déclencherait une forte dépréciation du taux de change, puisqu'il serait inattendu et donc non évalué par le marché.

En plus du risque de crédit souverain, plusieurs autres facteurs de marché influencent la dépréciation implicite. D'abord, les rendements positifs (négatifs) passés de l'euro par rapport à l'USD réduisent (augmentent) l'importance de la dépréciation implicite estimée. Par conséquent, plus l'euro perd de sa valeur, plus les courtiers désirent payer une prime contre de potentielles futures dépréciations. Les prix des SCDS en USD se renchérissent alors vis-à-vis de ceux en euro. Nous obtenons des résultats similaires lorsque nous prenons en compte les rendements espérés plutôt que réalisés. Plus précisément, nous considérons la prime des contrats à terme euro/USD à 6 mois pour capturer les attentes à court terme du marché, tandis que nous utilisons le différentiel d'inflation (entre la zone euro et les États-Unis) afin d'obtenir, selon la théorie de la parité de pouvoir d'achat relative, un indicateur à long terme.

Ensuite, nous observons que les contraintes globales de financement de la liquidité sur les marchés déterminent le niveau de la dépréciation implicite, signalant aussi que les investisseurs cherchant à se couvrir du risque de dépréciation payent une prime de risque en cas d'assèchement de la liquidité. Cet aspect est d'ailleurs plus prononcé dans un environnement où le risque souverain est faible et aussi pour les pays montrant le plus fort risque systémique comme la France et l'Allemagne. Enfin, la dépréciation implicite est influencée positivement par le niveau des taux d'intérêt USD, indiquant que son niveau décroit lorsque les investisseurs recherchent la sécurité d'investissement.

À notre connaissance, cette étude est la première recherche empirique évaluant les déterminants de la dépréciation implicite. Les recherches les plus proches analysent la différence entre le taux de SCDS en USD et celui dans la devise locale qui est appelé écart quanto. D'un côté, Pu et Zhang (2012) concentrent leur analyse sur la relation prévisionnelle unissant le rendement journalier de l'euro avec l'USD et la variation de la différence des primes de SCDS libellés en devise locale et en USD, alors que De Santis (2015) utilise aussi l'écart quanto pour analyser le risque de la redénomination de l'euro en monnaie nationale. De l'autre côté, Corradin et Moreno (2014) et Buraschi Menguturk et Sener (2015) utilisent l'écart quanto pour essayer d'expliquer l'anomalie de prix entre les rendements d'obligations écrit en euro et USD, respectivement pour la zone euro et les pays émergents.

Cet article se rattache aussi à la littérature examinant l'effet du risque souverain sur les variations du taux de change, en particulier sur le risque de dépréciation. Les études antérieures reposent sur les mesures de volatilité implicite incorporées dans les options sur devises afin d'estimer le risque de baisse du cours de change : une option de vente hors de la monnaie avec une plus forte volatilité implicite qu'une option d'achat hors de la monnaie indique un risque d'asymétrie négatif sur la distribution des rendements du taux de change (Carr et Wu, 2007a; Brunnermeier, Nagel et Pedersen, 2008). Carr et Wu (2007b) et Della Corte et coll. (2015) présentent des arguments en faveur d'une probabilité de dépréciation plus forte lorsque le risque de défaut souverain s'accroit. Les investisseurs payent ainsi une prime d'assurance plus élevée pour se couvrir contre une baisse probable du taux de change lorsque le risque de crédit augmente. Ici, nous démontrons que la dépréciation implicite est élevée lorsque le risque de crédit souverain est faible. Par conséquent, les investisseurs payent dans ces conditions une prime d'assurance relativement plus élevée pour se couvrir d'une dépréciation conditionnelle à un défaut souverain. Les prix des SCDS en USD sont alors relativement beaucoup plus couteux, par rapport à ceux en Euro, que dans un environnement de fort risque de défaut souverain. Bien que ces résultats semblent différents en apparence, ils sont en réalité complémentaires. En effet, la littérature existante s'intéresse principalement à l'espérance de la dépréciation de la devise, qui combine l'intensité de la dépréciation en cas défaut et la probabilité de cet évènement, tandis que notre mesure de dépréciation implicite est conditionnelle à un défaut souverain.

Le mémoire s'organise de la façon suivante : Le chapitre 2 du mémoire est constitué de l'article qui s'ordonne en cinq sections. La section 1 introduit la recherche. Dans la section 2, nous décrivons succinctement le marché des SCDS et introduisons l'espérance de dépréciation du taux de change en cas de défaut. Dans la section 3, nous dérivons la dépréciation implicite et nous discutons des différences et similarités avec les recherches antérieures. Dans la section 4, nous procédons à l'analyse empirique. La section 5 conclut la recherche.

Chapitre 2:
Determinants of the Expected Euro Depreciation upon a Sovereign Default

2. Determinants of the Expected Euro Depreciation upon a Sovereign Default

Abstract

This paper analyzes the expected depreciation of the Euro in the case of a sovereign default in Europe. Using an arbitrage-free model and country-level sovereign credit default swap (CDS) rates denominated in both USD and Euro, we obtain a market-based estimate of the expected Euro depreciation. We find that the Euro is expected to decline by 32.1%, on average, relative to the USD upon a country's default. A CDS in USD protects investors against depreciation risk and thus trades at a significant premium relative to its Euro counterpart. Notably, the expected Euro depreciation greatly varies across countries and over time. Our analysis shows that it increases with a country's sovereign credit risk, when funding market liquidity dries out, and when the Euro performs poorly.

2.1. Introduction

Investors face two specific risks when investing in foreign assets denominated in local currencies: First, they have to deal with currency risk, i.e., the threat of the potential decline of the local currency, and second, they face macroeconomic risk, i.e., the plausible deterioration of the foreign country's economic outlook. Importantly, the empirical evidence indicates that these risks are actually intertwined. In particular, sovereign defaults tend to be associated with exchange rate crises, which further decrease the value of foreign assets measured in the investors' currency (e.g., see Frankel and Rose, 1996; Reinhart, 2002; Herz and Tong, 2008; Mano, 2013; Popov and Wiczer, 2014). While there exists an abundant literature on understanding sovereign default risk,[2] we have a limited knowledge thus far about the expected currency depreciation associated with a sovereign default. Having such an ex-ante measure would be highly relevant to market participants and corporate managers for their investment decisions.

This paper estimates the expected depreciation of the local currency in case of a sovereign default. The analysis focuses especially on the expected depreciation of the Euro relative to the US dollar (USD), which constitutes one of the most traded exchange rates today. Our first objective consists of understanding the level of the expected depreciation of the Euro conditional to a sovereign default, as well as its variations across time and across countries.[3] Second, we aim to determine the factors driving this default-implied Euro depreciation.

Our approach computes a market-based measure of the expected depreciation upon a sovereign default, as inferred by credit default swap (CDS) spreads quoted in two different currencies. Sovereign credit default swaps (SCDS) with the same entity and maturity are indeed typically quoted in various currencies with different prices (spreads). For example, Spain's five-year CDS spreads were 378 basis points in USD and 290 basis points in Euro on 2 January, 2012. Based on previous evidence, one can expect the Euro to decline at the time of sovereign default. A long position in a SCDS denominated in

[2] See Augustin, Subrahmanyam, Tang, and Wang (2014) for a recent literature survey on sovereign credit default swaps.
[3] We refer to the Eurozone as the group of European countries sharing the Euro as a common currency. The Eurozone included 16 countries in 2010.

Euro thus protects investors against credit losses but exposes them to currency risk. This risk can be removed if the investor has instead a long position in a SCDS quoted in USD. The difference in spreads should therefore include relevant information about the risk of currency depreciation in the case of sovereign default.

In comparison, estimating the implied depreciation from sovereign bond data is less straightforward. It requires extrapolating the credit risk information from debt financial instruments written on the same entity with the same maturity and in at least two currencies. Government bonds respecting these constraints may be hard to find, especially for industrialized countries that tend to emit their debt in their own currency. Using an alternative method, Du and Schreger (2015) compute credit risk components of sovereign yields in local and foreign currencies by creating an artificial local risk-free rate, based on the US treasury bonds, the US LIBOR rates, local LIBOR rates, and currency swaps. Their approach allows them to calculate the implied depreciation for emerging countries. However, a more natural way consists in exploiting directly sovereign credit derivatives (SCDS), as we propose in this paper. Effectively, this method avoids some additional computations and assumptions, since SCDS spreads measure directly the sovereign credit risk and are typically available in different currencies for the same entity and with the same maturity.

Using SCDS spreads and an arbitrage-free approach, we propose a derivation of the expected currency depreciation upon a sovereign default, which is hereafter referred to as "implied depreciation." With a panel of eight Eurozone countries, we gauge that the Euro relative to USD is expected to lose 32.1% of its value, on average, if one country's government defaults. This average measure obviously hides strong disparities between Eurozone members' implied depreciation, thereby calling for an exploration of the factors explaining cross-country variations and fluctuations across time.

We thus investigate empirically the determinants of the implied Euro depreciation. Our main result suggests that the implied depreciation depends greatly on the current level of a country's sovereign risk: A greater default probability decreases the implied depreciation. The relationship also implies that the effect is highly nonlinear, because the effect of sovereign credit risk is more acute when such risk is low. This result is consistent with the idea that traders take into account a higher likelihood of default by selling the Euro against the USD, which implies that the Euro is not expected to decline severely once the credit event occurs. At the other extreme, one can expect a credit event to trigger a strong decline in the Euro if a default remains unlikely, because such an event would be essentially unexpected and thus barely priced by market participants.

Besides the level of sovereign risk, several market-wide factors contribute to explaining the implied depreciation. First, past (negative) returns of the Euro relative to the USD reduce (amplify) the magnitude of the implied depreciation. Hence, the weaker the Euro, the more traders are willing to pay a premium to be hedged against its further depreciation, implying that a SCDS in USD becomes more expensive than its Euro counterpart. We obtain similar results when we consider expected, rather than realized, Euro returns. More specifically, we consider the six-month forward premium to capture short-run expectations and the inflation differential (between EU and the US) to obtain a long-run indicator, as implied by the purchasing power parity.

Second, we find that global funding liquidity constraints drive the level of the implied depreciation, signaling that investors willing to hedge the depreciation risk pay a risk premium in case liquidity dries up. This aspect is even more pronounced in a low sovereign risk environment and for countries showing the highest systemic risk such as France and Germany. Finally, we find that the US interest rates also influence positively the level of the implied depreciation, which would indicate that the implied depreciation decreases during flight-to-safety episodes. All these determinants maintain a similar effect when we use one-month lags to deal with potential endogeneity and reverse causality issues.

To the best of our knowledge, this is the first empirical study on the drivers of the implied depreciation of a currency conditional on a sovereign default. The closest studies analyze the difference between SCDS denominated in USD and in local currency, which is commonly referred to as the “quanto spread.” On the one hand, Pu and Zhang (2012) focus their analysis on the forecasting power of the quanto spread for exchange returns, while De Santis (2015) uses the quanto spread to analyze the risk of currency redenomination in the Eurozone. On the other hand, Corradin and Moreno (2014) and

Buraschi, Menguturk, and Sener (2015) exploit quanto spreads to explain pricing anomalies between bond yields denominated in different currencies, respectively for the Eurozone and for emerging markets.

This paper also relates to the literature examining the effect of sovereign credit risk on exchange rate variations, especially on its downside risk. Conventionally, the downside risk of exchange rates is estimated with volatility measures implied by currency options: the higher the difference between implied volatilities of an out-of-the-money put and an out-of-the-money call, the greater the negative skewness of the exchange rate returns distribution and therefore the higher the downside risk (Carr and Wu, 2007a; Brunnermeier, Nagel and Pedersen, 2008). Considering this approach to estimate downside risk, Carr and Wu (2007b) and Della Corte et al. (2015) find that an increase of sovereign risk amplifies the probability of future depreciation of the local currency because investors pay a higher option premium to hedge against potential depreciation of the exchange rate. Here, we demonstrate that the expected depreciation of the currency conditional to a sovereign default is higher in a low sovereign risk environment. Hence, investors pay a higher premium to hedge the implied depreciation by asking relatively higher prices of SCDS denominated in USD, relative to those in Euro, than in a high sovereign risk environment. The reason for the discrepancy in findings is that the existing literature essentially concludes on the expected currency depreciation, which combines the depreciation upon default and the probability of this event, whereas our implied depreciation estimate is conditional on a sovereign default. Hence, both approaches complement each other.

The remainder of the paper is organized as follows. Section 2 provides an overview of the sovereign CDS market and introduces the expected depreciation of the exchange rate upon a sovereign default. Section 3 derives the implied depreciation and discusses the difference and similarities with previous research. Section 4 discusses the empirical analysis. Section 5 concludes.

2.2. Sovereign credit default swaps (SCDS) and currency denomination

This section provides an overview of the SCDS market, with a particular focus on the specificities associated with the currency denomination.

2.2.1 SCDS market

It is useful to first analyze the characteristics and describe the main players of the SCDS market, which is a subcategory of the CDS market (Augustin, 2014). A SCDS is a credit derivative that protects the holder (usually an owner of a country's government bond) from a sovereign credit event in that country (Pan and Singleton, 2008; Longstaff et al., 2011).[4] As is the case for CDS, there are four main types of credit events, as defined by the International Swaps and Derivatives Association (ISDA, 2003): obligation acceleration, failure to pay the interest or principal, restructuring of debt, and repudiation or moratorium of debt.

To be insured, the default protection buyer pays the default protection seller a premium each trimester. The annualized premium paid quarterly is determined by the CDS spread, which can be defined as the ratio of the yearly premium on the amount covered by the contract, i.e., the notional.[5] The notional protected is specified at the inception of the contract. In the case of one of the pre-specified credit events, the protection seller compensates the holder with a contingent payment. The contract is settled either by cash or by a physical delivery of admissible bonds in exchange of the face value of the bonds (ISDA, 2003).[6] The set of deliverable obligations can be quoted in the six main currencies: the USD, the Euro, the Japanese Yen, the Canadian dollar, the Swiss Franc, and the British pound. For pricing purposes, the recovery rate has to be specified in the contract, as well as the maturity of the SCDS, which may range between six months to 30 years (Markit, 2009).

[4] The specified sovereign government, the bonds of which are protected, is called the reference entity. A credit event is commonly called a "default."

[5] More exactly, a SCDS spread is the rate such that a CDS holder cannot arbitrage between paying premiums until maturity or default and receiving the contingent payment if there is a default. The SCDS is thus a measure of a country's default likelihood.

[6] The face value is the amount invested at the inception of the bond.

For example, a holder of a 2% SCDS on a French government bond with a five-year maturity and a notional of 1000 USD will pay 20 USD annually to be insured against a credit event. If the French government defaults, the recovery of the debt will be negotiated with diverse stakeholders. If debt negotiation results in a haircut of 50% of the face value or $500, the protection seller will pay back $500.

SCDS are sold and bought in the over-the-counter market in which multiple actors with diverse strategies interact (ISDA, 2003). Figure 1 indicates that the dominant actors in the SCDS market are reporting dealers, banks and security firms, and hedge funds, which account respectively for 72%, 14%, and 5% of the notional amount outstanding between 2011 and 2013.[7] The main activities of reporting dealers are market-making and hedging of sovereign debt exposures (IMF, 2013). Reporting dealers and hedge funds are net sellers, while banks and security firms are net buyers.[8]

According to the IMF (2013), participants in the SCDS market follow three different strategies: hedging activities, speculating operations, and arbitrage basis trading. The hedging activities aim to cover an underlying debt exposure of a sovereign government entity and are also used as a hedging proxy of other assets such as banks and utilities. The speculating activities consist in taking naked positions (entering into a SCDS without holding the underlying debt exposure) to benefit from a deterioration of a country's financial condition. Arbitrage-basis trading is based on finding differences between the quotation of the SCDS spread and the underlying bond spread with the risk-free rate. This strategy may, however, be unreliable due to frictions and costs in the shorting of the underlying bond.

Thus, SCDS are derivative products engineered to protect their holder against a sovereign default. Market participants such as banks, security firms, hedge funds, and reporting dealers employ them to hedge, to arbitrage, or to speculate on the credit risk of a sovereign country. However, the currency denomination can also expose them to a depreciation of the exchange rate. We describe, in the next subsection, how traders can in

[7] We use the data of Bank of International Settlement to identify the main actors and compute their share in the SCDS' notional amount outstanding.
[8] We use the International Monetary Fund (IMF) methodology (IMF, 2013) to distinguish, thanks to the data of the Bank of International Settlement, their net position between 2011 and 2013.

turn benefit from the SCDS denomination to speculate on (or to hedge them from) the currency depreciation that is expected to occur at times of a sovereign default.

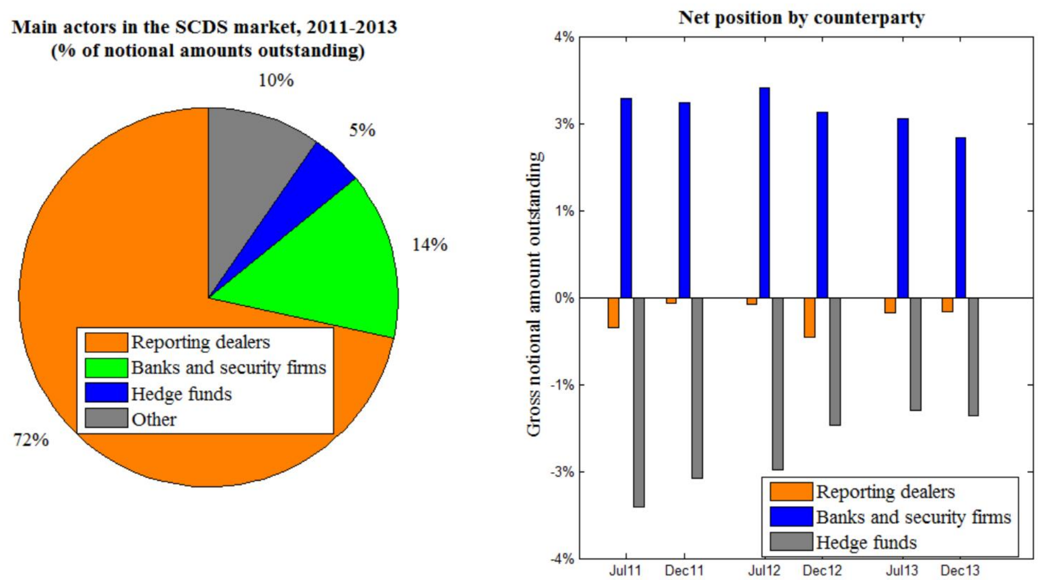


Figure 1—Participants and net position in the SCDS market
This figure shows the different actors in the SCDS market. It reports their notional amount of contracts outstanding and their net position in percentage of the gross notional outstanding. The data are taken from the BIS, and the computations are made according to the IMF (2013) methodology.

2.2.2 Currency denominations of SCDS

SCDS can be denominated in multiple currencies to protect for a specific credit-event. When quoted in local currency, a SCDS provides exposure to local exchange rate movements. This is important given the existing evidence that local currencies tend to depreciate upon a sovereign default. For example, Reinhart (2002) shows that sovereign defaults in emerging countries and currency crises are strongly related.[9] The author calculates that the probability of having a strong depreciation of the local exchange rate before or after a sovereign default is about 84%. In addition, a sovereign default occurs after a currency crisis 46% of the time, whereas the opposite is true 69% of the time. Similarly, Herz and Tong (2008) find that debt crises, based on dates of the Paris Club debt's rescheduling, Granger cause currency crises in a sample of 108 emerging countries

[9] The author follows the definition of Frankel and Rose (1996) of a "currency crash" "as a nominal depreciation of the currency of at least 25% that is also at least a 10% increase in the rate of depreciation." She refers to this relationship as the "two D's" for default and depreciation.

covering the years 1975–2005. However, a small decline of the exchange rate after a default may not reach the definition of a currency crash and would, therefore, not be taken into account in such analyses. Some studies fill this gap and focus on gauging ex-post the magnitude of the depreciation against the USD after a credit event. For example, Mano (2013) explores a database of historical sovereign defaults between 1873 and 2008 and shows that nominal exchange rates fall on average by 17.6% of its value at the end of the default year compared to one year ago and by 29.2% compared to five years earlier. Popov and Wiczer (2014) also find that the nominal exchange rates lose 15% of their value on average at the end of the default year compared to one year ago. Overall, one can reasonably expect a sovereign credit event would be associated with a depreciation of the local currency.

The idea that exchange rates depreciate upon default seems to be taken into account in the SCDS market. Indeed, most of the SCDS are quoted in USD to protect their holders from eroding the value of the SCDS after a crash of the currency driven by the sovereign default. Importantly, even if there exists depreciation risk, SCDS continue to be denominated in local currencies, mostly for asset-liability management of banks' balance sheets and risk management purposes. In particular, European SCDS are denominated in Euro currency as an instrument of risk management for European banks and investment funds (Barclays, 2011). Of course, the question of the liquidity of Euro-denominated SCDS arises, but, according to market makers, SCDS quoted in Euro are in fact "reasonably liquid" for each member of the Eurozone (Barclays, 2011), with the five-year maturity being the most traded (J.P. Morgan, 2010).

Market participants appear to price SCDS in USD and Euro differently, even though they are otherwise identical. This difference between the USD-denominated SCDS and the Euro-quoted SCDS with equivalent maturity and the same recovery rate is called "quanto spread" by reporting dealers (J.P. Morgan, 2010). Market makers mainly justify the existence of this spread as a compensation for the currency depreciation risk.[10] SCDS

[10] This view is clearly shared by market participants. For example, "a Eurozone default can be expected to have knock-on effects which affect the [Euro] adversely, increasing the value of a USD-denominated CDS contract" (Barclays, 2011).

investors therefore prefer to pay a higher premium to be hedged in USD rather than in Euro.[11]

Based on this price differential, the market has developed a derivative product called the Quanto SCDS, which aims to protect its holder from a depreciation of the exchange rate upon default. The product is engineered by taking offsetting positions of SCDS with two different currency denominations. We will now explain in greater detail this long-short strategy.

2.2.3 Long-short SCDS strategy

Because of the difference in currency denomination of SCDS, traders may design a long-short strategy to gain exposure on the exchange rate upon default (J.P. Morgan, 2010, Barclays, 2011). The idea behind being long and short SCDS written in different currencies is that it should eliminate the credit risk, while being long (or short) on the depreciation risk. For instance, if investors consider that the Euro should strongly depreciate against the dollar, traders may enter into respectively, a long position in an SCDS denominated in USD and a short position in an SCDS denominated in Euro. Since one may expect a higher SCDS spreads in USD than in Euro, the trader pays each quarter a fourth of the difference in spreads, and, in the case of a default event, the payoff would be the loss given default multiplied by the variation of the exchange rate since the inception of the strategy.

Table 1 summarizes the characteristics of this long-short strategy. As we can see, the trader combines SCDS denominated in Euro and USD to become notional neutral. This strategy generates a net exposure to the spread difference of 46.48 basis points. Therefore, each year until default or the expiration of the strategy, the trader pays 46480 Euros to benefit from the depreciation of the Euro at default.

[11] Ehlers and Schonbücher (2004) show that market participants also price differently corporate CDS denominated in Yen and USD. The spread difference is thus not restricted to SCDS denominated in Euro and USD. Note that it can also be generalized to SCDS denominated in other currencies, as we will show using quotes from Brazil, Great Britain, and Russia (see Section 2.4.6).

Table 1—Mechanism of the long-short strategy

This table synthesizes the use of a long-short strategy with SCDS denominated in USD and Euro. The left panel describes the inception of the long-short strategy with SCDS of Spain on March 3, 2013, while the right panel shows the payoff in the case of a sovereign default.

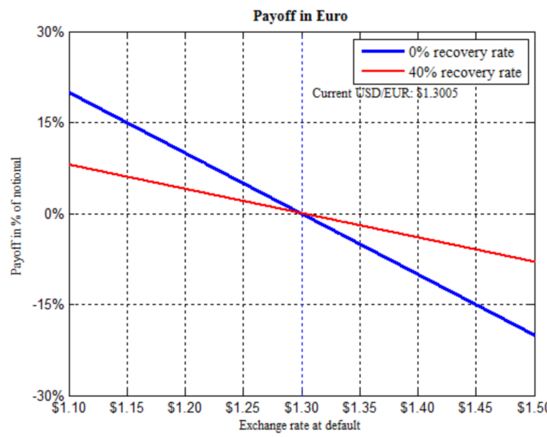
Long-short strategy initiated on 03/14/13 with Spain 5y-SCDS

	Spread	Notional	Net premium payment
Long SCDS in $	267.86 bps	$13M (= 10 x 1.30)	- €267860
Short SCDS in €	221.38 bps	€10M	+ €221380
Cost of protection	46.48 bps	€10M	- €46480

Maturity (year)	Cumulative cost until default	Cumulative cost (in % of notional)
1	- €46480	-0.46%
2	- €92960	-0.93%
3	- €139440	-1.39%
4	- €185920	-1.86%
5	- €232400	-2.32%

Note: We assume that the current spot rate is at $1.30 and that the yield curve is flat at 0%.

Payoff at default (in Euro) = (1 - Recovery rate) x SCDS Notional x Change in USD/Euro



Spreads between SCDS quoted in different currencies have been the object of recent academic scrutiny. Indeed, some studies use quanto spreads as a proxy for the implied depreciation of the exchange rate upon a sovereign default to explore their relationship with future exchange rate variations (Pu and Zhang, 2012; Della Corte et al., 2015), with spreads of bonds denominated in Euro and USD (Corradin and Moreno, 2014; Buraschi, Menguturk and Sener, 2015), or with the risk of a currency redenomination in the Eurozone (De Santis, 2015).

In this paper, we focus on quantifying this implied depreciation and on understanding how it varies over time and across countries. Therefore, we now derive the expected depreciation upon default using SCDS denominated both in USD and Euro.

2.3. Default-implied currency depreciation

In this section, we derive a measure of expected exchange rate depreciation upon default, as implied by the SCDS market. To this end, we develop an arbitrage-free strategy that uses SCDS denominated in two different currencies. Appendix A.1 reports the technical details.

2.3.1 Methodology

We consider an arbitrage-free strategy in which the currency risk is hedged and there is no net cash outflow until default. It is assumed that the premium payments are made annually. Let CS_{eur,t_0} and CS_{usd,t_0} be, respectively, the current (t_0) SCDS spread with maturity *T* denominated in Euro and USD, and N_{eur} and N_{usd} their respective notional. Let *R* be the recovery rate of the bond upon default. We assume that the current exchange rate S_{t_0} is also the current swap rate for the currency swap until maturity, as in Du and Schreger (2015).

The strategy is the following until maturity *T*, assuming that no default occurs: At inception, we are long a SCDS denominated in Euro with nominal N_{eur} that pays annually CS_{eur,t_0}, and we are short a SCDS denominated in USD with nominal N_{usd} that pays annually CS_{usd,t_0}. We also enter into a fix for fix annuity currency swap in which Euro is received and USD is paid at the fix exchange rate S_{t_0}.[12] Hence, the exchange rate is fixed for the annual premium payments. Given that this is a self-financing strategy, we must have:

$$CS_{eur,t_0} N_{eur} S_{t_0} = CS_{usd,t_0} N_{usd}. \tag{1}$$

Therefore, the notional of SCDS denominated in USD that is required to implement the strategy is:

$$N_{usd} = \frac{CS_{eur,t_0}\, N_{eur}}{CS_{usd,t_0}} S_{t_0}. \tag{2}$$

[12] There are no exchange of notionals for annuity currency swap.

Let S_{t_D} be the exchange rate at time of default t_D and $\mathbb{E}_{t_0}(S_{t_D})$ be the current expected USD/Euro exchange rate conditional on a default at time $t_D \in (t_0, T)$.[13] If a default occurs between the inception of the strategy and maturity *T*, the long position receives the contingent payment of the SCDS denominated in Euro and pays the value of the currency swap $(1-R)\, N_{eur}S_{t_D} - \chi_{eur}S_{t_D} + V_{t_D,T}$, while the short position in USD pays $(1-R)\, N_{usd} - \chi_{usd}$. Here, $V_{t_D,T}$, χ_{eur}, and χ_{usd} are, respectively, the value of the long Euro position of the currency swap at time t_D with maturity *T* and the accrued premiums of the SCDS swaps in Euro and USD.[14] Table 2 and Figure 2 summarize the strategy. We then divide the derivation into two scenarios. In the base case scenario, we assume that the value of the currency swap is null at the time of default ($V_{t_D,T} = 0$) and that no accrued premiums are paid. The swap-case scenario will relax those assumptions.

Table 2—Cash flows of a swapped strategy

This table describes the arbitrage-free strategy that consists of two offsetting SCDS positions in different currencies. It shows that there is no cash outflow at the inception of the strategy and when premium payments are made annually.

Strategy	At inception of the strategy	Each quarter	If default
Long N_{eur} SCDS denominated in Euro	0	$-CS_{eur,t_0}N_{eur}S_{t_0}$	$(1-R)\, N_{eur}S_{t_D} - \chi_{eur}S_{t_D}$
Short N_{usd} SCDS denominated in USD $N_{usd} = \frac{CS_{eur,t_0}\, N_{eur}}{CS_{usd,t_0}} S_{t_0}$	0	$CS_{usd,t_0}N_{usd}$	$-(1-R)\, N_{usd} - \chi_{usd}$
Enter into a currency swap	0	--	$V_{t_D,T}$
Net cash outflow	0	0	Expected to be 0

2.3.1.1 Base Case

Here we assume that the currency swap has no value when default occurs and that there are no remaining accrued premiums for the SCDS. According to no arbitrage conditions, it is expected (at the inception) that the net cash flow at time of default satisfies:

$$0 = \mathbb{E}_{t_0}\Big((1-R)\, N_{eur}S_{t_D} - (1-R)\, N_{usd}\Big), \tag{3}$$

[13] The conditional depreciation of the Euro only relates to a default in Europe, thus implicitly ignoring the possibility of a default in the US. That is, we do not analyze the case in which the Euro appreciates against the US dollar if a credit event is triggered in the US.

[14] The SCDS premium is accrued when a credit event is triggered. An accrued premium is the remaining part of the SCDS premium the protection buyer has to pay.

which is equivalent to: $0 = (1-R)\, N_{eur}\mathbb{E}_{t_0}\left(S_{t_D}\right) - (1-R)\, \frac{CS_{eur,t_0}N_{eur}}{CS_{usd,t_0}} S_{t_0}$. This expression yields the following expected exchange rate upon default:

$$\mathbb{E}_{t_0}\left(S_{t_D}\right) = \frac{CS_{eur,t_0}}{CS_{usd,t_0}} S_{t_0}. \tag{4}$$

As a result, we can obtain the implied depreciation (ID) upon default as follows:[15]

$$ID = \frac{S_{t_0} - \mathbb{E}_{t_0}\left(S_{t_D}\right)}{S_{t_0}} = 1 - \frac{CS_{eur,t_0}}{CS_{usd,t_0}} > 0. \tag{5}$$

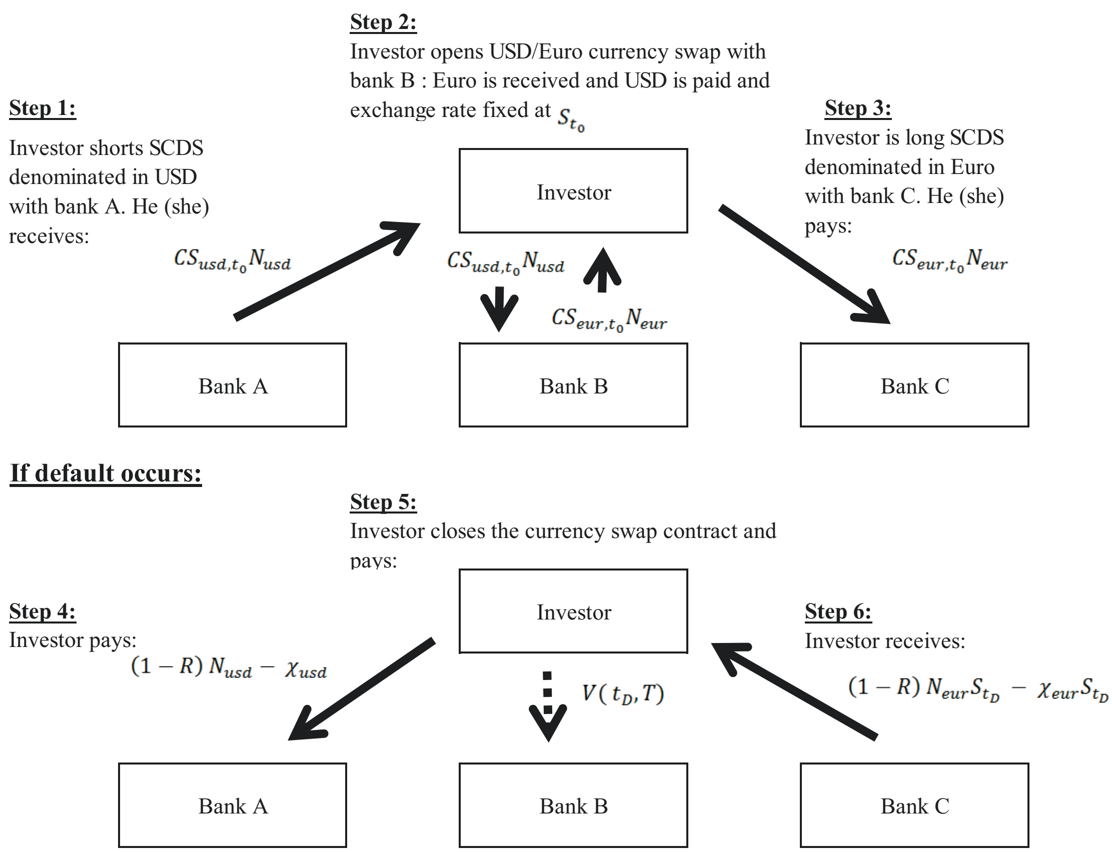


Figure 2—Cash flows of the strategy

This diagram shows the various steps of the arbitrage-free strategy, which involves a long position in the Euro SCDS and a short position in the USD SCDS. To reduce the counterparty risk of derivative products, the investor deals with three different intermediaries (A, B, and C). Steps 1 to 3 describe the exchange of

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[15] Alternatively, we could assume that the implied depreciation is compared to the expected exchange rate level to isolate the expected depreciation purely caused by a sovereign default. The implied depreciation relatively to the expected exchange rate conditional to no default at t_D equals $ID = \frac{\mathbb{E}_{t_0}\left(\left(S_{t_D} \middle| No\ default\right)\right) - \mathbb{E}_{t_0}\left(S_{t_D}\right)}{\mathbb{E}_{t_0}\left(\left(S_{t_D} \middle| No\ default\right)\right)}$, where we determine the expected exchange rate conditional to no default at t_D with the average of the forward rates calculated with the uncovered interest rate parity.

SCDS spreads at premium dates. Steps 4 to 6 describe cash-flow exchanges in case of default. Step 5 shows where the swap case differs from the base case scenario.

2.3.1.2 Swap Case

We now briefly discuss the differences arising when we consider the swap case, which is derived in Appendix A.1. In the case of depreciation upon default, we expect $S_{t_D} < S_{t_0}$. The value of the swap $V_{t_D,T}$ should be therefore negative, because the Euro should be received and USD be paid at the fixed exchange rate S_{t_0}. Hence, the implied depreciation should be lower in the swap case than in the base case. In addition, the swap case takes into account the information of the term structure of SCDS to calculate the expected value of the currency swap at default.[16] The probability extracted from the SCDS term structure thus influences the value of the currency swap. The higher the default probability, the more negative the expected value of the swap, and the higher the difference in implied depreciation across the two cases. Yet, as we will verify in Section (2.4.2.4), the differences are generally small and do not affect the findings of the paper.

2.3.2 Comparison with previous approaches

The derivation of the implied depreciation contributes to the growing literature related to the currency denomination of SCDS. It is thus useful to compare our approach with that of previous studies. Using corporate CDS data, Ehlers and Schönbucher (2004) derive the expected change in the USD relative to Yen, assuming that the exchange rate follows an affine jump diffusion process. Instead of estimating the jump with the instantaneous default intensity measured in both currencies, they use Japanese corporate CDS denominated in USD and in Yen as a proxy. Closer to our study, Mano (2013) builds a notional neutral strategy based on the spread differential and currency forwards to quantify the depreciation upon a sovereign credit event. This initial strategy is similar to

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[16] We assume, as in Choudhry and Ali (2010), that the SCDS spreads can be written as:
$CS^T_{usd,t_0} = \frac{\sum_{t_i=t_1}^{t_M}\left(Q_{t_i} Z^{usd}_{t_0,t_i}(1-R)\right)}{\left(\sum_{t_i=t_1}^{t_M} Z^{usd}_{t_0,t_i}\left(\Gamma_{t_i}+\frac{Q_{t_i}}{2}\right)\right)}$ –, where $Z^{usd}_{t_0,t_i}$ is the zero coupon price at time t_0 with maturity t_i, Γ_{t_i} is the probability of no default at time t_i conditional to no default previously, and Q_{t_i} is the probability of default at time t_i conditional to no default previously. The estimation of default probabilities is based on the approach of Jarrow and Turnbull (1995), Hull and White (2000) and O'Kane and Turnbull (2003) to price credit derivatives.

engineering a quanto SCDS. This author then exploits the forward premium as the unbiased estimator of the expected exchange rate and uses it to distinguish two states of the local currency conditional to a default: an expected default state and an expected non-default state, the probabilities of which occurring are extracted from SCDS denominated in USD. The exchange rate in case of a default is then extrapolated from the information conveyed by the currency forward and by the SCDS written in two currencies.[17] Overall, both his approach and formula differ from ours. In contrast, Du and Schreger (2015) find a similar measure as we propose in Equation (5), although their research essentially focuses on the spread differential between credit spreads of emerging markets sovereign bonds denominated in foreign and local currency.

[17] Similar to our base case scenario, Mano (2013) does not use currency forwards (or swaps) to hedge the SCDS premium payments.

2.4. Empirical analysis

Having derived the implied depreciation upon sovereign default, we now quantify its magnitude and examine how it varies across time and countries. We base our analysis on the European market.

2.4.1 SCDS data

We first describe the SCDS data that we analyze in this study. We use middle price SCDS spreads in Euro and USD with maturities going from one to ten years, as provided by Markit.[18] We select countries that are part of the Eurozone, which includes Belgium, France, Germany, Greece, Ireland, Italy, Portugal, and Spain.[19] Our sample spans the period between August 20, 2010, and December 31, 2013. Thus, our dataset contains a total of 6675 quotes per maturity. Our analysis will essentially extract the implied Euro depreciation from the five-year SCDS spreads, although we include other maturities for comparison.

We compute a daily measure of the implied Euro depreciation for each country as well as an average measure for the Eurozone.[20] We focus our analysis on the estimates of the implied Euro depreciation using the base case scenario, but we will still verify that the results of the paper hold under the more general case.[21]

Table 3 provides information on the economic and financial data used in the paper.

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[18] We select SCDS data in both currencies with the complete restructuring ("CR") clause.

[19] These eight Eurozone members accounted for 86.2% of the Gross Domestic Product (GDP) of the whole Eurozone in 2010, according to European Central Bank data. Greece accounts for 2.4% of the Eurozone's GDP.

[20] To obtain the average implied Euro depreciation for the Eurozone, we first compute the time-series of the implied Euro depreciation for each country and then compute an average across countries with their respective GDP weight in the Eurozone. We thus avoid the convexity effect arising from computing the implied Euro depreciation for an "average" Eurozone country (i.e., by using the average SCDS spreads across countries). We exclude Greece to remain consistent in the calculation, since there are no quotes available after its sovereign default in March 2012.

[21] To compute the swap case implied depreciation for each country as well as an average Eurozone implied depreciation, we use the SCDS and the interest rate swaps denominated in USD and Euro with maturity spanning from one year to five years. We assume that the recovery rate fixed at 40%.

Table 3—Information on economic and financial data

The table below provides information on the economic and financial data. It provides the frequency of the variables, whether time series data are taken in YoY or in level, their sources (Bloomberg tickers are provided), and the computation formulas.

Variables	Frequency	Data	Source	Computation
Economic variable				
US industrial production growth	Monthly	YoY	Bloomberg (Ticker: IP YoY)	Original data
US inflation	Monthly	YoY	Bloomberg (Ticker: CPI YoY)	Original data
EU industrial production growth	Monthly	YoY	Bloomberg (Ticker: EUIPEMUY)	Original data
EU inflation	Monthly	YoY	Bloomberg (Ticker: ECCPEMUY)	Original data
Local industrial production growth	Monthly	YoY	Bloomberg (Tickers: BEPDREYS (Belgium), FPIPYOY (France), GEINYY (Germany), GKIPIYOY(Greece), IEIPIYOY (Ireland), ITPRWAY (Italy), PTIPTOTY (Portugal), SPIOYOY (spain))	Original data
Local inflation	Monthly	YoY	Bloomberg (Tickers: BECPYOY (Belgium), FRCPIYYOY (France), GRCP20YY (Germany), GKCPNEWY (Greece), IECPIYOY (Ireland), ITCPNICY (Italy), PLCPYOY (Portugal), SPIPCYOY (Spain), UKRPCJYR (Great-Britain), RUCPIYOY	Original data
Financial variable				
CDS in local currency (1y to 5y)	Daily	Level	Markit	Original data
CDS in USD (1 y to 5y)	Daily	Level	Markit	Original data
Exchange rate USD/Local returns	Daily	YoY	Bloomberg (Ticker: EURUSD (Euro), GBPUSD (Pound), USDRUB (Russia),	(S (t+1) - S(t)) / S(t))* 100
Forward premium 6 months USD/Euro	Daily	Level	Bloomberg (Ticker : EUR 6M)	Forward premium / (USD/EUR)*100
TED spread	Daily	Level	Bloomberg (Ticker : BASPTDSP)	Original data
Swap rates in Euro (1y to 5y)	Daily	Level	Bloomberg (Tickers : EUSA1, EUSA2, EUSA3, EUSA4, EUSA5)	Original data
Swap rates in USD (1y to 5y)	Daily	Level	Bloomberg (Tickers : USSA1, USSA2, USA3, USSA4, USSA5)	Original data
VSTOXX	Daily	Level	Eurostoxx	Original data
Local European Indexes returns	Daily	YoY	Bloomberg (Indexes: BEL 20 (Belgium), CAC 40 (France), DAX (Germany), ASE (Greece), FTSE MIB (Italy), PSI 20 (Portugal), IBEX (Spain))	(S (t+1) - S(t)) / S(t))* 100

2.4.2 Analysis of the implied depreciation upon default

This section provides a preliminary analysis of the implied Euro depreciation upon a sovereign default in the Eurozone. Table 4 suggests that, on average, the Euro is expected to depreciate by 32.1% if one country’s government defaults. We first explore how this result varies with SCDS maturity, across countries, and over time. Finally, we compare the prediction of the baseline scenario with that of the swap case.

2.4.2.1 Descriptive statistics by maturity

Analysis of Table 4 (Panel A) suggests that the implied depreciation increases with the maturity. To see that, the Euro is expected to lose 27.5%, on average, in the case of a default within one year, while the prediction increases to 30.4% if it happens within ten years. It is reasonable to expect sovereign risk to augment with maturity because a country is more likely to experience an economic or financial crisis within ten years than within one year. Still, our implied depreciation estimate is conditional on a sovereign default. Hence, this channel cannot drive this effect. Here, the reason SCDS in USD are relatively more expensive than those in Euro when the maturity increases is because a longer time horizon amplifies the uncertainty surrounding the exchange rates and thus increases the risk of a severe Euro depreciation.

2.4.2.2 Cross-country analysis

We have thus far considered an average implied Euro depreciation for the Euro area. This measure hides strong disparities between Eurozone members. Table 5 reports the descriptive statistics of the implied Euro depreciation by country. Notably, Non-PIIGS countries have a higher average implied depreciation than PIIGS countries.[22] For instance, Germany's average implied depreciation is around 44%, while Portugal's is around 9%. Since Germany is less likely to default on its debt than Portugal, it seems that the level of credit risk influences the magnitude of the implied depreciation.

[22] PIIGS stands for Portugal, Ireland, Italy, Greece, and Spain. These are countries that had to face a real or potential debt crisis between 2008 and 2012.

Table 4—Descriptive statistics of the average implied Euro depreciation

This table reports some descriptive statistics of the Eurozone's average implied Euro depreciation. Panel A compares the predictions obtained with SCDS of one-, five-, and ten-year maturity. Panel B compares the implied Euro depreciation computed with the base and swap cases. The computation of the implied depreciation measures is detailed in Section 2.3.1, while the data are described in Section 2.4.1. The countries included are Belgium, France, Germany, Italy, Ireland, Portugal, Spain and Greece. The reported implied depreciation (expressed in percentage terms) is the average prediction for these countries. The sample consists of observations between August 20, 2010, and December 31, 2013.

Panel A—Implied Euro depreciation by maturity

	N	Mean	Median	Standard deviation	Minimum	Maximum
Implied depreciation 1y	861	27.54	27.75	8.48	-6.39	51.33
Implied depreciation 5y	875	32.13	34.00	6.94	12.04	45.94
Implied depreciation 10y	875	30.38	31.83	6.68	12.20	44.31

Panel B—Implied Euro depreciation by approach

	N	Mean	Median	Standard deviation	Minimum	Maximum
Implied depreciation base case	875	32.13	34.00	6.94	12.04	45.94
Implied depreciation swap case	875	31.05	33.13	7.01	10.76	44.49
Correlation Swap-Base cases	0.998					

Table 5—Descriptive statistics of the implied Euro depreciation by country

This table reports predictions on the implied Euro depreciation by country. Panel A presents some descriptive statistics at the country level, whereas Panel B reports the correlations. Implied depreciation is expressed in percentage terms. The computation of the implied depreciation measure is detailed in Section 2.3.1, while the data are described in Section 2.4.1. The sample consists of observations between August 20, 2010, and December 31, 2013.

Panel A—Implied Euro depreciation by country

	N	Mean	Median	Standard deviation	Minimum	Maximum
Belgium	878	32.61	32.06	11.02	2.14	57.89
France	878	36.30	38.78	10.82	-0.49	56.12
Germany	875	43.73	47.84	13.16	11.91	73.36
Italy	878	19.33	17.39	4.75	11.36	36.94
Ireland	878	15.19	13.35	6.65	1.41	31.82
Portugal	878	9.37	8.61	3.45	1.58	22.12
Spain	878	21.95	22.02	3.37	13.21	32.76
Greece	532	5.90	6.83	5.54	-25.20	21.51

Panel B—Correlations between each country's implied Euro depreciation

	Belgium	France	Germany	Italy	Ireland	Portugal	Spain
Belgium	1.000						
France	0.826	1.000					
Germany	0.772	0.847	1.000				
Italy	-0.300	-0.340	-0.468	1.000			
Ireland	0.857	0.683	0.691	-0.343	1.000		
Portugal	-0.134	-0.338	-0.374	0.503	0.003	1.000	
Spain	0.065	0.126	0.080	0.652	-0.026	0.191	1.000
Greece	0.153	0.034	0.055	0.039	0.212	0.311	0.013

Observations: 875

Furthermore, the implied depreciation across countries does not co-move strongly: Table 5 shows that the implied depreciations of PIIGS countries are weakly correlated with non-PIIGS ones, suggesting that different determinants affect the implied depreciation.

2.4.2.3 Time variation

We now examine how our market-based implied depreciation measure varies over the sample period. Figure 3 illustrates the predictions for the Eurozone's average implied depreciation between 2010 and 2013. The upper left panel of Figure 3 reports the expected exchange rate upon default, which is compared to the spot exchange rate. Both series co-move strongly. However, this does not mean that the difference between the two is constant over time. The upper right panel displays the time-series of the implied depreciation, which appears to be clearly positive and to exhibit strong time variations. Notably, there is also a maturity effect illustrated by the lower left panel, which shows the (five-day smoothed) difference between five-year and one-year implied depreciations of the Eurozone. Because the one-year implied depreciation is generally lower than the five-year one, market players seem to estimate the magnitude of the potential Euro depreciation differently across time and across the horizon.

Furthermore, we find great differences in the time variation of the implied depreciation across countries. Figure 4 shows the predictions for each individual country, which clearly indicate the presence of a strong heterogeneity. It also appears that non-PIIGS countries have an implied Euro depreciation that varies in a more homogenous way than is the case for PIIGS countries.[23]

Overall, our preliminary analysis reveals a strong time variation in the implied Euro depreciation as well as substantial heterogeneity across countries. Understanding such variations therefore appears to be important and thus constitutes the main objective of this paper.

[23] We provide in Appendix A.3 a closer look at the expected Euro level upon a Greek default between August 20, 2010, and March 9, 2012. Greece defaulted on its debt on March 9, 2012.

2.4.2.4 Comparison of the approaches

It is useful to compare the baseline predictions with those obtained with the swap case. Table 4 (Panel B) shows that both methods of computation yield close measures of the implied depreciation, with the swap estimate being slightly lower than the base case. Both approaches also yield measures that are strongly correlated (over 99%) at the daily frequency. Confirming this result, the upper right panel of Figure 3 shows that both estimates co-move strongly over time. The lower right panel shows that the difference between both approaches is mainly driven by the expected negative value of the currency swap at default.[24] Since both estimates are strongly correlated and yield close estimates, it is reasonable to focus the remainder of the analysis on the implied depreciation calculated with the base case equation.[25]

[24] We provide a more thorough analysis of the difference between both estimates in Appendix A.2. We find that both cases differ when sovereign credit risk is important: the higher the SCDS premium, the lower the value of the currency swap, and thus the greater the gap between the two methods. Along this line, the difference between both methods is more pronounced for PIIGS countries than for non-PIIGS countries.

[25] Using the implied depreciation measure derived with the swap case does not change the conclusions of our analysis, as we will show in Section 2.4.7.

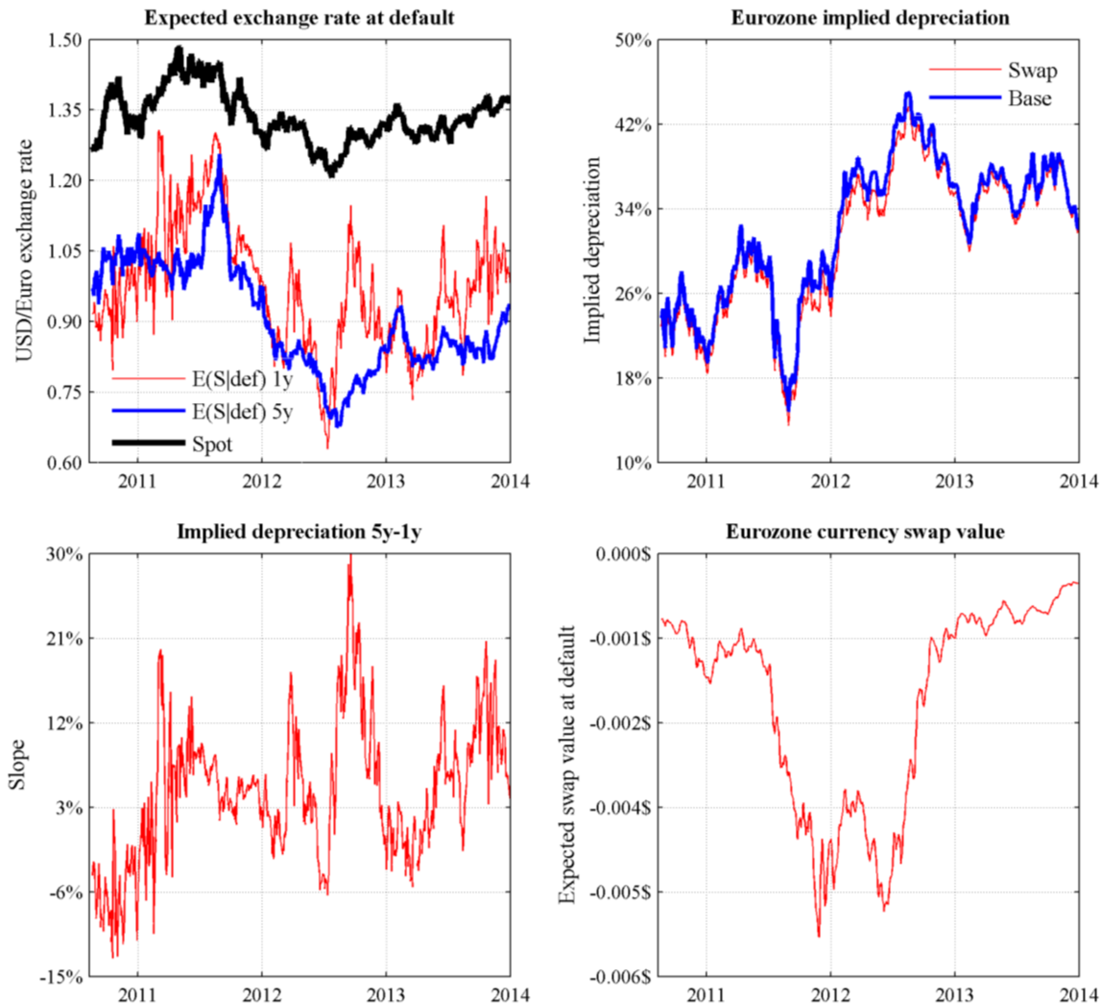

Figure 3—Time variation in the average implied Euro depreciation

This figure shows the time variation in the expected exchange rate upon default, which is compared to the spot exchange rate (upper left panel). The lower left panel illustrates the variation in the slope between five-year and one-year implied Euro depreciation. The upper right panel compares the variation in the implied depreciation computed with the swap and the base cases. The lower right panel shows the time variation of the expected value of the currency swap at default when implementing the no-arbitrage strategy with a SCDS notional of one Euro. The computation of the implied depreciation measure is detailed in Section 2.3.1, while the data are described in Section 2.4.1. The countries included are Belgium, France, Germany, Italy, Ireland, Portugal, Spain, and Greece. The reported implied depreciation is the average prediction for these countries and is smoothed over five days. The sample consists of observations between August 20, 2010, and December 31, 2013.

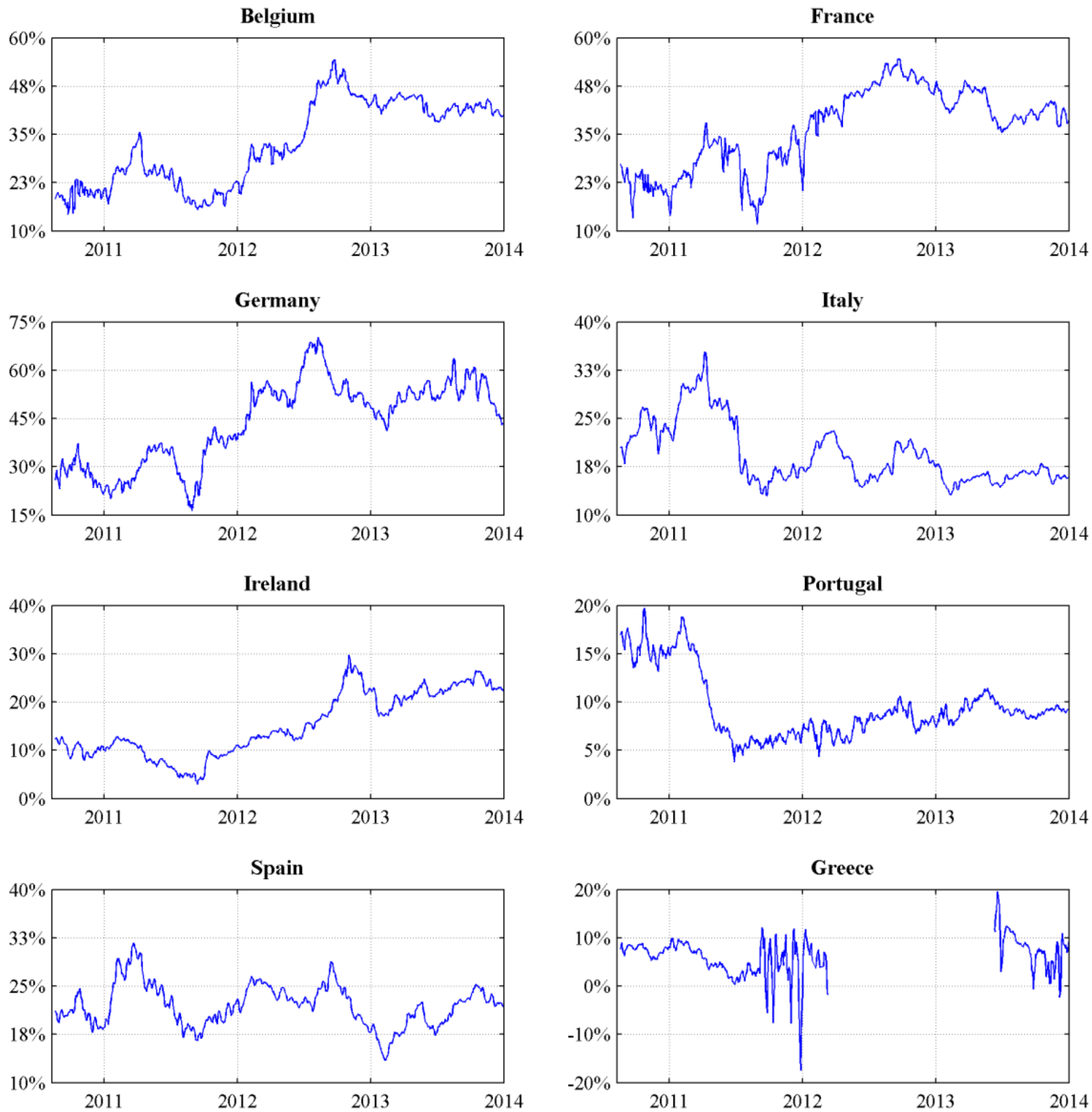

Figure 4—Implied Euro depreciation for individual Eurozone countries
This figure shows the implied Euro depreciation for Belgium, France, Germany, Italy, Ireland, Portugal, Spain, and Greece. The computation of the implied depreciation measure for the base case is detailed in Section 2.3.1, while the data are described in Section 2.4.1. The implied depreciation is smoothed over five days. The sample consists of observations between August 20, 2010, and December 31, 2013.

2.4.3 Drivers of the implied depreciation

The main focus of this study consists of identifying the factors driving the implied depreciation of the Euro in the case of a sovereign default, both across countries and over time. We first discuss the potential determinants of the implied depreciation that we later consider in our econometric analysis.

2.4.3.1 Role of sovereign credit risk

When deriving the implied depreciation (see Equation 5), one can notice that this measure essentially depends on the SCDS spread written in Euro and of the spread difference between the SCDS quoted in USD and in Euro (CDSQD):

$$ID_{i,t} = \frac{CDSQD_{i,t}}{CS_{eur,i,t} + CDSQD_{i,t}}, \quad (6)$$

where $ID_{i,t}$ denotes the implied depreciation of country i at time t, $CS_{eur,i,t}$ is the Euro denominated CDS spread, while $CDSQD_{i,t} = CS_{usd,i,t} - CS_{eur,i,t}$.

Based on this expression, a higher sovereign credit spread should imply a lower depreciation of the Euro. To illustrate this effect, Figure 5 displays the relationship between the implied depreciation and the SCDS spread denominated in Euro.[26] The level of sovereign credit risk as measured by the Euro-SCDS spread has a clear negative and non-linear relation with the magnitude of the implied depreciation. When fitting a quadratic regression on the logarithm of the SCDS quoted in Euro, both coefficients are statistically significant, thus confirming the negative and convex link between sovereign credit risk and the implied depreciation.

Notably, the negative relation between the implied depreciation and the CDS spread seems robust for each of the considered Eurozone countries (see Figure 6). The slopes are always negative and seem to differ depending on the level of credit risk. Indeed, the higher the average level of a country's sovereign risk, the less pronounced the negative slope, which explains the non-linearity in the relation obtained for the full sample (see Figure 5). Overall, the level of a country's credit risk is expected to be an important driver of the level of the implied depreciation, not only between countries but also over time. We now consider other potential determinants related to financial and economic factors.

[26] To remove outliers, we include all the observations across time and countries except the extreme 2% on the left and on the right of the distribution.

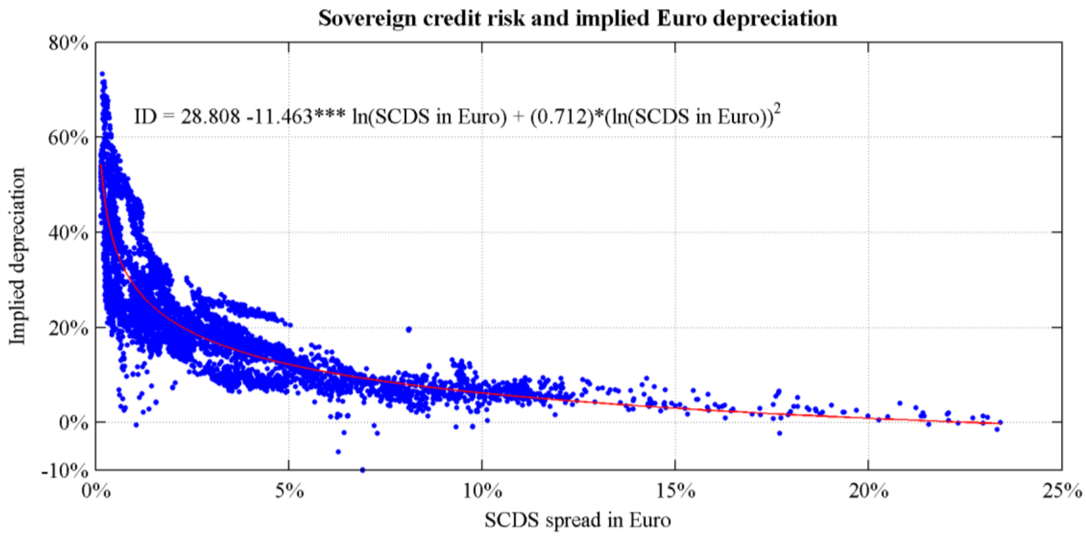

Figure 5—Implied depreciation and sovereign credit risk

The figure shows scatterplots of the relation between the implied Euro depreciation and the CDS denominated in Euro. The countries included are Belgium, France, Germany, Italy, Ireland, Portugal, Spain, and Greece. We exclude 2% of the extreme values of SCDS on the left and on the right. The implied depreciation is computed with the base case, as detailed in Section 2.3.1. The sample consists of observations between August 20, 2010, and December 31, 2013. Reported regressions are run in panel with country clustering and Newey-West corrections. *, ** and *** show statistical significance at the 10%, 5%, and 1% levels, respectively.

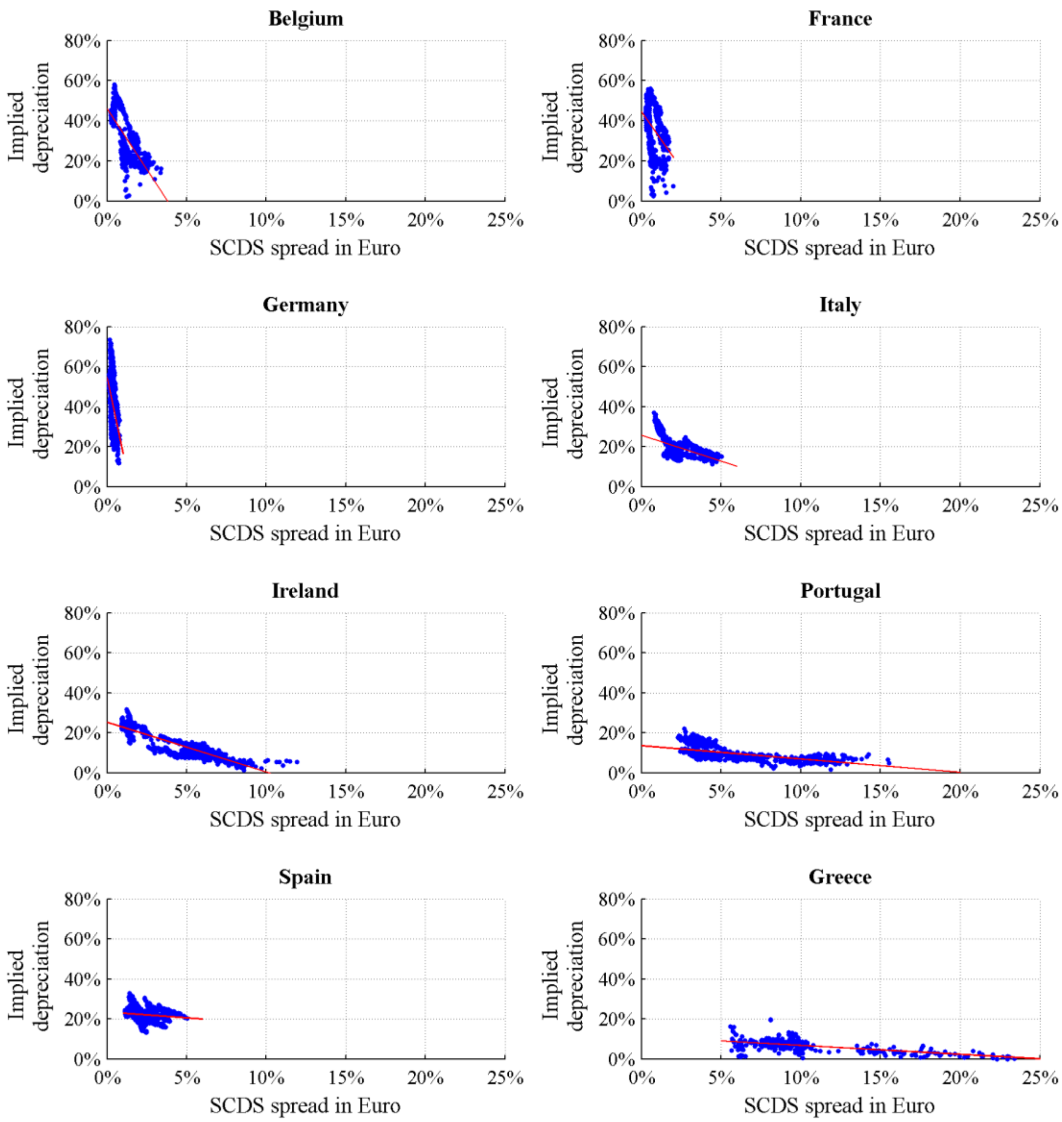

Figure 6—Implied depreciation and sovereign credit risk by country

This figure shows the linear relation between the implied depreciation and the Euro CDS spreads at the country level. We exclude 2% of the extreme values of the global distribution of SCDS on the left and on the right. The computation of the implied depreciation measure uses the base case, as detailed in Section 2.3.1. The data are described in Section 2.4.1. The sample consists of observations between August 20, 2010, and December 31, 2013.

2.4.3.2 Exchange rate and financial conditions

We here consider a set of financial determinants that we disentangle into factors related to the Euro currency and to those associated with global or local market conditions.

Currency market conditions

The strength of the Euro is likely to be informative about the implied depreciation. On the one hand, a strong Euro relative to the USD could indicate that market participants view a sovereign credit event as rather unlikely.[27] We may expect the currency depreciation to be large once a default occurs, given that this event remains mostly unexpected and thus is not priced in the current exchange rate. On the other hand, one may expect risk-averse investors to seek additional (less) protection when the Euro has recently performed badly (well). Thus, the SCDS in USD should become more (less) expensive than the Euro counterpart, thereby implying a higher (lower) implied depreciation. This suggests a negative relationship between the Euro and implied depreciation.

The upper left chart of Figure 7 shows that average implied depreciation seems to be negatively related to the spot USD/Euro exchange rate, which is in favor of the second mechanism. Therefore, we expect the performance of the Euro, which we measure as the year-on-year percent change relative to the USD, to be a central driver of the implied depreciation. Equally important could be the expected change in the Euro, since the implied depreciation is an ex-ante expectation of its depreciation upon a sovereign default. Under the unbiasedness hypothesis, the forward exchange rate is the best estimator of the future spot exchange rate (Bekaert and Hodrick, 2009). We thus consider the six-month forward premium of the USD/Euro another potential factor of the implied depreciation.

Global and local market conditions

Regarding indicators of global conditions, we consider the five-year interest swap rates in Euro and in USD, which are liquid proxies of risk-free interest rates in these currencies. These variables capture the monetary policies within the Eurozone and the United States, as well as the rates at which banks are lending money among themselves. To that extent, lower swap rates may signal a flight-to-safety episode.

[27] Della Corte et al. (2015) demonstrate that the exchange rate returns are negatively linked with the fluctuation of sovereign credit risk.

Funding liquidity constraints may also drive the implied depreciation because they influence trades and returns in the currency market (Brunnermeier, Nagel, and Pedersen, 2008). Following this intuition, we use the TED spread, measured by the gap between the three-month LIBOR and the three-month US T-bills, as a proxy for funding liquidity. A higher TED spread means that the liquidity condition deteriorates and that investors may prefer to hold liquid and safe assets such as US Treasury bills. The middle right panel of Figure 7 suggests that the TED spread is negatively, although weakly, related with the implied Euro depreciation.

Measures of global financial uncertainty can also influence the magnitude of the implied depreciation because financial volatility is known to explain fluctuations in SCDS spreads (Pan and Singleton, 2008; Longstaff et al., 2011). We choose the VSTOXX, a volatility index computed from options on the Eurostoxx 50. This measure should better capture the level of uncertainty in the Eurozone than the VIX, which is the US counterpart, although the latter is more commonly used. Figure 7 (lower left panel) indicates that the implied Euro depreciation is negatively correlated with the VSTOXX.

Local financial risk factors can also affect the implied depreciation because they influence SCDS spreads in time of distress (Augustin, 2013). To this end, we use the performance of the local stock market index computed as the year-on-year return.[28] The stock market performance should adequately proxy for a country's economic outlook and thus for the probability of a sovereign default. The lower part of Figure 7 illustrates a positive relationship between the implied Euro depreciation and the European stock market index.

[28] We compute the year-on-year return on the BEL 20, CAC 40, DAX, FTSE MIB, ISEQ, IBEX, PSI, and ASE for Belgium, France, Germany, Italy, Ireland, Spain, Portugal, and Greece, respectively.

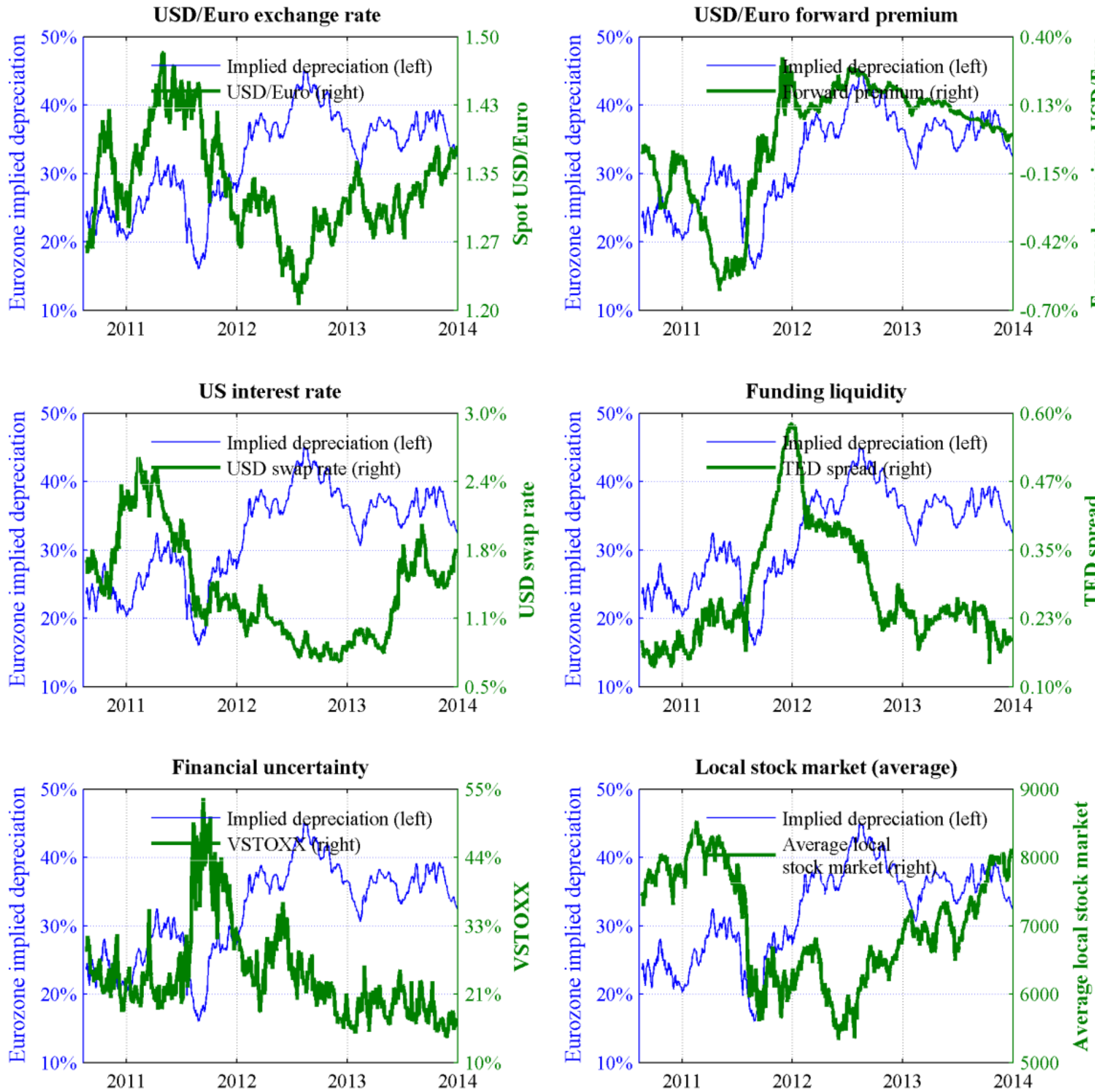

Figure 7—Implied depreciation, exchange rate, and financial conditions

This figure illustrates the dynamics of the Eurozone's average implied depreciation, which is compared to changes in financial conditions. Such conditions include the USD/Euro exchange rate (top left panel), the six-month forward premium of the USD/Euro (top right panel), the US five-year swap rate (middle left panel), the TED spread (middle right panel), the VSTOXX (bottom left panel), and the average local stock market (bottom right panel). The countries included are Belgium, France, Germany, Italy, Ireland, Portugal, Spain and Greece. The reported implied depreciation is the average prediction for these countries and is smoothed over five days. The implied depreciation is computed with the base case, as detailed in Section 2.3.1. The average local stock market is computed as the arithmetic average across countries of local indexes. The sample consists of observations between August 20, 2010, and December 31, 2013.

2.4.3.3 Economic determinants

We also consider a set of economic factors. Global macroeconomic factors could have an explaining power on the implied depreciation because they tend to explain variations in

SCDS spreads (Longstaff et al., 2011) and in exchange rates (Bekaert and Hodrick, 2009). We select global macroeconomic conditions based on their monthly availability and their capacity in describing the state of the economy. We consider the year-on-year-Eurozone aggregate industrial production (EU output growth) to measure local business conditions and the year-on-year Eurozone aggregate consumer price index (EU inflation) to measure the inflation level. We also incorporate the US counterparts of these economic factors.

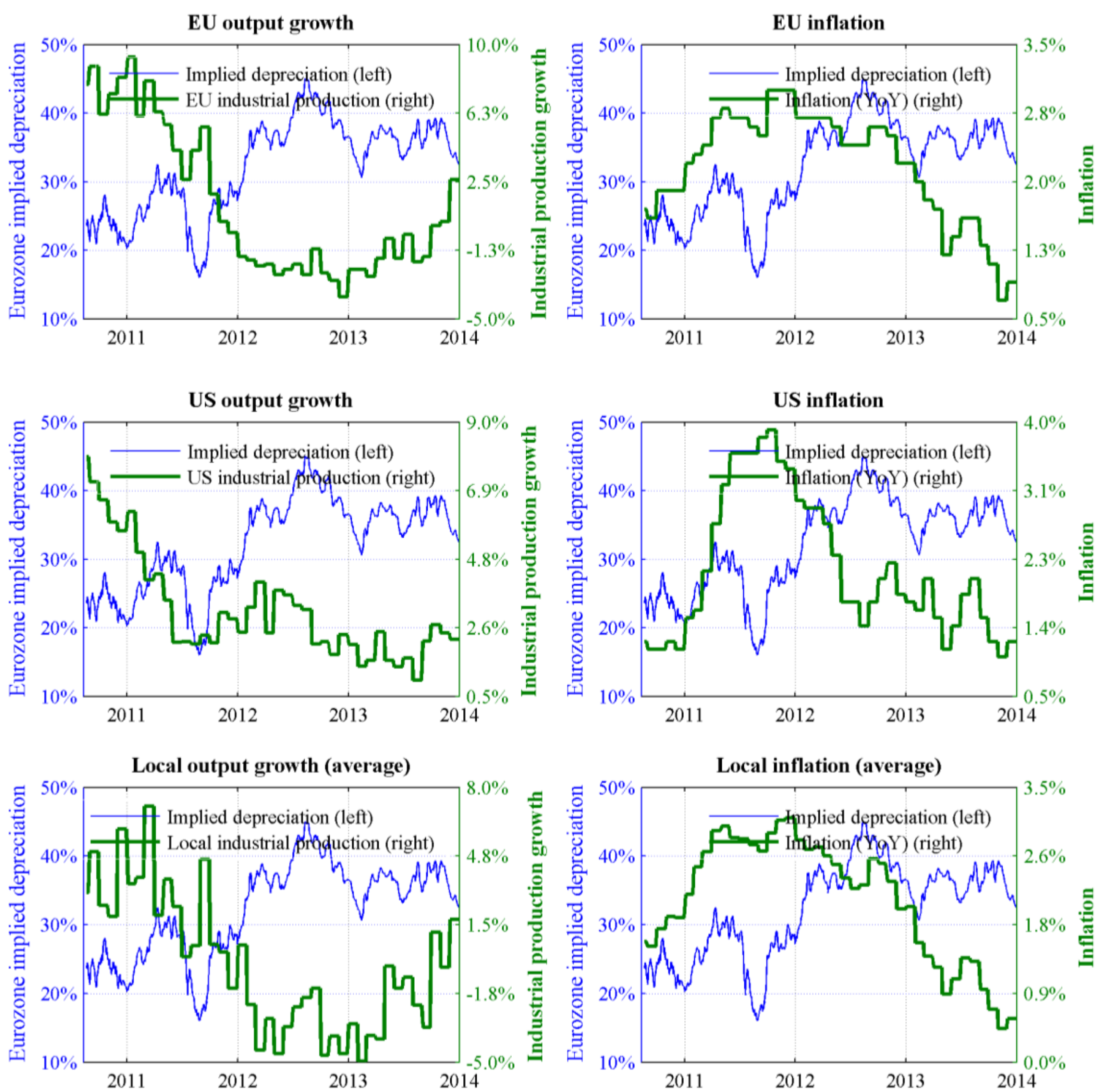

Figure 8—Implied depreciation and economic conditions

This figure illustrates the dynamics of the Eurozone's average implied depreciation, which is compared to changes in economic conditions: the EU output growth (top left panel), the EU inflation (top right panel), the US output growth (middle left panel), the US inflation (middle right panel), the average local output growth (bottom left panel), and the local average inflation (bottom right panel). The countries included are

Belgium, France, Germany, Italy, Ireland, Portugal, Spain, and Greece. The reported implied depreciation is the average prediction for these countries and is smoothed over five days. The implied depreciation is computed with the base case, as detailed in Section 2.3.1. The average local output growth and inflation are computed as the arithmetic average across countries of local industrial production growth and consumer price growth. The sample consists of observations between August 20, 2010, and December 31, 2013.

Previous research also shows that local economic factors such as inflation and local industrial production help explain sovereign credit risk variations (Remonala, Scatigna, and Wu, 2008; Altman and Rijken, 2011). Our choice of local economic conditions thus includes the year-on-year local industrial production (local output growth) and the year-on-year growth in the local consumer price index (local inflation), both at the country level.

Table 6 gives descriptive statistics of these financial and economic variables and their correlations with the average implied depreciation of the Eurozone.[29] It appears that most of the variables are strongly correlated with the Eurozone implied depreciation, which justifies their inclusion in the following empirical analysis.

[29] Table 6 also reports the statistics of the country-level implied depreciation. One can notice that the mean differs from that of the average implied Euro depreciation for the Eurozone (see Table 4), which excluded Greece.

Table 6—Descriptive statistics of the implied depreciation's determinants

This table reports the descriptive statistics of selected financial and macroeconomic variables (Panel A) and their correlation with the Eurozone's five-year implied depreciation (Panel B). All variables are expressed in percentages. The implied depreciation is computed with the base case, as detailed in Section 2.3.1. The sample consists of observations between August 20, 2010, and December 31, 2013.

Panel A—Descriptive statistics

Variable	N	Mean	Median	Standard deviation	Min	Max
Implied depreciation 5y	6237	24.00	21.32	14.75	-23.03	73.36
SCDS in Euro 5y	6237	4.28	1.86	11.10	0.08	235.72
Exchange rate USD/Euro return (YoY)	817	-0.55	-0.18	7.80	-16.10	21.50
Forward premium 6-month USD/Euro	817	-0.01	0.08	0.23	-0.62	0.32
EUR swap rate 5y	817	1.66	1.49	0.69	0.71	3.23
USD swap rate 5y	817	1.38	1.31	0.47	0.73	2.60
TED spread	817	0.27	0.24	0.10	0.13	0.58
VSTOXX	817	24.37	22.49	7.42	14.12	53.55
Local stock market return (YoY)	817	1.75	3.70	15.08	-24.14	35.83
EU industrial production growth (YoY)	817	1.17	-0.40	3.97	-3.80	9.30
EU inflation (YoY)	817	2.18	2.40	0.60	0.70	3.00
US industrial production growth (YoY)	817	3.11	2.48	1.55	0.99	7.93
US inflation (YoY)	817	2.13	1.80	0.90	1.00	3.90
Local industrial production growth (YoY)	817	-0.36	-0.52	3.22	-4.96	7.11
Local inflation (YoY)	817	2.07	2.26	0.77	0.43	3.11

Panel B—Correlation with Eurozone implied Euro depreciation

Financial variables		Economic variables	
Exchange rate USD/Euro return (YoY)	-0.2194	EU industrial production growth (YoY)	-0.7926
Forward premium 6-month USD/Euro	0.6275	EU inflation (YoY)	-0.1829
EUR swap rate 5y	-0.7212	US industrial production growth (YoY)	-0.4586
USD swap rate 5y	-0.5417	US inflation (YoY)	-0.3197
TED spread	0.1465	Local industrial production growth (YoY)	-0.7043
VSTOXX	-0.485	Local inflation (YoY)	-0.2795
Local stock market return (YoY)	0.3456		

2.4.4 Empirical specification

To understand the influence of the potential drivers of the implied depreciation, we run OLS regressions by panel using the following specification:

$$ID_{i,t} = a + \beta_{cds} CDS_{i,t} + \beta_{cds^2} CDS_{i,t}^2 + b' X_{i,t} + \varepsilon_{i,t} \,, \quad (7)$$

where $X_{i,t} = \left(FX_t^k \quad Mkt_t^m \quad Glo_t^n \quad Loc_{i,t}^p\right)$, $ID_{i,t}$ consists of the implied depreciation of country i at time t, $CDS_{eur,i,t}$ is the logarithm of Euro denominated CDS spread of country i at time t, FX_t^k is a vector of exchange rate factors at time t, Mkt_t^m is a vector of market factors at time t, Glo_t^n is a vector of global factors at time t, and $Loc_{i,t}^p$ is a vector of the local factors for country *i* at time *t*. We mitigate the effect of heteroscedasticity using the Huber-White correction of the residuals, along a clustering at the country level.

We gradually add the economic and financial groups in the specification and report the results in Table 7. We first consider sovereign credit risk (Column 1), then add currency market conditions (Column 2), market conditions (Column 3), global European economic conditions (Column 4), global American economic conditions (Column 5), and finally local European conditions (Column 6). We focus our discussion of the results on Column (6), which includes all variables. Overall, the R^2 of 87.3% suggests that the model explains a large fraction of the variations in the implied Euro depreciation. We now discuss the results and identify the main drivers.

2.4.5 Main results

2.4.5.1 Influence of sovereign risk

Table 7 shows that changes in sovereign credit risk capture most of the variations in the implied depreciation level, with an adjusted $R^2$of 78.4%. Moreover, both coefficients are statistically significant at a 99% confidence level and remain of similar magnitude when we gradually account for other factors. Moreover, sovereign credit risk appears to be economically important. To see that, the coefficients of $CDS_{i,t}$ and $CDS_{i,t}^2$, respectively equal to -12.57 and 0.95, suggest that an increase of one standard deviation of the SCDS spread in Euro (i.e., 1110 basis points) decreases the average estimate of the implied depreciation by approximately 11 percentage points (i.e., from an average implied depreciation of 24% to 13%).[30]

The convexity implies that the higher the sovereign risk, the lower the decline of the implied depreciation. Indeed, an increase from 100 basis points (bps) to 200 bps (from 500 bps to 600 bps) of the SCDS spread decreases the magnitude of the implied depreciation by approximately 8.26 percentage points (1.83 percentage points). This result is consistent with the idea that market participants take into account the level of a

[30] We gauge the economic effect by computing the exact variation, as follows: $\Delta = -12.57 \times (\text{CDS}_B - \text{CDS}_A) + 0.95 \times (\text{CDS}_B{}^2 - \text{CDS}_A{}^2)$. Using $\text{CDS}_B = \ln(15.38)$ and $\text{CDS}_A = \ln(4.28)$, one obtains $\Delta = -11$.

country's sovereign credit risk when pricing SCDS in different currencies: When a default is likely, traders do not expect the local currency to decline severely once the event occurs. One possible explanation is that they have already integrated the likelihood of the default by having already sold the Euro against the USD. At the other extreme, when default is unlikely, a credit event would trigger a strong depreciation of Euro, given that it would be unexpected and therefore hardly priced in the current exchange rate.

Our results thus far complement the findings of Della Corte et al. (2015). They discover that an increase of SCDS spreads causes an expected depreciation of the local currency, a higher option-implied volatility, a more negative skewness, and a greater kurtosis.[31] They conclude that investors perceive a higher probability of large decline of the local currency relative to the USD when sovereign credit risk increases and that they are therefore willing to buy insurance at a higher price to protect themselves from this downside risk (Della Corte et al., 2015).[32] Here, we find that the expected depreciation conditional to a default is higher in a low sovereign risk environment. Therefore, traders pay a higher premium to hedge the implied depreciation by bidding relatively higher prices (spreads) in SCDS denominated in USD, relative to those in Euro, than in a high sovereign risk environment. The reason for the difference of results is that Della Corte et al. (2015) focus their analysis on the expected currency depreciation (i.e., the combination of the depreciation upon default and the probability of this event), while we only consider the expected currency depreciation conditional to a default.[33] In short, a higher probability of default increases the expected currency depreciation (Della Corte et al., 2015), but decreases the expected currency depreciation conditional to a default. Thus, both sets of findings complement each other.

[31] Della Corte et al. (2015) use a reverse collar and a butterfly strategy to measure the skewness and the kurtosis of the risk-neutral distribution of returns, respectively.

[32] Carr and Wu (2007a, 2007b) also provide evidence that the negative skewness implied by options can be better captured if the exchange rate follows a diffusion process with a jump at default. They also find that when the likelihood of default increases, it should amplify the negative risk-neutral skewness, either with the jump at default or with a higher volatility.

[33] Other reasons may explain why our findings differ from those of Della Corte et al. (2015). First, each analysis considers a different market, i.e., the SCDS and currency options market, that is likely to involve different participants with varying trading motives. Second, the time horizon differs substantially because they consider one-month currency options, while we use five-year SCDS.

Table 7—Determinants of the implied Euro depreciation

The table reports coefficient estimates of the regressions that examine the determinants of the implied Euro depreciation in the case of a sovereign default. The dependent variable consists of the country-level implied Euro depreciation computed with the base case, as detailed in Section 2.3.1. Table 6 reports the statistics of the different variables. The sample consists of observations between August 20, 2010, and December 31, 2013. We report *t*-statistics, using Huber-White heteroskedasticity-robust standard errors adjusted for country clustering, in parentheses below the coefficient estimates. *, **, and *** show statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Sovereign credit risk						
Ln(SCDS in Euro)	-11.41	-11.37	-12.19	-12.21	-12.25	-12.57
	(-16.87)***	(-14.67)***	(-16.70)***	(-16.30)***	(-16.48)***	(-22.60)***
Ln(SCDS in Euro)^2	1.08	1.10	0.95	0.97	0.98	0.95
	(4.29)***	(3.95)***	(3.68)***	(3.69)***	(3.73)***	(3.55)***
Currency market						
Exchange rate return (USD/Euro, YoY)		-0.15	-0.08	-0.17	-0.14	-0.16
		(-2.90)**	(-2.51)**	(-5.89)***	(-5.47)***	(-3.73)***
Forward premium (6-months, USD/Euro)		8.15	2.58	-1.26	-6.93	-6.85
		(1.29)	(0.91)	(-0.56)	(-2.30)*	(-2.52)**
Global and local market conditions						
EUR swap rate (5y)			0.79	-3.17	-4.13	-3.80
			(0.31)	(-1.48)	(-1.81)	(-1.79)
USD swap rate (5y)			-2.38	3.82	4.23	4.05
			(-1.33)	(2.86)**	(3.09)**	(2.98)**
TED spread			27.09	10.81	19.74	23.32
			(3.97)***	(2.34)*	(4.21)***	(3.74)***
VSTOXX			-0.21	-0.09	-0.01	0.00
			(-2.35)*	(-1.62)	(-0.18)	(0.09)
Local stock market return (YoY)			-0.08	-0.08	-0.09	-0.07
			(-1.64)	(-1.52)	(-1.64)	(-1.51)
Global economic conditions						
EU industrial production growth (YoY)				-0.49	-0.37	-0.15
				(-2.21)*	(-2.12)*	(-1.08)
EU inflation (YoY)				3.90	5.92	6.04
				(4.21)***	(4.11)***	(3.59)***
US industrial production growth (YoY)					-0.80	-0.92
					(-1.96)*	(-1.99)*
US inflation (YoY)					-3.10	-3.13
					(-2.96)**	(-2.83)**
Local economic conditions						
Local industrial production growth (YoY)						-0.22
						(-1.37)
Local inflation (YoY)						-0.18
						(-0.41)
Constant	28.24	28.31	28.74	20.32	21.36	20.11
	(28.25)***	(26.63)***	(6.57)***	(7.71)***	(6.20)***	(6.25)***
Observations	6,237	6,237	6,237	6,237	6,237	6,237
Adjusted R-squared	0.784	0.818	0.854	0.866	0.870	0.873
Frequency	Daily	Daily	Daily	Daily	Daily	Daily

Period: 09/10-12/13

Eurozone countries: Belgium, France, Germany, Ireland, Italy, Portugal, Spain and Greece

2.4.5.2 Currency market conditions

Table 7 clearly indicates that the stronger the recent performance of the Euro relative to the USD, the lower the implied depreciation. The effect is statistically and economically significant. If the Euro appreciates by one standard deviation, the implied depreciation decreases by 1.25 percentage points (i.e., from 24% to 22.75%). This finding suggests that traders are willing to pay a higher premium against depreciation risk when the Euro becomes weaker. The reasoning is that, following a depreciation of the Euro, investors seek to avoid further losses on their Euro positions and thus prefer SCDS in USD than the Euro counterparts. Thus, the SCDS in USD becomes relatively more expensive. This timing consideration is consistent with Brunnermeier, Nagel, and Pedersen (2008), who find that a depreciation of the exchange rate increases the current price of insurance against a crash risk, even if future downside risk is actually lower.

Similarly, expected returns of the Euro relative to the USD, as measured by the forward market, also negatively affect the implied depreciation, which decreases by 1.58 percentage points (i.e., from 24% to 22.42%) when the six-month forward premium increases by one standard deviation. Hence, traders prefer to buy SCDS in Euro when the forward contract implies a short-term appreciation of the Euro, which translates into a decline in the implied Euro depreciation. Overall, the implied depreciation is thus particularly high when either the realized or the expected Euro depreciation is severe.

2.4.5.3 Financial and economic conditions

We now turn to global and local market conditions. Table 7 shows that the level of liquidity in the funding market appears to play a critical role in explaining the implied depreciation. The impact of the TED spread is positive and highly statistically significant. We find that a one standard deviation increase in the TED spread causes the implied depreciation to appreciate by 2.45 percentage points, all else being equal. As investors become more constrained by their funding liquidity capacity, they value SCDS in USD more than Euro SCDS, therefore paying a higher premium to hedge depreciation risk. This result corroborates the existing findings that investors reduce their positions in risky and volatile currencies when funding liquidity dries up (Brunnermeier, Nagel, and Pedersen, 2008).

US interest rates also influence positively the magnitude of the implied depreciation. A one standard deviation decline of the swap rates increases the implied depreciation by 1.89 percentage points. Therefore, the implied depreciation appears to decrease during flight-to-safety episodes beyond the information already captured by other financial and economic conditions. By contrast, neither the EU interest rates nor global and local stock market returns seem to convey significant information.

Among the variables related to global macroeconomic conditions, only the inflation level has a strong and significant effect on the Euro depreciation that we expect to see at the time of a sovereign default. We find that the higher inflation in the Eurozone, the greater the implied depreciation. In contrast, greater inflation in the US has the opposite effect. This result suggests that the EU-US inflation rate differential influences the magnitude of the Euro depreciation upon a sovereign default. This is consistent with the purchasing power parity, which stipulates that countries with high inflation should see their local currency decline in the long run. Hence, it is the important to account for the information related to expected changes in the Euro, both over the short term, as implied by the six-month forwards, and over the long run, as implied by the inflation differential. In contrast, local economic conditions are not material drivers of the implied depreciation.

Overall, the implied Euro depreciation upon a sovereign default decreases with a country's sovereign credit risk, the realized (or expected) strength of the Euro relative to the USD, when funding liquidity improves, and when interest rates increase in the US.

2.4.6 Analysis by country

We now investigate whether there exists cross-country heterogeneity in the role of the determinants of the implied Euro depreciation. To this end, we examine the influence of the main factors identified in the previous section but run the regression for each individual country. Table 8 reports the results. First, we observe a strong stability in the effects across countries. The level of a country's sovereign credit risk has a negative effect for all countries except Greece, and the stronger the performance of the Euro, the lower the implied depreciation for all countries except Spain and Portugal. By contrast, the TED spread has a positive effect for all countries except Portugal. In addition, all countries except Greece exhibit a positive effect of the European inflation rate on the implied Euro depreciation, while most countries except Greece, Italy, and France display a negative effect of the inflation rate in the US.

Notably, the results also suggest that the implied Euro depreciation upon a sovereign default in non-PIIGS countries reacts much more strongly to changes in funding liquidity conditions, all else being equal. The influence of the TED spread is greatest for Germany and France, thus indicating that investors pay a higher premium to hedge depreciation risk conditional on a default in countries with higher systemic risk.

Furthermore, we show that the effect of these factors is not restricted to Eurozone countries. As an additional analysis, Table 9 reports the results of the regressions that use data from Brazil, Great Britain, and Russia (we provide descriptive statistics of the selected variable and further figures in Appendix A.4). The model explains a large fraction of the variations of their implied currency depreciation and yields similar results.

Table 8—Drivers of the implied Euro depreciation by country

The table reports coefficient estimates of the regressions that examine the determinants of the implied Euro depreciation in the case of a sovereign default. We only consider factors related with sovereign credit risk, funding liquidity, and inflation conditions. The dependent variable consists of the country-level implied Euro depreciation computed with the base case, as detailed in Section 2.3.1. Table 6 reports the statistics of the different variables. The sample consists of observations between August 20, 2010, and December 31, 2013. We report *t*-statistics, using Huber-White heteroskedasticity-robust standard errors adjusted for country clustering, in parentheses below the coefficient estimates. *, **, and *** show statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1) Belgium	(2) France	(3) Germany	(4) Italy	(5) Ireland	(6) Portugal	(7) Spain	(8) Greece
Sovereign conditions								
Ln(CDS in Euro)	-21.33	-33.00	-36.03	-17.69	-18.03	-20.85	-27.23	4.35
	(-59.15)***	(-18.90)***	(-20.26)***	(-34.42)***	(-26.22)***	(-11.71)***	(-22.25)***	(1.02)
Ln(CDS in Euro)²	-1.27	-1.59	-3.10	2.28	3.75	5.05	10.00	-1.35
	(-2.64)***	(-0.97)	(-4.65)***	(7.36)***	(13.29)***	(9.70)***	(16.08)***	(-2.33)**
Currency market								
Exchange rate return (USD/Euro, YoY)	-0.24	-0.55	-0.51	-0.19	-0.07	-0.03	-0.01	-0.12
	(-9.73)***	(-13.30)***	(-13.83)***	(-14.46)***	(-5.62)***	(-1.58)	(-0.44)	(-2.40)**
Liquidity conditions								
TED spread	38.94	96.07	89.43	14.80	6.28	-11.58	11.59	25.79
	(17.38)***	(25.49)***	(25.58)***	(14.65)***	(7.26)***	(-8.57)***	(10.07)***	(4.33)***
Inflation conditions								
EU inflation (YoY)	9.30	4.27	2.77	4.14	6.27	3.67	6.52	0.64
	(16.59)***	(5.58)***	(4.18)***	(19.30)***	(17.48)***	(12.11)***	(25.46)***	(0.86)
US inflation (YoY)	-2.06	0.47	0.95	-0.15	-2.77	-2.21	-2.30	-0.95
	(-5.79)***	(0.76)	(1.93)*	(-0.94)	(-14.75)***	(-8.15)***	(-10.06)***	(-0.94)
Constant	3.71	-14.72	-30.61	18.84	19.27	28.83	24.40	-0.40
	(3.33)***	(-9.58)***	(-19.91)***	(54.45)***	(80.77)***	(20.25)***	(46.76)***	(-0.07)
Observations	822	822	820	819	820	822	821	491
Adjusted R-squared	0.898	0.746	0.860	0.905	0.937	0.624	0.532	0.173
F-Stat	1437	357.9	1059	1582	2379	243.7	230	45.67
Frequency	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily

Table 9—Determinants of the implied depreciation of the currency in non-Eurozone countries

The table reports coefficient estimates of the regressions that examine the determinants of the implied currency depreciation in the case of a sovereign default in non-European countries. We analyze the cases of Great Britain, Russia, and Brazil. We only consider factors related to sovereign credit risk, funding liquidity, and inflation conditions. The dependent variable consists of the country-level implied local currency depreciation computed with the base case, as detailed in Section 2.3.1. Table 6 and Table A.2 in Appendix A.4 report the statistics of the different variables. The sample consists of observations between August 20, 2010, and December 31, 2013. We report *t*-statistics, using Huber-White heteroskedasticity-robust standard errors adjusted for country clustering, in parentheses below the coefficient estimates. *, **, and *** show statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1) Great Britain	(2) Russia	(3) Brazil
Sovereign conditions			
Ln(SCDS in local currency)	-70.39	-36.37	-66.38
	(-23.28)***	(-15.92)***	(-40.10)***
Ln(SCDS in local currency)²	-13.69	-17.93	53.01
	(-10.42)***	(-4.93)***	(11.91)***
Currency market			
Exchange rate return (USD/Local, YoY)	-0.41	-0.97	-0.63
	(-4.44)***	(-11.24)***	(-9.35)***
Liquidity conditions			
TED spread	42.88	44.09	15.16
	(9.72)***	(9.47)***	(2.56)**
Inflation conditions			
Local inflation (YoY)	15.61	0.63	12.65
	(20.75)***	(1.97)**	(12.26)***
US inflation (YoY)	-4.31	1.85	-3.03
	(-6.30)***	(3.01)***	(-3.08)***
Constant	-78.87	16.77	-60.78
	(-26.47)***	(6.12)***	(-12.16)***
Observations	818	784	619
Adjusted R-squared	0.756	0.664	0.688
F-Stat	930.1	167.7	330.8
Frequency	Daily	Daily	Daily

2.4.7 Robustness tests

This section provides several extensions and alternative specifications to verify the robustness of the results.

2.4.7.1 Endogeneity and reverse causality

The main analysis of this paper suggests that our selection of factors can explain well contemporaneous variations in the implied Euro depreciation. To deal with potential endogeneity and reverse causality issues, we verify that one obtains similar results when we use past information.

To this end, we reproduce Table 7 using a one-month lag (i.e., of 20 trading days) for all independent variables. We report the results in Table 10, which yields similar results in terms of the magnitude and statistical significance of the coefficients. The explanatory power also remains strong with an adjusted R^2 of 72.9% in Column (1) and 83.2% in Column (6).

Table 10—Robustness analysis: endogeneity and reverse causality issues

The table reproduces Table 7 with a one-month lag for all the independent factors to address potential endogeneity and reverse causality issues. We report *t*-statistics, using Huber-White heteroskedasticity-robust standard errors adjusted for country clustering, in parentheses below the coefficient estimates. *, **, and *** show statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Sovereign credit risk						
Ln(SCDS in Euro)	-11.11	-11.06	-12.15	-12.17	-12.23	-12.40
	(-14.89)***	(-12.77)***	(-18.30)***	(-18.02)***	(-18.32)***	(-23.33)***
Ln(SCDS in Euro)²	1.00	1.03	0.84	0.86	0.86	0.83
	(2.84)**	(2.68)**	(2.29)*	(2.33)*	(2.35)*	(2.32)*
Currency market						
Exchange rate return (USD/Euro, YoY)		-0.20	-0.10	-0.15	-0.18	-0.19
		(-3.47)**	(-2.15)*	(-4.45)***	(-5.50)***	(-5.98)***
Forward premium (6-months, USD/Euro)		10.15	8.31	5.96	-0.12	-0.42
		(1.56)	(2.54)**	(2.32)*	(-0.04)	(-0.15)
Global and local market conditions						
EUR swap rate (5y)			0.11	-3.29	-3.90	-4.04
			(0.04)	(-1.27)	(-1.38)	(-1.46)
USD swap rate (5y)			0.70	5.57	5.69	5.80
			(0.37)	(3.05)**	(2.98)**	(3.07)**
TED spread			26.79	14.09	24.66	26.69
			(4.21)***	(3.13)**	(4.15)***	(3.68)***
VSTOXX			-0.10	-0.02	0.04	0.04
			(-1.45)	(-0.42)	(2.36)**	(1.47)
Local stock market return (YoY)			-0.10	-0.10	-0.12	-0.12
			(-1.70)	(-1.61)	(-1.71)	(-1.98)*
Global economic conditions						
EU industrial production growth (YoY)				-0.30	-0.02	0.14
				(-1.48)	(-0.12)	(0.95)
EU inflation (YoY)				3.52	5.47	6.17
				(3.66)***	(2.95)**	(3.05)**
US industrial production growth (YoY)					-1.39	-1.49
					(-2.65)**	(-2.73)**
US inflation (YoY)					-3.33	-3.50
					(-2.18)*	(-2.25)*
Local economic conditions						
Local industrial production growth (YoY)						-0.12
						(-0.79)
Local inflation (YoY)						-0.51
						(-1.03)
Constant	28.56	28.63	23.54	16.51	19.84	19.51
	(25.65)***	(23.92)***	(6.75)***	(9.06)***	(7.04)***	(7.53)***
Observations	6,075	6,075	6,075	6,075	6,075	6,075
Adjusted R-squared	0.729	0.786	0.829	0.836	0.841	0.842
Frequency	Daily	Daily	Daily	Daily	Daily	Daily

Period: 09/10-12/13

Eurozone countries: Belgium, France, Germany, Ireland, Italy, Portugal, Spain and Greece

2.4.7.2 Alternative specifications

As additional tests, we consider alternative specifications of the model.[34] We report the results in Table 11. Column (1) is the same as Column (6) of Table 7, which we report for comparison purposes. Columns (2) to (6) reproduce the specification of the main model except that Column (2) includes country fixed effects, Column (3) shows the results excluding Greece,[35] Column (4) replaces the 5-year SCDS in Euro with its 1-year counterpart, and Column (5) to (6) replace our dependent variable with the one obtained, respectively, with the swap case and with the expected exchange rate conditional to no default. Overall, the results confirm that sovereign credit risk, currency market conditions, funding liquidity, US interest rates, and inflation differentials help explain fluctuations in the implied Euro depreciation.

We also examine whether the results vary in low versus high sovereign credit risk environment. Column (7) and (8) display the results of the main model when a country's SCDS spreads in Euro are respectively lower and higher than the median. The level of the US interest rates appears to matter only in the low-risk environment, consistent with the notion that it proxies for flight-to-safety pressure. Moreover, the response of the implied depreciation to the TED spread is higher when sovereign credit risk is lower. This result confirms our previous finding that the role of funding liquidity is greater for systemic risk countries in which default may trigger a collapse of the European financial system and lead to a depreciation of the Euro.

We further examine whether the relative size of a country's economy affects the implied depreciation to test the role of systematic risk in sovereign default. Column (9) displays the results when adding the size of a country's GDP relative to the Eurozone GDP as a determinant.[36] This measure does not appear to be statistically significant, which suggests that the implied depreciation does not vary with the economic size of a country when we control for the country's credit risk level and economic conditions.

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[34] The lagged relation between the implied depreciation and the dependent variables also yields similar results.

[35] Not surprisingly, the relation becomes less convex, as we exclude data with the highest sovereign risk and the lowest implied depreciation.

[36] We choose 2010 as the reference year for the whole sample to compute the size of a country's GDP relative to the Eurozone GDP.

Table 11—Robustness analysis: alternative specifications

The table reports coefficient estimates of alternative regression specifications. The dependent variable consists of the country-level implied Euro depreciation computed with the base case, as detailed in Section 2.3.1. Table 6 reports the statistics of the different variables. The sample consists of observations between August 20, 2010, and December 31, 2013. We report *t*-statistics, using Huber-White heteroskedasticity-robust standard errors adjusted for country clustering, in parentheses below the coefficient estimates. *, **, and *** show statistical significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sovereign credit risk									
Ln(SCDS in Euro)	-12.57	-16.36	-12.92	-7.90	-13.13	-12.63	-12.66	-15.29	-13.32
	(-22.60)***	(-10.08)***	(-43.43)***	(-21.52)***	(-23.78)***	(-22.53)***	(-7.80)***	(-5.59)***	(-19.70)***
Ln(SCDS in Euro)²	0.95	1.26	0.20	0.45	0.90	0.92	-0.24	1.81	0.99
	(3.55)***	(6.51)***	(0.67)	(4.91)***	(3.14)**	(3.37)**	(-0.29)	(3.79)***	(4.15)***
Currency market									
Exchange rate return (USD/Euro, YoY)	-0.16	-0.25	-0.19	-0.17	-0.15	-0.16	-0.09	-0.16	-0.16
	(-3.73)***	(-3.84)***	(-4.01)***	(-3.98)***	(-3.36)**	(-3.71)***	(-0.85)	(-3.89)***	(-3.44)**
Forward premium (6-months, USD/Euro)	-6.85	-5.87	-7.16	-6.44	-5.89	-6.14	-13.98	-5.62	-6.91
	(-2.52)**	(-2.66)**	(-2.39)*	(-2.45)**	(-2.15)*	(-2.22)*	(-2.51)*	(-2.39)*	(-2.66)**
Global and local market conditions									
EUR swap rate (5y)	-3.80	-1.30	-2.55	-3.80	-3.74	-5.87	-8.43	-2.54	-3.78
	(-1.79)	(-0.70)	(-1.26)	(-1.59)	(-2.06)*	(-2.81)**	(-4.77)***	(-0.95)	(-1.85)
USD swap rate (5y)	4.05	2.30	2.99	4.16	3.94	5.95	5.84	3.81	4.12
	(2.98)**	(1.94)*	(2.74)**	(2.51)**	(3.45)**	(4.43)***	(4.09)***	(2.30)*	(3.07)**
TED spread	23.32	25.56	23.86	23.31	20.59	23.38	35.73	15.48	24.00
	(3.74)***	(3.48)**	(3.83)***	(4.57)***	(3.12)**	(3.71)***	(4.86)***	(5.09)***	(3.75)***
VSTOXX	0.00	0.07	-0.01	0.06	-0.01	-0.00	-0.13	0.06	0.01
	(0.09)	(1.45)	(-0.16)	(1.36)	(-0.21)	(-0.00)	(-2.66)**	(1.26)	(0.18)
Local stock market return (YoY)	-0.07	-0.05	-0.08	-0.07	-0.07	-0.07	-0.22	-0.01	-0.09
	(-1.51)	(-0.91)	(-1.83)	(-1.44)	(-1.45)	(-1.53)	(-4.58)***	(-0.16)	(-1.54)
Global economic conditions									
EU industrial production growth (YoY)	-0.15	-0.39	-0.30	-0.18	-0.15	-0.16	-0.54	0.05	-0.13
	(-1.08)	(-2.44)**	(-2.56)**	(-1.67)	(-1.28)	(-1.14)	(-2.28)*	(0.34)	(-1.06)
EU inflation (YoY)	6.04	6.63	4.78	4.75	5.90	6.25	7.77	4.73	6.40
	(3.59)***	(3.80)***	(2.00)*	(2.78)**	(3.75)***	(3.75)***	(3.03)**	(2.32)*	(3.28)**
US industrial production growth (YoY)	-0.92	-0.72	-0.95	0.10	-0.90	-0.92	-1.66	0.02	-0.95
	(-1.99)*	(-1.79)	(-1.95)*	(0.21)	(-2.00)*	(-2.01)*	(-2.96)**	(0.07)	(-2.05)*
US inflation (YoY)	-3.13	-2.56	-3.14	-1.30	-2.95	-3.20	-7.26	-1.24	-3.20
	(-2.83)**	(-2.41)**	(-2.41)*	(-1.25)	(-2.72)**	(-2.92)**	(-7.24)***	(-1.77)	(-2.72)**
Local economic conditions									
Local industrial production growth (YoY)	-0.22	-0.05	-0.18	-0.15	-0.20	-0.22	-0.12	-0.15	-0.22
	(-1.37)	(-0.52)	(-1.20)	(-1.03)	(-1.31)	(-1.37)	(-1.02)	(-2.55)**	(-1.42)
Local inflation (YoY)	-0.18	-0.49	0.63	0.02	-0.27	-0.25	2.51	-0.47	-0.38
	(-0.41)	(-0.93)	(0.83)	(0.03)	(-0.62)	(-0.57)	(1.94)	(-0.87)	(-0.78)
Economic size (% of Eurozone GDP)									-0.11
									(-1.12)
Constant	20.11	15.62	21.90	6.26	20.09	19.99	30.38	17.06	21.12
	(6.25)***	(5.29)***	(7.67)***	(2.33)*	(6.84)***	(6.22)***	(12.42)***	(6.39)***	(5.91)***
Observations	6,237	6,237	5,746	6,215	6,237	6,237	3,118	3,118	6,237
Adjusted R-squared	0.873	0.897	0.876	0.881	0.895	0.879	0.860	0.745	0.875
Country Fixed Effect		x							
Greece excluded			x						
CDS 1y				x					
Swap case implied depreciation					x				
Forward case implied depreciation						x			
Low sovereign risk							x		
High sovereign risk								x	
Frequency	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily

Period: 09/10-12/13

Eurozone countries: Belgium, France, Germany, Ireland, Italy, Portugal, Spain and Greece

2.5. Conclusion

This study analyzes the expected variation in the USD/Euro exchange rate in the case of a sovereign default in the Eurozone. We exploit dual-currency sovereign CDS to derive a market-based measure of the conditional Euro depreciation based on a no-arbitrage approach. Based on daily data over the period 2010–2013, we find that the Euro is expected to lose 32.1%, on average, in the case of a sovereign default. This magnitude strongly varies across Eurozone countries and over time.

We find that the implied depreciation of the Euro greatly depends on the current level of a country's sovereign credit risk. The relationship is negative, which is consistent with the notion that the current exchange rate accounts for the likelihood of default, since investors tend to sell Euro against the USD when sovereign credit risk increases. By contrast, we expect a credit event to trigger a severe depreciation of the Euro when default is unlikely because such a scenario is barely priced in the spot exchange rate. Similarly, the results show that the implied Euro depreciation decreases with past and expected appreciation of the Euro. In addition, lower funding liquidity appears to increase the implied Euro depreciation, signaling that investors willing to hedge the depreciation risk pay a risk premium that depends on their funding liquidity constraints. This aspect is even more pronounced in a low sovereign risk environment and for countries showing the highest systemic risk, such as France and Germany. In the end, the results of this paper call for further research in at least two directions. First, it would be insightful to investigate the information content of the implied Euro depreciation term structure and, second, to examine whether the implied depreciation is informative to predict future exchange rate returns.

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Appendix

A.1 Derivation of the implied Euro depreciation for the swap case

In this section, we derive the expected Euro depreciation conditional to a default (i.e., the implied Euro depreciation) in the more general case. We then show how to obtain this measure in what we consider to be the base case scenario.

A.1.1 Notation

CS_{a,t_0}: SCDS spread denominated in currency a, observed at time t_0, and with maturity T.

N_a: Notional of SCDS contract in currency a.

S_{t_0}: Current spot exchange rate for USD/Euro.

S_{t_D}: USD/Euro exchange rate at time of default t_D.

$\mathbb{E}_{t_0}(S_{t_D})$: Current expected USD/Euro exchange rate conditional on a default at t_D, $t_D \in (t_0, T)$.

R: Bond recovery rate at default.

$V_{t_0,t_D,T}$: USD/Euro swap value of a long Euro position at time of default t_D with maturity T.

χ_a: Accrued premium in currency a.

$F^a_{t_0,t,T}$: Forward discount factor in currency a, from time t to T, but observed at time t_0.

$Z^a_{t_0,T}$: Price of a zero-coupon bond in currency a at time t_0 with maturity T.

Γ_t: Risk-neutral probability of no-default over t_0 to t.

Q_t: Risk-neutral probability of a default at time t and conditional on no previous default (between t_0 and $t-1$).

A.1.2 Full case derivation

We derive here the arbitrage-free strategy that we implement to derive the implied depreciation. We consider the perspective of a USD-based investor. We assume that SCDS payments are made annually at fixed date and that there are M payments for a T-

year SCDS such that: $t_0 = 0, t_M = T, 0 < t_1 < \cdots < t_M$ and $\Delta_t = t_i - t_{i-1} = 1$.[37] We consider that the annual SCDS premium over the period of protection $[t_{i-1}, t_i]$, $i \epsilon [\![1, M]\!]$, is paid at time t_i. If the default happens between two payment dates, we consider that half of the annual SCDS premium over the period is accrued and has to be paid to the protection seller and that the terminal cash flows due to the default are exchanged at the next payment date.[38] We define this date as t_D, with $D \epsilon [\![1, M]\!]$ (e.g., if $t_D = t_1$, default happened between t_0 and t_1).

The strategy is the following over the horizon *T*, assuming that no default occurs.

Step 1: Determining the notional

At the inception (t_0), we are long a SCDS denominated in Euro with nominal N_{eur}, which pays annually CS_{eur,t_0}, and we are short a SCDS denominated in USD with nominal N_{usd}, which pays annually CS_{usd,t_0}. To convert all flows in USD and eliminate the currency risk involved in the payment of the premium of the SCDS in Euro, we also enter into a fix for fix annuity currency swap in which Euro is received and USD is paid at the constant exchange rate S_{t_0}.[39] Hence, the exchange rate is fixed for the annual premium payments, and given that this is a self-financing strategy, we must have at t_0, assuming that no default occurs:

$$CS_{eur,t_0} N_{eur} S_{t_0} = CS_{usd,t_0} N_{usd}. \quad \text{(A.1)}$$

This implies that the notional of SCDS denominated in USD that is required to implement the strategy at time t_0 is equal to:

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[37] We assume annual SCDS payments to exploit directly the SCDS term structure, given that SCDS spreads in USD and Euro with maturity one to five years are already available. We therefore avoid the technical issue of fitting the SCDS curve. We use the SCDS term structure in Section A.1.5. Even if we assume annual payments, we distinguish the number of payments (*M*) from the maturity (*T*) of the SCDS contracts to ease the understanding of the bootstrapping method used to calibrate the default probabilities in Section A.1.5.

[38] We account for accrued premiums as in Pan and Singleton (2008) and Longstaff et al. (2011). We therefore avoid any "free lunch" given to the protection buyer in the default year, since the SCDS contract ends at the time of default and since the annual SCDS premium is normally supposed to be paid at the end of the year of protection. As we do not know exactly the time of default between $[t_{i-1}, t_i]$, $i \epsilon [\![1, M]\!]$, we assume that, on average, the default happens at the middle of the period and therefore half of the SCDS premium is accrued, as in Choudhry and Ali (2010).

[39] There is no exchange of notionals for annuity currency swap.

$$N_{usd} = \frac{CS_{eur,t_0} N_{eur}}{CS_{usd,t_0}} S_{t_0}. \quad \text{(A.2)}$$

Step 2: Expected swap value at default

To derive the fixed Euro leg, we first discount all Euro flows at t_D and then convert their value at the current exchange rate S_{t_D}. The value of the fixed Euro leg is $\sum_{t=t_D}^{T} \left(CS_{eur,t_0} N_{eur} S_{t_D} F_{t_0,t_D,t}^{eur} \right)$, while the value of the fixed USD leg is $\sum_{t=t_D}^{T} \left(-CS_{usd,t_0} N_{usd} F_{t_0,t_D,t}^{usd} \right)$ for a long Euro position. $F_{t_0,t_D,t}^{eur}$ and $F_{t_0,t_D,t}^{usd}$ are the observed risk-free forward prices at time t_0, respectively, in Euro and USD from time t_D to t (the tenor is not always equal to one year). We explain in section A.1.4 how we calculate these prices and those of zero-coupon bonds in Euro and USD. We denote $V_{t_0,t_D,T}$ the t_0-expected value of the long Euro position of the *T*-year currency swap at t_D as the discounted value of the remaining net payments of the fixed Euro and USD leg.

This implies that the value of $V_{t_0,t_D,T}$ is:

$$V_{t_0,t_D,T} = \sum_{t=t_D}^{T} \begin{pmatrix} CS_{eur,t_0} N_{eur} S_{t_D} F_{t_0,t_D,t}^{eur} \\ -CS_{usd,t_0} N_{usd} F_{t_0,t_D,t}^{usd} \end{pmatrix}. \quad \text{(A.3)}$$

Step 3: Flows in default

If a default occurs between t_0 and maturity *T*, at t_D, the long position receives the contingent payment of the SCDS denominated in Euro and pays the value of the currency swap $(1 - R)\, N_{eur} S_{t_D} - \chi_{eur}\, S_{t_D} + V_{t_0,t_D,T}$, while the short position in USD pays $(1 - R)\, N_{usd} - \chi_{usd}$. Here, $V_{t_0,t_D,T}$, χ_{eur}, and χ_{usd} are the value expected at t_0 of the long Euro position of the *T*-year currency swap at time t_D and the accrued premiums of the SCDS swaps in Euro and USD, respectively. Because we assume that half of the annual SCDS premiums are accrued when default occurs, we define $\chi_{eur} = \frac{CS_{eur,t_0} N_{eur}}{2}$ and $\chi_{usd} = \frac{CS_{usd,t_0} N_{usd}}{2}$.

To ease the notation, the net terminal cash flows due to the default are defined at t_D as:

$$\delta_{t_0,t_D} = S_{t_D} \left((1 - R)\, N_{eur} - \chi_{eur} \right) - (1 - R)\, N_{usd} + \chi_{usd} + V_{t_D,T}$$

Since we cannot know exactly the time of default, estimating the value at default of the currency swap is not straightforward. For example, an investor who is long Euro with a five-year maturity USD/Euro currency swap will have four remaining annual payments if default happens after one year, while he or she will only have two remaining annual payments if it occurs after three years. To address this issue, we examine the probabilities of default implied in the term structure of SCDS in USD. We explain our calibration method of the probability in Section A.1.5. For now, we assume that the default probabilities are exogenously given.

Step 4: No arbitrage condition

We must now consider all the potential dates of default between t_0 and T. We filter the outcomes conditionally to the plausible time of default t_D. Given that the strategy is self-financing, the arbitrage-free condition remains if (at the inception) the unconditional expected discounted terminal cash flow value due to the default is null: $\mathbb{E}_{t_0,t_D}\left(ZC_{t_0,t_D}\delta_{t_0,t_D}\right) = 0$. Because the information at the inception is filtered by the date t_D, we weight all the plausible flows with their default probabilities of occurring. According to no arbitrage conditions, it is expected (at the inception) that the net discounted cash flow at time of default satisfies:

$$\mathbb{E}_{t_0,t_D}\left(Z^{usd}_{t_0,t_D}\delta_{t_0,t_D}\right) = \sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D} Z^{usd}_{t_0,t_D}\ \mathbb{E}_{t_0}\left(\delta_{t_0,t_D}\right)\right) = 0, \qquad \text{(A.4)}$$

where Q_{t_D} is the probability of default at time t_D and $Z^{usd}_{t_0,t_D}$ is the price of a zero-coupon bond in USD at time t_0 with maturity t_D.

Step 5: Exchange rate in the case of default

We now derive the expected exchange rate in case of default $\mathbb{E}_{t_0}\left(S_{t_D}\right)$ by solving equation A.4. Because we assume that the expected exchange rate at default is the same between the inception date t_0 and maturity date *T*, i.e., $\mathbb{E}_{t_0}\left(S_{t_D}\right) = \mathbb{E}_{t_0}\left(S_{t_1}\right) = \cdots = \mathbb{E}_{t_0}\left(S_{t_M}\right)$, we only need to isolate $\mathbb{E}_{t_0}\left(S_{t_D}\right)$ to solve A.4.

First, we replace N_{usd} by $\frac{CS_{eur,t_0}N_{eur}}{CS_{usd,t_0}}S_{t_0}$ in equation A.4 according to equation A.2, and then we divide by N_{eur}. We find:

$$\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D}Z_{t_0,t_D}^{usd}\begin{pmatrix}(1-R)\mathbb{E}_{t_0}(S_{t_D})-\frac{CS_{eur,t_0}\mathbb{E}_{t_0}(S_{t_D})}{2}\\ -(1-R)\frac{CS_{eur,t_0}}{CS_{usd,t_0}}S_{t_0}+\frac{CS_{eur,t_0}S_{t_0}}{2}\\ +\sum_{t=t_D}^{T}\begin{pmatrix}CS_{eur,t_0}\mathbb{E}_{t_0}(S_{t_D})F_{t_0,t_D,t}^{eur}\\ -CS_{eur,t_0}S_{t_0}F_{t_0,t_D,t}^{usd}\end{pmatrix}\end{pmatrix}\right)=0. \qquad \text{(A.5)}$$

By isolating the latter expression with $\mathbb{E}_{t_0}(S_{t_D})$, and S_{t_0}, respectively, we get:

$$\mathbb{E}_{t_0}(S_{t_D})\left[\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D}Z_{t_0,t_D}^{usd}\left((1-R)-\frac{CS_{eur,t_0}}{2}+B_{t_D,T}\right)\right)\right]-$$

$$S_{t_0}\left[\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D}Z_{t_0,t_D}^{usd}\left((1-R)\frac{CS_{eur,t_0}}{CS_{usd,t_0}}-\frac{CS_{eur,t_0}}{2}+A_{t_D,T}\right)\right)\right]=0,$$

where $A_{t_D,T}=\sum_{t=t_D}^{T}\left(CS_{eur,t_0}F_{t_0,t_D,t}^{usd}\right)$ and $B_{t_D,T}=\sum_{t=t_D}^{T}\left(CS_{eur,t_0}F_{t_0,t_D,t}^{eur}\right)$.

Hence, the expected exchange rate conditional to a default is:

$$\mathbb{E}_{t_0}(S_{t_D})=S_{t_0}\frac{\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D}Z_{t_0,t_D}^{usd}\left((1-R)\frac{CS_{eur,t_0}}{CS_{usd,t_0}}-\frac{CS_{eur,t_0}}{2}+A_{t_D,T}\right)\right)}{\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D}Z_{t_0,t_D}^{usd}\left((1-R)-\frac{CS_{eur,t_0}}{2}+B_{t_D,T}\right)\right)}, \qquad \text{(A.6)}$$

Step 6: Defining the implied depreciation

Defining the implied depreciation as: $ID=\frac{S_{t_0}-\mathbb{E}_{t_0}(S_{t_D})}{S_{t_0}}$, we thus have:

$$ID=1-\frac{\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D}Z_{t_0,t_D}^{usd}\left((1-R)\frac{CS_{eur,t_0}}{CS_{usd,t_0}}-\frac{CS_{eur,t_0}}{2}+A_{t_D,T}\right)\right)}{\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D}Z_{t_0,t_D}^{usd}\left((1-R)-\frac{CS_{eur,t_0}}{2}+B_{t_D,T}\right)\right)}. \qquad \text{(A.7)}$$

Alternatively, to better isolate the expected depreciation caused by default from the expected level of the exchange rate conditional on no default, one can define the implied depreciation as:

$$ID = \frac{\mathbb{E}_{t_0}\left(\left(S_{t_D} | No\ default\right)\right) - \mathbb{E}_{t_0}\left(S_{t_D}\right)}{\mathbb{E}_{t_0}\left(\left(S_{t_D} | No\ default\right)\right)}, \quad (A.8)$$

where $\mathbb{E}_{t_0}\left(\left(S_{t_D} \middle| No\ default\right)\right)$ is the expected exchange rate conditional to no default at t_D. We approximate $\mathbb{E}_{t_0}\left(\left(S_{t_D} \middle| No\ default\right)\right)$ as the average of the forward rate calculated with the uncovered interest rate parity over the maturity of the strategy:

$$\mathbb{E}_{t_0}\left(\left(S_{t_D} \middle| No\ default\right)\right) = \frac{1}{T}\sum_{t_D=t_1}^{T}\left(S_{t_0}\frac{Z_{t_0,t_D}^{eur}}{Z_{t_0,t_D}^{usd}}\right). \quad (A.9)$$

A.1.3 Base case derivation

Now, we derive the implied depreciation assuming that the currency swap has no value when default occurs and that there are no remaining accrued premiums for the SCDS (base case scenario). Equation A.5 becomes:

$$\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D} Z_{t_0,t_D}^{usd}\left((1-R)\mathbb{E}_{t_0}\left(S_{t_D}\right) - (1-R)\frac{CS_{eur,t_0}}{CS_{usd,t_0}}S_{t_0}\right)\right) = 0 \quad (A.10)$$

This yields the expected exchange conditional to a sovereign default according to the base case scenario:

$$\mathbb{E}_{t_0}\left(S_{t_D}\right) = S_{t_0}\frac{\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D} Z_{t_0,t_D}^{usd}\left((1-R)\frac{CS_{eur,t_0}}{CS_{usd,t_0}}\right)\right)}{\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D} Z_{t_0,t_D}^{usd}\left((1-R)\right)\right)} = S_{t_0}\frac{\left((1-R)\frac{CS_{eur,t_0}}{CS_{usd,t_0}}\right)\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D} Z_{t_0,t_D}^{usd}\right)}{\left((1-R)\right)\sum_{t_D=t_1}^{T}\left(\mathrm{Q}_{t_D} Z_{t_0,t_D}^{usd}\right)}$$

which equals, after some simplification:

$$\mathbb{E}_{t_0}\left(S_{t_D}\right) = S_{t_0}\frac{CS_{eur,t_0}}{CS_{usd,t_0}} \quad (A.11)$$

Hence, when defining the implied depreciation as: $ID = \frac{S_{t_0} - \mathbb{E}_{t_0}\left(S_{t_D}\right)}{S_{t_0}}$, we thus have:

$$ID = 1 - \frac{CS_{eur,t_0}}{CS_{usd,t_0}}. \quad (A.12)$$

A.1.4 Calculations of zero-coupons and forward prices

In this subsection, we explain how we calculate prices of risk-free zero-coupon bonds as well as forward prices in Euro and USD. We follow closely in the whole subsection the approach of Veronesi (2010). We assume that the yield curves of interest rate swap in USD and in Euro are available over maturity t_1 to T.[40] At inception, an interest rate swap value is null and the observed quoted yield y_{t_i}, $t_i \epsilon [t_1, T]$ is the fixed interest rate of the fix leg, which behaves like a plain vanilla bond. Let Y_{t_i} be the annual coupon of the fix leg.

We define $Z^a = \begin{pmatrix} Z^a_{t_0,t_1} \\ Z^a_{t_0,t_2} \\ \vdots \\ Z^a_{t_0,t_M} \end{pmatrix}$ as a $M \times 1$ vector of zero coupons prices, $P^a = \begin{pmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{pmatrix}$ as a $N \times 1$ vector of nominal prices set to 1, and $C = \begin{pmatrix} Y_{t_1}+1 & 0 & 0 & 0 \\ Y_{t_2} & Y_{t_2}+1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ Y_{t_m} & Y_{t_m} & \cdots & Y_{t_m}+1 \end{pmatrix}$ as a $M \times M$ lower triangular matrix of coupons payments (on the diagonal, we add principal repayments).

At the inception of the interest rate swap, we should therefore have the following equality, as in Veronesi (2010):

$$\begin{pmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{pmatrix} = \begin{pmatrix} Y_{t_1}+1 & 0 & 0 & 0 \\ Y_{t_2} & Y_{t_2}+1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ Y_{t_m} & Y_{t_m} & \cdots & Y_{t_m}+1 \end{pmatrix} \begin{pmatrix} Z^a_{t_0,t_1} \\ Z^a_{t_0,t_2} \\ \vdots \\ Z^a_{t_0,t_M} \end{pmatrix} \tag{A.13}$$

Therefore, we can calculate the zero coupon prices:

$$\begin{pmatrix} Z^a_{t_0,t_1} \\ Z^a_{t_0,t_2} \\ \vdots \\ Z^a_{t_0,t_M} \end{pmatrix} = \begin{pmatrix} Y_{t_1}+1 & 0 & 0 & 0 \\ Y_{t_2} & Y_{t_2}+1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ Y_{t_m} & Y_{t_m} & \cdots & Y_{t_m}+1 \end{pmatrix}^{-1} \begin{pmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{pmatrix} \tag{A.14}$$

[40] Given that interest swap rates in USD and Euro with maturity one to five years are already available, we avoid the technical issue of fitting the yield curve to exploit the following method of bootstrapping.

The forward price $F^a_{t_0,t_i,t}$ observed at t_0, from time t_i to t can be expressed from zero coupon prices since $Z^a_{t_0,t} = Z^a_{t_0,t_i} F^a_{t_0,t_i,t}$ according to arbitrage-free conditions. This implies that:

$$F^a_{t_0,t_i,t} = \frac{Z^a_{t_0,t}}{Z^a_{t_0,t_i}} \quad \text{(A.15)}$$

A.1.5 Calibration of default probabilities

This subsection shows how we compute the default probabilities used in equation A.7.

Given that SCDS spreads are especially informative of the likelihood of a sovereign default, we use them to derive default probabilities. We exploit the term structure of SCDS spreads in USD to compute the sovereign default probability, as in Mano (2013). The approach to compute the default probabilities is based on the method of pricing credit derivatives developed by Jarrow and Turnbull (1995) and follows the reduced-form method of Hull and White (2000) and O'Kane and Turnbull (2003).

We assume that the term structure of SCDS spreads of maturity over 1 to T years is available and that the value of a SCDS at inception is 0 and can be written following Choudhry and Ali (2010) as:

$$CS^T_{usd,t_0}\left(\sum_{t_i=t_1}^{t_M} Z^{usd}_{t_0,t_i}\left(\Gamma_{t_i} + \frac{Q_{t_i}}{2}\right)\right) - \sum_{t_i=t_1}^{t_M}\left(Q_{t_i} Z^{usd}_{t_0,t_i}(1-R)\right) = 0, \quad \text{(A.16)}$$

where Γ_{t_i} is the probability of no-default over t_0 to t_i, Q_{t_i} is the probability of default at time t_i (and that no default occurs previously), $\sum_{t_i=t_1}^{t_M}\left(Q_{t_i} Z^{usd}_{t_0,t_i}(1-R)\right) = B^T_M$ is the recovery leg of the SCDS with maturity T (which implies knowing M default probabilities Q_{t_i}), $CS^T_{usd,t_0}\left(\sum_{t_i=t_1}^{t_M} Z^{usd}_{t_0,t_i}\left(\Gamma_{t_i} + \frac{Q_{t_i}}{2}\right)\right) = A^T_M$ is the premium leg of the SCDS with maturity T (which implies to know M default probabilities Q_{t_i}), and CS^T_{usd,t_0} is the current SCDS spread denominated in USD with maturity T . The relation between Γ_{t_i} and Q_{t_i} for $i \epsilon [1, M]$ following O'Kane and Turnbull (2003) is:

$$\Gamma_{t_i} = \Gamma_{t_{i-1}} - Q_{t_i}. \quad \text{(A.17)}$$

By definition, $\Gamma_{t_0} = 1$, i.e., $Q_{t_0} = 0$. The calibration method requires computing progressively the probabilities Γ_{t_i} (and then Q_{t_i}) for $t_i \epsilon [t_0, T]$ with the SCDS spread of maturity t_i, while knowing the probabilities of $\Gamma_{t_{i-1}}, \Gamma_{t_{i-2}}, \dots, \Gamma_{t_1}$ calculated previously, as explained in O'Kane and Turnbull (2003). We use Γ_{t_i} to calculate Q_{t_i} to facilitate the computations.

Following the approach described in O'Kane and Turnbull (2003), we derive based on our assumptions a general equation to compute default probabilities.[41] We first calculate the probability Γ_{t_1} with a SCDS spread of maturity one year, and then we generalize.

Based on equation A.14, we have: $CS^1_{usd,t_0} Z^{usd}_{t_0,t_1} \left(\Gamma_{t_1} + \frac{Q_{t_1}}{2} \right) - \left(\Pi_{t_1} Z^{usd}_{t_0,t_1} (1-R) \right) = 0.$

This is equivalent to: $CS^1_{usd,t_0} Z^{usd}_{t_0,t_1} \left(\Gamma_{t_1} + \frac{\Gamma_{t_0} - \Gamma_{t_1}}{2} \right) - \left((\Gamma_{t_0} - \Gamma_{t_1}) Z^{usd}_{t_0,t_1} (1-R) \right) = 0.$

We isolate Γ_{t_1}; this yields: $\Gamma_{t_1} = \frac{\Gamma_{t_0} \left((1-R) - \frac{CS^1_{usd,t_0}}{2} \right)}{\left(\frac{CS^1_{usd,t_0}}{2} + (1-R) \right)}$ and $Q_{t_1} = \Gamma_{t_0} - \Gamma_{t_1}$.

We now derive the probability Γ_{t_M} of no default over t_0 to t_M with a SCDS of maturity $T = t_M$, assuming that we have already estimated the probabilities of defaulting at time $t_{M-1}, \dots, t_1, t_0$. We know that at the inception the SCDS value is null: $A^T_M - B^T_M = 0$. Since we have estimated the default probabilities at $t_{M-1}, \dots, t_1$, we can compute the value of A^T_{M-1} and B^T_{M-1} (which are not the full premium and recovery legs of a SCDS of maturity $T = t_M$). Therefore, we can disentangle the equation $A^T_M - B^T_{M-1} = 0$ into: $A^T_{M-1} - B^T_{M-1} + Z^{usd}_{t_0,t_M} \left(CS^T_{usd,t_0} \Gamma_{t_M} + \left(\frac{1}{2} - (1-R) \right) \left(\Gamma_{t_{M-1}} - \Gamma_{t_M} \right) \right) = 0.$

Hence, when we isolate by Γ_{t_M}, we find:

[41] Since we made the (simple) assumptions that SCDS contracts pay annual premiums and that SCDS spreads quotes and zero coupon prices with maturity one to five years are available, we can solve algebraically the default probabilities. O'Kane and Turnbull (2003) do not provide a general formula that can be used to compute default probabilities with our assumptions. Because they consider monthly or quarterly premium payments, they resort to a root-searching algorithm to calculate default probabilities.

$$\Gamma_{t_M} = \frac{-A_{M-1}^T + B_{M-1}^T + Z_{t_0,t_M}^{usd}\,\Gamma_{t_{M-1}}\left((1-R) - \frac{cs_{usd,t_0}^T}{2}\right)}{Z_{t_0,t_M}^{usd}\left(\frac{cs_{usd,t_0}^T}{2} + (1-R)\right)}. \quad \text{(A.18)}$$

We compute this equation to calculate the probability of default $Q_{t_M} = \Gamma_{t_{M-1}} - \Gamma_{t_M}$.

Special case: Inverted SCDS curve

When the USD-denominated SCDS spread curve is strongly inverted (especially in the case of Greece), we can compute default probabilities above 100% for the first maturity year. In that case, we fix the default probabilities to 100% for the first year and 0% for the following years.

Validity of the calibration

We compare the calibration method of default probabilities we used to the one given by the matlab function *cdsbootstrap.* Table A.1 shows the mean absolute error between the cumulative default probabilities computed with both approaches, per maturity and by country. For instance, if the first year default probability computed with *cdsbootstrap* is 12% for Portugal, we find on average a default probability equal to 12.12% or 11.88%. The errors of estimation of default probabilities are acceptable and may come from the particularities of the function *cdsbootstrap* (day count convention, accrued premiums calculation, etc.).

Table A.1—Comparison of computation of default probabilities

This table contains descriptive statistics on the mean absolute error (MAE) between the computations of the cumulative default probabilities using the calibration method and the matlab function *cdsbootstrap*. The considered maturities go from one to five years. The countries included are Belgium, France, Germany, Italy, Ireland, Portugal, Spain, and Greece. The computation of the default probabilities is detailed in Section A.1.5 of the Appendix. The data are described in Section 2.4.1. The sample consists of observations between August 20, 2010, and December 31, 2013.

	MAE between cumulative probabilities of default				
	1y	**2y**	**3y**	**4y**	**5y**
Belgium	0.02%	0.04%	0.06%	0.07%	0.07%
France	0.01%	0.02%	0.04%	0.05%	0.05%
Germany	0.00%	0.01%	0.01%	0.02%	0.02%
Italy	0.04%	0.08%	0.12%	0.14%	0.14%
Ireland	0.08%	0.14%	0.17%	0.18%	0.17%
Portugal	0.12%	0.20%	0.23%	0.23%	0.22%
Spain	0.04%	0.09%	0.13%	0.14%	0.14%
Greece	0.23%	0.27%	0.27%	0.23%	0.18%

A.1.6 Computation of the Eurozone's average implied Euro depreciation measure

To calculate the Eurozone's average implied Euro depreciation measure, we use the following formula:

$$ID_t^{Eurozone} = \sum_i \; w_i \, ID_{i,t}, \tag{A.19}$$

where $w_i = \frac{GDP_i}{\sum_j \; GDP_j}$ and GDP_i represents the growth domestic product of country *i*.

Table A.2 provides the weights used for each country in the calculation of the Eurozone's average implied Euro depreciation as well as their relative size in the Eurozone in 2010.

Table A.2—Comparison between Swap Case and Base Case derivations

This table shows the weights used for each country in the calculation of the Eurozone's average implied Euro depreciation as well as their relative size in the Eurozone. The countries included are Belgium, France, Germany, Italy, Ireland, Portugal, Spain, and Greece. The computation of the weights is detailed in Appendix A.1. The data are taken from the ECB database and consists of observations of GDP for each country in 2010.

	Country GDP/Eurozone GDP	Weight in average implied depreciation index
Belgium	3.8	4.6
France	21.0	25.1
Germany	27.1	32.3
Italy	16.9	20.1
Irlande	1.7	2.1
Portugal	1.9	2.3
Spain	11.4	13.6
Greece	2.4	-
Total	86.2	100.0

A.2 Implied depreciation approaches

In this subsection, we compute the difference between the base and swap cases computation of the implied depreciation for the Eurozone. Table A.3 provides descriptive statistics of the difference between both measures. The difference is statistically significant for all countries except France and Germany. It seems that the higher the sovereign risk, the lower the measured depreciation with the swap case model, and therefore, the higher the difference with the implied depreciation measured with the base case model. For example, the difference is 2.2% for Portugal's implied depreciation, while it is 0.4% for Germany. Figures A.1 displays the time-series of the implied depreciation measured with both approaches for each country. Both series co-move strongly. However, the difference between the two is not constant and varies over time.

Table A.4 provides descriptive statistics on the difference between the computation methods of the base case without and with the expected exchange rate conditional to no default at the five-year maturity. It appears that the difference in estimation is not material.

Table A.3—Comparison between Swap Case and Base Case derivations

This table contains descriptive statistics on the difference between the base and the swap cases at the five-year maturity. The p-value corresponds to the hypothesis test: "Both implied depreciations are identical." The countries included are Belgium, France, Germany, Italy, Ireland, Portugal, Spain, and Greece. The average prediction of the implied depreciation of these countries is also displayed. The computation of the implied depreciation measure for the base case is detailed in Section 2.3.1, while the calculation of the implied depreciation measure for the swap case is detailed in Appendix A.1. The data are described in Section 2.4.1. The sample consists of observations between August 20, 2010, and December 31, 2013.

	Eurozone	Belgium	France	Germany	Italy	Ireland	Portugal	Spain	Greece
Mean	1.07%	1.06%	0.79%	0.36%	1.68%	1.99%	2.17%	2.06%	3.22%
Median	0.91%	1.03%	0.56%	0.29%	1.39%	2.27%	2.42%	1.92%	2.96%
Max	2.20%	2.53%	2.11%	0.96%	3.44%	3.76%	5.19%	3.97%	19.20%
Min	0.39%	0.22%	0.12%	0.11%	0.58%	0.52%	0.71%	0.72%	-20.91%
P-value	0.39%	4.69%	12.47%	56.62%	0.00%	0.00%	0.00%	0.00%	0.00%

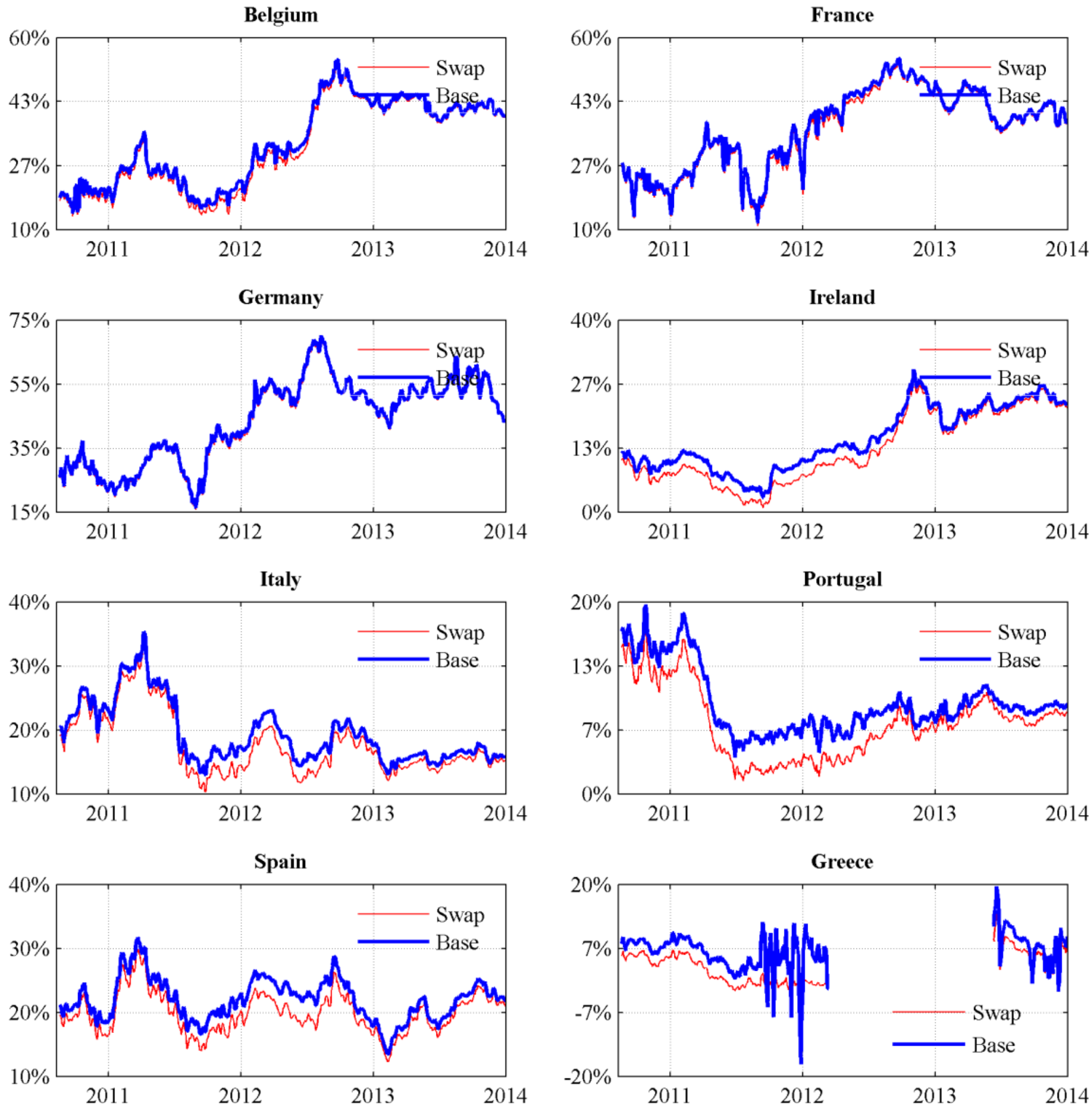

Figure A.1—Implied Euro depreciation by country and approach

This figure shows the variation of the expected exchange rate upon default for Belgium, France, Germany, Italy, Ireland, Portugal, Spain, and Greece. The computation of the implied depreciation measure for the base case is detailed in Section 2.3.1, while the calculation of the implied depreciation measure for the swap case is detailed in Appendix A.1. The data are described in Section 2.4.1. The implied depreciation is smoothed over five days. The sample consists of observations between August 20, 2010, and December 31, 2013.

Table A.4—Base Case derivation with forward condition

This table contains descriptive statistics on the difference between the computation methods of the base case without and with the expected exchange rate conditional to no default, at the five-year maturity. The p-value corresponds to the hypothesis test: "Both implied depreciations are identical." The countries included are Belgium, France, Germany, Italy, Ireland, Portugal, Spain, and Greece. The computation of the implied depreciation measure for the base case is detailed in Section 2.3.1, while the calculation of the implied depreciation measure with the expected exchange rate conditional to no default is detailed in Appendix A.1. The data are described in Section 2.4.1. The sample consists of observations between August 20, 2010, and December 31, 2013.

	Eurozone	Belgium	France	Germany	Italy	Ireland	Portugal	Spain	Greece
Mean	0.86%	0.91%	0.84%	0.79%	0.92%	1.08%	1.07%	0.91%	1.55%
Median	0.69%	0.76%	0.63%	0.49%	0.85%	0.93%	0.95%	0.82%	1.87%
Max	2.78%	2.88%	3.44%	2.65%	2.84%	3.63%	3.64%	2.96%	3.89%
Min	-0.78%	-0.73%	-0.75%	-0.58%	-1.00%	-0.92%	-1.08%	-0.96%	-1.06%
P-value	1.39%	9.76%	11.54%	22.42%	0.00%	0.18%	0.00%	0.00%	0.00%

A.3 Greek default

In this subsection, we study the implied depreciation as implied by Greek SCDS before the default on 9 March 2012 (Mano, 2013). Figure A.2 features variations smoothed over 20 days of the exchange rate conditional to the default of Greece. It shows that the gap between the Euro and the expected Euro level in case of a Greek default narrowed until the end of 2011. In January 2012, the gap widens before converging again in February. It seems therefore that when default became inevitable, SCDS dealers were cautious about the depreciation risk and increased their anticipation of the depreciation upon default.

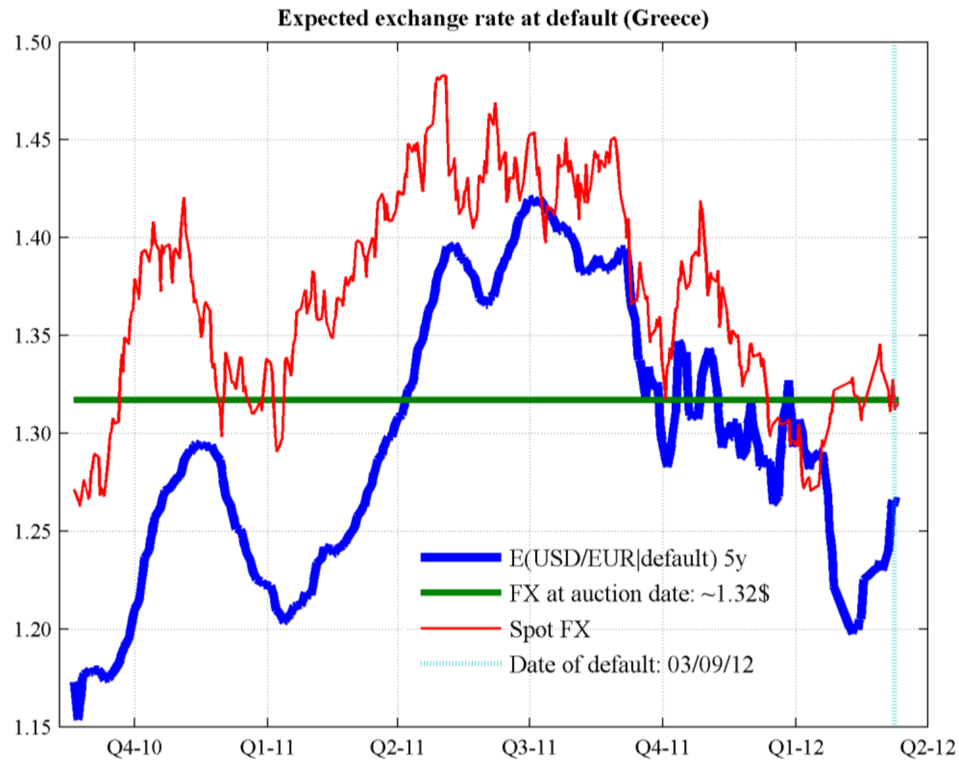

Figure A.2—Expected Euro at default for Greece.

This figure shows, based on SCDS in USD and Euro of Greece, the variations of the 20-day smoothed expected exchange rate upon default. The date of default and the exchange rate at default are also indicated on the graph. The computation of the implied depreciation measure for the base case is detailed in Section 2.3.1. The data are described in Section 2.4.1. The implied depreciation is smoothed over twenty days. The sample consists of observations between August 20, 2010, and March 09, 2012.

A.4 Implied depreciation of other countries

In this section, we provide descriptive statistics of selected financial and economic variables for Great Britain, Russia and Brazil. Table A.5 suggests that their average implied depreciation is 26.2%, 32.9% and 13%, respectively. Figure A.3 displays the time variation of the implied depreciation by country. There are strong variations of the implied depreciation for each country. Figure A.4 shows scatterplots of the relationship between sovereign credit risk and the implied depreciation at the country level. Overall, it exhibits a negative linear relationship for each of the considered countries, which is consistent with what we obtain for Eurozone countries.

Table A.5—Descriptive statistics

This table reports descriptive statistics of selected financial and economic variables for Great Britain, Russia and Brazil. All variables are expressed in percentage terms. The computation of the implied depreciation measure for the base case is detailed in Section 2.3.1. The data are described in Table 3 of Section 2.4.1. The implied depreciation is smoothed over five days. The sample consists of observations between August 20, 2010, and December 31, 2013.

Country	N	Mean	Median	Standard deviation	Minimum	Maximum
Great Britain						
Implied depreciation 5y	818	26.17	30.45	17.39	-3.22	51.45
SCDS 5y in Pound	818	0.44	0.42	0.19	0.14	0.87
Exchange rate return (USD/Pound, YoY)	818	0.03	-0.82	4.20	-6.92	15.02
Local inflation (YoY)	818	3.33	3.10	0.85	2.10	5.20
Russia						
Implied depreciation 5y	784	32.92	37.61	11.84	-15.89	43.21
SCDS 5y in Ruble	784	1.17	1.04	0.38	0.73	2.72
Exchange rate return (USD/Ruble, YoY)	784	-1.55	-2.23	5.75	-16.62	13.45
Local inflation (YoY)	784	6.87	6.80	1.68	3.60	9.60
Brazil						
Implied depreciation 5y	619	12.96	1.31	19.55	-14.72	58.28
SCDS 5y in Real	619	1.20	1.21	0.31	0.54	2.12
Exchange rate return (USD/Real, YoY)	619	-7.46	-8.54	8.56	-24.67	14.94
Local inflation (YoY)	619	5.95	5.86	0.69	4.49	7.31

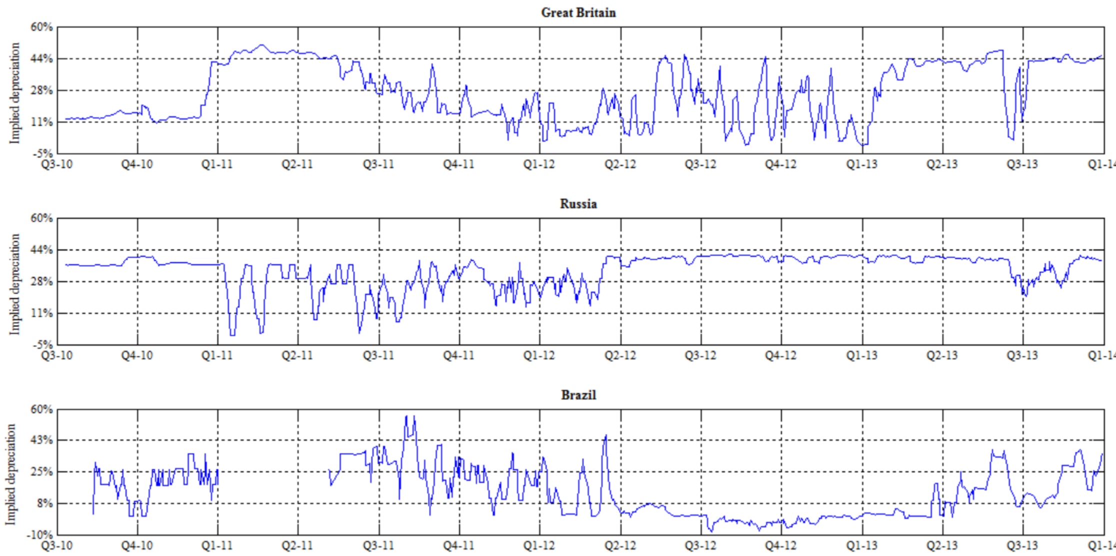

Figure A.3—Other countries implied depreciations

This figure shows the implied currency depreciations of Great Britain, Russia, and Brazil. The computation of the implied depreciation measure for the base case is detailed in Section 2.3.1. The data are described in Table 3 of Section 2.4.1. The implied depreciation is smoothed over five days. The sample consists of observations between August 20, 2010, and December 31, 2013.

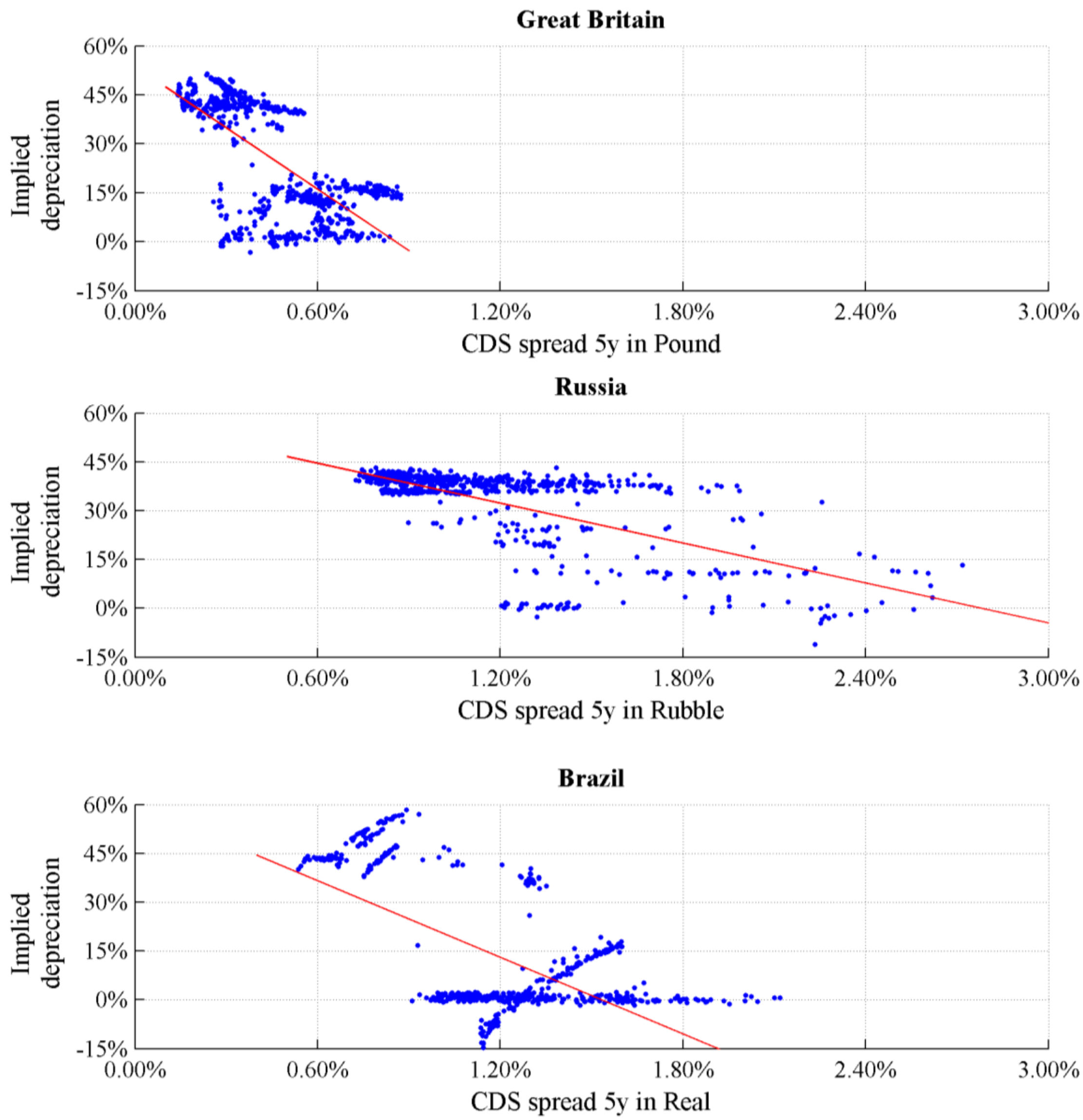

Figure A.4—Implied depreciation and sovereign credit risk by country

This figure shows the linear relationship between five-year implied depreciations and five-year local CDS rates for Great Britain, Russia, and Brazil. The computation of the implied depreciation measure for the base case is detailed in Section 2.3.1. The data are described in Table 3 of Section 2.4.1. The implied depreciation is smoothed over five days. The sample consists of observations between August 20, 2010, and December 31, 2013.

Chapitre 3 :
Conclusion générale

3. Conclusion

Cette étude analyse la variation attendue du taux de change euro/USD en cas d'un défaut souverain dans l'Eurozone. Nous utilisons des SCDS libellés dans les deux monnaies pour dériver selon une approche de non-arbitrage la dépréciation implicite de l'euro anticipée par le marché. Nous évaluons que sur la période 2010-2013, le marché escomptait une dépréciation de l'euro de l'ordre de 32,1% en moyenne dans le cas d'un défaut d'un pays de la zone euro. L'intensité de la dépréciation implicite varie fortement avec le temps et selon les pays membre de l'Eurozone.

Nous trouvons que la dépréciation implicite de l'euro dépend fortement du niveau actuel du risque de crédit souverain. Cette relation est négative, ce qui est cohérent avec l'idée que le taux de change actuel prend en compte la probabilité de défaut, puisque les investisseurs tendent à vendre l'euro par rapport à l'USD lorsque le risque souverain augmente. Néanmoins, lorsque le défaut est très improbable, un évènement de crédit déclencherait une forte dépréciation du taux de change, puisqu'il serait inattendu et donc à peine évalué par le marché. De plus, la dépréciation implicite diminue en cas d'appréciation passée et attendue de l'euro par rapport à l'USD. Enfin, les contraintes globales de financement de la liquidité sur les marchés déterminent le niveau de la dépréciation implicite, signalant aussi que les investisseurs cherchant à se couvrir du risque de dépréciation payent une prime de risque en cas d'assèchement de la liquidité. Cet aspect est d'ailleurs plus prononcé dans un environnement où le risque souverain est faible et aussi pour les pays montrant le plus fort risque systémique comme la France et l'Allemagne.

Les résultats de ce papier appellent à poursuivre la recherche dans au moins deux directions. D'abord, comme discuté dans l'article, un examen de l'information contenue dans la structure à terme de la dépréciation implicite serait intéressant. Ensuite, une recherche consisterait à mettre à examiner le pouvoir prédictif de la dépréciation implicite sur les rendements du taux de change.

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