A Credit-Based Theory of the Currency Risk Premium*

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First Draft: September 2018. This Draft: September 2020

*We are grateful for comments and suggestions from Patrick Augustin, Giovanni Cespa, Mike Chernov, Thomas Dangl, Roman Kozhan, Lukas Kremens, Ian Martin, Richard Payne, Andreas Stathopoulos, Fabrice Tourre, Josef Zechner, Irina Zviadadze, conference participants at the 2018 Canadian Derivatives Institute conference, 2019 Asset Pricing Workshop at the University of York, 2019 Annual QES European Quantitative and Macro Investing Conference in London, 2019 Annual Risk Management Conference at the National University of Singapore, 2019 Vienna Symposium on Foreign Exchange Markets, 2019 NFA Annual Conference, 2020 AFA Annual Meeting, 2020 EFA Annual Meeting, as well as seminar participants at the Boston University, Cass Business School, LUISS Guido Carli University, McGill University, Renmin University of China, Tsinghua University, and University of Loughborough. We thank Lukas Kremens and Ian Martin for sharing their constructed measure of the quanto-implied risk premium. Pasquale Della Corte (*corresponding author*) is with Imperial College Business School, Imperial College London, and the Centre for Economic Policy Research (CEPR). Email: `p.dellacorte@imperial.ac.uk`. Alexandre Jeanneret is with HEC Montréal, Department of Finance. Email: `alexandre.jeanneret@hec.ca`. Ella D.S. Patelli is with HEC Montréal, Department of Finance. Email: `ella.patelli@hec.ca`. Alexandre Jeanneret acknowledges the financial support of the Canada Research Chair in Macro Finance.

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Abstract

This paper extends Kremens and Martin (2019) and uncovers a novel component for exchange rate predictability based on the price difference between sovereign credit default swaps denominated in different currencies. This new forecasting variable – the credit-implied risk premium – captures the expected currency depreciation conditional on a severe but rare credit event. Using data for 16 Eurozone countries, we find that the credit-implied risk premium positively forecasts the dollar-euro exchange rate return at various horizons, both in-sample and out-of-sample. A currency strategy that exploits the informative content of our predictor, moreover, generates substantial out-of-sample economic value.

Keywords: Exchange rate, predictability, risk premium, credit risk, sovereign default.

JEL Classification: F31, F37, F47, G12, G15.

1 Introduction

Investors holding international government bonds face two major sources of risk. They bear, first, the risk of a potential depreciation of the local currency and, second, the risk of bond value erosion caused by a deterioration in sovereign creditworthiness. These sources of risk are highly intertwined as sovereign defaults are commonly accompanied by large currency depreciation (e.g., Reinhart, 2002; Na et al., 2018).[1] Also, this interaction has fundamental asset pricing implications for investors as the risk-adjusted probability of a currency depreciation conditional on default is substantially higher than the true probability, which implies that such events tend to occur in bad economic times (e.g., Augustin et al., 2020). We may then presume that currencies that are expected to depreciate severely in times of default are particularly risky and should deliver higher excess returns. We lack, however, a theoretically-motivated measure of the risk premium associated with this tight relation between currency depreciation and sovereign default, as well as empirical evidence on its implications for exchange rate predictability.

This paper attempts to fill this gap in the literature in two respects. First, we develop a simple theory that uncovers a novel component for exchange rate predictability labeled as the *credit-implied risk premium*. This component adds to the *quanto-implied risk premium* of Kremens and Martin (2019), upon which our theory builds. While the quanto-implied risk premium captures the expected covariation between currency returns and frequent but small changes in US market conditions, the credit-implied risk premium reflects investors' expectations about

[1] Specifically, Reinhart (2002) shows that the probability of a severe currency depreciation around a sovereign default is about 84% for a sample of 58 countries between 1970 and 2002. Herz and Tong (2008) show that debt crises Granger cause currency crises in a sample of 108 emerging countries over the 1975-2005 period, while Mano (2013) shows, over the 1873-2008 period, that currencies fall on average by 17.6% during the default year and by 29.2% compared to five years earlier. Na et al. (2018) use data for 70 countries for the period 1975-2013 and report that the median exchange rate depreciates by 45% in a three-year window around a default event. Related literature finds that countries with higher sovereign credit risk, proxied by sovereign credit default swaps, experience a significant currency depreciation (e.g., Della Corte et al., 2020).

excess currency movements in times of rare but severe events abroad, such as a sovereign default. This risk premium compensates investors for a currency depreciation conditional on default *in excess* of what is predicted by the traditional uncovered interest rate parity condition. Second, we empirically assess the exchange rate predictive ability of our novel risk premium component. We find robust evidence using statistical and economic criteria both in-sample and out-of-sample, thus overturning the general wisdom that exchange rates are well approximated by a random walk model (e.g., Meese and Rogoff, 1983; Engel and West, 2005).

We measure expected currency depreciation conditional on default by exploiting a unique feature of the sovereign credit default swap (CDS) market, i.e., sovereign CDS for the same entity, maturity, and restructuring clauses are typically quoted in various currencies. Specifically, CDS contracts provide insurance against different risks depending on the currency denomination. A long position in a country's CDS quoted in local currency protects a US investor against default in that country, whereas a long position in the same CDS but quoted in dollars provides an additional hedge against the risk of a local currency depreciation upon default. Since the probability of default underlying a CDS quoted in different currencies is the same, under no arbitrage, the difference in CDS prices must reflect investors' expectations about the relation between the local currency and default.[2] Forward-looking CDS prices become then the critical ingredients to derive the expected local currency depreciation conditional upon sovereign default, which is the primary determinant of our credit-implied risk premium.

The Eurozone is a perfect setting for our study because most member states have a liquid market for CDS instruments quoted both in dollars and euros (Augustin et al., 2020). In

[2]Alternatively, it is possible to estimate expected currency depreciation from sovereign bond data, but this approach is less straightforward. It requires extrapolating credit risk from debt financial instruments written on the same entity with the same maturity and in at least two currencies. Government bonds respecting these constraints are rare, especially for industrialized countries that tend to issue debt in their own currency.

addition, the price difference between dollar-denominated and euro-denominated CDS has been fairly large for several Eurozone countries with the unfolding of the European sovereign debt crisis, as illustrated by Figure 1. For example, Spain's one-year CDS premium quoted on January 2, 2012, was worth 339 basis points per annum in dollars but only 266 basis points per annum in euros. Armed with daily CDS premia on 16 Eurozone member states quoted in both currencies between August 2010 and April 2019, we compute a daily credit-implied risk premium for each member state. We then construct an aggregate measure of the credit-implied risk premium for the Eurozone by weighting countries with their outstanding debt. In essence, the credit-implied risk premium reflects the expected euro depreciation conditional on a sovereign default in the Eurozone, which varies substantially over the sample period. A sovereign default event, however, may not necessarily happen in our sample and, in this case, the difference in CDS prices would reflect the possibility of peso events (e.g., Burnside et al., 2011). If investors expect a possible sovereign default in the Eurozone, this risk should be then reflected in the future dollar-euro exchange rate return even if no such events materialize in our sample.

FIGURE 1 ABOUT HERE

We test our theory by investigating the predictability of the credit-implied risk premium for the dollar-euro exchange rate, which is the most liquid currency pair with a daily turnover that exceeds half a trillion dollars (e.g., BIS, 2019). We find that the credit-implied risk premium positively predicts future dollar-euro exchange rate returns at any horizon between one week and one year, beyond the interest rate differential (Fama, 1984) and the quanto-implied risk premium (Kremens and Martin, 2019). This finding is robust to controlling for global foreign exchange volatility and liquidity (e.g., Menkhoff et al., 2012; Karnaukh et al., 2015) as well as portfolio-based currency factors (e.g., Lustig et al., 2011). At the one-month horizon, a one-standard-deviation increase in the credit-implied risk premium is associated with a positive exchange rate return of 7.9% per annum. We also find superior out-of-sample exchange rate predictability relative to the traditional benchmark random walk model of Meese and Rogoff (1983), based on the historical average. We assess this predictive power using the out-of-sample R^2 of Campbell and Thompson (2008) as well as the tests of equal accuracy for nested models developed by McCracken (2007) and Clark and West (2007), while bootstrapping the *p*-values using the algorithm of Mark (1995) and Kilian (1999). Our results lead to the conclusion that dollar-euro exchange rate returns are predictable out-of-sample over a horizon that varies between one week and six months.

In addition to statistical evidence of exchange rate predictability, the credit-implied risk premium generates tangible out-of-sample economic gains to an investor exploiting active portfolio management. Following Fleming et al. (2001), among many others, we design an international asset allocation strategy whereby a US investor allocates her wealth between a dollar-denominated bond and a euro-denominated cash account using the credit-implied risk premium to predict the exchange rate return. We evaluate the performance of mean-variance strategies rebalanced weekly using non-overlapping observations. We find that a strategy based on the credit-implied risk premium generates a substantial amount of out-of-sample economic value that outperforms the random walk model. Specifically, a risk-averse investor is willing to pay more than 200 basis points per annum for switching from a portfolio strategy based on the benchmark model to a competing one that exploits information in the credit-implied risk premium. The profitability of our strategy also survives reasonably high transaction costs.

In sum, a currency carries a greater risk premium when investors expect a more severe depreciation upon sovereign default and, thus, our credit-implied predictor contains valuable information for exchange rate predictability. We provide evidence that our results are not due to alternative explanations. First, we can rule out that changes in the credit-implied risk premium merely reflect variations in global currency risk premia (Lustig et al., 2011), as we do not observe any predictability for non-euro currency pairs. Second, we provide empirical evidence that our predictor is distinct from the quanto-implied risk premium (Kremens and Martin, 2019) and sovereign risk, as both risk measures differ fundamentally with our predictor in terms of their economic, financial, and monetary determinants. We thus confirm our theory that the quanto-implied risk and the credit-implied risk premia coexist and span different information. Sovereign risk and the credit-implied risk premium also complement each other, as the former captures the probability of default while the latter reflects the expected currency movements *conditional* on default. Third, one may argue that the difference between euro-denominated and dollar-denominated CDS premia on the same underlying entity could be attributed to dealers' credit risk, as opposed to the interaction between default and depreciation. However, we find that our results are robust to controlling for dealers' counterparty risk. Fourth, we confirm that the predictability is not an econometric artifact arising from the persistence in returns, as our results also hold using weekly non-overlapping observations. Finally, we conduct a country-level study and conclude that the predictability of the credit-implied risk premium is concentrated among the economically most important Eurozone economies, such as France and Germany, which rules out the possibility that some small countries with less liquid CDS contracts drive our findings.

Our work relates to a growing literature on the currency denomination of sovereign CDS. Mano (2013) is the first to exploit the difference between sovereign CDS denominated in dollars and local currency.[3] He concludes that a model with segmented markets can generate predictions consistent with the empirical evidence on the currency depreciation during sovereign defaults. Du and Schreger (2016) quantify the expected currency depreciation in emerging markets from the credit spread differential between sovereign bonds denominated

[3] The approach builds on Ehlers and Schoenbucher (2004), who use Japanese corporate CDS denominated in dollars and yen to analyze the expected exchange rate.

in dollars and local currency.[4] Corradin and Rodriguez-Moreno (2014) and Buraschi et al. (2015) exploit quanto spreads to explain pricing anomalies between bond yields denominated in different currencies, while De Santis (2019) uses the quanto spread to analyze the risk of currency redenomination in the Eurozone.[5]

This paper also complements two recent studies. Lando and Bang Nielsen (2018) show that quanto spreads reflect the risk that a currency depreciates not only at the time of default but also as default risk increases. Their contribution is to decompose theoretically and empirically these two effects. Augustin et al. (2020) use the term structure of quanto spreads to offer an asset-pricing perspective on the relationship between sovereign defaults and currency depreciation in the Eurozone and on the possibility of credit contagion. They address the debate on whether a default has an immediate or gradual impact on the exchange rate, thereby contributing to a better understanding of the "Twin Ds" (depreciation and default). Their findings provide strong support in favor of the first channel. They show that the currency risk premium associated with depreciation in default has an upward term structure (i.e., increases with the horizon), while we focus on the conditional properties of the currency risk premium at a given horizon to study exchange rate predictability. Taken together, these papers offer a complete picture on the asset pricing implications of the interaction between currency depreciation and default for the credit derivative and currency markets.

Overall, we contribute to the existing literature by identifying a credit-based currency risk premium that has strong implications for exchange rate predictability. Since the path-breaking contribution of Meese and Rogoff (1983), a vast body of empirical studies finds that economically meaningful variables fail to empirically predict exchange rate returns. While there

[4]The authors compute the 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, US LIBOR rates, local LIBOR rates, and currency swaps.

[5]In a complement study, Kremens (2020) exploits the legal differences of sovereign CDS contracts for a given country (i.e., the ISDA basis) to understand currency redenomination risk for Eurozone member states.

is some evidence that exchange rates and economic fundamentals move together over long horizons (Mark, 1995), the general view is that exchange rates are not predictable, especially at short horizons. The contribution of our paper is to report robust empirical evidence that the dollar-euro exchange rate is predictable at short horizons, both in-sample and out-of-sample, using a novel theoretically-motivated risk premium measure. Our findings confirm the view that a risk premium capturing investors' expectations about a currency depreciation upon default is informative about future exchange rate movements.

The remainder of the paper is organized as follows. Section 2 develops a theory that identifies the credit-implied currency risk premium, which we quantify using the price difference of dollar-denominated and euro-denominated CDS contracts. Section 3 describes the data and provides a descriptive analysis. Sections 4 and 5 conduct an analysis of exchange rate predictability in-sample and out-of-sample, respectively. We discuss the economic value of such predictability in Section 6, while Section 7 concludes. The Internet Appendix contains technical details and presents additional results not included in the main body of the paper.

2 Theory

In this section, we extend the theory of Kremens and Martin (2019) and identify a novel component for exchange rate predictability.

2.1 Environment

Consider a currency strategy that converts a dollar into euros, lends at the euro riskless rate for a period, and finally exchanges the proceeds in euros for dollars next period. According to the fundamental equation of asset pricing, the expected gross exchange rate return is then given by

$$\mathbb{E}_t\left[\frac{S_{t+1}}{S_t}\right]=\frac{R_{f,t}^{\$}}{R_{f,t}^{€}}-R_{f,t}^{\$}cov_t\left(M_{t+1},\frac{S_{t+1}}{S_t}\right), \tag{1}$$

where $\mathbb{E}_t$ is the expectation operator (under the physical measure) conditional on the information available at time t, S_t is the dollar-euro (USD/EUR) spot exchange rate defined as units of dollars per euro such that an increase in S_t reflects a euro appreciation, $R_{f,t}^{\$}$ ($R_{f,t}^{€}$) is the one-period gross dollar (euro) interest rate, and M_{t+1} is a stochastic discount factor (SDF) that prices assets denominated in dollars.

Under the risk-neutral expectation $\mathbb{E}_t^*$, the covariance term disappears and the identity in Equation (1) simplifies to the Uncovered Interest Parity (UIP) condition, which predicts a depreciation of the higher interest rate yielding currency

$$\mathbb{E}_t^*\left[\frac{S_{t+1}}{S_t}\right] \;=\; \frac{R_{f,t}^{\$}}{R_{f,t}^{€}}. \tag{2}$$

The UIP condition, however, has generally failed to empirically predict future exchange rate returns and the resulting currency excess return has been interpreted as compensation for time-varying risk (e.g., Fama, 1984; Lustig et al., 2011). This is equivalent to saying that expected exchange rate returns depend not only on the interest rate differential but also on a risk adjustment component captured by the covariance between the SDF and the gross exchange rate return.

The challenging aspect of the identity in Equation (1) is that the SDF is ex-ante unobservable and likely to change over time, thus not being helpful in a forecasting exercise. To overcome this problem, Kremens and Martin (2019) rewrite Equation (1) in terms of the risk-neutral covariance between the exchange rate return and the dollar return of a diversified portfolio of stocks, which is a primary ingredient of their quanto-implied risk premium. The next section shows that a novel risk premium component, which we label the credit-implied risk premium, coexists with the quanto-implied risk premium.

2.2 Global portfolio

Consider an investor holding a global portfolio measured in dollars, whose gross return X_{t+1} satisfies the fundamental equation of asset pricing:

$$1 \;=\; \mathbb{E}_t\left[M_{t+1}X_{t+1}\right]. \tag{3}$$

The gross return X_{t+1} consists of two risky components:

$$X_{t+1} = 1 + r_{t+1} + d_{t+1}, \tag{4}$$

where $R_{t+1} = 1 + r_{t+1}$ captures the *gross* return on a dollar-denominated diversified portfolio of stocks and d_{t+1} is the additional *net* return reflecting the investor's exposure to a dollar-denominated contingent claim. The former is the gross return on the S&P 500 index as in Kremens and Martin (2019) whereas the latter is defined as $d_{t+1} = a - \boldsymbol{D}b$ such that the investor receives a constant payoff a but incurs a loss of b when $\boldsymbol{D} = 1$, where $\boldsymbol{D}$ is an indicator function that takes on the value of one (and zero otherwise) if a specific event occurs with a risk-neutral probability $\mathbb{Q}_t$ between times t and $t+1$. The contingent claim is akin to an investment whose payoff is conditional on the realization of a rare but severe event in the foreign country, like a sovereign default.[6] To fix ideas, think of an exposure to foreign government bonds, which yields a total coupon payment a and a loss b (the unrecovered bond value) in the case of a default. Alternatively, the investor can write a CDS on such a bond, which entails receiving a periodic premium a and delivering b (the unrecovered bond value)

[6] Suppose that between times t and $t+1$, for example, the stock return r_{t+1} is 10%, the payoff on the contingent claim a is 5%, and the state-contingent loss b is 40%. If there is a default event, $\boldsymbol{D} = 1$, $R_{t+1} =$ 1.1, $d_{t+1} = -0.35$, and $X_{t+1} =$ 0.75. Alternatively, if there is no default event, $\boldsymbol{D} = 0$, $R_{t+1} =$ 1.1, $d_{t+1} =$ 0.05, and $X_{t+1} =$ 1.15.

to the protection buyer in the case of a default. Both cases induce a loss to the investor in the case of a sovereign default.[7] This environment nests Kremens and Martin (2019) when neglecting the contingent part of the portfolio return.

The global portfolio does not expose the investor to currency risk as both R_{t+1} and d_{t+1} are measured in dollars. However, the euro becomes risky for the investor if it covaries with the performance of her global portfolio. In this case, the expected gross exchange rate return between t and $t+1$ is given by the following identity where the expected exchange rate return depends, beyond the interest rate differential and a residual term A_t, on two distinct risk adjustment terms:

$$\mathbb{E}_t\left[\frac{S_{t+1}}{S_t}\right] = \underbrace{\frac{R^{\$}_{f,t}}{R^{€}_{f,t}}}_{\text{UIP forecast}} + \underbrace{\frac{1}{R^{\$}_{f,t}} cov^*_t\left(\frac{S_{t+1}}{S_t}, R_{t+1}\right)}_{\text{Quanto-implied risk premium}}$$
$$+ \underbrace{\frac{\mathbb{Q}_t b}{R^{\$}_{f,t}}\left(\mathbb{E}^*_t\left[\frac{S_t - S_{t+1}}{S_t}\bigg|_{\boldsymbol{D}=1}\right] - \mathbb{E}^*_t\left[\frac{S_t - S_{t+1}}{S_t}\right]\right)}_{\text{Credit-implied risk premium}} + A_t \qquad (5)$$

with the detailed derivation reported in Internet Appendix A to save space. While the residual component A_t is not directly observable as in Kremens and Martin (2019), we will proxy for it using a variety of control variables suggested by the recent literature, which we describe in Section 3.3.

The second term in Equation (5) captures the conditional risk-neutral covariance between the gross exchange rate return and the dollar-denominated gross portfolio return R_{t+1}. Investors demand a positive risk premium if the euro is expected to depreciate, under the risk-neutral measure, when the return on the domestic portfolio of stocks is low. Kremens and Martin

[7]The contingent claim can also be a bond, derivative, or structured product whose payoff can also depend, for example, on a recession, natural disaster, war, and a political crisis.

(2019) refer to it as the *quanto-implied risk premium* (QRP). The third term in Equation (5) reflects the conditional risk-neutral covariance between the gross exchange rate return and the payoff of a dollar-denominated contingent claim d_{t+1}, which we label the *credit-implied risk premium* (CRP). This risk premium component captures the difference between the risk-neutral expected euro depreciation conditional on a sovereign default $\boldsymbol{D}$ in the foreign country and the risk-neutral expected euro depreciation implied from the UIP condition.[8]

Our extension of Kremens and Martin (2019)'s framework highlights the presence of two separate and complementary currency risk premia. While QRP arises from small but frequent shocks in the domestic country, CRP captures the euro depreciation during a rare but severe shock that does not necessarily impact the investor's stock portfolio. Investors are compensated for the risk associated with the expected *excess* euro depreciation upon default rather than the expected *total* currency depreciation. For example, the sovereign default of Greece in 2012 caused large losses to the government bondholders and CDS protection sellers without having a significant effect on the US stock market investors. We expect CRP to be positive since sovereign defaults are typically associated with a large currency depreciation (Na et al., 2018).

Kremens and Martin (2019) show that QRP can be extracted from a quanto forward, i.e., a derivative settled in a currency that is different from the currency of the underlying instrument. For example, a quanto forward on the S&P 500 index is a forward contract settled in euro and its value is sensitive to the correlation between the S&P 500 index and the USD/EUR exchange rate. If the euro appreciates (depreciates) against the dollar when the index is high (low), then QRP is positive as investors holding euros are expected to receive a higher reward than the one predicted by the UIP. The next section shows that the risk-neutral expected depreciation upon default, a key ingredient of CRP, can be constructed using differences in

[8]The risk premium vanishes if either the exchange rate is independent on the event, the corresponding probability is nill ($\mathbb{Q}_t$), or if the portfolio has no exposure to the event ($b = 0$).

sovereign CDS premia of the same reference entity but quoted in different currencies. This difference is commonly called the quanto CDS by market participants (see, for example, Elizalde et al., 2010; Lando and Bang Nielsen, 2018).

2.3 Expected depreciation conditional on default

A sovereign CDS is a credit derivative that offers protection against a sovereign credit event.[9] For this protection, the buyer pays a periodic annualized CDS premium to the seller, which is quoted as a percentage of the notional value specified at the inception date. The seller, in turn, compensates the holder with a contingent payment related to the unrecovered value of the underlying bond in the case of a defined credit event. Sovereign CDS contracts on the same reference entity can be denominated in different currencies. While dollar-denominated CDS contracts are widely traded, local-currency denominated instruments are frequently used for asset-liability and risk management purposes. For example, European banks and investment funds largely use euro-denominated sovereign CDS written on Eurozone member states to offset a credit valuation adjustment.

In contrast to a dollar-denominated CDS, a euro-denominated CDS exposes a US protection buyer to currency risk as the euro is expected to depreciate against the dollar in a default event, precisely when the protection buyer receives the payoff from the protection seller. An investor would then pay a higher premium on a dollar-denominated CDS than on a euro-denominated contract although these instruments are otherwise identical. Figure 1 plots one-year dollar-denominated and euro-denominated CDS premia for selected Eurozone member states and confirms the relatively higher price for dollar-denominated instruments, especially during the European sovereign debt crisis.

[9] The ISDA identifies four main types of credit or default events, namely, obligation acceleration, failure to pay the interest or principal, restructuring of debt, and repudiation or moratorium of debt (e.g., ISDA, 2003).

FIGURE 2 ABOUT HERE

We now exploit the price differences between CDS denominated in different currencies. Specifically, we show that the risk-neutral expected currency depreciation conditional on a sovereign default in Equation (5) can be synthesized from an arbitrage-free strategy implemented with dollar-denominated and euro-denominated CDS contracts written on the same reference entity. To ease the exposition, we present a one-period strategy that starts at time t and ends at time $t+1$ with a potential default event that occurs at time $t+1$ as summarized by Figure 2. A more general setting is discussed in the Internet Appendix B.

Let $C_t^{€}$ and $C_t^{\$}$ be the euro-denominated and dollar-denominated CDS premia on the same sovereign debt at time t, respectively, with corresponding notional values $N^{€}$ and $N^{\$}$. We consider a US investor that offsets sovereign risk by going long the euro-denominated CDS and short the dollar-denominated CDS. On this long-short strategy, the investor will pay a premium of $C_t^{€}N^{€}$ on the long position and receive a premium of $C_t^{\$}N^{\$}$ on the short position while hedging the currency risk associated with the euro-denominated premium via a fixed-for-fixed currency swap that delivers dollars for euros at a given swap rate. The latter is set equal to S_t, namely, the spot exchange rate observed at the inception date of the strategy as in Du and Schreger (2016). The recovery rate of the underlying sovereign bond is $R_r \in (0,1)$ such that the CDS protection buyer receives the fraction of the unrecovered bond value $(1-R_r)$ times the exposure of the CDS contract.

The cash flow CF_t on our arbitrage-free strategy at the inception date t is given by

$$CF_t = C_t^{\$}N^{\$} - C_t^{€}N^{€}S_t, \tag{6}$$

which implies that $N^{\$} = C_t^{€}N^{€}S_t/C_t^{\$}$ for a self-financing strategy with $CF_t = 0$. At default, the investor receives $(1-R_r)N^{€}$ from the euro-denominated CDS converted in dollars at the spot exchange rate S_{t+1} and delivers $(1-R_r)N^{\$}$ on the dollar-denominated CDS. In the absence of arbitrage, the risk-neutral expectation of the future cash flow conditional on default must then satisfy the following condition

$$\mathbb{E}_t^* \left[CF_{t+1}|_{\boldsymbol{D}=1}\right] = (1-R_r)N^{€}\mathbb{E}_t^* \left[S_{t+1}|_{\boldsymbol{D}=1}\right] - (1-R_r)N^{\$} = 0. \tag{7}$$

It then follows, by combining Equations (6) and (7), that the risk-neutral expectation at time t of the euro depreciation conditional on default corresponds to the relative CDS premium difference, labeled *implied currency depreciation*, as

$$\mathbb{E}_t^* \left[\frac{S_t - S_{t+1}}{S_t} \bigg|_{\boldsymbol{D}=1} \right] = \frac{C_t^{\$} - C_t^{€}}{C_t^{\$}}. \tag{8}$$

The arbitrage-free strategy underlying the closed-form solution in Equation (8) assumes for simplicity that the default event can only occur at time $t+1$. Such a default, however, may also happen between times t and $t+1$. In this case, we should account for the accrued CDS premium, i.e., the residual part of the CDS premium paid (received) by the protection buyer (seller), and the residual value of the currency swap. Also, our investor could trade multi-period CDS contracts as opposed to one-period contracts. We consider these additional aspects in the Internet Appendix B.[10]

3 Data and preliminary analysis

In this section, we describe the sovereign CDS data and the computation of the credit-implied risk premium for the Eurozone. We then present a descriptive analysis and introduce

[10] In the general setting, the residual value of the currency swap depends on the remaining time to maturity in the case of a default. We can determine the cash flow for each possible default time and weigh it with the corresponding risk-neutral default probability extracted from the term structure of CDS premia. Closed-form solutions for the implied currency depreciation do not longer exist and we must rely on an iterative procedure. Using one-period maturity CDS contracts help to conveniently overcome this issue.

the remaining variables we consider in the paper.

3.1 Sovereign CDS data

Our analysis uses mid-quotes on dollar-denominated and euro-denominated sovereign CDS premia with the complete restructuring clause from IHS Markit. Although dollar-denominated sovereign CDS are the most traded contracts, euro-denominated sovereign CDS are also fairly liquid for the Eurozone member states (Augustin et al., 2020). We collect daily observations for 16 countries, which are Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, the Netherlands, Portugal, Slovenia, Slovakia, and Spain from August 2010 to April 2019 for a total of 38,046 quotes. In our core analysis, we exclude Greece because of infrequent quotes and focus on one-year CDS premia because the currency swap would have a negligible residual value in default. Moreover, short-maturity CDS contracts tend to be particularly informative compared to longer-maturity ones (e.g., Augustin, 2018).

3.2 Credit-implied risk premium

We construct the credit-implied risk premium presented in Equation (5) by first computing its empirical counterpart for each Eurozone country i as follows

$$CRP_{i,t} = \frac{b\overline{\mathbb{Q}}_i}{R^{\$}_{f,t}}\left(\frac{C^{\$}_{i,t} - C^{€}_{i,t}}{C^{\$}_{i,t}} - \frac{R^{€}_{f,t} - R^{\$}_{f,t}}{R^{€}_{f,t}}\right), \tag{9}$$

where $C^{\$}_{i,t}$ ($C^{€}_{i,t}$) is the one-year dollar-denominated (euro-denominated) CDS premium, $R^{\$}_{f,t}$ ($R^{€}_{f,t}$) is the one-year dollar (euro) gross interest rate from Bloomberg, and b is the loss given default set equal to 0.6 following the ISDA convention. The first component in parentheses denotes the risk-neutral expected euro depreciation upon default and varies across different countries whereas the second term is the risk-neutral expected euro depreciation predicted by the UIP condition and is common across all countries.

In Equation (9), $\overline{\mathbb{Q}}_i$ denotes the constant risk-neutral probability of default extracted from one-year dollar-denominated CDS premia.[11] Longstaff et al. (2011), among others, show that time-variations in CDS premia and thus in risk-neutral probabilities of default are related to changes in global financial factors as opposed to local financial conditions. Since our main objective is to study the role of expected currency depreciation upon sovereign default for exchange rate predictability, we work with time-invariant $\overline{\mathbb{Q}}_i$ as opposed to time-variant $\mathbb{Q}_{i,t}$ throughout our core analysis. In doing so, we avoid that CRP is contaminated with variations in global financial conditions. In the robustness section 4.3, however, we relax our assumption and show that time-variant $\mathbb{Q}_{i,t}$ carry no predictive power for future exchange rate returns.

The country-specific quantities in Equation (9) are then combined using a cross-country weighted average

$$CRP_t = \sum_i \omega_i CRP_{i,t}, \tag{10}$$

where ω_i reflects the relative size of country i's sovereign debt such that a country with a larger outstanding debt naturally contributes more to the credit-implied risk premium. As an alternative weighting scheme, we also employ the relative size of each country i's gross domestic product (GDP). In both cases, the weights are calculated at the beginning of our sample using data collected from Bloomberg and then kept fixed until the end of the sample such that any time-series variation should be solely attributed to changes in country-specific credit-implied risk premia.

TABLE 1 ABOUT HERE

[11] Estimates of $\overline{\mathbb{Q}}_i$ are based on the full sample of dollar-denominated CDS premia for the in-sample exercise and the first year of data only for the out-sample analysis. Additional computational details are provided in the Internet Appendix B.4.

We report descriptive statistics for the credit-implied risk premium and its underlying components in percentage per annum in Table 1. In Panel A, we present country-specific descriptive statistics for the credit-implied risk premium ($CRP_{i,t}$) and the implied currency depreciation upon default ($ICD_{i,t}$) based on the difference between one-year dollar-denominated and euro-denominated CDS premia. We also report, for each Eurozone country, the risk-neutral probability of default ($\overline{\mathbb{Q}}_i$) extracted from the full-sample of one-year dollar-denominated CDS premia and the weights (ω_i) constructed using public debt or GDP data for the year 2010. We find that the safest and economically most important countries exhibit, on average, the highest implied currency depreciation upon default. The mean value of $ICD_{i,t}$, for example, ranges between 27.6% and 30.5% per annum for France, Germany, and the Netherlands. The level of creditworthiness as measured by $\overline{\mathbb{Q}}_i$ is also highly heterogeneous among Eurozone countries: high for Cyprus, Portugal, Ireland, Italy, and Spain (ranging between 7.78% and 1.63% per annum) and low for Germany, France, and the Netherlands (ranging between 0.35% and 0.14% per annum). Taken together, Portugal, Ireland, Cyprus, Spain, and Italy have, on average, the highest credit-implied risk premium. In contrast, countries playing a negligible financial role (e.g., Estonia, Finland, and Latvia) or with high creditworthiness (e.g., Germany, France, and the Netherlands) have the lowest credit-implied risk premium.

FIGURE 3 ABOUT HERE

In Panel B, we present descriptive statistics for the credit-implied risk premium for the Eurozone based on two different static weighting schemes. The debt-weighted (GDP-weighted) credit-implied risk premium amounts to 0.11% (0.10%) per annum.[12] The average magnitude of this component is driven by a low risk-neutral probability of default for large Eurozone countries and is consistent with the findings of Augustin et al. (2020), who use an affine non-

[12]We find that the difference in CRP with and without the accrued premium is negligible (approximately 0.001%) and that the sample correlation between the two versions is above 99%. We thus ignore the accrued premium throughout the paper.

arbitrage model to estimate the risk premium associated with the euro depreciation. While being small on average, the credit-implied risk premium varies substantially over time as illustrated by Figure 3, which plots the USD/EUR exchange rate in the top panel and the credit-implied risk premia (debt-weighted and GDP-weighted) in the bottom panel. Visually, this figure reveals a positive predictive correlation between credit-implied risk premia and future exchange rate returns. We will quantitatively assess this predictive relationship, both statistically and economically, in the next sections.

3.3 Other data

The identity presented in Equation (5) requires at least three ingredients. In the previous section, we have presented our recipe to construct the credit-implied risk premium. Below, we summarize the additional components that we will utilize in our empirical analysis.

Exchange rates. We collect the USD/EUR spot exchange rate from Bloomberg and express it in units of dollars per unit of euro such that an increase denotes a euro appreciation. In the robustness analysis, we employ other currency pairs from the same source with the first (second) currency being the quote (base) currency.

Interest rates. The first term in Equation (5) is the traditional UIP forecast that we approximate with the one-year interest rate differential between the US and the Eurozone to match the maturity of the CDS contracts. For the construction of this component, we rely on daily zero-coupon rates bootstrapped from money market rates and interest rate swaps obtained from Bloomberg. We use the same source/methodology for other currency pairs in the robustness section.

Quanto-implied risk premium. The second component in Equation (5) is the quanto-implied risk premium, which Kremens and Martin (2019) construct with euro-denominated two-year quanto forwards on the S&P500 index available monthly until October 2015 from IHS Markit.[13] In the next section, we will discuss several approaches to retrieve daily observations and extend the sample beyond October 2015.

Control variables. The identity presented in Equation (5) holds up to a residual term, which we do not directly observe. We attempt to account for this missing term by augmenting our predictive regressions with additional variables that are known to empirically matter for exchange rate returns. Recent empirical evidence suggests that both liquidity and volatility play an important role in currency markets (e.g., Menkhoff et al., 2012; Karnaukh et al., 2015), and we thus employ an updated version of their measure of global illiquidity and volatility. The former is based on the bid-ask spreads of the spot exchange rate and is available from the authors' website, whereas we construct the latter using average absolute exchange rate returns for a cross-section of the 20 most liquid currency pairs.[14] Recent literature also highlights the role of portfolio-based currency factors such as carry, dollar, global imbalance, momentum, risk-reversal, and value (e.g., Lustig et al., 2011; Della Corte et al., 2016a,b). While these factors are generally available at the monthly frequency, we retrieve daily observations by tracking the intra-month exchange rate returns on the underlying long and short baskets. Since the time-series variation of these factors only depends on exchange rate changes, we ignore for simplicity the daily forward premium adjustment and focus purely on the exchange rate return component. Specifically, we first group currencies

[13]A quanto forward on the S&P 500 index is a forward contract settled in euro and its value is sensitive to the correlation between the S&P 500 index and the dollar-euro exchange rate. If the euro appreciates (depreciates) against the dollar when the index is high (low), then QRP is positive.

[14]This sample includes the currencies of Australia, Brazil, Canada, Czech Republic, Denmark, Eurozone, Hungary, Japan, Mexico, New Zealand, Norway, Poland, Singapore, South Africa, South Korea, Sweden, Switzerland, Taiwan, Turkey, and United Kingdom. See, for example, the Deutsche Bank Currency Harvest Indices.

into five portfolios at the end of each month t using a pre-defined signal and then record the daily average exchange rate return of long-short baskets. We construct our factors using the 20 most liquid currency pairs.

4 Exchange rate return predictability

In this section, we empirically test our theory by examining the exchange rate predictive ability of the credit-implied risk premium.

4.1 Baseline specification

We evaluate the predictive information content of the credit-implied risk premium by running regressions at the daily frequency based on the following specification:

$$\Delta_\kappa s_{t+\kappa} = \alpha_\kappa + \beta_\kappa IRD_t + \gamma_\kappa CRP_t + \phi_\kappa X_t + \varepsilon_{t+\kappa}, \tag{11}$$

where s_t is the log of the nominal USD/EUR exchange rate on day t, $\Delta_\kappa s_{t+\kappa} = s_{t+\kappa} - s_t$ is the exchange rate return between days t and $t+\kappa$, CRP_t is the credit-implied risk premium for the Eurozone based on country-level dollar-denominated and euro-denominated one-year CDS premia observed on day t, IRD_t is the one-year interest rate differential between the US and Eurozone observed on day t, X_t comprises a set of control variables observed on day t, and κ is the forecast horizon. To ease the comparison across different horizons, we convert all exchange rate returns in annual terms, i.e., we multiply the dependent variable in Equation (11) by the constant term 252/κ. We report the least squares estimates of γ_κ with and without control variables in Table 2 using the full sample period, which ranges between August 2010 and April 2019. Since the quanto-implied risk premium is not available for the full-sample and at the daily frequency, we do not include it in our baseline specification, but examine its role in the next section. We report estimates of γ_κ for different forecast horizons

κ ranging between one week (five business days) and one year (252 business days).

Extending the forecast horizon beyond the sampling interval ($\kappa > 1$) may induce higher-order serial correlation, at least of order $\kappa - 1$, in the residuals $\varepsilon_{t+\kappa}$. We deal with this issue in two different ways. First, we calculate *p*-values based on Hansen and Hodrick (1980) standard errors with a lag truncation equal to κ and report them in parentheses. Second, we construct confidence intervals via the stationary bootstrap of Politis and Romano (1994) and report estimates of γ_κ in bold when we detect statistical significance at 5% (or lower). The exercise consists of 1,000 replications in which blocks with a random length of dependent and independent variable realizations are simulated with replacement from the original sample without imposing any restrictions. The block length is drawn from a geometric distribution and the expected block size is set according to Patton et al. (2009), as detailed in the Internet Appendix D.1.

TABLE 2 ABOUT HERE

Consistent with our theory, Table 2 reports positive and statistically significant estimates of γ_κ, thus implying that CRP_t positively predicts future USD/EUR exchange rate returns. Estimates of α_κ, moreover, are always statistically indistinguishable from zero and remain unreported to save space. Panel A focuses on the benchmark specifications without the control variables in X_t and displays estimates of γ_κ ranging between 2.229 (with a *p*-value of 0.023) at the one-week horizon and 1.009 (with a *p*-value of 0.034) at the one-year horizon. The statistical evidence is further confirmed by our bootstrap exercise as all estimates of γ_κ are reported in bold. Panel B adds global FX illiquidity and FX volatility (e.g., Menkhoff et al., 2012; Karnaukh et al., 2015) as control variables but reports qualitatively similar results. Panel C adds a variety of portfolio-based currency factors such as the dollar, carry, momentum, value, external imbalances, and option risk reversals (e.g., Lustig et al., 2011) as control variables and continues to find statistically significant estimates of γ_κ at any horizon κ. Panel D, finally, considers all control variables and CRP_t remains a strong predictor of future exchange rate returns. The estimates of γ_κ range between 2.314 (significant at the 5% level) at the one-week horizon and 1.045 (significant at the 1% level) at the one-year horizon. In economic terms, a coefficient estimate of 2.472 at the one-month horizon suggest that a one standard deviation increase in CRP_t predicts a future appreciation of the euro of about 7.9% per annum.[15]

TABLE 3 ABOUT HERE

In our core exercise, the credit-implied risk premium for the Eurozone weighs a country's credit-implied risk premium by its level of outstanding sovereign debt. We repeat our predictability analysis using a different weighting scheme, i.e., we build the credit-implied risk premium for the Eurozone by weighting a country's credit-implied risk premium by its GDP, also measured at the beginning of our sample. We report the results in Table 3 and obtain qualitatively identical results. Overall, our analysis indicates that the credit-implied risk premium helps positively predict future USD/EUR exchange rate returns. The effect is both statistically and economically important, and is not spanned by existing exchange rate return predictors.

4.2 Controlling for the quanto-implied risk premium

We now augment the baseline specification presented in Equation (11) and evaluate the predictive ability of the credit-implied risk premium based on the following specification:

$$\Delta_\kappa s_{t+\kappa} = \alpha_\kappa + \beta_\kappa IRD_t + \gamma_\kappa CRP_t + \delta_\kappa QRP_t + \phi_\kappa X_t + \varepsilon_{t+\kappa}, \tag{12}$$

[15] We also employ both Newey and West (1987) standard errors with a lag truncation equal to κ and Newey and West (1987) standard errors with Andrews (1991) optimal lag length and obtain comparable results. The evidence is reported in Table A.2 in the Internet Appendix.

where QRP_t is the quanto-implied risk premium of Kremens and Martin (2019) based on euro-denominated quanto forwards on the S&P 500 index. Recall that this predictor is only available at the monthly frequency and until October 2015. To fill this gap, we run additional predictive regressions using alternative methods to proxy for the daily quanto-implied risk premium over the full sample. We report the least-squares estimates of γ_κ in Table 4.

TABLE 4 ABOUT HERE

In Panel A, we retrieve daily missing observations on the quanto-implied risk premium between August 2010 and November 2015 by forward-filling, i.e., we keep the latest available observation constant until a new observation becomes available. Empirically, our credit-implied risk premium continues to predict the USD/EUR exchange rate return for any horizon κ.

The forward-filling procedure, despite being common in empirical work for its simplicity, may underestimate the information content of the quanto-implied risk premium and introduce a bias in the estimation. To overcome this legitimate concern, we can retrieve daily missing observations on the quanto-implied risk premium in Equation 5 by relying on a simple decomposition that involves risk-neutral volatility and correlation components, i.e., $cov_t^*(S_{t+1}/S_t, R_{t+1}) = \sqrt{var_t^*(S_{t+1}/S_t)}\sqrt{var_t^*(R_{t+1})}\,cor_t^*(S_{t+1}/S_t, R_{t+1})$.[16] In our calculations, we measure the daily risk-neutral volatilities using the one-year USD/EUR option implied volatility and the one-year VIX index, respectively, whereas the construction of the implied correlation is discussed in the Internet Appendix C.1. Panel A of Figure 4 plots our daily expanded version of the quanto-implied risk premium. As reported in Panel B, controlling for daily variations in the quanto-implied risk premium over the full sample yields estimates of γ_κ that are very similar to those presented in Panel A.

FIGURE 4 ABOUT HERE

[16]We are grateful to Lukas Kremens for suggesting this approach.

An alternative approach to synthetically construct the daily quanto-implied risk premium builds on the assumption that an investor holds a foreign riskless bond rather than a portfolio of domestic stocks such that $R_{t+1} = R^{€}_{f,t}(S_{t+1}/S_t)$. As shown in Internet Appendix C.2, we can use the risk-neutral variance of the exchange rate return to construct a synthetic version of the quanto-implied risk premium, which is illustrated in the bottom panel of Figure 4. The risk-neutral variance can be inferred from the cross-section of currency option implied volatilities for different strikes using, for example, the methodology proposed by Britten-Jones and Neuberger (2000) or the method recently suggested by Martin (2017). We rely on one-year currency options, thus matching the maturity of the credit-implied risk premium, and employ the former (latter) methodology in Panel C (Panel D) of Table 4. We obtain virtually identically results in both Panels, thereby confirming the exchange rate predictive ability of the credit-implied risk premium after accounting for daily fluctuations in the quanto-implied risk premium.[17]

4.3 Other sources of risk

The previous section has revealed that the credit-implied risk premium is a valuable predictor of future exchange rate returns. We now show that our results are not driven by variations in global currency risk premia, sovereign risk, or counterparty risk.

Global currency risk. A body of literature shows that undiversifiable global risk matters in currency markets (e.g., Lustig et al., 2011). It is then natural to verify that the credit-implied risk premium measures risk that is related to currency depreciation conditional upon default and is not another proxy for global risk. If the credit-implied risk premium captures variations

[17] We conduct additional robustness exercises, which we report in the Internet Appendix. Table A.3 reports the estimates of γ_κ without controlling for X_t, whereas Tables A.4–A.5 use proxies of the quanto-implied risk premium based on different maturities of implied volatility. Results remain both qualitatively and quantitatively similar.

in global risk premia, we should find similar evidence of predictability for other currency pairs. To test this hypothesis, we run a simple counterfactual exercise that uses exchange rates with a likely negligible amount of sovereign default risk as the dependent variable.

TABLE 5 ABOUT HERE

The first set of exchange rates consists of the JPY/USD and JPY/CHF, which include safe-haven currencies that typically appreciate in bad states of the world. The second group comprises the CAD/NZD and CAD/AUD, which involve commodity currencies that are expected to fluctuate pro-cyclically with the state of the economy. We run predictive regressions based on Equation (11) where the dependent variable is the selected exchange rate and the set of independent variables includes the debt-weighted credit-implied risk premium for the Eurozone and the interest rate differential for the corresponding currency pair. We report the results in Table 5 and find no evidence of exchange rate predictability. We can thus conclude that the credit-implied risk premium is unlikely to be related to variations in aggregate risk premia.

Sovereign risk. Does our credit-implied risk premium merely proxy for sovereign risk? Intuitively, these measures should capture different information as the former is related to the implied currency depreciation *conditional* upon default and the latter to the risk-neutral probability of sovereign default.[18] This is confirmed by the top panel of Figure 5, which displays the credit-implied risk premium and a measure of sovereign risk for the Eurozone. The former is based on the debt-weighted average of one-year dual-currency CDS premia and the latter on the debt-weighted average of one-year CDS premia in dollar terms. Sovereign risk is fairly high at the beginning of the sample, peaking at 315 *bps* around late November 2011, but

[18] The estimates of $\overline{\mathbb{Q}}_i$ in Equation (9) are time-invariant and should not deliver any predictability.

rapidly drops in the aftermath of the “whatever it takes” speech given by the ECB President Mario Draghi on July 26, 2012. From this date onwards, credit-implied and sovereign risk premia become virtually unrelated, with a sample correlation of -4.6%.

FIGURE 5 ABOUT HERE

To further demonstrate that time-varying sovereign risk plays no role in our exercise, we consider a counterfactual measure of the credit-implied risk premium and run a battery of predictive regressions subsumed by Equations (11)–(12). Specifically, we compute the credit-implied risk premium with the time-varying risk-neutral probability of default ($\mathbb{Q}_{i,t}$) from dollar-denominated one-year CDS premia but time-invariant (sample average) implied currency depreciation (ICD_i) in Equation (9). The results, which are reported in Table A.6 in the Internet Appendix, indicate that a credit-implied risk premium driven solely by time-varying default risk has no predictive power for the USD/EUR exchange rate return.

Counterparty risk. The credit-implied risk premium could also reflect dealers' counterparty risk. For example, if euro-denominated (dollar-denominated) CDS are largely quoted by European (US) banks, the implied currency depreciation in Equation (9) could be attributed to dealers' counterparty risk. To rule out this possibility, we employ the five-year Markit iTraxx Europe Senior Financials index, widely used by market participants to monitor the credit risk exposure of financial institutions in Europe, as an additional control variable in the predictive regressions described by Equations (11)–(12). We present our results in Table A.7 in the Internet Appendix and show that counterparty risk is not harming the predictive power of our credit-implied risk premium. In the bottom panel of Figure 5, we also plot the debt-weighted credit-implied risk premium and our measure of dealers' counterparty risk, whose correlation is as low as 0.1% after Draghi's speech in July 2012.

Underlying determinants. We now study the determinants of the credit-implied risk premium, which we compare to those driving both quanto-implied and sovereign risk premia. We run daily contemporaneous regressions and report the estimates for different specifications in Table 6. For this exercise, we use the debt-weighted credit-implied risk premium, our daily version of the quanto-implied risk premium, and sovereign risk based on the debt-weighted one-year dollar-denominated CDS premium.

TABLE 6 ABOUT HERE

We find that the credit-implied risk premium decreases with the level of economic uncertainty as measured by the VSTOXX (i.e., the one-month implied volatility of the EURO STOXX 50) and increases with economic activity, as measured by the year-on-year growth of industrial production for the Eurozone. The latter is available monthly and we retrieve daily observations by forward filling. As an alternative indicator, we also use the Citi Economic Surprise Index for the Eurozone, which measures the pace at which economic indicators are coming in ahead of or below consensus forecasts. We also record a positive and statistically significant relationship with this indicator, thus confirming that the credit-implied risk premium is procyclical relative to economic conditions. In contrast, quanto-implied and sovereign risk premia are both countercyclical, being positively (negatively) correlated with the level of economic uncertainty (economic activity), in line with the properties of currency risk premia (Lustig et al., 2014).

Nominal conditions, as measured by the two-year German Bund yield, strongly impact all measures of risk but, interestingly, the sign is negative for the credit-implied risk premium and positive for the alternative measures of risk. Following a growing literature on the role of central bank communication for asset prices, we disentangle ECB monetary news (i.e., news about monetary policy) and ECB economic news (i.e., news about economic growth and news affecting financial risk premia) using the direction of the comovement between the stock market and Bund yield on the day of the news, as in Cieslak and Schrimpf (2019). We find that the relation between the credit-implied risk premium and the Bund yield is negative (positive) when ECB announcements essentially reflect monetary (economic and financial) news. In comparison, we find no such evidence for the other sources of risk. Overall, these results show that the credit-implied risk premium contains information that differs fundamentally from what is embedded in the quanto-implied risk premium and in sovereign risk.

4.4 Further robustness

We now conduct two additional tests that provide further robustness for our findings. First, we show that our predictability does not arise mechanically from the return persistence induced by overlapping observations. Second, we conduct a country-level study and verify that the predictability stemming from the credit-implied risk premium is concentrated among major and high credit risk Eurozone countries.

Non-overlapping observations. In our core analysis, we consider predictive regressions with overlapping exchange rate returns. Despite being widely used in the literature, this approach may be a source of concern, especially when the horizon κ is relatively large. Here we provide an additional exercise that complements the Hansen and Hodrick (1980) standard errors and the Politis and Romano (1994) bootstrapped confidence intervals used earlier in our analysis. Specifically, we run predictive regressions with non-overlapping USD/EUR exchange rate returns, i.e., the horizon κ matches the sampling interval. We first convert daily data into weekly observations by sampling every Wednesday as in Burnside et al. (2011) and then focus on a forecast horizon matched with the sampling interval κ, which ranges between one week and four weeks. As robustness, we also sample data on every Tuesday and Thursday. The set of predictors includes the credit-implied risk premium, the one-year interest rate differential, and our daily quanto-implied risk premium.[19]

TABLE 7 ABOUT HERE

We report our empirical evidence in Table 7 and find that estimates of the slope coefficient associated with the credit-implied risk premium is statistically significant in most cases, even after controlling for the quanto-implied risk premium. Also, sampling different days of the week does not affect our results as the magnitude of the coefficient estimates are largely comparable. Overall, this exercise provides evidence that our findings on the exchange rate predictability of the credit-implied risk premium cannot be attributed to the use of overlapping observations.[20]

Country-level analysis In our analysis, the credit-implied risk premium for the Eurozone is constructed by aggregating country-level credit-implied risk premia. The weighting scheme gives more importance to member states with a relatively higher outstanding government debt and, thus, more liquid CDS contracts. While this approach mitigates the impact of less liquid CDS quotes on our evidence, it may hide valuable country-level information. We address this concern by running predictive regressions based on country-level credit-implied risk premia. In Figure 6, we display country-level estimates of γ_κ (including the 90% confidence intervals) in Panel A and the corresponding R^2 in Panel B, for a forecast horizon of six months.

FIGURE 6 ABOUT HERE

[19] Results are similar with the synthetic quanto-implied risk premium based on the USD/EUR implied variance.

[20] Using weekly observations, moreover, rules out the concern that CDS quoted in different currencies may not be fully synchronized due to time zone differences between trading centers. This may happen in our case as euro-denominated CDS are mostly traded in London while dollar-denominated CDS are generally traded in New York.

The highest level of predictive power comes from the credit-implied risk premia of two groups of countries. The first one includes Ireland, Italy, Portugal, and Spain, i.e., countries that largely contributed to the European sovereign debt crisis. The second group comprises Austria, Belgium, France, Germany, and the Netherlands, i.e., economically important countries with a strong interconnection. By contrast, the countries that do not seem to contain any predictability are those playing a minor economic role within the Eurozone, such as Cyprus, Estonia, Latvia, or Lithuania. In sum, the main contributors to exchange rate predictability are either countries with high risk of default or large countries with sound economic conditions. We can thus rule out the possibility that our credit-implied risk premium at the Eurozone level is driven by small-country or less liquid CDS contracts.

5 Forecast evaluation: A statistical perspective

Since the seminal contribution of Meese and Rogoff (1983), a large body of research finds that economically meaningful variables fail to provide accurate out-of-sample exchange rate forecasts. Given the prevailing view that exchange rates are not predictable, especially at short horizons (e.g., Mark, 1995), the random walk (RW) model has become *de facto* the benchmark model to evaluate the predictive ability for exchange rate returns. In this section, we compute out-of-sample tests of forecast accuracy and test the null hypothesis of equal predictive ability between the RW model and a model based on the credit-implied risk premium (CRP model, thereafter).

5.1 Setting

For the CRP model, on each day t, we regress the exchange rate return measured between time t and $t-\kappa$ on the lagged credit-implied risk premium through the following predictive regression:

$$\Delta_\kappa s_t = \alpha_\kappa + \gamma_\kappa CRP_{t-\kappa} + \varepsilon_t. \tag{13}$$

We then produce the κ-period ahead out-of-sample forecast given the information available at time t as $\mathbb{E}_t[\Delta_\kappa s_{t+\kappa}] = \widehat{\alpha}_\kappa + \widehat{\gamma}_\kappa CRP_t$, where $\widehat{\alpha}_\kappa$ and $\widehat{\gamma}_\kappa$ denote the least-squares estimates based on a one-year rolling window of daily data. Following Campbell and Thompson (2008), we also impose an economic sign restriction by setting γ_κ equal to zero when its estimate is negative. Such restriction is consistent with the prediction of our theory and mitigates the parameter instability arising from using a short window of data.

The RW model generates the κ-period ahead forecast as $\mathbb{E}_t[\Delta_\kappa s_{t+\kappa}] = \overline{\alpha}$, where $\overline{\alpha}$ is the one-year rolling average of the exchange rate return. Equivalently, we can estimate the predictive regression in Equation (13) without $CRP_{t-\kappa}$ and generate the out-of-sample forecast using the estimate of the constant term. Ultimately, we compare the performance of a parsimonious restricted null model (with $\gamma_\kappa = 0$) to an unrestricted model that nests the parsimonious model (with $\gamma_\kappa \neq 0$). We now describe a set of statistical criteria based on out-of-sample forecasts and then summarize our empirical findings.

5.2 Tests of forecast accuracy and empirical evidence

We first compute the out-of-sample R^2 statistic of Campbell and Thompson (2008) for a given forecast horizon κ as $R^2_{oos,\kappa} = 1 - (MSE^{CRP}_\kappa / MSE^{RW}_\kappa)$, where MSE_κ is the mean-squared error (MSE) of a given model. A related statistic is the out-of-sample root mean-squared error difference of Welch and Goyal (2008), which is computed as $\Delta RMSE_\kappa = \sqrt{MSE^{RW}_\kappa} - \sqrt{MSE^{CRP}_\kappa}$. For both statistics, a positive value would imply that using CRP outperforms the benchmark RW model.

We also assess whether the CRP model delivers a lower MSE than the RW model using the statistics of McCracken (2007) and Clark and West (2007), respectively, for the null of equal predictive ability for nested models. The statistic of McCracken (2007) is defined as $MSE_{F,\kappa} = (M - \kappa + 1) \times (MSE_{\kappa}^{RW} - MSE_{\kappa}^{CRP})/MSE_{\kappa}^{CRP}$, where M is the number of out-of-sample forecasts. Clark and West (2007) acknowledge that under the null of no predictability the MSE of a competing model could be greater than the MSE of the benchmark model, as the former introduces noise in the forecasting process by estimating an additional parameter that is not helpful for prediction. Thus, finding that the benchmark model has a smaller MSE does not necessarily provide clear evidence against the competing model. The statistic of Clark and West (2007) is conveniently constructed to address this concern as $CW_{\kappa} = MSE_{\kappa}^{RW} - (MSE_{\kappa}^{CRP} - adj)$, where the adjustment term adj captures the average squared difference between the RW-based forecasts and the CRP-based forecasts. For both statistics, we compute bootstrapped critical values by generating 1,000 artificial samples under the null of no predictability as in Mark (1995) and Kilian (1999). This procedure, summarized in Internet Appendix D.2, preserves the autocorrelation structure of the predictive variable and maintains the cross-correlation structure of the residual.

TABLE 8 ABOUT HERE

We report the test statistics discussed above along with the bootstrapped *p*-values in Table 8. Panel A displays the results for the debt-weighted credit-implied risk premium and reports evidence of superior predictive ability against the benchmark model for k ranging between one month and six months. When $\kappa = 3$ months, for instance, the R_{oos}^2 is above 4% when we impose no economic sign restrictions and is statistically different from zero at the 5% confidence level. This result is further corroborated by all statistics, which point in the same direction. In Panel B, we use an alternative weighting scheme based on GDP for our credit-implied risk premium and find qualitatively similar results. We also impose economic sign restrictions akin Campbell and Thompson (2008) and find even better out-of-sample results when using CRP against the RW benchmark.

6 The economic value of FX predictability

In this section, we assess the performance of an asset allocation strategy that exploits the out-of-sample predictability of the USD/EUR exchange rate. We first describe the framework and then present the empirical evidence based on weekly non-overlapping out-of-sample forecasts.

6.1 Setting

We design a simple mean-variance asset allocation strategy whereby a US investor allocates her wealth between a dollar-denominated short-term bond and a euro-denominated cash account. While the bond yields a riskless dollar return, the euro position delivers a risky dollar return R_{t+1} that (in expectation) amounts to the (expected) gross exchange rate return. Any positive excess return is then driven by exchange rate fluctuations. In the spirit of Fleming et al. (2001) and Della Corte et al. (2009), we evaluate whether a portfolio that employs CRP to forecast the USD/EUR exchange rate performs better than a trading strategy that conditions on the RW model.

At each period t, our investor solves the following problem:

$$\begin{aligned} \max_{w_t} \quad \mathbb{E}_t[R_{p,t+1}] &= w_t \left(\mathbb{E}_t[R_{t+1}] - R^{\$}_{f,t}\right) - R^{\$}_{f,t} \\ \text{s.t. } \sigma^\star_p &= w_t \mathbb{V}_t[R_{t+1}], \end{aligned}$$

where $\mathbb{E}_t[R_{p,t+1}]$ is the conditional mean of the gross portfolio return, $\mathbb{E}_t[R_{t+1}]$ is the conditional mean of the gross risky return, $\mathbb{V}_t[R_{t+1}]$ is the conditional volatility of R_{t+1}, $\sigma^\star_p$ is the target volatility of the portfolio strategy, and w_t is the weight of the investor's wealth in the euro cash account. In every period t, the investor rebalances her portfolio using the conditional mean forecast produced by a given model. For the conditional volatility, she simply uses the standard deviation of the regression residuals at time t such that the portfolio weights only vary to the extent that a model produces better forecasts. The weight w_t is available in closed form (e.g., Fleming et al., 2001) and the investor's realized portfolio return at time $t+1$ equals $R_{p,t+1} = w_t \left(R_{t+1} - R^{\$}_{f,t} \right) - R^{\$}_{f,t}$.

We sample observations on every Wednesday as in Burnside et al. (2007) and construct weekly non-overlapping exchange rate returns Δs_t. For the CRP strategy, each week t, we run the following predictive regression: $\Delta s_t = \alpha + \gamma CRP_{t-1} + \varepsilon_t$ using a one-year rolling window of weekly data. The conditional mean forecast at time t is then computed as $\mathbb{E}_t[\Delta s_{t+1}] = \widehat{\alpha} + \widehat{\gamma} CRP_t$, with $\widehat{\alpha}$ and $\widehat{\gamma}$ denoting least-squares estimates obtained at time t. Since the euro-denominated cash account yields a zero return, the expected and realized gross risky return are $\mathbb{E}_t[R_{t+1}] = 1 + \mathbb{E}_t[\Delta s_{t+1}]$ and $R_{t+1} = 1 + \Delta s_{t+1}$, respectively.[21] For robustness, we also sample data on every Tuesday and Thursday. We now discuss several measures of economic performance.

6.2 Performance measures

We start with the performance fee of Fleming et al. (2001) that equates the average utility of the RW model with the ones of the CRP strategy, where the latter is subject to expenses $\mathcal{F}$. Since the investor is indifferent between these strategies, $\mathcal{F}$ can be interpreted as the maximum performance fee she will pay to switch from the benchmark RW model to the competing CRP strategy. We find the value of $\mathcal{F}$ that satisfies:

$$\sum_{t=0}^{T-1} \left\{ \left[R^{CRP}_{p,t+1} - \mathcal{F} \right] - \eta \left[R^{CRP}_{p,t+1} - \mathcal{F} \right]^2 \right\} = \sum_{t=0}^{T-1} \left\{ R^{RW}_{p,t+1} - \eta \left[R^{RW}_{p,t+1} \right]^2 \right\}, \tag{14}$$

where $R^{CRP}_{p,t+1}$ is the gross portfolio return based on CRP forecasts, $R^{RW}_{p,t+1}$ is the gross portfolio return implied from the RW model, and $\eta = \rho/(2+2\rho)$ is a constant that depends on the

[21] We measure $R^{\$}_{f,t}$ using the one-week euro deposit rate, averaged on a five-day rolling window to mitigate day-of-the-week effects on interest rates. Also, investing in a short-term bond as opposed to holding cash account produce qualitatively identical results as Eurozone interest rates are approximately zero in our sample.

investor's degree of relative risk aversion ρ. Ultimately, this utility-based criterion measures how much a mean-variance investor is willing to pay for conditioning on better forecasts.

We also use the premium return difference that builds on the manipulation-proof performance measure of Goetzmann et al. (2007):

$$\mathcal{P} = \frac{1}{(1-\rho)} \left\{ \ln \sum_{t=0}^{T-1} \left(R_{p,t+1}^{CRP} / R_{f,t}^{\$} \right)^{1-\rho} - \ln \sum_{t=0}^{T-1} \left(R_{p,t+1}^{RW} / R_{f,t}^{\$} \right)^{1-\rho} \right\}, \tag{15}$$

where $\mathcal{P}$ measures the risk-adjusted excess return an investor enjoys for using the information content of the CRP strategy relative to the RW model and can be viewed as the maximum performance fee to switch from the benchmark to the competing strategy.[22]

We report both $\mathcal{F}$ and $\mathcal{P}$ in basis points (*bps*) per annum, while setting $\sigma_p^\star = 10\%$ per annum and $\rho = 6$. Different values of $\sigma_p^\star$ and ρ have qualitatively little impact on the asset allocation results. We further report commonly used measures of economic value such as the Sharpe ratio ($\mathcal{SR}$) and the Sortino ratio ($\mathcal{SO}$). The latter differentiates between volatility due to up and down movements in portfolio returns and measures the excess return per unit of bad volatility such that a large $\mathcal{SO}$ indicates a low risk of large losses.

6.3 Impact of transaction costs

The impact of transaction costs is also important in assessing the profitability of dynamic trading strategies. We calculate the break-even proportional transaction cost, τ^{be}, that makes investors indifferent between the two strategies (e.g., Han, 2006; Della Corte et al., 2009). We assume that τ^{be} is a fixed fraction of the value traded in all assets in the portfolio and the cost of the strategy depends on $\tau^{be} |w_t - w_{t-1} \frac{1+r_t}{1+r_{p,t}}|$. An investor who pays transaction costs lower than τ^{be} will prefer the CRP strategy. Since τ^{be} is a proportional cost paid every

[22] This criterion is robust to the distribution of portfolio returns and does not require the assumption of a particular utility function to rank portfolios, in contrast to $\mathcal{F}$ that assumes a quadratic utility function.

time the portfolio is rebalanced, we report τ^{be} in *bps* per week.

6.4 Empirical evidence

Table 9 reports the out-of-sample portfolio performance and shows that there is high economic value associated with using CRP to forecast exchange rate returns. The left-side panels employ no restrictions on the slope coefficient γ whereas the right-side panels impose a positive sign restriction in the spirit of Campbell and Thompson (2008). Panel B samples data on every Wednesday and shows that our theoretically-motivated predictor clearly outperforms the RW model. In particular, the unrestricted debt-weighted CRP strategy displays a $\mathcal{SR} = 0.31$ per annum and a US investor is willing to pay a performance fee higher than 300 *bps* per annum for switching from the RW model to the CRP strategy. The performance improves when imposing economic constraints akin to Campbell and Thompson (2008) since we uncover a $\mathcal{SR} = 0.42$ and $\mathcal{F} = 429$ *bps* per annum. The premium return $\mathcal{P}$ also leads to the same conclusion, suggesting that quadratic utility characterizing the Fleming et al. (2001) criterion is not affecting our results. The empirical evidence, moreover, remains qualitatively similar when CRP uses an alternative weighting scheme based on each country's GDP.

TABLE 9 ABOUT HERE

If transaction costs are sufficiently high, the period-by-period fluctuations in the dynamic weights of an optimal allocation will render the exercise too costly to implement relative to the static RW model. For the unconstrained debt-weighted CRP, we find a high τ^{be} meaning that a US investor will switch back to the RW model if she pays a proportional transaction cost higher than 28 *bps* per week when exploiting the CRP strategy. The τ^{be} increases when using economic restrictions on the slope coefficient, as $\tau^{be} = 49.3$ *bps* per week. By and large, these values remain reasonably high and unlikely to be hit by professional FX traders.

In Panels A and C, we repeat our asset allocation exercise by sampling data every Tuesday and Thursday, respectively, thus accounting for intra-week seasonal patterns (e.g., Bessembinder, 1994). While the results are qualitatively similar when sampling Tuesday, the economic value in support of the CRP strategy is substantially higher when our investor rebalances her allocation on Thursday. In this case, for example, the unconstrained debt-weighted CRP strategy produces an annualized $\mathcal{SR} = 0.61$, which is higher than the corresponding value recorded in Panel B. Recall from Table 6 that the credit-implied risk premium is highly sensitive to both ECB monetary and economic announcements, which are generally made Thursdays. This could explain why results are stronger in Panel C. Overall, we find that exploiting CRP generates tangible out-of-sample economic gains to an investor that uses exchange rate forecasts within an active portfolio strategy.

7 Conclusion

This paper uncovers, both theoretically and empirically, a novel source of currency risk premium, which we label the *credit-implied risk premium*. This risk premium component reflects investors' risk-neutral expectations about currency movements conditional on a severe but rare event, such as a sovereign default. We exploit dual-currency sovereign CDS to derive a market-based measure of the expected currency depreciation conditional on sovereign default, using daily data over the period 2010–2019.

We find that an aggregate measure of the credit-implied risk premium for the Eurozone positively predicts future USD/EUR exchange rate returns at various horizons, even after controlling for the interest rate differential, the quanto-implied risk premium of Kremens and Martin (2019), FX liquidity and volatility, and traditional currency factors. The predictability holds in- and out-of-sample, which indicates that investors are compensated for bearing the risk of currency depreciation in the case of a sovereign default. Furthermore, our predictor generates tangible economic gains to an investor using dynamic forecasts in active portfolio management. We obtain strong economic evidence against the random walk benchmark using a sample of weekly non-overlapping observations, and our results are robust to reasonably high transaction costs. Overall, the credit-implied risk premium appears to be a critical driver of exchange rate returns, and we provide evidence that investors can benefit from this new source of information.

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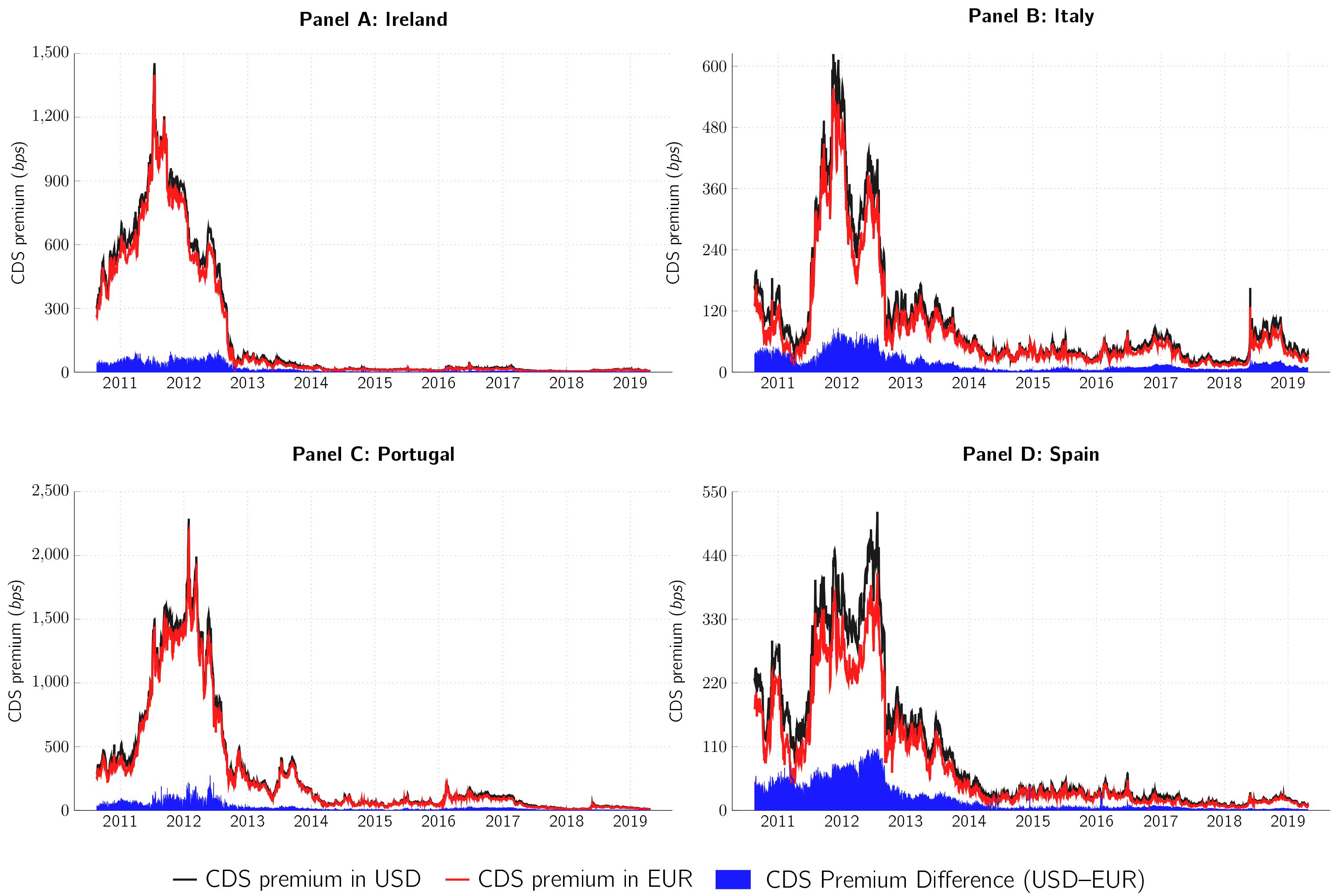


Figure 1. Sovereign CDS premium by currency denomination

This figure plots one-year dollar-denominated and euro-denominated sovereign credit default swap (CDS) premia of selected Eurozone member states in basis points (*bps*) per annum. The shaded area denotes the difference between CDS premia. The sample consists of daily observations between August 2010 and April 2019 from IHS Markit.

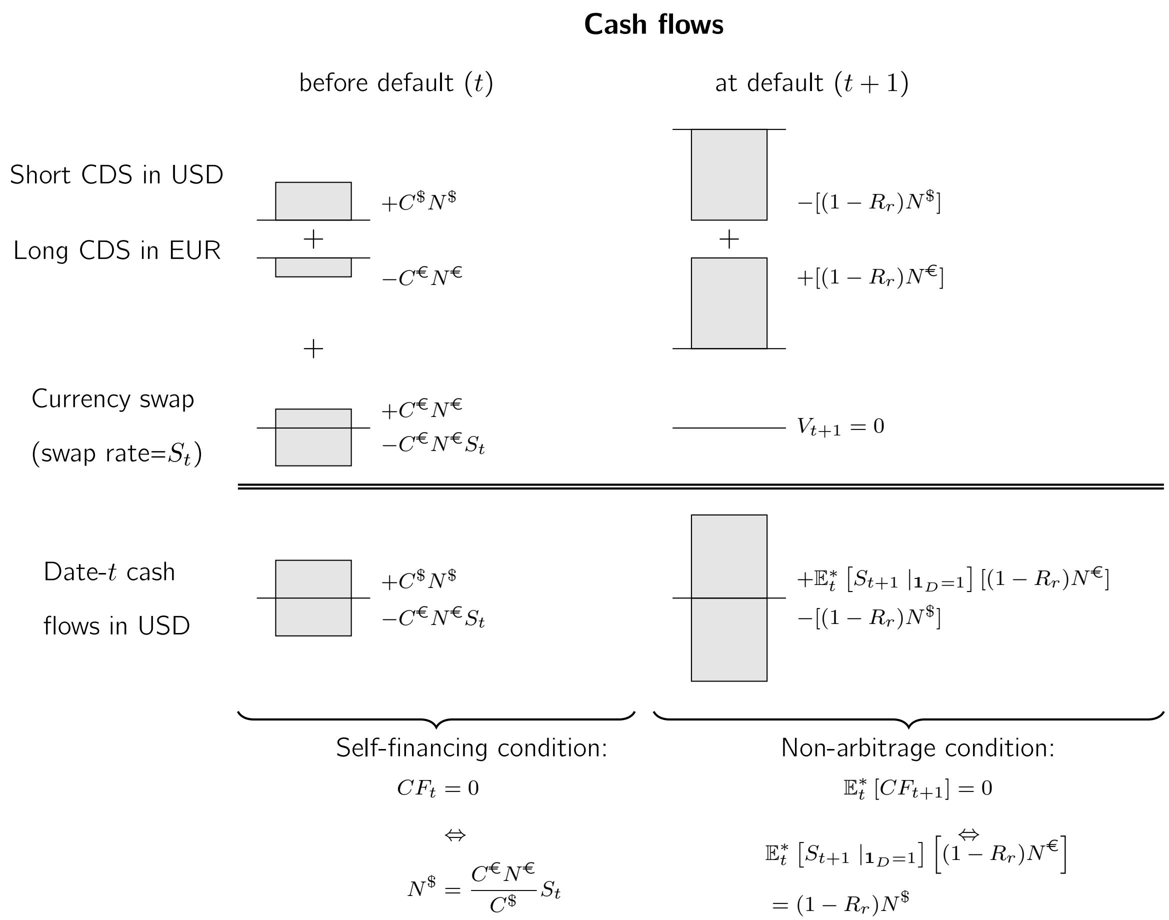


Figure 2. Cash flows of a long-short CDS strategy

This figure displays the cash flows of a strategy that simultaneously goes long a euro-denominated and short a dollar-denominated sovereign CDS written on the same underlying entity while hedging the exchange rate via a currency swap. The strategy starts at time t and ends at time $t+1$ with a potential default event at time $t+1$. This long-short strategy is discussed in Section 2.3

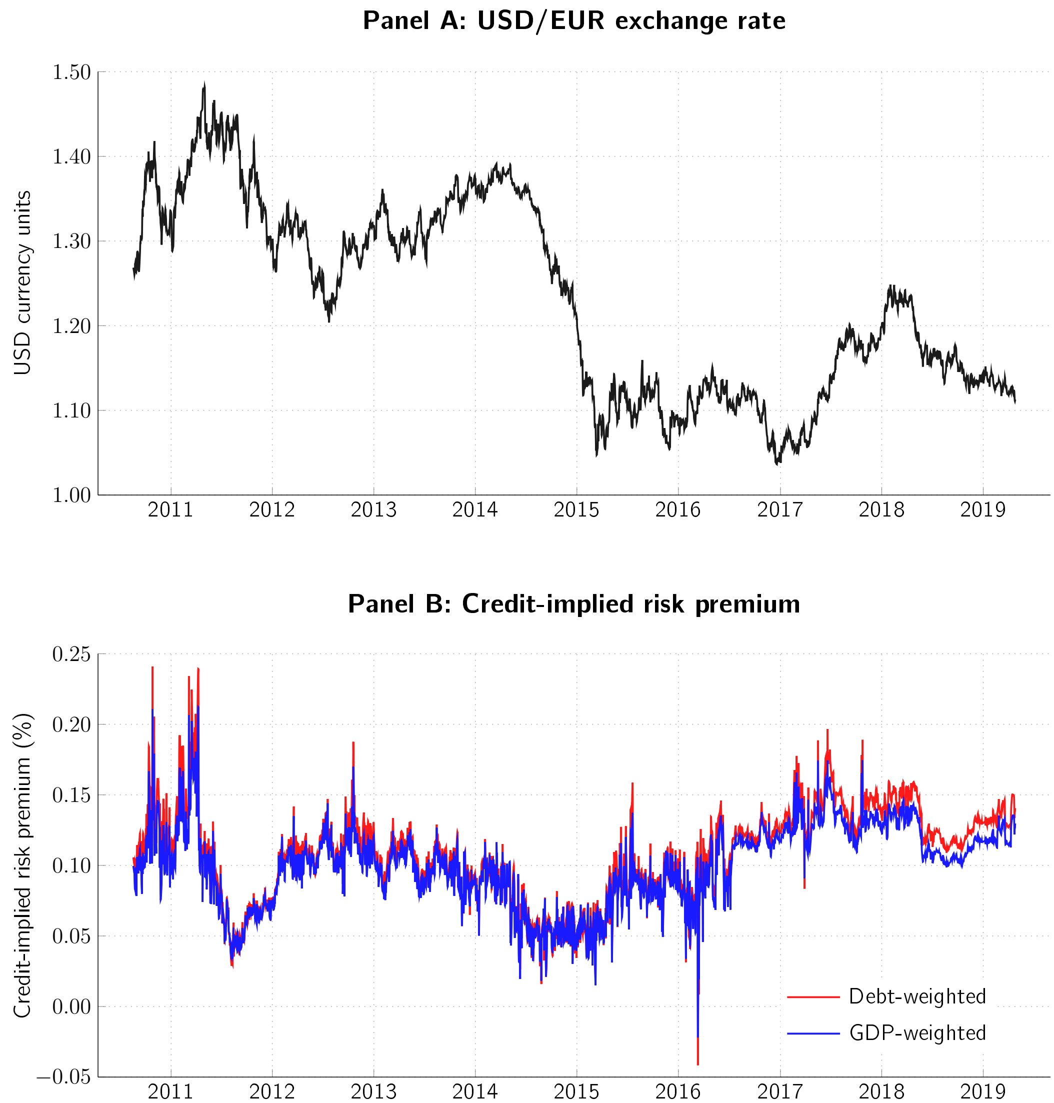
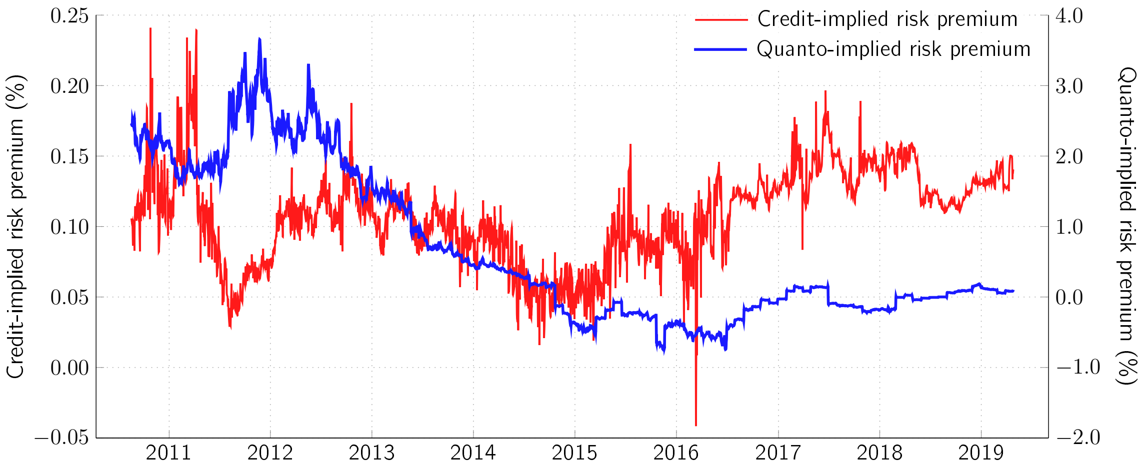


Figure 3. Credit-implied risk premium for the Eurozone

This figure plots the USD/EUR exchange rate (Panel A) and the credit-implied risk premium (CRP) for the Eurozone (Panel B). The exchange rate is defined as units of dollars per euro. CRP is constructed using country-level dollar-denominated and euro-denominated CDS premia weighted by sovereign debt or GDP. The countries included in the computation are Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, the Netherlands, Portugal, Slovenia, Slovakia, and Spain. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

Panel A: Daily quanto-implied risk premium



Panel B: Synthetic quanto-implied risk premium

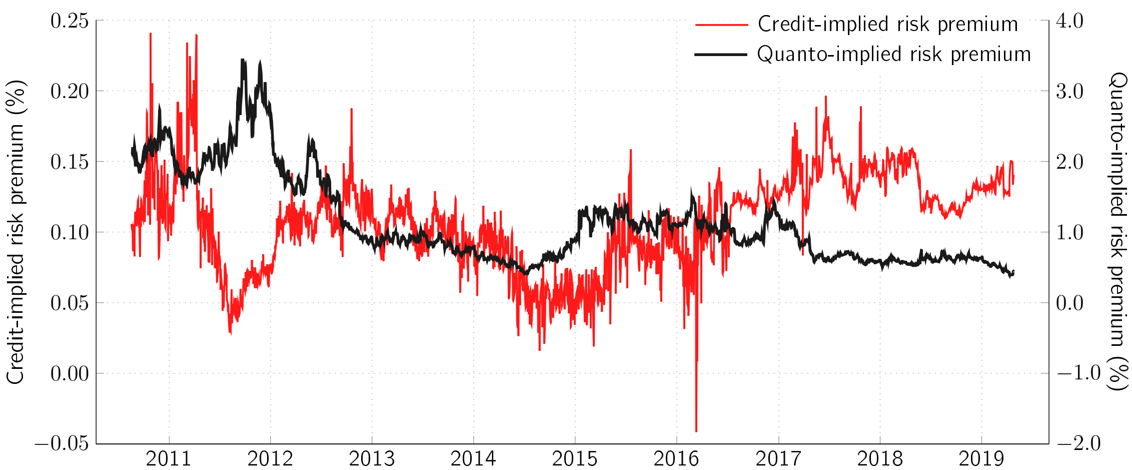
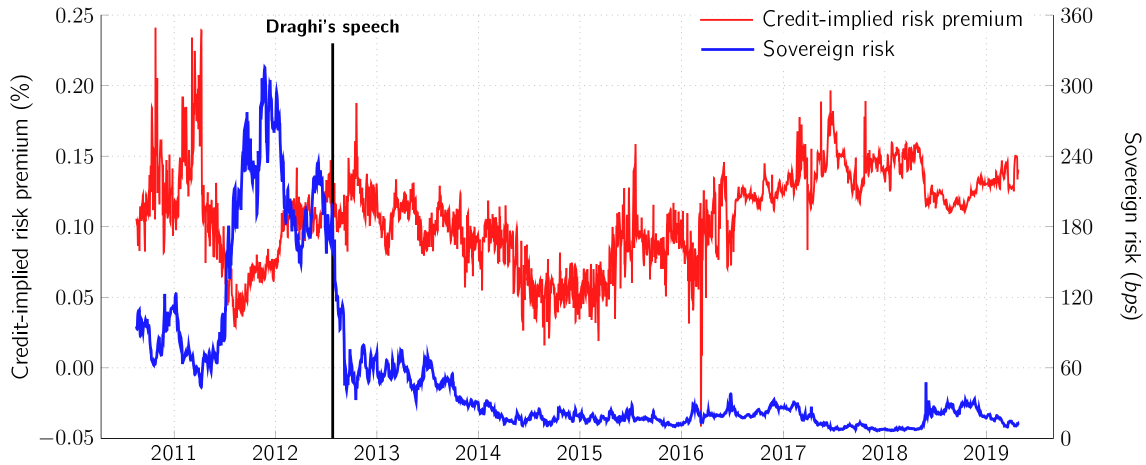


Figure 4. Quanto-implied risk premium for the Eurozone

Panel A displays a daily version of the quanto-implied risk premium of Kremens and Martin (2019) recovered by combining daily risk-neutral volatilities and correlation, i.e., one-year VIX index, one-year model-free USD/EUR option implied volatility, and the risk-neutral correlation inferred monthly (and kept constant intra-month) from quanto forwards on the S&P 500 index. The latter is replaced after October 2015 with the one-year realized return correlation between the S&P 500 index and the USD/EUR exchange rate. Panel B plots the daily synthetic quanto-implied risk premium based on the one-year model-free USD/EUR option implied variance, assuming that the investor holds a euro-denominated riskless bond rather than a diversified portfolio of stocks. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

Panel A: Sovereign risk



Panel B: Counterparty risk

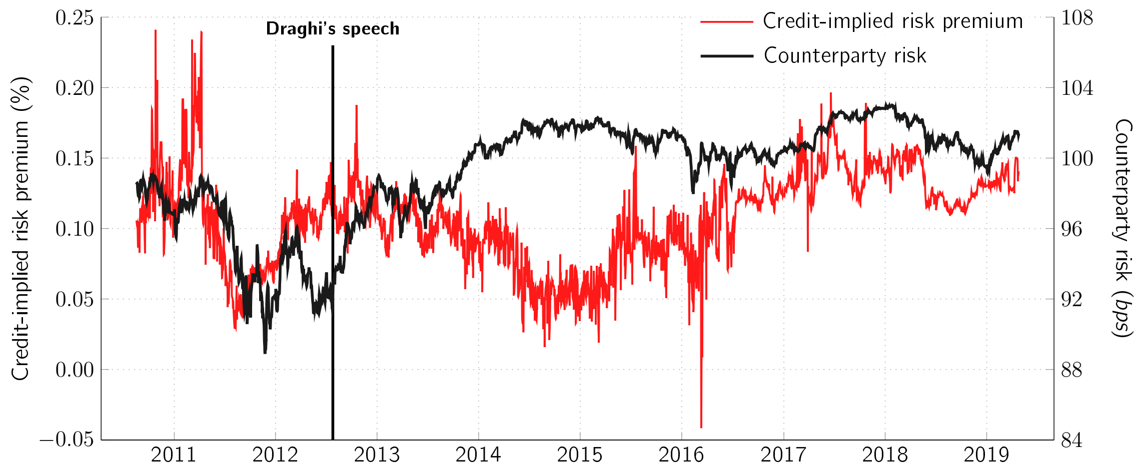


Figure 5. Sovereign and counterparty risk

Panel A plots the credit-implied risk premium and the level of sovereign risk for the Eurozone. The former is constructed using country-level dollar-denominated and euro-denominated CDS premia weighted by sovereign debt. The latter uses country-level dollar-denominated CDS premia weighted by sovereign debt. Panel B displays the credit-implied risk premium and the dealers' counterparty risk for the Eurozone. The latter is proxied with the Markit iTraxx Europe Senior Financials Index, which measures credit risk of 25 major financial institutions in Europe. The vertical line indicates the "whatever it takes" speech by the ECB President Mario Draghi on July 26, 2012. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

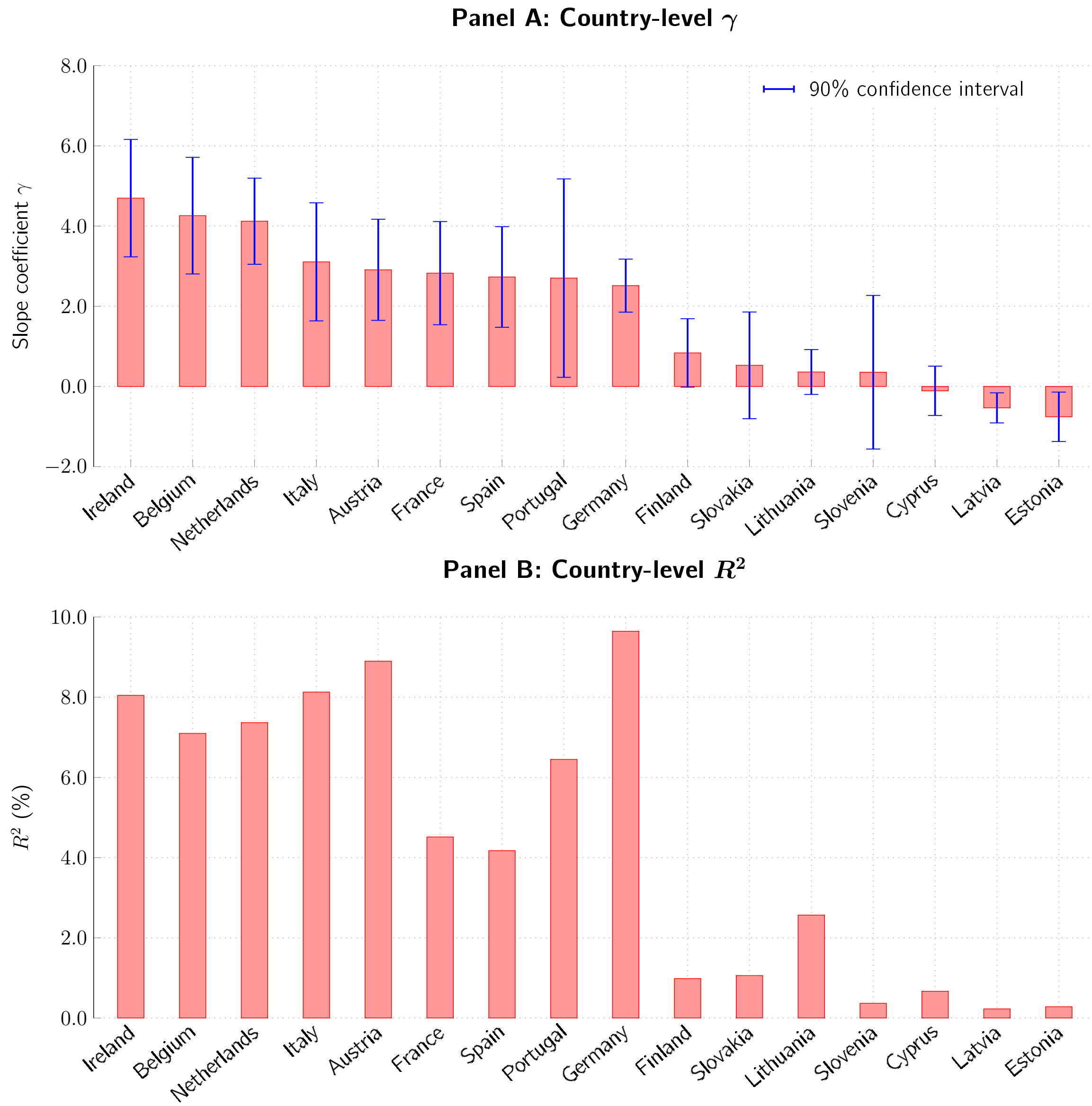


Figure 6. Country-level credit-implied risk premium

This figure illustrates the exchange rate predictive ability of the credit-implied risk premium (CRP) by country. The dependent variable is the daily average USD/EUR exchange rate return measured on a six-month forecast horizon and expressed in annual terms. CRPs are based on dollar-denominated and euro-denominated one-year CDS premia. Panel A presents the CRP slope coefficient γ, while controlling for the one-year interest rate differential between the US and Eurozone, the daily version of the quanto-implied risk premium, global FX illiquidity, FX volatility, and currency factors. The error bar denotes 90% confidence intervals based on Hansen and Hodrick (1980) standard errors with a lag length equal to six. Panel B reports the R^2, net of all control variables. CRPs are standardized to have zero means and unit standard deviations to ease the comparison across countries. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

Table 1. Descriptive statistics

This table describes the credit-implied risk premium and its underlying components in percentage per annum. Panel A displays, for each Eurozone country, descriptive statistics for the credit-implied risk premium ($CRP_{i,t}$) and the implied currency depreciation upon default ($ICD_{i,t}$) based on the price difference between one-year dollar-denominated and euro-denominated CDS premia. $\overline{\mathbb{Q}}_i$ is the risk-neutral probability of default extracted from one-year CDS data in dollars (full-sample) and ω_i is the weight of country i based on its level of sovereign debt or GDP for the year 2010. Panel B shows descriptive statistics for the debt-weighted and GDP-weighted CRP_t and ICD_t for the Eurozone. P_5 (P_{95}) denotes the 5th (95th) percentile. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

Panel A: Country variables

	$CRP_{i,t}$ (%)				$ICD_{i,t}$ (%)				$\overline{\mathbb{Q}}_i$ (%)	ω_i (%)	
	mean	std	P_5	P_{95}	mean	std	P_5	P_{95}		Debt	GDP
Austria	0.06	0.02	0.02	0.09	31.30	11.45	10.44	50.45	0.32	3.2	3.2
Belgium	0.08	0.05	−0.01	0.17	22.60	13.87	−1.81	45.80	0.61	4.7	3.9
Cyprus	0.27	0.44	−0.39	1.07	5.25	9.60	−8.34	24.31	7.78	0.1	0.2
Estonia	0.02	0.03	−0.02	0.08	8.09	11.36	−7.43	28.31	0.46	0.0	0.2
Finland	0.02	0.01	0.00	0.04	23.09	13.81	1.21	44.02	0.17	1.1	2.0
France	0.06	0.03	0.01	0.10	27.58	13.42	3.12	47.32	0.35	21.2	21.5
Germany	0.03	0.02	0.00	0.05	29.92	17.96	−2.26	57.75	0.14	27.2	27.8
Ireland	0.31	0.17	0.04	0.57	17.54	9.10	3.87	31.83	2.85	1.9	1.8
Italy	0.19	0.09	0.07	0.33	18.80	8.41	6.64	31.81	1.69	24.1	17.3
Latvia	0.03	0.07	−0.09	0.10	4.95	12.17	−15.82	18.49	0.94	0.1	0.2
Lithuania	0.04	0.05	−0.04	0.11	7.68	9.30	−6.86	20.94	0.92	0.1	0.3
Netherlands	0.04	0.02	0.01	0.07	30.50	13.04	4.54	50.88	0.22	4.9	6.9
Portugal	0.37	0.19	0.08	0.68	12.59	6.10	3.35	22.72	4.70	2.3	1.9
Slovakia	0.04	0.04	−0.01	0.11	11.33	11.78	−3.69	34.60	0.58	0.4	0.7
Slovenia	0.08	0.08	−0.02	0.26	10.97	11.35	−1.88	36.27	1.22	0.2	0.4
Spain	0.20	0.07	0.10	0.31	20.21	6.99	10.03	31.11	1.63	8.5	11.6

Panel B: Eurozone variables

	mean	std	P_5	P_{95}	mean	std	P_5	P_{95}			
Debt-weighted	0.11	0.03	0.05	0.15	24.70	7.65	9.83	36.05	–	–	–
GDP-weighted	0.10	0.03	0.05	0.14	24.79	7.79	10.15	36.76	–	–	–

Table 2. FX predictability and credit-implied risk premium

This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts. Panel A presents the benchmark specification, which controls for the one-year interest rate differential between the US and Eurozone. Panel B (Panel C) adds global FX illiquidity and volatility (currency factors), whereas Panel D adds all control variables to the benchmark specification. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Benchmark specification

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.229****	**2.407****	**2.155*****	**1.852****	**1.009****
	(0.023)	(0.016)	(0.004)	(0.013)	(0.034)
R^2 (%)	1.08	6.24	16.26	23.35	20.26
N	2,154	2,138	2,096	2,033	1,907

Panel B: Adding liquidity and volatility

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.272****	**2.447****	**2.181*****	**1.879*****	**1.039*****
	(0.021)	(0.014)	(0.002)	(0.000)	(0.001)
R^2 (%)	1.13	6.68	18.24	34.00	42.54
N	2,154	2,138	2,096	2,033	1,907

Panel C: Adding currency factors

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.267****	**2.432****	**2.168*****	**1.858****	**1.017****
	(0.022)	(0.015)	(0.004)	(0.013)	(0.034)
R^2 (%)	1.25	6.12	16.21	23.24	20.13
N	2,154	2,138	2,096	2,033	1,907

Panel D: Adding all controls

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.314****	**2.472****	**2.194*****	**1.886*****	**1.045*****
	(0.019)	(0.013)	(0.002)	(0.000)	(0.001)
R^2 (%)	1.32	6.57	18.24	33.96	42.56
N	2,154	2,138	2,096	2,033	1,907

Table 3. FX predictability and credit-implied risk premium: GDP-weighted

This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by GDPs. Panel A presents the benchmark specification, which controls for the one-year interest rate differential between the US and Eurozone. Panel B (Panel C) adds global FX illiquidity and volatility (currency factors), whereas Panel D adds all control variables to the benchmark specification. We report *p*-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Benchmark specification

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.562****	**2.717****	**2.484*****	**2.158*****	**1.176****
	(0.020)	(0.013)	(0.003)	(0.008)	(0.015)
R^2 (%)	1.12	6.21	16.82	24.56	20.86
N	2,154	2,138	2,096	2,033	1,907

Panel B: Adding liquidity and volatility

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.626****	**2.774****	**2.522*****	**2.194*****	**1.218*****
	(0.018)	(0.011)	(0.001)	(0.000)	(0.000)
R^2 (%)	1.18	6.69	18.89	35.29	43.32
N	2,154	2,138	2,096	2,033	1,907

Panel C: Adding currency factors

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.601****	**2.744****	**2.498*****	**2.166*****	**1.185****
	(0.020)	(0.013)	(0.003)	(0.008)	(0.014)
R^2 (%)	1.29	6.09	16.78	24.46	20.73
N	2,154	2,138	2,096	2,033	1,907

Panel D: Adding all control variables

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.669****	**2.802*****	**2.537*****	**2.202*****	**1.225*****
	(0.017)	(0.010)	(0.001)	(0.000)	(0.000)
R^2 (%)	1.37	6.58	18.89	35.25	43.34
N	2,154	2,138	2,096	2,033	1,907

Table 4. Controlling for the quanto-implied risk premium

This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP) accounting for the quanto-implied risk premium (QRP) of Kremens and Martin (2019). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts. In Panel A, QRP uses euro-denominated quanto forwards on the S&P500 index, which are available monthly until October 2015. Daily missing observations are retrieved by forward filling, i.e., we keep the latest available observation fixed over the next month. In Panel B, daily missing observations are recovered by combining risk-neutral volatility and correlation components, i.e., one-year VIX index, one-year model-free USD/EUR option implied volatility akin to Britten-Jones and Neuberger (2000), and risk-neutral correlation inferred monthly (and kept constant intra-month) from the quanto forwards. The latter is replaced after October 2015 with the one-year realized return correlation between the S&P 500 index and the USD/EUR exchange rate. In Panels C and D, QRP is synthetically replicated using the USD/EUR one-year option implied variance based, respectively, on the model-free approach of Britten-Jones and Neuberger (2000) and the simple variance method of Martin (2017). All specifications control for the one-year interest rate differential between the US and Eurozone, global FX liquidity, volatility, and currency factors. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and November 2015 (April 2019) in Panel A (Panels B–D). Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Controlling for monthly QRP

	1 week	1 month	3 months	6 months	1 year
CRP_t	2.150*	**2.625****	**2.561*****	**2.350*****	**0.948*****
	(0.088)	(0.027)	(0.000)	(0.000)	(0.000)
R^2 (%)	1.95	9.93	32.35	64.93	81.35
N	1,313	1,297	1,255	1,192	1,066

Panel B: Controlling for daily QRP

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.265****	**2.530*****	**2.195*****	**1.706*****	**0.662*****
	(0.025)	(0.008)	(0.000)	(0.000)	(0.000)
R^2 (%)	1.28	6.54	18.20	34.69	47.25
N	2,154	2,138	2,096	2,033	1,907

Panel C: Controlling for daily synthetic QRP_{MF}

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.329****	**2.500****	**2.157*****	**1.875*****	**0.979*****
	(0.019)	(0.008)	(0.001)	(0.001)	(0.001)
R^2 (%)	1.28	6.53	18.25	33.93	42.92
N	2,154	2,138	2,096	2,033	1,907

Panel D: Controlling for daily synthetic QRP_{SI}

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.281****	**2.471****	**2.140*****	**1.862*****	**0.974*****
	(0.022)	(0.008)	(0.001)	(0.001)	(0.001)
R^2 (%)	1.28	6.52	18.29	33.95	42.90
N	2,154	2,138	2,096	2,033	1,907

Table 5. Alternative currency pairs and credit-implied risk premium

This table presents results on the predictive ability of the credit-implied risk premium (CRP) for alternative currency pairs. The dependent variable is the daily average exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts. Each specification controls for the corresponding currency pair interest rate differential. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

	Panel A: Predicting the JPY/USD					Panel B: Predicting the JPY/CHF				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	−0.204	0.237	0.362	0.357	0.004	1.462	1.189	1.152	0.689	0.382
	(0.857)	(0.794)	(0.734)	(0.749)	(0.996)	(0.326)	(0.378)	(0.337)	(0.415)	(0.354)
R^2 (%)	0.12	0.80	2.07	3.22	5.85	0.61	2.84	8.01	10.65	17.76
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907

	Panel C: Predicting the CAD/NZD					Panel D: Predicting the CAD/AUD				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	−0.184	−0.735	−0.373	−0.104	0.359	0.681	0.429	0.279	0.192	−0.041
	(0.882)	(0.540)	(0.637)	(0.875)	(0.301)	(0.352)	(0.483)	(0.536)	(0.530)	(0.871)
R^2 (%)	0.00	0.59	1.53	0.86	2.09	0.18	0.45	0.98	3.02	4.51
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907

Table 6. Different sources of risk and underlying determinants

This table presents estimates of the determinants of different sources of risk. The set of explanatory variables includes economic uncertainty (VSTOXX), economic growth (year-on-year growth of the industrial production for the Eurozone), economic surprise (Citi Economic Surprise Index for the Eurozone), Bund yield (German two-year bond yield), ECB monetary news (i.e., news about monetary policy) and ECB economic news (i.e., news about economic growth and news affecting financial risk premia) constructed akin to Cieslak and Schrimpf (2019). The credit-implied risk premium for the Eurozone is based on country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts. The daily version of the quanto-implied risk premium is recovered by combining daily risk-neutral volatility and correlation components, i.e., one-year VIX index, one-year model-free USD/EUR option implied volatility akin to Britten-Jones and Neuberger (2000), and risk-neutral correlation inferred monthly (and kept constant intra-month) from the quanto forwards. The latter is replaced after October 2015 with the realized return correlation between the S&P 500 index and the USD/EUR exchange rate. Sovereign risk for the Eurozone is constructed using country-level dollar-denominated CDS premia weighted by sovereign debts. We report p-values based on Newey and West (1987) standard errors in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

	Credit-implied risk premium			Quanto-implied risk premium			Sovereign risk		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Economic uncertainty	−0.202***	−0.193***	−0.181***	0.078***	0.080***	0.041***	0.066***	0.067***	0.054***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Economic growth	0.141***	0.095*	0.120**	−0.029	−0.039*	−0.127***	−0.042***	−0.045***	−0.074***
	(0.003)	(0.074)	(0.012)	(0.137)	(0.052)	(0.000)	(0.000)	(0.000)	(0.000)
Economic surprise		0.007**	0.007**		0.001	0.002**		0.001	0.001
		(0.038)	(0.038)		(0.109)	(0.013)		(0.260)	(0.173)
Bund yield (2y)			−0.360			1.257***			0.406***
			(0.204)			(0.000)			(0.000)
2y×ECB monetary news			−1.297**			−0.078			−0.015
			(0.021)			(0.658)			(0.861)
2y×ECB economic news			1.588**			0.198			0.051
			(0.014)			(0.539)			(0.740)
ECB news dummy			−0.364			0.011			0.017
			(0.242)			(0.867)			(0.687)
Constant	14.744***	14.610***	14.313***	−0.950***	−0.978***	0.062	−0.801***	−0.811***	−0.475***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.610)	(0.000)	(0.000)	(0.000)
R^2 (%)	18.7	19.3	19.7	24.4	24.7	64.2	47.9	48.0	58.8
N	2,225	2,225	2,225	2,225	2,225	2,225	2,225	2,225	2,225

Table 7. FX return predictability: Non-overlapping observations

This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP) with non-overlapping observations. The dependent variable is the USD/EUR exchange rate return measured on a non-overlapping forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts. Results are presented with and without accounting for the daily version of the quanto-implied risk premium (QRP). QRP is recovered by combining risk-neutral volatility and correlation components, i.e., one-year VIX index, one-year model-free USD/EUR option implied volatility, and risk-neutral correlation inferred monthly (and kept constant intra-month) from the quanto forwards. The latter is replaced after October 2015 with the realized return correlation between the S&P 500 index and the USD/EUR exchange rate. All specifications control for the one-year interest rate differential between the US and Eurozone. We report *p*-values based on Newey and West (1987) with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. The sample runs between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

Panel A: Sampling every Tuesday

	Benchmark specification				Controlling for QRP			
	1 week	2 weeks	3 weeks	4 weeks	1 week	2 weeks	3 weeks	4 weeks
CRP_t	2.076**	2.251**	2.591***	2.759***	2.019**	2.259**	2.702***	2.914***
	(0.036)	(0.029)	(0.001)	(0.000)	(0.040)	(0.025)	(0.002)	(0.000)
R^2 (%)	0.62	1.57	3.82	6.79	0.40	1.13	3.24	6.11
N	452	226	150	113	452	226	150	113

Panel B: Sampling every Wednesday

	Benchmark specification				Controlling for QRP			
	1 week	2 weeks	3 weeks	4 weeks	1 week	2 weeks	3 weeks	4 weeks
CRP_t	2.231**	1.925	2.669***	1.839**	2.214*	1.941	2.809***	1.874**
	(0.063)	(0.114)	(0.004)	(0.017)	(0.075)	(1.430)	(0.003)	(0.019)
R^2 (%)	0.72	0.80	3.31	1.30	0.49	0.36	2.70	0.39
N	451	225	150	112	451	225	150	112

Panel C: Sampling every Thursday

	Benchmark specification				Controlling for QRP			
	1 week	2 weeks	3 weeks	4 weeks	1 week	2 weeks	3 weeks	4 weeks
CRP_t	2.375**	2.494**	1.974**	2.120***	2.397**	2.558***	2.010*	2.166***
	(0.016)	(0.011)	(0.044)	(0.004)	(0.016)	(0.009)	(0.069)	(0.007)
R^2 (%)	0.91	1.84	1.91	2.96	0.69	1.40	1.25	2.07
N	451	225	150	112	451	225	150	112

Table 8. Out-of-sample FX predictability: Statistical evaluation

This table reports out-of-sample tests of predictive ability for the credit-implied risk premium (CRP) against the random walk model. The predicted variable is the daily average USD/EUR exchange rate return measured over different forecast horizons. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts (GDPs) in Panel A (Panel B). Unconstrained predictability denotes out-of-sample forecasts without any economic constraints. Unconstrained predictability indicates that out-of-sample forecasts are subject to an economic sign restriction as in Campbell and Thompson (2008), i.e., the slope coefficient associated with CRP is set equal to zero when its estimate is negative. The out-of-sample forecasts are generated using a one-year rolling window. The *p*-values are computed using 1,000 bootstrap replications and are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. The sample consists of observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Debt-weighted CRP

	Unconstrained predictability					Constrained predictability				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
$R^2_{oos}(\%)$	−0.538**	3.975***	4.136**	6.545*	−1.483	0.414**	5.535***	9.227***	11.972**	2.900
	(0.035)	(0.007)	(0.036)	(0.075)	(0.312)	(0.014)	(0.002)	(0.007)	(0.022)	(0.187)
$\Delta RMSE$	−0.1865**	0.589***	0.411**	0.554*	−0.099	0.127**	0.823***	0.930***	1.028**	0.196
	(0.035)	(0.007)	(0.036)	(0.070)	(0.323)	(0.014)	(0.004)	(0.009)	(0.016)	(0.169)
MSE_F	−0.005**	0.041***	0.043**	0.070*	−0.015	0.004**	0.059***	0.102**	0.136**	0.030
	(0.035)	(0.007)	(0.036)	(0.075)	(0.312)	(0.034)	(0.005)	(0.027)	(0.013)	(0.128)
CW	1.755	6.422**	6.200	7.573	5.634	2.582**	7.115***	8.442**	10.788**	7.724
	(0.125)	(0.018)	(0.109)	(0.115)	(0.244)	(0.034)	(0.005)	(0.027)	(0.013)	(0.128)

Panel B: GDP-weighted CRP

	Unconstrained predictability					Constrained predictability				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
$R^2_{oos}(\%)$	−0.579**	3.526***	2.540*	5.892*	1.290	0.424**	5.086***	7.693**	10.944**	5.078
	(0.044)	(0.008)	(0.055)	(0.081)	(0.241)	(0.014)	(0.004)	(0.015)	(0.028)	(0.127)
$\Delta RMSE$	−0.178**	0.522***	0.252*	0.498*	0.087	0.130**	0.756***	0.772**	0.937**	0.345
	(0.042)	(0.009)	(0.055)	(0.075)	(0.236)	(0.014)	(0.006)	(0.016)	(0.024)	(0.111)
MSE_F	−0.006**	0.037***	0.026*	0.063*	0.013	0.004**	0.054***	0.083**	0.123**	0.053*
	(0.044)	(0.008)	(0.055)	(0.081)	(0.241)	(0.030)	(0.006)	(0.042)	(0.022)	(0.094)
CW	1.825	6.172**	5.426	7.217	6.624	2.699**	6.887***	7.706**	10.433**	8.676*
	(0.111)	(0.030)	(0.140)	(0.121)	(0.200)	(0.030)	(0.006)	(0.042)	(0.022)	(0.094)

Table 9. Out-of-sample FX predictability: Economic evaluation

This table presents the out-of-sample performance of an asset allocation strategy that exploits the predictability of the USD/EUR exchange rate return using the credit-implied risk premium (CRP) against the random walk (RW). The US investor employs non-overlapping weekly forecasts and allocates wealth between a dollar-denominated short-term bond and a euro-denominated cash account, seeking to maximize expected return subject to target volatility of 10% per annum. In each case, we report the percentage mean, percentage volatility, Sharpe ratio ($\mathcal{SR}$), and Sortino ratio ($\mathcal{SO}$) in annual terms. $\mathcal{F}$ denotes the performance fee a risk-averse investor is willing to pay for switching from the benchmark RW model to the competing CRP strategy. $\mathcal{P}$ is the premium return generated by the CRP strategy relative to the RW. $\mathcal{F}$ and $\mathcal{P}$ are computed for a degree of relative risk aversion equal to 6 and are expressed in annual basis points. τ^{be} is the break-even proportional transaction cost that cancels out the utility advantage of the CRP strategy relative to the RW model, and is expressed in weekly basis points. The predictive regressions are re-estimated on every Tuesday (Panel A), Wednesday (Panel B), and Thursday (Panel C) using a one-year rolling window. Unconstrained predictability indicates that out-of-sample forecasts are subject to an economic sign restriction as in Campbell and Thompson (2008), i.e., the slope coefficient associated with CRP is set equal to zero when its estimate is negative. The sample consists of weekly observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Sampling every Tuesday

	Unconstrained predictability							Constrained predictability						
	mean	vol	$\mathcal{SR}$	$\mathcal{SO}$	$\mathcal{F}$	$\mathcal{P}$	τ^{be}	mean	vol	$\mathcal{SR}$	$\mathcal{SO}$	$\mathcal{F}$	$\mathcal{P}$	τ^{be}
RW	1.30	10.05	0.13	0.23				1.30	10.05	0.13	0.23			
Debt-weighted CRP	3.37	10.14	0.33	0.58	201.6	201.8	23.0	3.84	9.54	0.40	0.69	284.0	284.2	32.3
GDP-weighted CRP	4.28	10.14	0.42	0.74	292.4	292.5	26.6	3.37	9.55	0.35	0.60	236.6	236.6	19.6

Panel B: Sampling every Wednesday

	mean	vol	$\mathcal{SR}$	$\mathcal{SO}$	$\mathcal{F}$	$\mathcal{P}$	τ^{be}	mean	vol	$\mathcal{SR}$	$\mathcal{SO}$	$\mathcal{F}$	$\mathcal{P}$	τ^{be}
RW	0.11	10.24	0.01	0.02				0.11	10.24	0.01	0.02			
Debt-weighted CRP	3.20	10.25	0.31	0.52	308.5	309.3	28.1	4.18	9.88	0.42	0.71	429.3	430.4	49.6
GDP-weighted CRP	2.87	10.25	0.28	0.47	275.4	276.1	25.3	4.46	9.86	0.45	0.75	457.4	458.3	42.0

Panel C: Sampling every Thursday

	mean	vol	$\mathcal{SR}$	$\mathcal{SO}$	$\mathcal{F}$	$\mathcal{P}$	τ^{be}	mean	vol	$\mathcal{SR}$	$\mathcal{SO}$	$\mathcal{F}$	$\mathcal{P}$	τ^{be}
RW	1.24	10.28	0.12	0.21				1.24	10.28	0.12	0.21			
Debt-weighted CRP	6.33	10.35	0.61	1.11	505.1	506.5	59.3	7.01	9.80	0.72	1.22	605.7	606.5	134.2
GDP-weighted CRP	6.90	10.34	0.67	1.20	562.7	563.7	76.7	6.92	9.79	0.71	1.20	597.2	598.0	138.2

Internet appendix to

“A Credit-Based Theory of the Currency Risk Premium”

(not for publication)

Abstract

This Internet Appendix presents supplementary material and results not included in the main body of the paper.

A Derivation of the identity in Equation (5)

We begin our derivation by expanding the following risk-neutral expectation as

$$\mathbb{E}_t^*\left[\frac{S_{t+1}}{S_t}X_{t+1}\right] = cov_t^*\left(\frac{S_{t+1}}{S_t}, X_{t+1}\right) + \underbrace{\mathbb{E}_t^*\left[\frac{S_{t+1}}{S_t}\right]}_{R_{f,t}^{\$}/R_{f,t}^{€}}\underbrace{\mathbb{E}_t^*\left[X_{t+1}\right]}_{R_{f,t}^{\$}}, \tag{A.1}$$

where S_t is the spot exchange rate defined as units of dollars per euro, $R_{f,t}^{\$}$ ($R_{f,t}^{€}$) is the one-period gross dollar (euro) interest rate, and X_{t+1} the gross return on a diversified portfolio. $\mathbb{E}_t^*\left[S_{t+1}/S_t\right] = R_{f,t}^{\$}/R_{f,t}^{€}$ follows from the UIP condition and $\mathbb{E}_t^*\left[X_{t+1}\right] = R_{f,t}^{\$}$ from the relation between the risk-neutral probability and the SDF valuation

$$\frac{1}{R_{f,t}^{\$}}\mathbb{E}_t^*\left[X_{t+1}\right] = \mathbb{E}_t\left[M_{t+1}X_{t+1}\right] = 1, \tag{A.2}$$

which also holds for the first risk-neutral expectation in Equation (A.1) since

$$\frac{1}{R_{f,t}^{\$}}\mathbb{E}_t^*\left[\frac{S_{t+1}}{S_t}X_{t+1}\right] = \mathbb{E}_t\left[M_{t+1}\frac{S_{t+1}}{S_t}X_{t+1}\right]. \tag{A.3}$$

By combining Equations (A.1) and (A.3) and rearranging, we obtain

$$\mathbb{E}_t\left[M_{t+1}\frac{S_{t+1}}{S_t}X_{t+1}\right] = \frac{1}{R_{f,t}^{\$}}cov_t^*\left(\frac{S_{t+1}}{S_t}, X_{t+1}\right) + \frac{R_{f,t}^{\$}}{R_{f,t}^{€}}, \tag{A.4}$$

which must also be equal to the following expansion

$$\mathbb{E}_t\left[M_{t+1}\frac{S_{t+1}}{S_t}X_{t+1}\right] = cov_t\left(M_{t+1}X_{t+1}, \frac{S_{t+1}}{S_t}\right) + \underbrace{\mathbb{E}_t\left[M_{t+1}X_{t+1}\right]}_{1}\mathbb{E}_t\left[\frac{S_{t+1}}{S_t}\right]. \tag{A.5}$$

Combining Equations (A.4) and (A.5) yields

$$\mathbb{E}_t\left[\frac{S_{t+1}}{S_t}\right] = \frac{R^{\$}_{f,t}}{R^{€}_{f,t}} + \frac{1}{R^{\$}_{f,t}} cov^*_t\left(\frac{S_{t+1}}{S_t}, X_{t+1}\right) - cov_t\left(M_{t+1}X_{t+1}, \frac{S_{t+1}}{S_t}\right). \tag{A.6}$$

Recall that $X_{t+1} = R_{t+1} + d_{t+1}$, where R_{t+1} is the gross return on a dollar-denominated portfolio of stocks and $d_{t+1} = a - \boldsymbol{D}b$ is the payoff of a dollar-denominated contingent claim that pays a constant return a and incurs a loss of b when $\boldsymbol{D} = 1$. We can decompose the risk-neutral covariance between the gross exchange rate return and the gross portfolio return as

$$cov^*_t\left(\frac{S_{t+1}}{S_t}, X_{t+1}\right) = cov^*_t\left(\frac{S_{t+1}}{S_t}, R_{t+1}\right) + cov^*_t\left(\frac{S_{t+1}}{S_t}, d_{t+1}\right), \tag{A.7}$$

where the second term can be expanded as follows

$$\begin{aligned} cov^*_t\left(\frac{S_{t+1}}{S_t}, d_{t+1}\right) &= cov^*_t\left(\frac{S_{t+1}}{S_t} - 1, a - \boldsymbol{D}b\right) && \text{(A.8)} \\ &= -b\mathbb{E}^*_t\left[\left(\frac{S_{t+1}}{S_t} - 1\right)\boldsymbol{D}\right] + b\mathbb{E}^*_t\left[\frac{S_{t+1}}{S_t} - 1\right]\underbrace{\mathbb{E}^*_t\left[\boldsymbol{D}\right]}_{\mathbb{Q}_t}. && \text{(A.9)} \end{aligned}$$

Using the law of total expectation,[23] we have then

$$\begin{aligned} \mathbb{E}^*_t\left[\left(\frac{S_{t+1}}{S_t} - 1\right)\boldsymbol{D}\right] &= \underbrace{\mathbb{E}^*_t\left[\boldsymbol{D} = 1\right]}_{\mathbb{Q}_t}\mathbb{E}^*_t\left[\frac{S_{t+1} - S_t}{S_t} \mid_{\boldsymbol{D}=1}\right] && \text{(A.10)} \\ &= -\mathbb{Q}_t\mathbb{E}^*_t\left[\frac{S_t - S_{t+1}}{S_t} \mid_{\boldsymbol{D}=1}\right]. && \text{(A.11)} \end{aligned}$$

[23]Let x_{t+1} be a random variable and $\boldsymbol{A}$ a binary indicator function, and write the following decomposition:

$$\begin{aligned} \mathbb{E}_t\left[x_{t+1}\boldsymbol{A}\right] &= P(A)\mathbb{E}_t\left[x_{t+1} \times \boldsymbol{A} \mid_{\boldsymbol{A}=1}\right] + (1 - P(A))\,\mathbb{E}_t\left[x_{t+1} \times \boldsymbol{A} \mid_{\boldsymbol{A}=0}\right] \\ &= P(A)\mathbb{E}_t\left[x_{t+1} \times 1 \mid_{\boldsymbol{A}=1}\right] + (1 - P(A))\,\mathbb{E}_t\left[x_{t+1} \times 0 \mid_{\boldsymbol{A}=0}\right] \\ &= P(A)\mathbb{E}_t\left[x_{t+1} \mid_{\boldsymbol{A}=1}\right], \end{aligned}$$

where $P(A)$ is the probability of $\boldsymbol{A} = 1$ and $\mathbb{E}_t\left[x_{t+1} \times 0 \mid_{\boldsymbol{A}=0}\right] = 0$.

Combining Equations (A.9) and (A.11) yields

$$cov_t^*\left(\frac{S_{t+1}}{S_t}, d_{t+1}\right) = \mathbb{Q}_t b \mathbb{E}_t^*\left[\frac{S_t - S_{t+1}}{S_t} \;|_{\boldsymbol{D}=1}\right] + \mathbb{Q}_t b\left[\frac{R_{f,t}^{\$}}{R_{f,t}^{€}} - 1\right]. \tag{A.12}$$

Finally, combining Equation (A.6) and (A.12) and rearranging yields the following identity:

$$\begin{aligned} \mathbb{E}_t\left[\frac{S_{t+1}}{S_t}\right] &= \frac{R_{f,t}^{\$}}{R_{f,t}^{€}} + \frac{1}{R_{f,t}^{\$}} cov_t^*\left(\frac{S_{t+1}}{S_t}, R_{t+1}\right) \\ &+ \frac{\mathbb{Q}_t b}{R_{f,t}^{\$}}\left(\mathbb{E}_t^*\left[\frac{S_t - S_{t+1}}{S_t} \;|_{\boldsymbol{D}=1}\right] - \mathbb{E}_t^*\left[\frac{S_t - S_{t+1}}{S_t}\right]\right) + A_t, \end{aligned} \tag{A.13}$$

where

$$A_t = -cov_t\left(M_{t+1} X_{t+1}, \frac{S_{t+1}}{S_t}\right). \tag{A.14}$$

B Implied currency depreciation and default probability

In this section, we derive the expected currency depreciation conditional on a sovereign default (i.e., implied currency depreciation) using the difference in sovereign CDS premia across currency denomination, as well as the default probability implied by CDS prices.

B.1 Notation

$C^a_{t,T}$: Date-t annual sovereign CDS premium of maturity T denominated in currency a.

N^a_t: Date-t notional of a sovereign CDS contract in currency a.

S_t: Date-t spot USD/EUR exchange rate.

$\mathbb{E}^*$: Expectation operator under the risk-neutral measure.

R_r: Bond recovery rate at default.

$V_{t,T}$: Date-t value of the USD/EUR currency swap with maturity T.

χ^a_t: Date-t accrued premium in currency a.

$F^a_{t,t+j,t+k}$: Date-t forward discount factor in currency a for the period between time $t+j$ and $t+k$, with $k>j$.

$Z^a_{t,t+j}$: Date-t price of a zero-coupon bond in currency a with maturity $t+j$.

Γ_{t+j}: Risk-neutral survival probability between time t and $t+j$.

t_D: Random default time between time t and T.

B.2 General case

Consider a US investor who implements a long-short strategy at time t by trading sovereign CDS contracts in EUR and USD with annual premium payments.[24] We denote the random default time by $t_D \in (t, T)$.

At date t, the investor enters a long position in a sovereign CDS denominated in EUR with notional $N_t^{€}$ and a short position in an identical sovereign CDS but denominated in USD with notional $N_t^{\$}$. Denote by $C_{t,T}^{€}$ and $C_{t,T}^{\$}$ the date-t CDS premia denominated in EUR and USD with maturity T. The long position in the CDS denominated in EUR costs $C_{t,T}^{€} N_t^{€}$ annually, while the short position in the CDS denominated in USD pays $C_{t,T}^{\$} N_t^{\$}$ annually. To convert all flows in USD and eliminate the currency risk involved in the payment of the CDS premium in EUR, the investor enters into a fixed-for-fixed currency swap in which EUR are received and USD are paid at the constant exchange rate $\bar{S}$. The strategy is self-financing and satisfies the following condition

$$C_{t,T}^{€} N_t^{€} \bar{S} \;\; = \;\; C_{t,T}^{\$} N_t^{\$}, \tag{B.1}$$

which implies that the notional of the CDS denominated in USD equals

$$N_t^{\$} \;\; = \;\; \frac{C_{t,T}^{€} N_t^{€}}{C_{t,T}^{\$}} \bar{S}. \tag{B.2}$$

B.2.1 Cash flows at default

At default time t_D, the long position in the CDS denominated in EUR pays the investor the amount $(1 - R_r) N_t^{€} S_{t_D}$, while the short position in CDS denominated in USD implies a

[24] The consideration of annual CDS payments offers the advantage of exploiting the term structure of CDS premia, as CDS quotes in USD and EUR are available for annual maturities only.

delivery of $(1-R_r)N_t^{\$}$ to the protection buyer, where R_r is the bond recovery rate in default. The investor is also left with a currency swap with remaining maturity $T-t_D$ that must be closed. We denote the date-t_D residual value of this currency swap by $V_{t_D,T}$, which we derive in Section B.2.2. In addition, the investor receives and pays an accrued premium, which we denote by $\chi_t^{€}$ and $\chi_t^{\$}$ for the CDS positions in EUR and USD, respectively.[25] Overall, the date-t_D net cash flow in USD that the investor receives/pays at default, denoted by CF_{t_D}, for a strategy implemented at time t with notionals $N_t^{€}$ and $N_t^{\$}$, is given by:

$$CF_{t_D} \;=\; \underbrace{S_{t_D}\left[(1-R_r)N_t^{€}-\chi_t^{€}\right]+V_{t_D,T}}_{\text{Long CDS in EUR}} - \underbrace{\left[(1-R_r)N_t^{\$}-\chi_t^{\$}\right]}_{\text{Short CDS in USD}}, \tag{B.3}$$

where $\chi_t^{€}=\frac{1}{2}C_{t,T}^{€}N_t^{€}$ and $\chi_t^{\$}=\frac{1}{2}C_{t,T}^{\$}N_t^{\$}$ represent the accrued premia in EUR and USD, respectively. Hence, in the case of a default, half of the annual CDS premium (determined at the inception of the strategy, i.e., time t) is paid to the protection seller at the next payment date.

B.2.2 Currency swap value at default

We determine the date-t_D residual value of the currency swap, which corresponds to the discounted value of the remaining net payments (between t_D and T) of the fixed EUR and USD legs. The (absolute) value of the swap is expected to decrease as the time of default approaches the maturity of the CDS contracts. To see that, an investor who is long EUR with a 5-year maturity USD/EUR currency swap will have 4 remaining annual payments if a default happens in the first year, while she will only have 2 remaining annual payments if it occurs during the third year. The swap has no residual value if default time coincides with

[25] We account for the accrued premium as in Pan and Singleton (2008) and Longstaff et al. (2011) to avoid a "free lunch" for the protection buyer in the default year: the CDS contract ends at the default time (e.g., in the first half of the year), while the annual CDS premium is paid at the end of the protection year. Because the exact time of future defaults is unknown, we assume that, on average, defaults happen in the middle of the year such that half of the CDS premium is accrued, as in Choudhry and Ali (2010).

swap maturity, i.e., $t_D = T$.

To compute the value of the fixed EUR leg, we first discount all EUR flows at time t_D and convert the obtained date-t_D value at the corresponding USD/EUR exchange rate level S_{t_D}. Similarly, we compute the value of the fixed USD leg by discounting all USD flows at time t_D. The date-t_D residual value of the currency swap $V_{t_D,T}$ is given by the difference in the discounted values of the two legs:

$$V_{t_D,T} = \left[S_{t_D} \sum_{j=1}^{T-t_D} \left(C^{€}_{t,T} N^{€}_t F^{€}_{t,t_D,t_D+j} \right) - \sum_{j=1}^{T-t_D} \left(C^{\$}_{t,T} N^{\$}_t F^{\$}_{t,t_D,t_D+j} \right) \right] \mathbf{1}_{T>t_D}, \tag{B.4}$$

where the indicator function $\mathbf{1}_{T>t_D}$ is equal to 1 if $T > t_D$, i.e., when the currency swap is still open at default, and zero otherwise. We denote by $F^{€}_{t,t_D,t_D+j}$ and $F^{\$}_{t,t_D,t_D+j}$ the forward prices observed at time t, respectively in EUR and USD, that discount risk-free cash flows between time t_D and $t_D + j$.[26]

B.2.3 Non-arbitrage condition

In the absence of arbitrage, the date-t value of the expected cash flow at default CF_{t_D} must be null. Because the time of default is unknown, we have to consider all potential dates of default between time t and T and use the term structure of default probabilities to weigh each scenario.[27] We define Γ_{t+k} as the risk-neutral survival probability (i.e., probability of no default) between time t and time $t+k$ with $k \geq 1$, so that $\Delta\Gamma_{t+k} = \Gamma_{t+k-1} - \Gamma_{t+k}$ captures the risk-neutral probability of a default at time $t+k$ conditional on no default until time $t+k-1$. The date-t value of the expected cash flow at default, accounting for any default

[26] The date-t forward price $F^a_{t,t+j,t+k}$ that discounts risk-free cash flows in currency a between time $t+j$ and $t+k$, with $k > j$, can be expressed in terms of the zero-coupon prices $Z_{t,t+j}$, following Veronesi (2010). Under non-arbitrage conditions, we have $Z^a_{t,t+k} = Z^a_{t,t+j} F^a_{t,t+j,t+k}$, which implies that $F^a_{t,t+j,t+k} = Z^a_{t,t+k}/Z^a_{t,t+j}$.

[27] The default probabilities can be retrieved from the term structure of CDS premia in USD, as discussed in Internet Appendix B.4.

time $t_D = t + k$, satisfies the following non-arbitrage condition:

$$\mathbb{E}_t^*(CF_{t_D}) = \sum_{k=1}^{T} \left[\Delta\Gamma_{t+k} Z_{t,t+k}^{\$} CF_{t+k} \right] = 0, \tag{B.5}$$

where $Z_{t,t+k}^{\$}$ is the time-discount factor in USD between t and $t+k$, i.e., the price of a zero-coupon risk-free bond at time t with maturity $t+k$.

We now combine Equations B.3, B.4, and B.5, replace $N_t^{\$}$ by $\frac{C_{t,T}^{€} N_t^{€}}{C_{t,T}^{\$}} \bar{S}$, according to Equation B.2, and divide all terms by $N_t^{€}$, which yields:

$$\sum_{k=1}^{T} \left[\Delta\Gamma_{t+k} Z_{t,t+k}^{\$} \left(\begin{array}{c} \mathbb{E}_t^*(S_{t_D}|_{t_D=t+k}) \left(1 - R_r - \frac{1}{2} C_{t,T}^{€}\right) \\ + \sum_{j=1}^{T-k} \left(\begin{array}{c} C_{t,T}^{€} \mathbb{E}_t^*(S_{t_D}|_{t_D=t+k}) F_{t,t+k,t+k+j}^{€} \\ -C_{t,T}^{€} \bar{S} F_{t,t+k,t+k+j}^{\$} \end{array} \right) \mathbf{1}_{T>k} \\ -(1-R_r) \frac{C_{t,T}^{€}}{C_{t,T}^{\$}} \bar{S} + \frac{1}{2} C_{t,T}^{€} \bar{S} \end{array} \right) \right] = 0, \tag{B.6}$$

where the indicator function $\mathbf{1}_{T>k}$ is equal to 1 if $T > k$, i.e., when there is a non-zero residual swap value in default, and zero otherwise.

B.3 Special case: one-year horizon ($T = 1$)

In the case of a strategy with one-year CDS contracts ($T = 1$), a default can only happen at time $t + 1$ and the currency swap has no residual value. Equation B.6 thus simplifies to

$$\Delta\Gamma_{t+1} Z_{t,t+1}^{\$} \left[\mathbb{E}_t^*(S_{t_D}) \left(1 - R - \frac{1}{2} C_{t,1}^{€}\right) - (1 - R_r) \frac{C_{t,1}^{€}}{C_{t,1}^{\$}} \bar{S} + \frac{1}{2} C_{t,1}^{€} \bar{S} \right] = 0. \tag{B.7}$$

Isolating the expected USD/EUR exchange rate conditional on a default, $\mathbb{E}_t^*(S_{t_D})$, in the above expression yields

$$\mathbb{E}_t^*(S_{t_D}) \quad = \quad S_t \frac{(1-R_r)\frac{C_{t,1}^{€}}{C_{t,1}^{\$}} - \frac{1}{2}C_{t,1}^{€}}{(1-R_r) - \frac{1}{2}C_{t,1}^{€}}, \tag{B.8}$$

where with set the currency swap rate to be equal to the exchange rate at issuance, i.e., $\overline{S} = S_t$.

Eventually, the date-t expected currency depreciation conditional on a default, defined by $ICD_{t,1} = \frac{S_t - \mathbb{E}_t^*(S_{t_D})}{S_t}$, is given by

$$ICD_{t,1} \quad = \quad 1 - \frac{(1-R_r)\frac{C_{t,1}^{€}}{C_{t,1}^{\$}} - \frac{1}{2}C_{t,1}^{€}}{(1-R_r) - \frac{1}{2}C_{t,1}^{€}}. \tag{B.9}$$

In the special case that neglects the accrued premium (i.e., $\chi_t^{€} = \chi_t^{\$} = 0$), Equation B.7 becomes

$$\mathbb{E}_t^*(S_{t_D}) \quad = \quad S_t \frac{C_{t,1}^{€}}{C_{t,1}^{\$}} \tag{B.10}$$

and the date-t implied currency depreciation over the one-year horizon simplifies to

$$ICD_{t,1} \quad = \quad \frac{C_{t,1}^{\$} - C_{t,1}^{€}}{C_{t,1}^{\$}}. \tag{B.11}$$

The same formula applies to the case of longer maturities ($T > 1$) when the residual currency swap value at default is assumed to be negligible and if we expect the currency depreciation upon default to be independent on default time, i.e., $\mathbb{E}_t^*(S_{t_D}) = \mathbb{E}_t^*(S_{t_D}|_{t_D = t+k}) \; \forall \; k \leq T$. For the more general case, $\mathbb{E}_t^*(S_{t_D})$ and $ICD_{t,T}$ are obtained by solving Equation B.6.

B.4 Risk-neutral default probability

We derive the one-year risk-neutral default probability using the CDS premium in USD, following the approach of Jarrow and Turnbull (1995) and Hull and White (2000).

At inception (time t), the value of a CDS is null and satisfies

$$\underbrace{C^{\$}_{t,1} Z^{\$}_{t,t+1} \left(\mathit{\Gamma}_{t+1} + \frac{\Delta\Gamma_{t+1}}{2} \right)}_{\text{Premium leg: } L_{P,T}} - \underbrace{\Delta\Gamma_{t+1} Z^{\$}_{t,t+1} (1 - R_r)}_{\text{Recovery leg: } L_{R,T}} = 0, \tag{B.12}$$

where $\Delta\Gamma_{t+1} = \Gamma_t - \Gamma_{t+1}$ is the risk-neutral probability of default at time $t+1$ conditional on no previous default, with $T \geq k \geq 1$. The first term of Equation B.12, denoted by $L_{P,T}$, is the premium leg of the CDS, while the second term of Equation B.12, denoted by $L_{R,T}$, is the recovery leg.

We can calculate the risk-neutral probability of a default within one year, Γ_{t+1}, from the one-year CDS premium in USD, $C^{\$}_{t,1}$, and the recovery rate, R_r. To see that, Equation B.12 simplifies to

$$\mathit{\Gamma}_{t+1} = \frac{(1 - R_r) - \frac{C^{\$}_{t,1}}{2}}{(1 - R_r) + \frac{C^{\$}_{t,1}}{2}}, \tag{B.13}$$

given that a CDS is never triggered at issuance time t, i.e., $\Gamma_t = 1$. The default probability is finally given by $\mathbb{Q}_t = 1 - \mathit{\Gamma}_{t+1}$.[28]

[28] One can generalize the computation for longer maturities ($T > 1$) with an iterative procedure, following O'Kane and Turnbull (2003).

C Replication of the quanto-implied risk premium

C.1 Daily quanto-implied risk premium

The quanto-implied risk premium of Kremens and Martin (2019) uses quanto forwards on the S&P500 index as a measure for the conditional risk-neutral covariance between the gross exchange rate return and the dollar-denominated gross stock return. Quanto forwards on the S&P 500 index are only available at the monthly frequency and until October 2015. We here describe how to construct a daily version of the quanto-implied risk premium over an updated sample period by computing the conditional risk-neutral covariance term as the product of daily conditional risk-neutral volatility and correlation terms

We start by decomposing the quanto-implied risk premium as follows:

$$\underbrace{\frac{1}{R^{\$}_{f,t}} cov^*_t\left(\frac{S_{t+1}}{S_t}, R_{t+1}\right)}_{QRP_t} = \frac{1}{R^{\$}_{f,t}} \underbrace{\sqrt{var^*_t\left(\frac{S_{t+1}}{S_t}\right)}}_{VS_t} \underbrace{\sqrt{var^*_t\left(R_{t+1}\right)}}_{VR_t} \underbrace{cor^*_t\left(\frac{S_{t+1}}{S_t}, R_{t+1}\right)}_{CSR_t}, \tag{C.1}$$

where VS_t (VR_t) is the risk-neutral exchange rate (stock) return volatility on day t and CSR_t is the corresponding risk-neutral correlation on day t. The risk-neutral volatilities are available daily and can be measured using the model-free volatility based on the USD/EUR options (see Section C.3) and the VIX index based on the S&P 500 index options, respectively. The risk-neutral correlation, in contrast, is not directly available at the daily frequency and is constructed using the procedure described below.

For computational convenience, we rewrite the identity in (C.1) as

$$QRP_{t,\tau} = \frac{VS_{t,\tau} \times VR_{t,\tau} \times CSR_{t,\tau}}{R^{\$}_{f,t,\tau}}, \tag{C.2}$$

where the subscripts indicate that each variable is observed on day t of month τ. We then keep the risk-neutral correlation constant intra-month and equal to the one recorded at the end of the previous month. Put differently, we set $CSR_{t,\tau} = CSR_{\tau-1}$ and then infer the monthly risk-neutral correlation from the monthly quanto forwards as follows

$$CSR_{\tau-1} = \frac{R^{\$}_{f,\tau-1} \times QRP_{\tau-1}}{VS_{\tau-1} \times VR_{\tau-1}}, \tag{C.3}$$

while dropping the subscript t to indicate that these variables are observed monthly. While this procedure helps retrieve a daily quanto-implied risk premium, it cannot be used to expand the sample beyond October 2015, i.e., when the sample of quanto forwards ends. Between November 2015 and April 2019, we instead approximate $CSR_{t,\tau}$ with the realized return correlation between the S&P 500 index and the USD/EUR exchange rate measured daily using a lagged one-year window.

FIGURE A.1 ABOUT HERE

Panel A of Figure A.1 compares, for the USD/EUR exchange rate, the monthly quanto-implied risk premium from Kremens and Martin (2019) between August 2010 and October 2015 and our expanded daily version from August 2010 to April 2019. Panel B of Figure A.1 plots both the monthly correlation implied from quanto forwards between August 2010 and October 2015 and the daily realized return correlation between the S&P 500 index and the USD/EUR exchange rate for the full sample period. We find that the sample correlation between these two quantities is higher than 96% over the period between August 2010 and October 2015.

C.2 Synthetic quanto-implied risk premium

We here present an alternative methodology to construct a daily version of the quanto-implied risk premium over the full sample period. We consider a variant of our theory in which the investor holds euro-denominated risk-free bonds, paying a risk-free rate $R_{f,t}^{€}$, instead of a dollar-stock portfolio. The gross-dollar return $X_{t+1} = R_{t+1} + d_{t+1}$ of the investor's total portfolio is now given by $R_{t+1} = R_{f,t}^{€}(S_{t+1}/S_t)$, which captures the return in dollars on a riskless bond denominated in euros, while $d_{t+1} = a - \boldsymbol{D}b$ continues to be the payoff of a dollar-denominated contingent claim.

The risk-neutral covariance between the gross exchange rate return and the portfolio gross return can be written as

$$cov_t^*\left(\frac{S_{t+1}}{S_t}, X_{t+1}\right) = \underbrace{\frac{1}{R_{f,t}^{\$}} cov_t^*\left(\frac{S_{t+1}}{S_t}, R_{t+1}\right)}_{QRP_t} + \underbrace{\frac{1}{R_{f,t}^{\$}} cov_t^*\left(\frac{S_{t+1}}{S_t}, d_{t+1}\right)}_{CRP_t} \tag{C.4}$$

with

$$QRP_t = \frac{1}{R_{f,t}^{\$}} cov_t^*\left(\frac{S_{t+1}}{S_t}, R_{f,t}^{€}\frac{S_{t+1}}{S_t}\right) = \frac{R_{f,t}^{€}}{R_{f,t}^{\$}} var_t^*\left(\frac{S_{t+1}}{S_t}\right), \tag{C.5}$$

which indicates that the quanto-implied risk premium depends now on the risk-neutral variance of the USD/EUR exchange rate, whereas the credit-implied risk premium remains unchanged. We compute the risk-neutral variance of the exchange rate returns using either the model-free implied variance of Britten-Jones and Neuberger (2000) or the simple implied variance recently proposed by Martin (2017). We describe both cases in Section C.3.

FIGURE A.2 ABOUT HERE

Figure A.2 displays the monthly quanto-implied risk premium for the USD/EUR exchange rate from Kremens and Martin (2019), between August 2010 and October 2015, and the daily synthetic replication of the quanto-implied risk premium for the full sample period. We report the case based on the model-free implied variance in the top panel and on the simple implied variance in the bottom panel. In both cases, the synthetic replication of the quanto-implied risk premium is closely related to the original series, with a sample correlation greater than 80%.

TABLE A.1 ABOUT HERE

We empirically test the validity of our synthetic replication using a set of panel regressions whose estimates are reported in Table A.1. As dependent variables, we use the entire sample of monthly data available from Kremens and Martin (2019), i.e., two-year quanto-implied risk premia on 11 currency pairs relative to the US dollar – Australian Dollar, Canadian Dollar, Swiss Franc, Danish Krone, Euro, Sterling, Japanese Yen, Norwegian Krone, Swedish Krona, South Korean Won, and Polish Zloty – between December 2009 to October 2015. As independent variables, Panel A uses the synthetic replication based on the model-free implied variance (MF) or simple implied variance (SI) through Equation (C.5) and uncovers a slope coefficient that is statistically indifferent from one, after accounting for currency and time (calendar month) fixed effects. In Panel B, we drop the ratio of the gross interest rates in Equation (C.5) and provide evidence that our results are indeed driven by our synthetic version of the quanto-implied risk premium based on the implied variance.

C.3 Risk-neutral variance

The risk-neutral variance between two dates t and T can be calculated by integrating over an infinite range of the strike prices from European call and put options expiring on these dates as

$$var_t^*\left(\frac{S_{t+1}}{S_t}\right) = \frac{2}{B_{t,T}}\Big\{\int_0^{F_{t,T}} \frac{P_{t,T}(K)}{K^2}dK + \int_{F_{t,T}}^{\infty} \frac{C_{t,T}(K)}{K^2}dK\Big\}, \tag{C.6}$$

where $P_{t,T}(K)$ and $C_{t,T}(K)$ are the put and call option prices at time t with strike price K and maturity date T, respectively, and $B_{t,T}$ is the price of a domestic bond at time t with maturity date T. The above equation is the model-free approach of Britten-Jones and Neuberger (2000), which is based on no-arbitrage conditions and requires no specific option pricing model. In our implementation, we follow Jiang and Tian (2005) and use a cubic spline around the available implied volatility points. This interpolation method is standard in the literature and has the advantage that the implied volatility smile is smooth between the maximum and minimum available strikes. The model-free implied volatility is the square root of the model-free implied variance. The simple implied variance of Martin (2017) replaces the K^2 with the square of the spot exchange rate S_t^2 in Equation (C.6). Finally, we compute the option values using the Garman and Kohlhagen (1983) valuation formula and solve the integral in Equation (C.6) via trapezoidal integration.

For this exercise, we collect over-the-counter (OTC) currency options from Bloomberg, which are quoted in terms of Garman and Kohlhagen (1983) implied volatility on baskets of constant maturity plain vanilla options for fixed deltas (δ). From these data, we recover the implied volatility smile ranging from a 10δ put to a 10δ call option. To convert deltas into strike prices and implied volatilities into option prices, we employ exchange rates and zero-yield rates obtained by bootstrapping money market rates and interest rate swap data from Bloomberg.

D Bootstrap Algorithms

D.1 Bootstrap for confidence intervals

The bootstrap algorithm associated with the in-sample regressions consists of the following steps (we consider a model with one predictor for illustration purposes):

1. Starting from the original dataset $\{y_t, x_t\}_{t=1}^{T}$, we generate a new sample of pseudo exchange rate returns and predictors $\{y_t^r, x_t^r\}_{t=1}^{T}$ using the stationary bootstrap of Politis and Romano (1994), i.e., by drawing with replacement blocks of observations whose starting point and length are both random. The block length is drawn from a geometric distribution and the expected block size is set according to Patton et al. (2009). $r = 1, \ldots, N$ is an indicator that refers to the bootstrap repetition and we set $N = 1{,}000$ in our exercise.

2. For each bootstrap replication r, we execute the predictive regressions using the artificial data, i.e., we run $y_{t+\kappa}^r = a_\kappa^r + b_\kappa^r x_t^r + \varepsilon_{t+\kappa}^r$ and then save the least-square estimates $\widehat{a}_\kappa^r$ and $\widehat{b}_\kappa^r$, respectively.

3. The 95% confidence intervals of b_κ, for example, is constructed as $[2\widehat{b}_\kappa - \widehat{b}_\kappa^{.025},\ 2\widehat{b}_\kappa - \widehat{b}_\kappa^{.975}]$, where $\widehat{b}_\kappa$ is the least-square estimate from the actual sample and $\widehat{b}_\kappa^{.025}$ and $\widehat{b}_\kappa^{.975}$ are the 2.5th and 97.5th percentiles of the bootstrapped estimates.

4. As robustness, we also construct confidence intervals using the bias-corrected and accelerated (BC_a) percentile method which automatically adjusts for underlying higher-order effects. See Chapter 13 in Efron and Tibshirani (1993) for a description.

D.2 Bootstrap for statistical accuracy

Our bootstrap algorithm follows Mark (1995) and Kilian (1999) and imposes the null of no predictability to generate the critical values for our out-of-sample test statistics. This procedure consists of the following steps:

1. Given the sequence of observations for $\{y_t, x_t\}$, define the out-of-sample window and generate M out-of-sample forecasts by running the predictive regressions

$$y_{t+\kappa} = a_\kappa + b_\kappa x_t + \varepsilon_{t+\kappa}$$

both under the null (i.e., $b_\kappa = 0$) and the alternative. For each horizon κ, compute the statistic of interest $\widehat{\tau}_\kappa$.

2. The data generating process for $\{y_t, x_t\}$ under the null is assumed to be

$$\begin{aligned} y_t &= a + u_{1,t} \\ x_t &= \phi_0 + \phi_1 x_{t-1} + \ldots + \phi_p x_{t-p} + u_{2,t}, \end{aligned}$$

where the lag order p is determined by a suitable lag order selection criterion such as the Bayesian information criterion (BIC). Estimate this specification using the full sample of observations via least-squares, and store the estimates $\widehat{a}$, $\widehat{\phi}_0, \ldots, \widehat{\phi}_p$, and the residual residuals $\widehat{u}_t = (\widehat{u}_{1,t}, \widehat{u}_{2,t})'$.

3. Generate a sequence of pseudo-observations $\{y_t^r, x_t^r\}$ of the same length as the original data series $\{y_t, x_t\}$ as follows:

$$\begin{aligned} \Delta s_t^r &= \widehat{a} + u_{1,t}^r \\ x_t^r &= \widehat{\phi}_0 + \widehat{\phi}_1 x_{t-1}^r + \ldots + \widehat{\phi}_p x_{t-p}^r + u_{2,t}^r, \end{aligned}$$

where the pseudo-innovation term $u_t^r = (u_{1,t}^r, u_{2,t}^r)'$ is randomly drawn with replacement from the set of observed residuals $\widehat{u}_t = (\widehat{u}_{1,t}, \widehat{u}_{2,t})'$. The initial observations $\left(x_{t-1}^r, \ldots, x_{t-p}^r\right)'$ are randomly drawn from the actual data. $r = 1, \ldots, N$ is an indicator that refers to the bootstrap repetition and we set $N = 1{,}000$ in our exercise.

4. For each bootstrap replication, generate M out-of-sample forecasts by running the predictive regressions

$$y_{t+\kappa}^r = a_\kappa^r + b_\kappa^r x_t^r + u_{1,t+\kappa}^r$$

both under the null and the alternative. For each horizon κ, construct the test statistic of interest $\widehat{\tau}_\kappa^\star$.

5. Compute the one-sided p-value as follows

$$p\text{-value} = \frac{1}{N}\sum_{j=1}^{N} I(\widehat{\tau}_\kappa^\star > \widehat{\tau}_\kappa),$$

where $I(\cdot)$ denotes an indicator function that equals one when its argument is true and zero otherwise.

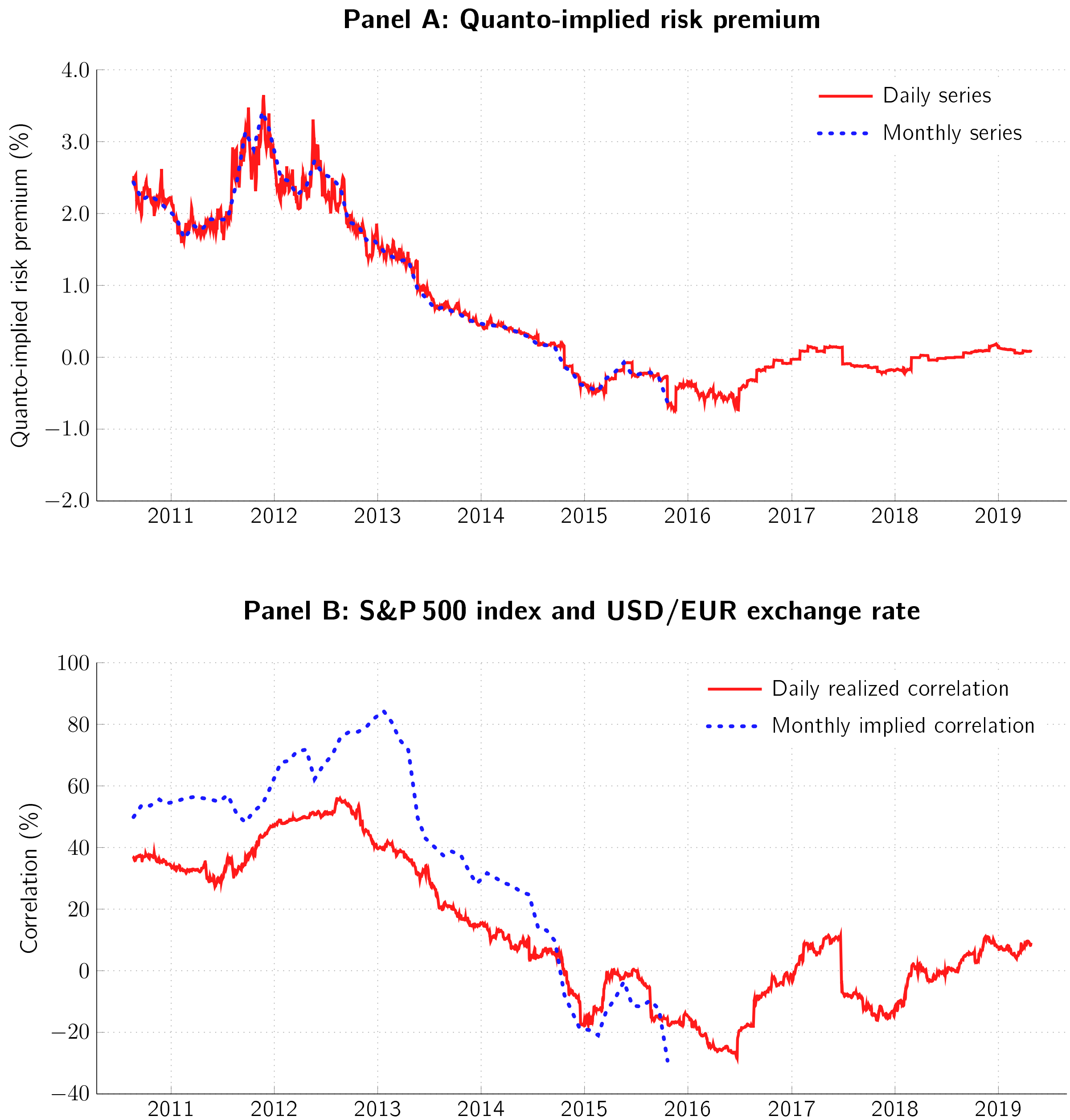
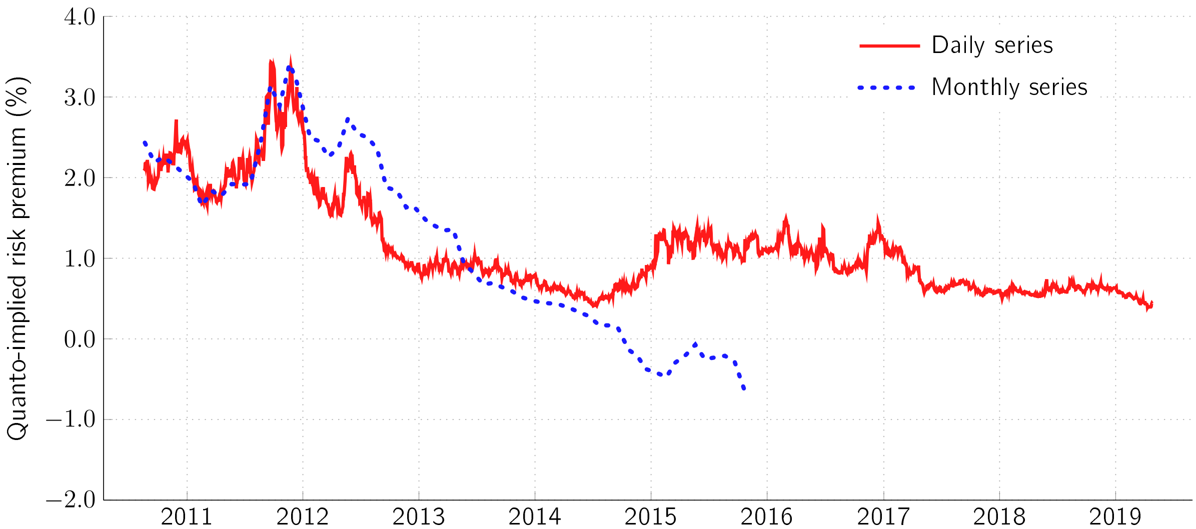


Figure A.1. Daily quanto-implied risk premium

Panel A displays, for the USD/EUR exchange rate return, the monthly quanto-implied risk premium (QRP) from Kremens and Martin (2019) between August 2010 and October 2015 and the daily quanto-implied risk premium computed with Equation (C.2) between August 2010 and April 2019. Panel B plots, for the S&P 500 index returns and the USD/EUR exchange rate returns, the monthly correlation implied from quanto forwards through Equation (C.3) between August 2010 and October 2015 and the daily realized correlation computed with a one-year rolling window between August 2010 and April 2019. Data are from Bloomberg and IHS Markit.

Panel A: Model-free implied variance



Panel B: Simple implied variance

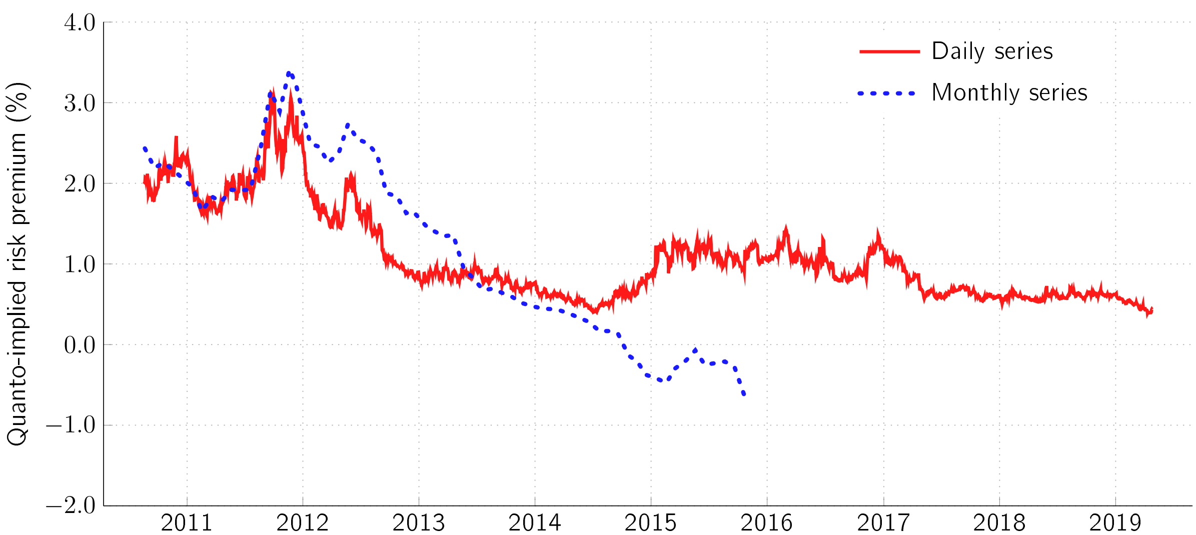


Figure A.2. Synthetic quanto-implied risk premium

Panel A displays, for the USD/EUR exchange rate return, the monthly quanto-implied risk premium (QRP) from Kremens and Martin (2019) between August 2010 and October 2015 and the daily synthetic replication based on the model-free implied variance of Britten-Jones and Neuberger (2000) through Equation (C.5) between August 2010 and April 2019. Panel B replaces the model-free implied variance with the simple implied variance of Martin (2017). Data are from Bloomberg and IHS Markit.

Table A.1. Implied variance and quanto-implied risk premium

This table presents panel regression estimates with $QRP_{i,t}$, the quanto-implied risk premium of Kremens and Martin (2019) for month t and currency i relative to the dollar, as the dependent variable. In Panel A, the independent variable is the synthetic quanto-implied risk premium constructed as $QRP_{i,t} = var_t^*(S_{t+1}^i/S_t^i) \times R_{f,t}^i/R_{f,t}^{\$}$, where $R_{f,t}$ is the one-year gross interest rate and $var_t^*(S_{t+1}^i/S_t^i)$ is the one-year exchange rate implied variance based on the model-free approach (MF) of Britten-Jones and Neuberger (2000) or the simple method (SI) of Martin (2017). In Panel B, we neglect the gross interest rates and simply use $var_t^*(S_{t+1}^i/S_t^i)$ as the independent variable. We use time (calendar month) and currency fixed effects. Standard errors are clustered by currency and time dimensions and reported in parentheses. The superscripts *, **, and *** indicate statistical significance at 10%, 5%, and 1% respectively. The sample includes monthly observations from December 2009 to October 2015 for a cross-section of 11 currency pairs relative to the dollar as in Kremens and Martin (2019). Data are from Bloomberg and IHS Markit.

Panel A: QRP regressed on the synthetic QRP

	(1)	(2)	(3)	(4)	(5)	(6)
QRP_{MF}	1.082***	0.989***	0.988***			
	(0.118)	(0.110)	(0.109)			
QRP_{SI}				1.126***	1.066***	1.065***
				(0.107)	(0.150)	(0.148)
Constant	0.017	0.175	0.175	0.044	0.140	0.141
	(0.477)	(0.181)	(0.183)	(0.420)	(0.235)	(0.236)
R^2 (%)	40.3	88.1	88.1	34.3	86.9	86.8
N	656	656	656	656	656	656
Currency FE		×	×		×	×
Time FE			×			×

Panel B: QRP regressed on the implied variance

	(1)	(2)	(3)	(4)	(5)	(6)
var^*_{MF}	1.111***	1.013***	1.013***			
	(0.114)	(0.115)	(0.114)			
var^*_{SI}				1.146***	1.088***	1.087***
				(0.110)	(0.158)	(0.157)
Constant	−0.001	0.161	0.161	0.039	0.131	0.132
	(0.469)	(0.187)	(0.189)	(0.409)	(0.244)	(0.246)
R^2 (%)	39.2	88.0	87.9	33.0	86.6	86.6
N	656	656	656	656	656	656
Currency FE		×	×		×	×
Time FE			×			×

Table A.2. FX predictability and credit-implied risk premium: Newey-West correction

This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts. Panel A presents the benchmark specification, which controls for the one-year interest rate differential between the US and Eurozone. Panel B (Panel C) adds global FX illiquidity and volatility (currency factors) whereas Panel D adds all control variables to the benchmark specification. We report p-values based on Newey and West (1987) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using Newey and West (1987) standard errors with Andrews (1991) optimal lag length. The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Benchmark specification

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.229*****	**2.407*****	**2.155*****	**1.852*****	**1.009****
	(0.009)	(0.004)	(0.001)	(0.006)	(0.038)
R^2 (%)	1.08	6.24	16.26	23.35	20.26
N	2,154	2,138	2,096	2,033	1,907

Panel B: Adding liquidity and volatility

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.272*****	**2.447*****	**2.181*****	**1.879*****	**1.039*****
	(0.008)	(0.003)	(0.001)	(0.000)	(0.001)
R^2 (%)	1.13	6.68	18.24	34.00	42.54
N	2,154	2,138	2,096	2,033	1,907

Panel C: Adding currency factors

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.267*****	**2.432*****	**2.168*****	**1.858*****	**1.017****
	(0.009)	(0.003)	(0.001)	(0.006)	(0.038)
R^2 (%)	1.25	6.12	16.21	23.24	20.13
N	2,154	2,138	2,096	2,033	1,907

Panel D: Adding all control variables

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.314*****	**2.472*****	**2.194*****	**1.886*****	**1.045*****
	(0.007)	(0.003)	(0.001)	(0.000)	(0.001)
R^2 (%)	1.32	6.57	18.24	33.96	42.56
N	2,154	2,138	2,096	2,033	1,907

Table A.3. Controlling for the quanto-implied risk premium: Without controls

This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP) accounting for the quanto-implied risk premium (QRP) of Kremens and Martin (2019). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts. In Panel A, QRP uses euro-denominated quanto forwards on the S&P500 index, which are available monthly until October 2015. Daily missing observations are retrieved by forward filling, i.e., we keep the latest available observation fixed over the next month. In Panel B, daily missing observations are retrieved using S&P500 and USD/EUR one-year option implied volatilities, i.e., VIX index and model-free approach of Britten-Jones and Neuberger (2000), respectively. In Panels C and D, QRP is synthetically replicated using the USD/EUR one-year option implied variance based, respectively, on the model-free approach of Britten-Jones and Neuberger (2000) and the simple variance method of Martin (2017). All specifications control for the one-year interest rate differential between the US and Eurozone. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and November 2015 (April 2019) in Panel A (Panels B–D). Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Controlling for monthly QRP

	1 week	1 month	3 months	6 months	1 year
CRP_t	2.065*	**2.569****	**2.402*****	**1.978*****	**0.917*****
	(0.095)	(0.033)	(0.000)	(0.000)	(0.000)
R^2 (%)	1.82	10.04	30.59	49.43	74.66
N	1,313	1,297	1,255	1,192	1,066

Panel B: Controlling for daily QRP

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.100****	**2.396****	**2.123*****	**1.687*****	**0.597*****
	(0.034)	(0.012)	(0.000)	(0.005)	(0.000)
R^2 (%)	1.05	6.20	16.23	24.06	25.99
N	2,154	2,138	2,096	2,033	1,907

Panel C: Controlling for daily synthetic QRP_{MF}

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.173****	**2.351****	**2.046*****	**1.689*****	**0.772****
	(0.029)	(0.016)	(0.003)	(0.003)	(0.018)
R^2 (%)	1.06	6.33	17.73	28.84	36.23
N	2,154	2,138	2,096	2,033	1,907

Panel D: Controlling for daily synthetic QRP_{SI}

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.148****	**2.332****	**2.024*****	**1.660*****	**0.742****
	(0.032)	(0.017)	(0.003)	(0.003)	(0.024)
R^2 (%)	1.08	6.38	17.85	29.18	36.26
N	2,154	2,138	2,096	2,033	1,907

Table A.4. Daily quanto-implied risk premium: Different maturities

This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP) accounting for the quanto-implied risk premium (QRP) of Kremens and Martin (2019). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts. QRP uses euro-denominated quanto forwards on the S&P500 index, which are available monthly until October 2015. Daily missing observations are recovered by combining risk-neutral volatility and correlation components, i.e., VIX index, model-free USD/EUR option implied volatility (Britten-Jones and Neuberger, 2000), and risk-neutral correlation inferred monthly (and kept constant intra-month) from the quanto forwards. The latter is replaced after October 2015 with the realized return correlation between the S&P 500 index and the USD/EUR exchange rate. Panel A uses the one-month VIX index, one-month model-free USD/EUR option implied volatility, and one-month realized correlation between the S&P 500 index and the USD/EUR exchange rate after October 2015. Panel B and Panel use three-month and six-month instruments, respectively. All specifications control for the one-year interest rate differential between the US and Eurozone, global FX liquidity, volatility, and currency factors. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Controlling for daily QRP (one month)

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.252****	**2.737*****	**2.308*****	**1.887*****	**0.818*****
	(0.022)	(0.002)	(0.000)	(0.000)	(0.000)
R^2 (%)	1.28	6.96	18.44	33.93	44.67
N	2,154	2,138	2,096	2,033	1,907

Panel B: Controlling for daily QRP (three months)

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.378****	**2.740*****	**2.392*****	**1.893*****	**0.713*****
	(0.017)	(0.003)	(0.000)	(0.000)	(0.000)
R^2 (%)	1.28	6.90	18.81	33.93	46.27
N	2,154	2,138	2,096	2,033	1,907

Panel C: Controlling for daily QRP (six months)

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.378****	**2.740*****	**2.392*****	**1.893*****	**0.713*****
	(0.017)	(0.003)	(0.000)	(0.000)	(0.000)
R^2 (%)	1.28	6.90	18.81	33.93	46.27
N	2,154	2,138	2,096	2,033	1,907

Table A.5. Synthetic quanto-implied risk premium: Different maturities

This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP) accounting for the quanto-implied risk premium (QRP) of Kremens and Martin (2019). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts. QRP is synthetically replicated using the USD/EUR option implied variance based on the model-free approach of Britten-Jones and Neuberger (2000). Panel A uses one-month options, Panel B uses tree-month options, and Panel C uses six-month options. All specifications control for the one-year interest rate differential between the US and Eurozone, global FX liquidity, volatility, and currency factors. We report p-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Controlling for daily QRP_{MF} (one month)

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.332****	**2.468****	**2.208*****	**1.890*****	**1.047*****
	(0.019)	(0.015)	(0.002)	(0.000)	(0.001)
R^2	1.31	6.53	18.46	33.96	42.54
N	2,154	2,138	2,096	2,033	1,907

Panel A: Controlling for daily QRP_{MF} (three months)

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.316****	**2.483****	**2.182*****	**1.882*****	**1.039*****
	(0.019)	(0.011)	(0.001)	(0.000)	(0.001)
R^2 (%)	1.27	6.54	18.28	33.94	42.57
N	2,154	2,138	2,096	2,033	1,907

Panel A: Controlling for daily QRP_{MF} (six months)

	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.345****	**2.503*****	**2.171*****	**1.883*****	**1.021*****
	(0.017)	(0.008)	(0.001)	(0.000)	(0.001)
R^2 (%)	1.28	6.55	18.25	33.93	42.66
N	2,154	2,138	2,096	2,033	1,907

Table A.6. FX predictability and counterfactual credit-implied risk premium

This table presents results on the exchange rate predictive ability of the counterfactual credit-implied risk premium (CRP). The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts, with a time-varying risk-neutral probability of default and a time-invariant (sample average) implied currency depreciation. Panel A presents the benchmark specification that includes the one-year interest rate differential between the US and Eurozone. Panel B adds all control variables, i.e., global FX illiquidity and volatility, and currency factors. Panel C adds QRP recovered by combining risk-neutral volatility and correlation components, i.e., one-year VIX index, one-year model-free USD/EUR option implied volatility, and risk-neutral correlation inferred monthly (and kept constant intra-month) from the quanto forwards. The latter is replaced after October 2015 with the realized return correlation between the S&P 500 index and the USD/EUR exchange rate. Panel D adds both QRP and all control variables to the benchmark specification. We report *p*-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

Panel A: Benchmark specification

	1 week	1 month	3 months	6 months	1 year
CRP_t	−0.065	−0.055	0.057	0.148	0.330
	(0.839)	(0.850)	(0.813)	(0.620)	(0.133)
R^2 (%)	-0.06	0.09	1.41	4.11	19.83
N	2,154	2,138	2,096	2,033	1,907

Panel B: Adding all controls

	1 week	1 month	3 months	6 months	1 year
CRP_t	0.178	−0.154	−0.024	0.046	0.204*
	(0.629)	(0.612)	(0.910)	(0.844)	(0.073)
R^2 (%)	0.15	0.30	2.87	12.95	33.78
N	2,154	2,138	2,096	2,033	1,907

Panel C: Adding QRP

	1 week	1 month	3 months	6 months	1 year
CRP_t	−0.456	−0.451	−0.355	−0.279	0.030
	(0.359)	(0.313)	(0.142)	(0.243)	(0.846)
R^2 (%)	0.23	1.64	6.57	14.50	29.80
N	2,154	2,138	2,096	2,033	1,907

Panel D: Adding QRP and all controls

	1 week	1 month	3 months	6 months	1 year
CRP_t	−0.641	−0.594	−0.396	−0.191	0.137
	(0.255)	(0.253)	(0.119)	(0.473)	(0.407)
R^2 (%)	0.53	2.04	6.70	15.79	34.22
N	2,154	2,138	2,096	2,033	1,907

Table A.7. FX predictability, credit-implied risk premium, and counterparty risk

This table presents results on the exchange rate predictive ability of the credit-implied risk premium (CRP) while controlling for the counterparty risk of European banks. The dependent variable is the daily average USD/EUR exchange rate return measured on a forecast horizon κ and expressed in annual terms. CRP is constructed for the Eurozone using country-level dollar-denominated and euro-denominated one-year CDS premia weighted by sovereign debts. Counterparty risk is proxied with the Markit iTraxx Europe Senior Financials Index, which measures the credit risk of 25 major financial institutions in Europe. Panel A presents the benchmark specification that includes the one-year interest rate differential between the US and Eurozone. Panel B adds all control variables, i.e., global FX illiquidity and volatility, and currency factors. Panel C adds QRP recovered by combining risk-neutral volatility and correlation components, i.e., one-year VIX index, one-year model-free USD/EUR option implied volatility, and risk-neutral correlation inferred monthly (and kept constant intra-month) from the quanto forwards. The latter is replaced after October 2015 with the realized return correlation between the S&P 500 index and the USD/EUR exchange rate. Panel D adds both QRP and all control variables to the benchmark specification. We report *p*-values based on Hansen and Hodrick (1980) standard errors with a lag length equal to κ in parentheses. Statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively. We report the slope coefficient in bold when its statistical significance is at 5% (or lower) using confidence intervals based on 1,000 stationary bootstrap repetitions (Politis and Romano, 1994). The sample consists of daily observations between August 2010 and April 2019. Data are from Bloomberg, Datastream, and IHS Markit.

	Panel A: Benchmark specification					Panel B: Adding all controls				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.213****	**2.387****	**2.033*****	**1.670*****	**0.670*****	**2.369****	**2.512****	**2.098*****	**1.732*****	**0.762*****
	(0.025)	(0.017)	(0.002)	(0.002)	(0.009)	(0.019)	(0.014)	(0.001)	(0.000)	(0.000)
R^2 (%)	1.04	6.21	17.61	28.01	40.16	1.29	6.55	18.77	36.11	53.04
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907

	Panel C: Adding QRP					Panel D: Adding QRP and all controls				
	1 week	1 month	3 months	6 months	1 year	1 week	1 month	3 months	6 months	1 year
CRP_t	**2.017****	**2.438*****	**2.425*****	**1.973*****	**0.975*****	**2.101****	**2.495*****	**2.404*****	**1.848*****	**0.882*****
	(0.037)	(0.007)	(0.000)	(0.001)	(0.000)	(0.036)	(0.007)	(0.000)	(0.000)	(0.000)
R^2 (%)	1.03	6.18	19.65	30.12	43.03	1.31	6.51	20.01	36.39	53.48
N	2,154	2,138	2,096	2,033	1,907	2,154	2,138	2,096	2,033	1,907