Currency Redenomination Risk*

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Abstract

I construct a time-series measure of currency redenomination risk in French, Italian, and German government bonds based on two types of CDS contracts. I use the measure to assess which spillover effects from a French or Italian Eurozone exit are priced in the cross-section of Eurozone sovereign yields. Sovereign yields across the Eurozone fall with increases in Italian redenomination risk, but respond heterogeneously to French redenomination risk: German and Austrian yields fall, while Portuguese yields rise. The findings are consistent with the interpretation that an Italian exit from the Eurozone would remain isolated, while a French exit is associated with further withdrawals from the Eurozone.

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How stable is the Eurozone? The debate about its composition is older than the currency union itself. However, while this debate has focused on potential new members for most of its history, more recent controversy has evolved around potential exits by current members. Current members could, in principle, re-introduce their own currencies to restore monetary sovereignty. This option exposes holders of outstanding sovereign bonds to currency redenomination risk: the risk of receiving the fixed payments of interest and principal in a different currency from the original numéraire. In this paper, I present a quantitative measure of this redenomination risk in French, Italian, and German government bonds, which is forward-looking, based solely on asset prices, and observable in real time.

Greece came close to exiting the Eurozone in the summer of 2015, when the Greek government imposed severe capital controls and bank closures for almost 20 days, during negotiations with its public international creditors regarding extended loan facilities. Three years earlier, Greece had restructured a large portion of its outstanding bonds, but remained a member of the currency union. The two episodes highlight the distinction between redenomination and 'conventional' credit risk. While bondholders face losses in either scenario, other stakeholders throughout the Eurozone (e.g., depositors or banks) experience vastly different shocks. In addressing the empirical question of spillovers from a Eurozone exit, it is therefore crucial to distinguish exit risk from other forms of default. A key determinant of spillovers from redenomination risk is whether or not an initial single exit from the Eurozone is contagious and followed by a Eurozone break-up. The fear of such contagion spreading from a 'Grexit' (or 'Graccident') was undoubtedly an important factor in the decision taken by Greece's public creditors to restructure and extend their loans in 2015.

An empirical approach to assessing the risk of such contagion requires a clean, observable measure of redenomination risk for different Eurozone countries. I construct a measure of redenomination risk for three large Eurozone members (France, Italy, and Germany), using a change in the standardized terms of sovereign credit default swaps (CDS). CDS contracts issued before September 2014 effectively allow for a redenomination into a new national currency for any G7 country without triggering payouts from the CDS, regardless of any exchange rate losses incurred by bondholders in the process. Contracts signed under the new terms, implemented in September 2014, are triggered by a redenomination out of euros into a new national currency, unless such redenomination occurs at a freely determined market exchange rate.

To illustrate the different economics of the two CDS contract types, suppose that France and Spain both decide to leave the Eurozone and change the currency of payments on outstanding bonds into new francs and new pesetas, respectively, each with a conversion rate of 1-to-1. Suppose further that once the new currencies are traded, the first freely determined market exchange rate is 0.8€ per franc and 0.75€ per peseta, and, that French and Spanish bonds trade at par in the new currencies following redenomination. This last assumption ensures that the only loss to bondholders stems from the initial depreciation of the new currency. In this simple example, redenomination triggers payouts for French CDS contracts issued under the 2014 definitions, and these pay out 20% of the notional value, that is, the loss to bondholders from redenomination $(= 1 - 0.8)$. However, French CDS based on the previous definitions, are not triggered and therefore make no payout at all, since the new currency of denomination (the new franc) is that of a G7 country (France) and the redenomination itself, therefore, does not constitute a credit event. In contrast, both contract types are triggered in a CDS written on Spain, and CDS holders receive 25% $(= 1 - 0.75)$ of the notional value.

The pricing difference between French contracts under the two definitions reflects how market participants asses the likelihood of a redenomination and the contingent losses incurred by bondholders. I account for other contractual changes and potential liquidity differences by subtracting the same difference measure for a matched synthetic control country constructed from non-G7 Eurozone countries. The resulting time-series measure is analogous to other commonly used difference-in-difference approaches, with the important feature that it uses contemporaneous differences rather than before-after relations. I will refer to this measure as the *redenomination spread*. This daily time series reflects the cost of insurance against losses from currency redenomination and is directly observable from sovereign CDS spreads.

Armed with the measure, I establish various empirical facts. French redenomination risk is economically small for most of the sample period, but spikes to 25 basis points per year in the run-up to the first round of the French presidential elections in April 2017. At its peak, redenomination risk accounts for 40% of the total French CDS spread. With the first-round victory of pro-EU candidate Emmanuel Macron, redenomination risk drops sharply. In the case of Italy, redenomination risk spikes sharply to around 80 basis points following the formation of a Eurosceptic government in May 2018, accounting for almost one third of the total Italian CDS spread. In both cases, redenomination risk is driven by political shocks: as such, the measure reveals shocks a country's political willingness to remain in a Eurozone member. German redenomination risk is close to zero throughout the sample period, consistent with the interpretation that a redenomination into a new German currency is not expected to cause losses for bondholders and/or such a redenomination is highly unlikely.

If such a measure were available for all members of the currency union, the covariance matrix of these time series would directly reveal contagion of redenomination risk. In the absence of a broader cross-section of redenomination risk measures, I will document signs of contagion in other asset prices. Prior to an exit, the prospect of initial depreciation for some of the new national currencies induces capital flight out of weaker and into stronger countries.[1] The distinctive feature of a currency union is that exchange rates cannot adjust to such flows. Instead, the adjustment works through the yields of the assets targeted by such flows, such as sovereign bonds. Investors demand higher nominal yields on assets that are likely to be redenominated into a depreciating new currency, and yields in other Eurozone countries fall if their bonds remain denominated in euros or repay in a new, stronger currency.[2]

A Eurozone exit by, say, France can either be *isolated* or *contagious*. The signature of the latter type is that pricing spillovers to other Eurozone bonds are heterogeneous: if each country's bonds are ultimately repaid in a new national currency, bond prices reflect the expected gains or losses that the currency redenomination imposes on bondholders. In contrast, an isolated exit implies no such consequences for the remaining Eurozone bonds. All other bonds repay in euros, and function as potential substitutes to French debt for euro-investors tilting their portfolios away from redenominatable French bonds. I model the two cases formally in Section 4.1.

I find that sovereign yields drop significantly with increases in Italian redenomination risk for all Eurozone countries other than Italy. In contrast, Eurozone yields comove heterogeneously with French redenomination risk. German and Austrian yields

[1]The dissolution of Czechoslovakia in February 1993 provides a historical example of such capital movements from the subsequently weaker currency area (Slovakia) into the stronger one.

[2]Brunnermeier et al. (2016b, p. 226) make a similar point, arguing that "*as [...] redenomination risk does not exist for 'German euros', a Greek euro will necessarily be worth less than a German euro. As long as Greek euros can be converted one-to-one into German euros, Greeks may thus decide to withdraw their deposits [...] and buy German Bunds...*".

fall as French redenomination risk rises. However, yields in Italy, Portugal, and—naturally—France rise with French redenomination risk. Corporate credit spreads paint a similar picture: spreads tend to drop with increases in Italian redenomination risk for financial and non-financial firms outside Italy. Similarly to German Bund yields, US Treasury yields fall with rising French redenomination risk, but the effect is weaker in magnitude than for Bunds. In relation to Italian redenomination risk, however, Treasury yields do not fall like Eurozone yields. The euro-dollar exchange rate tends to depreciate with French, but not with Italian redenomination risk. This set of findings is consistent with the interpretation that a French exit from the monetary union is contagious and expected to be associated with further redenominations and a broader break-up of the Eurozone, while an Italian exit is expected to remain isolated. The heterogeneity in responses to French (i.e., contagious) redenomination risk corresponds to heterogeneity in the countries' fiscal positions, labor productivities, and current account balances, consistent with the interpretation that these responses reflect expected post-Eurozone appreciation and depreciation of national shadow currencies.

Literature: On the surface, my empirical measure of redenomination risk is related to the measure of de Santis (2018), who uses *quanto* CDS; that is, the difference between dollar-denominated CDS and contracts denominated in euros. As Mano (2013) shows, this difference measures the (risk-neutral) expected depreciation of the euro against the dollar in the event that CDS payouts for a given country are triggered. Similarly, Augustin et al. (2018) disentangle expected depreciation from the default event risk in a structural model, using the term structure of quanto CDS. While this provides an important measure of euro currency risk and its connection to sovereign default risk, it does not distinguish between credit risk and redenomination risk. Instead, my measure isolates the currency redenomination event as a particular form of default and relates directly to the depreciation of the new national currency versus the euro, as opposed to the euro versus the US dollar. The wide-spread view that a sovereign default by a Eurozone member is likely to lead to a euro depreciation has also led to the gradual disappearance of euro-denominated CDS contracts for Eurozone sovereigns. My redenomination risk measure uses only the more liquid dollar-denominated contracts.

My empirical analysis of sovereign CDS spreads adds to a wide literature, including Pan and Singleton (2008), Augustin (2014), and Fontana and Scheicher (2016). Augustin et al. (2014) provide a broad survey of sovereign CDS markets. Longstaff et al.

(2011) show strong co-movement in sovereign CDS. Beyond the study of CDS, this paper links to the extensive literature on sovereign risk and contagion (e.g. Reinhart and Rogoff, 2011). Arellano et al. (2018) look at the financial linkages responsible for such spillovers of sovereign risk in the Eurozone. Aguiar et al. (2015) show how debt crises in one member country impact other members through centralized monetary policy. The distinction between credit risk and redenomination risk in a currency union is analogous to the question of local currency sovereign risk, studied by Du and Schreger (2016). In addressing the impact of political risk on asset prices, my approach also relates to the work of Pastor and Veronesi (2013) and Kelly et al. (2016). Neuberg et al. (2018) exploit other differences relating to government intervention and bail-in events between CR14 and CR restructuring clauses in CDS contracts written on financial institutions. In analogy to my approach, Berndt et al. (2007) distinguish between restructuring events and default events and estimate restructuring risk premia in US corporate debt by comparing CDS contracts with, and without, restructuring clauses.

Redenomination risk has also been identified by the ECB as a risk to the transmission of monetary policy and an explicit target of policy measures.[3] Krishnamurthy et al. (2018) assess the effect of three specific ECB policy measures launched in 2011-2012 on bond yields and redenomination risk. They quantify redenomination risk in sovereign bonds by decomposing a panel of sovereign and corporate yields. The key identifying assumptions are that (i) default affects bonds under foreign law and bonds under domestic law in the same way; and (ii) corporate and sovereign bonds are affected in the same way by redenomination. Bayer et al. (2018) construct a term structure of redenomination risk. Importantly, my measure does not rely on combinations of bonds CDS and is therefore robust to variation in the so-called CDS-bond basis (see, e.g., Bai and Collin-Dufresne (2018)). Redenomination risk affects, through deposit redenomination, the portfolio choice of banks holding euro-denominated sovereign debt. The well-documented home bias of banks in euro sovereign bonds has sparked a large literature on sovereign-bank feedback loops.[4] The simple model I present in Section 4.1 features home bias as a natural equilibrium outcome of redenomination risk.

[3]See, for instance, Benoît Cœuré's speech on the objectives of the OMT program (03/09/2013): ecb.europa.eu/press/key/date/2013/html/sp130902.en.html. See also Leombroni et al. (2017).

[4]See, for instance, Acharya et al. (2014), Farhi and Tirole (2016), and Brunnermeier et al. (2016a).

1 Redenomination and credit default swaps

A credit default swap is a bilateral financial contract wherein one party (the *protection seller*) provides insurance to the other party (the *protection buyer*) against losses to the holders of bonds issued by a particular entity (the *reference entity* or *issuer*). In the event (referred to as a *credit event*) that the reference entity fails to honor its contractual obligations as the issuer of its outstanding bonds, the protection buyer receives from the protection seller a payment of a prespecified face value (*notional*) minus the recovery on this face value. This recovery is typically set at the market value of defaulted bonds, which is determined in an auction of such defaulted bonds arranged by the International Swaps and Derivatives Association (ISDA). In exchange, the protection buyer pays the protection seller a periodic (typically quarterly) insurance premium: the so-called CDS *spread*.

Denote the spread today for a swap with maturity T by $S_{0,T}$. Swaps are quoted such that the market value of the swap is zero and no money is exchanged at inception, i.e., the expected discounted value of payments to the protection seller equals that of payments to the protection buyer. For expositional purposes, consider the simplified case of a hypothetical single-period CDS:

$$\begin{aligned} S_{0,T} =& e^{-rT}\, \mathbb{E}_0^{\mathbb{Q}} \left(\mathbb{1}_T (1 - R_T) \right) \\ =& e^{-rT} q_T \, \mathbb{E}_0^{\mathbb{Q}} (1 - R_T \mid \mathbb{1}_T = 1), \end{aligned} \tag{1}$$

where the indicator denotes the occurrence of a credit event between 0 and T, q_T the probability of said credit event, and R_T denotes the contingent recovery rate. While I will not, without further assumptions, be able to disentangle the probability q_T from the conditional loss $(1 - R_T)$, the CDS spread is economically meaningful in itself, as it reflects the economic cost of insurance against losses (net of recovery) to creditors of a certain entity from a range of credit events. To facilitate the trading of CDS, the contract terms typically follow a standardized set of definitions, governed by ISDA, including the precise circumstances, which constitute a credit event and trigger the insurance payout. Currency redenomination may be one of these circumstances, but the insurance premium will also reflect other risks, such as the bankruptcy filing of the issuer, the failure to make a contractual interest or principal payment, or the restructuring of the bonds to the detriment of bondholders.

For the purposes of this paper, the reference entities of the CDS will predominantly be sovereign countries, and—for lack of established bankruptcy procedures for such borrowers—'defaults' typically occur in the form of a restructuring. However, a restructuring itself may take many different forms and is not limited to currency redenomination: for instance, Greece restructured a large part of its outstanding debt in 2012 by exchanging existing bonds for a package of new securities with longer maturity, lower face value, and lower coupon rate, while, at the same time, keeping the euro as the currency of denomination. The CDS spread reflects the risk of all of these credit events, rather than isolate the risk of currency redenomination. For the remainder of this paper, and in a slight abuse of terminology, I will use 'default' to refer to any credit event that does *not* involve a change in the currency of denomination. In contrast, I will use 'redenomination' to refer to a restructuring involving *only* this change of currency.

1.1 Credit event definitions – 2003 versus 2014

ISDA periodically updates the standardized definitions. The most recent update was implemented in September 2014. Many of the revisions from the earlier definitions (released in 2003) address problems in CDS on corporate issuers, some responding directly to events unfolding over the Eurozone sovereign debt crisis (particularly relating to financial institutions and government interventions such as bail-outs or bail-ins). However, a few changes relate specifically to sovereign reference entities. One of the new terms refers to the set of events that constitute a restructuring, defined in Section 4.7 of the ISDA definitions. Subsection (a)(v) specifies a number of "permitted currencies" into which an obligation may be redenominated without triggering the CDS payout. Under the 2003 definitions,

> *"Permitted Currency" means (1) the legal tender of any Group of 7 country (or any country that becomes a member of the Group of 7 if such Group of 7 expands its membership) or (2) the legal tender of any country which, as of the date of such change, is a member of the Organization for Economic Cooperation and Development and has a local currency long-term debt rating of AAA or higher [...].*[5]

[5] ISDA (2003, p. 32-33) Credit Derivatives Definitions

The Group of 7 (G7) consists of Canada, France, Germany, Italy, Japan, the UK, and the US. The three current Eurozone members France, Germany, and Italy would therefore—without triggering CDS payouts—be able to leave the Eurozone, issue a national currency, and redenominate any existing debt into this new currency, regardless of any market value losses that such a redenomination may imply for bondholders. During the Eurozone sovereign debt crisis, the potential consequences for CDS contracts of a member country exiting the currency union, as well as the distinction between G7 countries and other Eurozone members, became a widely debated topic among market participants.[6] In response to the unwanted special status of French, German, and Italian debt, ISDA amended Section 4.7(a) (v) in its 2014 definitions to define the relevant redenomination event as

> *... any change in the currency of any payment of interest, principal or premium to any currency other than the lawful currency of Canada, Japan, Switzerland, the United Kingdom and the United States of America and the euro and any successor currency to any of the aforementioned currencies (which in the case of the euro, shall mean the currency which succeeds to and replaces the euro in whole).*[7]

Therefore, redenomination into a new French, German, or Italian currency triggers CDS contracts under the 2014 definitions (if such a redenomination leads to market value losses for bondholders), but not for contracts under the 2003 definitions. Accordingly, the two contracts are quoted separately in financial markets, specifying the applicable restructuring clause as either 'CR14' for 2014 definitions or 'CR' for 2003.

For an illustrative example of the pricing consequences, we revisit the case of the potential exits of France and Spain from the Eurozone, as well as the simplified pricing equation (1). Consider at time t the pricing of single-period CDS contracts with maturity $t+1$. Suppose that the net risk-free interest rate, r, is equal to zero, and that the risk-neutral probability of either exit at time $t+1$ is $q^R_{i,t+1} = 0.1$ for $i = \{FRA, ESP\}$. As previously, the expected depreciations of the new national currencies against the euro, are $\mathbb{E}^{\mathbb{Q}}_t R^R_{FRA,t+1} = 0.8$ and $\mathbb{E}^{\mathbb{Q}}_t R^R_{ESP,t+1} = 0.75$. The loss from redenomination, $1 - R^R$, may stem from a number of sources: in the absence of further amendments to the debt contract, depreciation of the new currency is likely to be responsible for

[6] See, e.g., ftalphaville.ft.com/2010/02/12/148481/euro-breakup-not-necessarily-a-credit-event/.

[7] ISDA (2014) Credit Derivatives Definitions, p. 42

a large part of the losses suffered by bondholders. Upon introduction, the leaving country chooses an initial 'conversion rate' of its new national currency against the euro, for the purposes of redenominating various contracts within the economy, such as sovereign debt. In the above example of France and Spain, both conversion rates are 1-to-1. However, this rate does not represent a market exchange rate. With the split from the euro and the re-nationalization of monetary policy, the new currency obtains its own risk characteristics and risk premium as well as its own future interest rate path. If the new currency differs from the euro in either of these two dimensions, the new market exchange rate has to deviate from the initially chosen conversion rate. This is an incarnation of the *Mundell-Fleming trilemma*: keeping the exchange rate at the level of the conversion rate amounts to fixing the exchange rate against the euro, while the monetary policy path is allowed to deviate from that of the currency union, both of which are not jointly attainable in the absence of capital controls.

In addition, the prices of the redenominated bonds may also reflect changes in credit risk, if the country's fiscal position changes following the Eurozone exit. At the same time, suppose that the risk-neutral probability of either country restructuring its debt without a change of currency, i.e., 'defaulting' at $t+1$ is $q^D_{i,t+1} = 0.1$, with an expected recovery of $\mathbb{E}^{\mathbb{Q}}_t R^D_{i,t+1} = 0.5$. Also suppose that the events of redenomination and default are independent. This assumption may not seem innocuous, but is in line with the contractual differences between CR and CR14 clauses: a default occurring *simultaneously* with redenomination would constitute a credit event under either contract. As such, my approach of looking at the difference between CR and CR14 spreads neglects such an event of simultaneous redenomination and default. To the extent that redenomination is likely to be accompanied by simultaneous default, my measure of redenomination risk in isolation from default provides a lower bound on the true magnitude of redenomination risk.

Returning to the illustrative example, denote by S^{CR14}_i and S^{CR}_i country i's single-period CDS spread under CR14 and CR restructuring clauses, respectively. For France, only CR14 contracts recognize redenomination into new francs as a credit event, so

$$\begin{aligned} S^{CR14}_{FRA} &= q^D_{FRA,t+1}\,\mathbb{E}^{\mathbb{Q}}_t(1 - R^D_{FRA,t+1}) + q^R_{FRA,t+1}\,\mathbb{E}^{\mathbb{Q}}_t(1 - R^R_{FRA,t+1}) = 0.07 \\ S^{CR}_{FRA} &= q^D_{FRA,t+1}\,\mathbb{E}^{\mathbb{Q}}_t(1 - R^D_{FRA,t+1}) = 0.05. \end{aligned}$$

The spread-difference between CR14 and CR contracts is sometimes referred to as the 'ISDA basis'. If there are no other pricing differences between CR and CR14 contracts, the ISDA basis directly measures the insurance premium due to redenomination risk.

However, the clause on permitted currencies is not the only difference between the two contract types relevant to sovereign issuers. A clause referred to as 'Asset Package Delivery' (APD) affects the calculation of the recovery value and may, therefore, lead to differential pricing of the two contracts. The clause is described in more detail in Subsection 5.2. Unlike the clause on permitted currencies, APD does not distinguish issuers based on G7 membership. Similarly, liquidity may differ between the newer CR14 CDS and the superseded CR contracts. Therefore, a diff-in-diff approach is well-suited to isolate the pricing impact of redenomination risk. Suppose that all potential pricing differences between the two contract types, which are unrelated to redenomination risk (notably APD or liquidity), are captured by an extra spread $\lambda_t = 0.02$. The pricing equation (1) for French contracts under 2003 definitions becomes $S_{FRA}^{CR} = e^{-r} q_{i,t+1}\, \mathbb{E}_t^{\mathbb{Q}}(1 - R_{i,t+1}) - \lambda_t = 0.03$. For Spain, both restructuring clauses are triggered by redenomination into new pesetas, and therefore

$$\begin{aligned} S_{ESP}^{CR14} &= q_{ESP,t+1}^{D}\, \mathbb{E}_t^{\mathbb{Q}}(1 - R_{ESP,t+1}^{D}) + q_{ESP,t+1}^{R}\, \mathbb{E}_t^{\mathbb{Q}}(1 - R_{ESP,t+1}^{R}) = 0.075 \\ S_{ESP}^{CR} &= S_{ESP}^{CR14} - \lambda_t = 0.055. \end{aligned}$$

While simply taking the difference between S_{FRA}^{CR14} and S_{FRA}^{CR} jointly reveals redenomination risk and liquidity- or APD-driven components of the spread, the diff-in-diff measure isolates the component of the spread that is due to redenomination risk:

$$\left(S_{FRA}^{CR14} - S_{FRA}^{CR}\right) - \left(S_{ESP}^{CR14} - S_{ESP}^{CR}\right) = q_{FRA,t+1}^{R}\, \mathbb{E}_t^{\mathbb{Q}}(1 - R_{FRA,t+1}^{R}) = 0.02.$$

Of course, λ_t may itself be a function of other variables and therefore differ across countries. For the diff-in-diff measure, I construct a synthetic control country to match the time-variation in several characteristics of French and Italian CDS and bond markets, such as yield levels and bid-ask spreads.

2 The redenomination spread

I collect daily CDS spreads for dollar-denominated contracts with a maturity of five years for the Eurozone member countries Austria, Belgium, France, Germany, Ireland, Italy, the Netherlands, Portugal, and Spain. The CDS time series range from September 2014 when the CR14 contracts were launched, to June 2018. I focus on the five-year maturity, because these CDS contracts tend to be the most liquid. Since CDS are traded over-the-counter, transaction prices are difficult to observe.[8] However, Markit collects quotes from a range of market makers and financial intermediaries and reports consensus measures obtained from these quotes. These consensus measures are then widely used by derivatives market participants as an external valuation of their accounting positions as well as to fulfil regulatory requirements. I assess the liquidity and reliability of the quotes provided to Markit in Subsection 5.1.

Figure 1 reports the time series of outstanding notionals by country. Net notionals are shown in Panel A and gross notionals in Panel B. Unfortunately, volumes are only available on an aggregated basis rather than by contract type (CR14 and CR).[9] The Italian CDS market is by far the largest in the Eurozone with over \$12bn outstanding net notional as of February 2018, followed by the French, German, and Spanish CDS markets with over \$6bn, \$5bn, and \$4bn aggregate net notional, respectively. Among the sampled Eurozone economies, CDS markets are smallest for Austria (\$1.6bn), the Netherlands (\$1.6bn), and Belgium (\$2.5bn). Outstanding notionals have been trending downwards across all countries since the height of the European sovereign debt crisis in 2012. Overall CDS market volumes have been declining since 2008 (Oehmke and Zawadowski, 2017) reflecting a reduction in inter-dealer volumes; relative to corporate single-name CDS, the share of sovereign reference entities has risen steadily and quadrupled to 16% in June 2015, from 4% in December 2008 (BIS, 2015). Total outstanding volumes rose slightly in late 2014 to early 2015 for French and Italian CDS, consistent with the introduction of the new CR14 contracts.

Table 1 reports summary statistics on the different CDS spreads. Spreads on CR and CR14 contracts are strongly positively correlated for all countries in the sample. However, since the contracts differ in their treatment of currency redenomination for

[8] See Oehmke and Zawadowski (2017) for an overview of trading in (corporate) CDS markets.

[9] Outstanding notional data are obtained from swapsinfo.org.

France and Italy, the correlation is much weaker ($\rho_{FRA} = 0.86$ and $\rho_{ITA} = 0.75$, respectively) than for non-G7 countries, where correlation coefficients are in excess of 0.97. Similarly, the difference between CR and CR14 spreads (i.e., the ISDA basis) is more volatile relative to its mean for France and Italy than for other countries. Based on summary statistics, Germany resembles the control group countries: the difference between CR14 and CR spreads is close to zero, as is its volatility, and the correlation of the two CDS spreads is close to perfect at $\rho_{GER} = 0.97$.

The CDS spread does not measure the probability of a redenomination event, but rather the cost of insurance against *losses* from the event. For any restructuring event to trigger the CDS payout, the restructuring must be to the detriment of bondholders. For a currency redenomination, this means that the exchange rate must depreciate from its conversion rate at redenomination. In the case of a newly issued national currency, there is no established market exchange rate. Broadly speaking, the new exchange rate will depreciate from the conversion rate fixed for redenomination if (i) market participants expect monetary policy at the national level to be more inflationary than the previously centralized policy in the currency union, and/or (ii) the risk characteristics of the newly issued currency are such that investors demand a higher risk premium to hold the new currency than the euro.[10] If market participants expect, say, a new German mark to appreciate upon introduction, a potential redenomination would not cause losses for bondholders and therefore not trigger CDS payouts. Consequently, the ISDA basis for Germany would be (close to) zero in this case.

Figure 2 plots CDS spreads for Austria, Belgium Spain, Ireland, the Netherlands, and Portugal. Despite not being affected by the change to permitted redenomination currencies, the ISDA basis is positive for all control group members and widens slightly over the last year of the sample. Figure 3 plots the different spreads for France, Italy, and Germany. Buying protection via a CR14 contract (solid) is consistently more expensive than via a CR contract (dashed). The difference is indeed close to zero, but positive, for Germany throughout the sample period. The sign of the basis in the control group suggests that the liquidity- or APD-driven component of the off-the-run CDS spread is positive, i.e., $\lambda_t > 0$. Consequently, the ISDA basis itself is not a clean measure of redenomination risk since it compares older and newer CDS contracts which

[10]Hassan et al. (2016) discuss to what extent these risk characteristics are chosen by policy makers.

are subject to different levels of liquidity and different calculations of recovery values.

To isolate redenomination risk, I construct—in the spirit of Abadie and Gardeazabal (2003)—synthetic controls from the different control group countries, which match the treated countries as closely as possible on relevant dimensions. Since treatment (i.e., being a G7 country) affects the economics of the (old) CR contract, the goal of the synthetic control is to construct a counterfactual CR CDS spread for France, Italy, and Germany without their respective G7-membership. For each trading day of the sample period, the synthetic control for each treated country is a convex combination of control group countries, matched on variables, which are successful contemporaneous predictors of the counterfactual CR spread. The four variables I choose for this matching are: (i) the CR14 CDS spread (which does not distinguish between issuers based on G7-membership); (ii) the bid-ask spread for the CR14 CDS spread; (iii) the five-year sovereign bond yield; and (iv) the bid-ask spread of the five-year sovereign bond yield. Daily time series for the three latter variables are obtained from Bloomberg.

For days, where no observations are available for a particular control group country on one or more of the matching variables, that country is excluded from the control group for that day, and the synthetic control is formed as a convex combination of the remaining control group countries. Similarly, if on any given day, observations are missing on any particular matching variable for more than one control group country, that variable is omitted from the matching process for that day.

Similarly to Abadie et al. (2010), I pick the weights of the matching variables by optimizing the fit of the synthetically constructed CR spread for a control group country to the observed CR spread of that country. Figure 4 plots the observed (solid) and synthetic (dashed) CR spreads for Belgium, Spain, and Ireland over the sample period, showing that the synthetic control procedure generates a close fit in these 'placebo' countries. Across the three different placebo countries, the optimal weights are similar, and I will use the median set of optimal weights (Spain) to generate the synthetic controls for the three G7 countries. The resulting optimal matching procedure places the largest weight on the two CDS variables: the CR14 spread plays the dominant role (with a weight of 0.8626), followed by its bid-ask spread (0.1332). The two bond market variables do not contribute sizeably to the matching, with the optimal weight on the five-year sovereign yield and bond market bid-ask spread close to zero at 0.0013 and 0.0029, respectively. These matching weights are constant over the sample period.

The time-varying weights of each control group country in the synthetic control are then chosen each day to minimize the weighted sum of squared deviations of the matching variables for the synthetic control from the observed matching variables for, respectively, France, Italy, and Germany for that day. Using these time-varying country-weights, I then compute the time series of credit spreads $CR14_{s(i),t}$ and $CR_{s(i),t}$ for the synthetic control country as convex combinations of the control group observations for the respective CDS spread. The final diff-in-diff measure is then computed as $RS_{i,t} = CR14_{i,t} - CR_{i,t} - \left(CR14_{s(i),t} - CR_{s(i),t}\right)$ for $i = \{FRA, ITA, GER\}$. The diff-in-diff measure is designed to eliminate the confounding factors contained in the raw difference between CR14 and CR spreads, such as differential liquidity between older and newer contracts. I discuss in Section 5 two empirical concerns and outline why my diff-in-diff methodology is appropriate in this particular setting.

Table 2 reports summary statistics by country for the diff-in-diff measure. The redenomination spread measures are distinct from conventional credit risk: the correlation coefficients between the redenomination spreads and CR CDS spreads are -0.03 for France, -0.01 for Italy, and 0.08 for Germany. Figure 5 plots the diff-in-diff measure for France and Germany. As discussed above, the new currency must be expected to depreciate for redenomination to render sovereign bonds *risky* (with respect to redenomination) and for this risk to show up in CDS spreads. The lower plot shows the German redenomination spread against RS_{FRA}: German redenomination risk is close to zero throughout the sample period, consistent with the interpretation that either (i) the probability of redenomination is close to zero, or (ii) conditional on redenomination, the new currency is not expected to depreciate against the euro.

The French redenomination spread hovers around zero for most of the sample, but spikes dramatically to 25 basis points in the run-up to the presidential elections in spring 2017: the two red asterisks indicate the Fridays before each of the two election rounds (Sunday, April 23rd, and Sunday, May 7th, 2017). In the two-round system, a president is elected by absolute majority in the first round. If—as is commonly the case—no candidate receives an absolute majority, the two candidates with the highest vote move to the second round, in which one candidate will attain more than 50% of the votes. In 2017, pre-election polls saw four candidates as potential contenders in the decisive second round, including far-left candidate Jean-Luc Mélenchon and far-right candidate Marine Le Pen, both vocal critics of the European Union and widely considered potential supporters of a French exit from the Eurozone. Figure 6 shows the combined vote share of Mélenchon and Le Pen from February through April against RS_{FRA}.[11] On Sunday, April 23rd, the results of the first round eliminated the possibility of a run-off between these two candidates, since pro-European candidate Emmanuel Macron placed first. The following Monday, the redenomination spread drops sharply to 7 from 21 basis points. According to polls, first-round runner-up Le Pen was expected to lose the run-off to Macron and the remaining uncertainty ahead of Macron's eventual second-round win only raises redenomination risk by 2 basis points to 5 basis points over the second-round election weekend in May.

At its peak, the redenomination spread accounts for approximately 40% of the French CR14 CDS spread. Suppose, for illustrative purposes, that the (risk-neutral) expected recovery of bondholders in a redenomination scenario is 90% of face value (implying a 10% depreciation against the euro) and that the risk-free rate is 1%. Under these two assumptions, the simplified pricing equation (1) for q_T translates the redenomination spread into a back-of-the-envelope estimate of the redenomination probability. On April 21st, 2017, just before the first presidential election round, the redenomination spread of 0.21% translates into a risk-neutral probability of 2.21% that France will change the currency-denomination of its outstanding bonds within the following five years.

Figure 7 plots the redenomination spread for Italy. The possibility of an Italian exit from the Eurozone (termed 'Italexit', 'Italeave', or—domestically—'Euroscita') has received a lot of attention during the formation of the coalition government supported by the populist *Five Star Movement* and the right-wing *League*. Ahead of the March 2018 elections, both parties had been strictly opposed to any form of cooperation, resulting in a hung parliament post-election. The election period itself is associated with mildly elevated levels of the redenomination spread, consistent with all relevant parties confirming Italy's Eurozone membership during their campaigns. However, during coalition negotiations in May, the question was raised, and a draft coalition agreement was leaked to the media, citing as objectives the *"introduction of specific technical procedures for single states to leave the Eurozone and regain monetary sovereignty"*, along with a request for €250bn debt relief from the ECB, and a radical reform of

[11] Polling results are obtained from various sources. A convenient summary is available on Wikipedia.

the *Stability and Growth Pact*.[12] While both parties immediately claimed the document was "outdated", the redenomination spread rises from 13 to 18bps on the day the draft leaked, and rises further over the following week of negotiations. The spread then jumps to 85 basis points at the end of May, amid further uncertainty surrounding the government formation, including the possibility of repeat elections within a few months. It stays above 60 basis points following the appointment and inauguration of the cabinet under Prime Minister Giuseppe Conte.[13] For both France and Italy, the difference-in-difference measure evidently identifies redenomination-relevant political events. Figure 8 plots the ratio of redenomination spread and the total CR14 CDS spread for France and Italy. While low on average, redenomination risk is at times economically large in magnitude, contributing up to 40% of the total CDS spread for France, and up to 32% for Italy. Having established an observable quantitative measure of redenomination risk, I now examine its association with yields and asset prices both in the country at risk of redenomination and elsewhere.

3 Redenomination risk and asset prices

This section documents a set of empirical results about the co-movement of different asset prices with the redenomination risk measure identified in the previous Section.

Eurozone sovereign debt. To examine the relationship between redenomination risk and the cross-section of Eurozone yields, I collect yields for Austria (AUT), Belgium (BEL), Spain (ESP), France (FRA), Germany (GER), Ireland (IRE), Italy (ITA), the Netherlands (NED), Portugal (POR), and Denmark (DEN). I restrict attention to Eurozone countries, for which I have daily yield and CDS data (including bid-ask spreads), adding Denmark as a country with a fixed exchange rate against the euro throughout the sample period. I subtract the maturity-matched euro overnight swap rate (OIS) and then regress these yield spreads on the French and Italian redenomination spreads. Country j's yield with maturity T, $y_{j,T,t}$ is observed daily and the sample period ranges from September 2014 to June 2018:

[12]The draft document was published by HuffingtonPost.it on May15th, and is available here.

[13]Figure 16 in Appendix D plots the French and Italian *RS* against the respective *Economic Policy Uncertainty* index created by Baker et al. (2016), available at policyuncertainty.com.

$$y_{j,T,t} - OIS_{€,T,t} = \alpha_{j,T} + \beta_{FRA,j,T} RS_{FRA,t} + \beta_{ITA,j,T} RS_{ITA,t} + \varepsilon_{j,T,t}, \tag{2}$$

for $j = \{$AUT, BEL, ESP, FRA, GER, IRE, ITA, NED, POR, DEN$\}$ and $T = 5$ years. Table 3 reports the results and Figure 9 plots the β-coefficients with their 95% confidence intervals for the Eurozone countries.

The left panels show large cross-sectional variation in yield responses to French redenomination risk: the estimates are negative for German and Austrian government bond yields. Dutch, Irish, and Belgian responses are close to zero. Spanish yields rise, but not significantly at 5%. Portuguese and French yields rise sharply, with the French coefficient statistically indistinguishable from 1. The near-zero coefficient for Italian yields is misleading, since Regression (2) directly controls for Italian redenomination risk. Dropping RS_{ITA} from the regressors produces a strongly significant β_{FRA}-estimate of 1.698. Similarly, the coefficient is positive and strongly significant at 1.099 regressing the observable RS_{ITA} directly on French redenomination risk.

In comparison, the coefficients on the Italian redenomination spread—shown in the right panels—are significantly negative for all countries other than Italy. Further, the responses of other countries' sovereign yields to Italian redenomination risk, unlike for French risk, are also similar in magnitude. The Italian coefficient on Italian redenomination risk is indistinguishable from 1, just like in the case of France.

Another interesting place to look for responses to Eurozone redenomination risk is Denmark. Denmark has the right to opt-out of the eventual adoption of the euro under the Maastricht Treaty, and in 2000, the introduction of the euro was rejected in a public referendum (with 53.2% of votes in favor of retaining the krone). Nonetheless, the Danish krone (DKK) has been pegged to the euro under the European Exchange Rate Mechanism (ERM II) since 1999, which requires it to trade within 2.25% of 7.46038 kroner per euro. ERM II membership is one of criteria for a country to join the Eurozone, and, hence, the peg allows Denmark to keep the option of euro membership despite the opt-out. The tight peg de facto makes Denmark a Eurozone member as far as the risk and return characteristics of its sovereign bonds are concerned, with the crucial distinction that an 'exit' (i.e., abandoning the peg) is substantially simpler to implement for Denmark than for de jure Eurozone members. As a quasi-Eurozone member, Danish yields behave similarly to Austrian yields, with significantly negative coefficients on French and Italian redenomination risk.

Exchange rates. Regarding the patterns of responses to French and Italian risk, a similar discrepancy exists in the response of the euro in currency markets. Denote by $e_{\$/€}$ the natural logarithm of the euro-dollar exchange rate defined as the \$-price of 1€. Consequently, an increase in this variable reflects an appreciation of the euro against the dollar. Similarly, $e_{€}$ and $e_{\$}$ denote, respectively, the logarithms of the euro index constructed by Bloomberg and the ICE US dollar index, each measuring the respective currency's value against a trade- and liquidity-weighted basket of global currencies. I obtain daily exchange rates from September 2014 to June 2018 and run the following time-series regressions:

$$e_{€,t} = \alpha + \beta_{FRA} RS_{FRA,t} + \beta_{ITA} RS_{ITA,t} + \gamma_{€} OIS_{€,t} + \varepsilon_t, \tag{3}$$

$$e_{\$/€,t} = \alpha + \beta_{FRA} RS_{FRA,t} + \beta_{ITA} RS_{ITA,t} + \gamma_{€} OIS_{€,t} + \gamma_{\$} OIS_{\$,t} + \varepsilon_t, \tag{4}$$

$$e_{\$,t} = \alpha + \beta_{FRA} RS_{FRA,t} + \beta_{ITA} RS_{ITA,t} + \gamma_{\$} OIS_{\$,t} + \varepsilon_t. \tag{5}$$

I report the results in Table 4. The euro depreciates significantly against the dollar and a broader currency basket in response to higher French redenomination risk. The magnitudes of the coefficients indicate that a 1 basis point increase in the French redenomination spread is associated with a 0.3% lower euro exchange rate against the currency basket (0.5% against the dollar directly). In contrast, the euro exchange rate appreciates slightly but significantly by 0.1% on average against the currency basket for one basis point higher Italian redenomination risk. The US dollar appreciates significantly against the currency basket in response to French redenomination risk. The dollar index is not significantly correlated with Italian redenomination risk.

US Treasuries. Next, I compare the sensitivity of German yields to redenomination risk to that of yields outside of the universe of €-denominated assets (or pegged, as in the case of Denmark), specifically US Treasury yields. I obtain daily Bund yields for maturities of 1, 2, 3, 5, and 10 years from Bloomberg, matching the sample period of the redenomination spread from September 2014 until June 2018, and run Regression (2) for Bund yields for maturities $T = \{1, 2, 3, 5, 10\}$. The coefficient estimates are reported in Panel A of Table 5. The estimates for β are significantly negative for all but the 10-year maturity for the French redenomination spread, and for all maturities for the Italian redenomination spread. I then run the same time-series regression with US Treasury yields as the dependent variable, replacing euro swap rates with US dollar swap rates:

$$y_{US,T,t} = \alpha_T + \beta_{FRA,T} RS_{FRA,t} + \beta_{ITA,T} RS_{ITA,t} + \gamma_T OIS_{\$,T,t} + \varepsilon_{i,T,t}. \tag{6}$$

Panel B of Table 5 reports the results for US Treasuries. Figure 10 visualizes the comparison between Bunds and Treasuries from Table (5) by plotting the regression coefficients and their 95% confidence intervals across the term structure. The response of US Treasuries to French redenomination risk is similar to that of German Bunds. The coefficients for German yields are more negative than those for US yields, but the 95% confidence intervals overlap slightly across most of the term structure, so the distinction in magnitudes resides in the margins of statistical significance. Focusing next on the estimates for $\beta_{ITA,T}$ in the right panel of Figure 10, dollar-denominated US Treasuries behave differently from euro-denominated Bunds. Much like most other euro-denominated sovereign yields, Bund yields tend to fall significantly in times of high Italian redenomination risk. This is not true for US Treasuries of any maturity.

Corporate credit spreads. I now extend the above examination of redenomination risk to corporate credit spreads across Europe. To this end, I collect five-year CDS spreads (denominated in euros, and with CR14 restructuring clauses) for the 125 European companies included in the iTraxx Europe Index—a tradable CDS-index of the most liquid European corporates with an investment-grade rating. These credit spreads refer to senior unsecured bonds issued by these 125 corporates. In addition, I collect five-year subordinated credit spreads for 30 financial corporates (banks and insurance companies included in the 125 sampled companies, for which these subordinated CDS are traded separately). I repeat Regression (2), substituting as the dependent variable (i) the portfolio of 125 senior corporate CDS (iTraxx Europe), (ii) the portfolio of 30 senior financial CDS (iTraxx Financials Senior), (iii) the portfolio of 30 subordinated financial CDS, and (iv) 10 portfolios of corporate CDS spreads sorted by country and split into financial and non-financial companies. These country portfolios span five Eurozone countries (GER, NED, ITA, ESP, and FRA), with at least one financial company within the original set of 125. These countries cover 71 of the original 125 individual companies. All portfolios are equally weighted. The results are reported in Table 6 and illustrated in Figure 11.

Broadly speaking, the results are weaker than those for sovereign yields in Table 3:

corporate credit spreads across Europe are positively associated with French redenomination risk, but this association lacks statistical significance for Spain and non-financial companies in Italy. The point estimate for German non-financial corporates is negative and insignificant. Among non-financial companies, the response to French risk is strongest for French corporates.

Just like sovereign yields, corporate credit spreads are negatively associated with Italian redenomination risk, and the results are significant for the non-financial companies in Germany, the Netherlands, Spain, and France. However, in contrast to Italian sovereign yields, non-financial Italian corporate spreads react only marginally, and insignificantly positively to Italian redenomination risk.

The coefficients are generally more positive for the CDS spreads of financial companies, and even more so for their subordinated CDS spreads. Credit spreads of Italian financial companies are significantly positively associated with French redenomination risk, unlike their non-financial counterparts. With respect to Italian redenomination risk, only Dutch and French banks have significant negative coefficients.

3.1 Redenomination risk vs. credit risk

Ultimately, I consider the co-movement of Eurozone sovereign yields and the two redenomination risk measures to document signs of redenomination risks in sovereign debt beyond France and Italy. In regressing sovereign yields on redenomination risk, the idea is to think of the yield as the sum of different components:

$$y_{j,T,t} = \text{risk-free rate}_{€,T,t} + \text{credit risk}_{j,T,t} + \text{redenomination risk}_{j,T,t}, \qquad (7)$$

where *credit risk* is meant to capture all default risk unrelated to redenomination. The risk-free rate is meant to include all euro-wide return components (e.g., a term premium). I account for the latter using maturity-matched swap rates on the right-hand side of the yield regressions. For the three G7-Eurozone members, the redenomination spread presented in Section 2 measures [redenomination risk]$^+$, that is, the positive part of redenomination risk. The asymmetry stems from the fact that CDS contracts cover only losses from credit events. A redenomination to the benefit of bondholders would therefore not trigger CDS payouts.

However, regarding the credit risk component, finding a suitable measure is more difficult: for all non-G7 Eurozone members, CDS spreads measure the sum of credit risk and [redenomination risk]$^+$, irrespective of which contract type I consider. An isolated observable measure of credit risk only exists for the three G7-countries. Since the CR contracts do not cover redenomination into a G7-currency, these spreads are a suitable measure for conventional credit risk, *excluding* redenomination. As a sense-check for this decomposition, I regress French and Italian five-year yields on the five-year swap rate, each country's respective redenomination spread, and its CR spread:

$$y_{j,T,t} = \alpha_{j,T} + \beta_{j,T} RS_{j,t} + \psi_{j,T} CR_{j,t} + \gamma_{j,T} OIS_{€,T,t} + \varepsilon_{j,T,t}, \tag{8}$$

for $j = \{FRA, ITA\}$. The results are reported in Table 8. For both countries, the ψ-coefficients are indistinguishable from one and R^2 are high at 0.93 and 0.85, respectively. Since $RS_{ITA} > 0$ for the vast majority of the sample period, the limitation that the CDS-based measure only captures positive redenomination risk has little bearing. Accordingly, the coefficient β_{ITA} is indistinguishable from one. For France, this coefficient is statistically below one over the full sample, but becomes indistinguishable from one once I drop the earlier part of the sample (pre-February 2017), when RS_{FRA} hovers around zero but appears to be noisy.

The only other country, for which credit and redenomination risk are directly observable in isolation is Germany. For Germany, however, the limitation that $RS_{GER} =$ [redenomination risk$_{GER}$]$^+$ becomes more problematic, as RS_{GER} is essentially zero throughout the sample. This raises the concern that the CDS-based measure fails to capture a negative redenomination risk component in Bund yields arising from expected currency gains conditional on redenomination. Table 8 reports the results for a variant of Regression (2), now including a direct control for German credit risk (the CR spread). The coefficients on French and Italian redenomination risk remain significantly negative, and increase in magnitude relative to those reported in Table 3. Adding credit risk raises the R^2 of the yield regression by 15 percentage points to 0.59. For all other Eurozone members, credit spreads or other observable variables do not control for credit risk in isolation from redenomination risk.

Taking a different approach, I compare the response coefficients of yields to redenomination risk to those of credit risk, each measured in isolation for France and Italy. To this end, I add to the redenomination risk measures in Regression (2) the French and Italian CR credit spreads and run an analogous set of time-series regressions.

$$\begin{aligned} y_{j,T,t} - OIS_{€,T,t} = \alpha_{j,T} + \beta_{FRA,j,T} RS_{FRA,t} + \beta_{ITA,j,T} RS_{ITA,t} + \\ + \psi_{FRA,j,T} CR_{FRA,t} + \psi_{ITA,j,T} CR_{ITA,t} + \varepsilon_{j,T,t}, \end{aligned} \tag{9}$$

Table 7 and the middle and lower panels of Figure 9 report the results. The pattern in the β-coefficients remains. Unlike for redenomination risk, sovereign yields are positively and significantly associated with French credit risk. The exceptions to this are Danish and Portuguese yields, which both have insignificant coefficients. In stark contrast to the results from Regression (2), German Bund yields show the largest positive response among five-year yields. Similarly, the coefficients on Italian credit risk differ from those on Italian redenomination risk. While the responses to redenomination risk are significantly negative for all countries other than Italy, the credit-risk correlations are close to zero, with the exceptions of Italy and Portugal. The latter yields rise significantly with the reaction even larger in magnitude than that of Italian yields. These results confirm the notion that redenomination risk—as measured by the approach introduced in this paper—is genuinely distinct from non-redenomination credit risk.

Since CR spreads and redenomination spreads are close to uncorrelated within-country for France and Italy, the β-estimates for Regressions (2) and (9) do not differ substantially.

As a further robustness check, I limit the sample to the years 2017 and 2018, where the most substantial variation in redenomination risk occurs. The subsample results in Table 9 confirm the findings from the headline regressions: loadings on French redenomination risk vary widely across countries. The β_{FRA} estimates are significantly negative for Germany and Austria, and significantly positive for France and Portugal. Again, the Italian estimate for β_{FRA} is misleadingly low, since the regression controls for RS_{ITA} directly. Once the Italian regressors are dropped from the regressors, the coefficient jumps to 0.71. In comparison, the estimates for β_{ITA} are close together, ranging from -0.51 (ESP) to 0.46 (BEL); the Portuguese coefficient presents is more negative at -1.65. Crucially, the β_{ITA}-estimates do not share the cross-sectional dispersion seen for β_{FRA}.

3.2 Negative redenomination risk

I return to the previous observation that—for all countries—CR14 credit spreads measure the sum of credit risk and the positive part of redenomination risk, i.e.,

$$CR14_{j,T,t} = \text{credit risk}_{j,T,t} + [\text{redenomination risk}_{j,T,t}]^{+}$$

To examine the asymmetry in redenomination risk more closely, I repeat Regression (2) with each country's five-year CR14 spread as the dependent variable, instead of its yield:

$$CR14_{j,t} = \alpha_j + \beta_{FRA,j} RS_{FRA,t} + \beta_{ITA,j} RS_{ITA,t} + \varepsilon_{j,t}, \tag{10}$$

for $j = \{\text{AUT, BEL, ESP, GER, IRE, NED, POR}\}$. I drop the observations for France and Italy from the dependent variables, as both variables are mechanically included in the construction of the redenomination spreads on the right-hand side. If the negative yield responses in other Eurozone government bonds reflect negative redenomination risk, these responses will be absent from the CDS spreads and the resulting coefficients are bounded below by zero. I report the results in Table 10 and Figure 12 illustrates the comparison of the point estimates for credit spreads with those for yields. As shown in the left panel, the point estimates for $\beta_{FRA,j}$ are indeed non-negative. While bond yields for Germany, Austria, and the Netherlands have negative point estimates for their respective correlations with French redenomination risk, the coefficients for their respective CDS spreads are all significantly positive. In stark contrast, just like the coefficients for yields, all coefficients on the Italian redenomination spread are significantly negative, albeit generally smaller in magnitude than the yield coefficients.[14] This result suggests that the negative β_{ITA} coefficients in Regression (3) do not reflect negative redenomination risk across other Eurozone bonds, but instead stem from changes in credit risk premia. The comparison between the two panels points once more to the systematic distinction between French and Italian redenomination risk and their associations with asset prices. In the next section, I provide an economic rationale for the joint set of the above results.

[14]The findings in Table 10 are robust to estimating Regression (10) as a Tobit model.

4 Contagion, safety, and substitution

When measuring redenomination risk and its co-movement with asset prices, the imminent question is whether a hypothetical Eurozone exit of any given country is likely to be associated with a break-up of the currency union, or whether such an exit would remain isolated. To make this question more empirically tangible, this section lays out a simple model to sketch possible spillover effects across a range of asset prices in response to the risk of each type of exit—contagious or isolated. The redenomination risk measure presented in Section 2 of this paper quantifies exit risk for France and Italy and I interpret the empirical results presented in Section 3 as symptoms of spillovers from this exit risk to other asset prices.

The prospect of a Eurozone break-up and re-introduction of national currencies sparks capital flight out of countries with expected weaker national currencies and into those with stronger ones. As outlined at the start of Section 2, the redenomination risk measure presented in this paper only captures the downside of redenomination, that is, if the national shadow currency of, say, France is expected to depreciate against the euro. As a consequence of the repricing of redenominatable bonds at risk of such depreciation, the nominal yields on such bonds rise. As a first consistency check, a positive redenomination spread for France should therefore be associated with higher yields for French sovereign bonds. The results reported in Table 3 and Figure 9 show that this is true for both France and Italy (with yields rising close to 1-for-1 with redenomination risk).

Looking beyond France or Italy and towards spillover effects, the question of contagion versus isolation becomes crucial: if an exit of, say, Italy becomes more likely, but this event is not expected to lead to a redenomination of bonds issued by, say, Spain, this may lead investors in Eurozone government bonds to shift their investments out of Italian bonds and into Spanish ones, regardless of how the Spanish national shadow currency would fare, because that currency remains hypothetical in the absence of break-up risk. To illustrate this channel more formally, consider the simple model presented in the following subsection.

4.1 A simple model

There are two dates, *today* and *tomorrow*, and the model describes the bond market in a currency union of three countries, A, B, and H. On the supply side of the bond market, the asset universe consists of four zero-coupon bonds: a risk-free bond with a net supply of σ_S in nominal face value, and three redenominatable government bonds issued by countries A, B, and H in nominal net supplies σ_A, σ_B, and σ_H, respectively. Today, all bonds are denominated in the common numéraire (let's call it 'euro') and their prices are determined by market clearing. Prices are expressed in terms of gross yield denoted by y_J for bond J, such that its price per unit of face value is $P_J = 1/y_J$. Countries A and B are individually at risk of exiting the currency union and redenominating their bonds into a national currency. Country H, however, only redenominates its bonds if both A and B jointly exit, that is, if the currency union ceases to exist. Consequently, there are four possible states of the world tomorrow, denoted by $s \in \{1, 2, 3, 4\}$:

(1) Stability: no exit, no bond is redenominated,

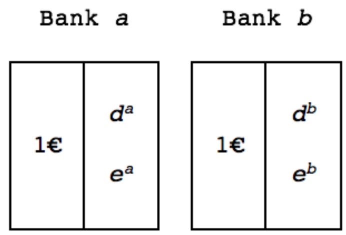
(2) Isolated exit A: only A is redenominated,

(3) Isolated exit B: only B is redenominated,

(4) Break-up: all bonds, A, B, and H, are redenominated.

In case of redenomination, the face value is repaid in the new currency worth a euro-equivalent of $(1-\delta_J)$ per unit, such that the gross return on bond J in case of redenomination is $y_J(1-\delta_J)$. $\delta_A > 0$ and $\delta_B > 0$, meaning that currencies A and B depreciate against the euro-numéraire once they are introduced. In contrast, the new currency of country H (for *haven*) appreciates, $\delta_H < 0$, resulting in exchange rate gains from redenomination for bondholders. The risk-free bond denoted by subscript S repays one unit of the numéraire per unit of face value in all states of the world. This bond can be thought of as a privately issued euro-denominated security with sufficient collateral to be default-free and remote from redenomination. With four linearly independent assets and four states of the world, markets are complete.

The demand side of the asset market consists of two risk-averse banks, a and b operating in countries A and B, respectively. Adding a third bank operating in country H does not change any of the model results in a meaningful way. For clarity of notation, I use lower case superscripts to refer to banks, and upper case subscripts to refer to countries/bonds. Today, the right-hand side of each bank's balance sheet consists of deposits, d raised from households in the respective country, and bank equity, e, such that the total endowment of each bank amounts to one unit of the common numéraire as shown below. Households are passive, and their decisions are not modelled.



Crucially, redenomination also extends to bank deposits: the euro-equivalent of deposits taken by bank a falls to $d^a(1-\delta_A)$ after redenomination by country A, and equivalently for bank b and country B.

Today, banks choose a portfolio of the four assets in order to maximize expected log utility over their respective equity tomorrow. Let w_J^i be the euro-investment of bank i in bond J, and by e_s^i the value of bank i's equity in state s. State-probabilities are denoted by p_s. I assume that deposits, d, and redenomination losses, δ, are sufficiently small, such that bank equity is strictly positive in all states and utility is well-defined:

$$max_{\{w_A^i, w_B^i, w_H^i, w_S^i\}} \sum_s p_s \log\left(e_s^i\right) \quad \text{s. t.} \quad w_A^i + w_B^i + w_H^i + w_S^i = 1$$

Rather than to *generate* contagion in redenominations, the purpose of the model is to formally examine the relationships of the different asset prices *given* contagion or the lack thereof. Starting with the latter case, *isolation*, suppose that exits by A and B are independent, and the redenomination probabilities are ρ_A and ρ_B, respectively. The probabilities of the four possible states in the isolation case are:

(1) Stability: $p_1 = (1-\rho_A)(1-\rho_B)$,

(2) Isolated exit A: $p_2 = \rho_A(1-\rho_B)$,

(3) Isolated exit B: $p_3 = (1-\rho_A)\rho_B$, and

(4) Break-up: $p_4 = \rho_A \cdot \rho_B$.

Next, I consider the other extreme case: the *contagion* case with perfect correlation in redenominations. To this end, suppose that B exits and redenominates if and only if

A does, such that the state probabilities in the contagion case are:

(1) Stability: $p_1 = (1 - \rho_A)$,

(2) Isolated exit A: $p_2 = 0$,

(3) Isolated exit B: $p_3 = 0$, and

(4) Break-up: $p_4 = \rho_A$.

In this configuration of the contagion case, country A drives the disintegration of the currency union and the model therefore studies spillover effects from A to B, but not vice versa. The equilibrium in this model exhibits the following relationships between redenomination risk (ρ_A) and bond yields.

Spillover effects: In the isolation case (with independent redenominations), an increase in A's redenomination probability, ρ_A, *lowers* the yield on country B's bonds. This result is illustrated in terms of comparative statics of equilibrium yields with respect to ρ_A in Panel A of Figure 13. It is an indirect spillover effect through portfolio substitution: rising risk in country A lowers yields in country B, because absent a change in yields, both banks shift portfolio weight from country A's bonds to those of country B (and those of country H, and the risk-free bond). Yields on bond B therefore need to fall to restore market clearing. In the contagion case, however, the sign and magnitude of spillover effects on another country's bond yield from an increase in ρ_A are dictated by, respectively, the sign and magnitude of the other country's δ: since $\delta_B > 0$, country B's bond yield increases with redenomination risk in country A, while the yield on the bonds of country H falls ($\delta_H < 0$). Panel B of Figure 13 illustrates the yield spillovers in the contagion case. Aside from the spillover effects, the model delivers two additional results, which are notable in the empirical context of the Eurozone.

Home bias: Sovereign bonds are predominantly held by domestic banks. Battistini et al. (2014) note that the redenomination of liabilities gives domestic banks a "comparative advantage" in holding domestic sovereign debt.[15] This is precisely the mechanism behind this model result, which is a direct consequence of deposit rede-

[15] Alongside redenomination risk, they note two primary motives for home bias in Eurozone banks: (i) "moral suasion" by authorities in order to raise demand for domestic sovereign debt; and (ii) "carry trade" investments into particularly high-yield euro-denominated sovereign debt, funded with low-yield euro borrowing (see also Acharya and Steffen (2015)).

nomination: the losses from a redenomination of domestic government bonds on the bank's asset side are partially offset by the redenomination of its deposits. Accordingly, domestic bonds are less risky to domestic banks than to foreign banks, resulting in home bias in bank bond holdings. The proof is left to Appendix C. I document home bias in Table 11 using data as of year-end 2015, provided by the EBA: banks domiciled in most European countries hold a larger fraction of their liquid sovereign debt holdings in domestic government debt, in which most of their deposit-taking activity occurs. For non-Eurozone countries, such as Poland (98.8% of net sovereign bond exposure of Polish banks is to the Polish government) or Norway (63.2%), this likely represents a straight-forward currency matching between assets and liabilities. For Eurozone-domiciled banks, for instance in Italy (65.8%), Ireland (67.6%), Spain (50.5%), or Germany (44.4%), redenomination risk makes this currency matching more subtle and currency bias implies home bias even in a currency union.[16]

Sub-zero lower bound: The nominal yield on bond H is below that of the risk-free asset. This effect is straight-forward if redenomination leads to exchange rate gains. Bonds from a country whose currency is expected to appreciate in the break-up scenario carry a yield below the risk-free rate. Even if the risk-free rate is bounded below (say, by zero), 'haven' bond yields are not. This intuitive notion is important for the assessment of monetary policy and its transmission in the presence of redenomination risk and negative bond yields. Again, the proof is left to Appendix C.

4.2 Interpreting the empirical results

I now compare the model results to the empirical results in Section 3. The spillovers through portfolio substitution described above apply to all other assets in the model (all sharing the common numéraire). The right-hand side panels of Figure 9 show that the statistical relationship of the Italian redenomination spread with Eurozone government yields outside Italy is indeed significantly negative and homogeneous in the cross-section. As shown in Table 6, the same is true for corporate credit spreads in Germany, the Netherlands, Spain, and France. Dollar-denominated US Treasuries do not exhibit the same behavior as Eurozone yields and remain flat across most of the term structure

[16] Among Eurozone-domiciled banks, home bias is relatively low for the two Austrian banks included in the EBA stress tests. Both have relatively large exposures to central and eastern European sovereigns, consistent with their prominent consumer banking presence and deposit base in that region.

with respect to increases in Italian redenomination risk (Figure 10). Furthermore, the euro-dollar exchange rate is uncorrelated with Italian redenomination risk. Against a broad currency basket, the euro appreciates slightly with Italian redenomination risk. The results for Treasuries and exchange rates speak against the notion that Italian redenomination risk is associated with a broader flight-to-safety phenomenon.

In contrast, spillovers from contagious redenomination risk separate the remaining Eurozone members—observably, through the reaction of their sovereign bonds—into those with expected strong currencies and those with expected weak national currencies. Bonds that are redenominated into a stronger national currency (or stronger miniature-currency unions) are more desirable, and these bonds appreciate. If, say, the new German currency is expected to appreciate against other national euro-successor currencies, then 'German euros', which are converted in the event of a Eurozone break-up, provide an effective hedge against the break-up event and exhibit 'safe haven' properties. In a similar way, safe haven candidate assets denominated in other currencies, such as US Treasuries, might benefit similarly, if the future of the euro is at risk. Instead, countries, for which national currencies are expected to be weaker exhibit rising yields. The implied cross-sectional heterogeneity in bond yield responses is evident in the left panels of Figure 9, which plots the yield-coefficients with respect to the French redenomination spread. Similarly to German Bunds, US Treasury yields—a plausible safe-haven asset in the case of a Eurozone break-up—drop with rising French redenomination risk, as shown in Figure 10. The interpretation that the negative response of German and Austrian yields to the French RS-measure reflects negative redenomination risk in these countries is corroborated by the absence of this response in German and Austrian CDS spreads: since CDS contracts only cover losses from credit events, their prices reflect redenomination risk asymmetrically, unlike bond yields which reflect both expected losses and gains from redenomination.[17] Table 4 further points to the negative association of bilateral euro exchange rates with the French redenomination spread: the euro depreciates significantly, consistent with the interpretation that a French redenomination would put the existence of the euro at risk.

The results for corporate credit spreads in Table 6 are weaker in magnitude and sig-

[17] An important caveat in the comparison between yields and CDS spreads is the large literature on the CDS-bond basis (Bai and Collin-Dufresne, 2018, e.g.) and the potential disconnect between sovereign yields and CDS spreads due to financial regulation and the price impact of financial institutions in CDS markets (Antón et al., 2015; Klingler and Lando, 2018).

nificance than those for sovereign yields. Credit spreads of Italian companies (financial as well as non-financial) are not significantly correlated with Italian redenomination risk with coefficients close to zero, while their sovereign counterparts show significantly positive coefficients close to one. This result suggests that an isolated Eurozone exit would not necessarily imply currency redenomination for the debt of large domestic corporate borrowers. Therefore, the ability of the diff-in-diff measure to identify sovereign redenomination risk without assumptions on corporate redenomination marks an important contribution of this paper relative to Krishnamurthy et al. (2018) and Bayer et al. (2018). Redenomination of corporate debt is more likely in a break-up scenario, where the common currency ceases to exist. In line with this interpretation, French corporate credit spreads rise significantly with French redenomination risk. Cross-sectional patterns in the coefficients on credit spreads outside France or Italy are difficult to interpret, due to the differing size and industry composition of the country portfolios. With this caveat, I note that the β_{FRA}-coefficients are smallest for German corporates (financial as well as non-financial), mirroring some of the cross-sectional pattern observed for sovereign debt. Overall, a within-country comparison of the β_{FRA} and β_{ITA} coefficients suggests once more that the risk of a French exit from the Eurozone is priced more severely than that of an Italian exit in European corporate CDS markets.

As an additional test, the risk of a contagious redenomination in one country should—by virtue of being contagious—also be correlated with redenomination risk in other countries, and, therefore, with the observable redenomination spread. Throughout the sample period over which I can observe redenomination spreads, the Italian measure is high whenever the French redenomination spread is high, but not vice versa, consistent with contagious French risk and isolated Italian risk (after accounting for the French component in Italian risk). The German spread is essentially zero throughout, and this exception is consistent with the inability of the measure to capture negative redenomination risk, that is an expected appreciation of a country's national currency following the euro break-up. The hypothesis that this applies to a new German mark is further consistent with the behavior shown by German sovereign yields and CDS spreads with respect to French redenomination risk.

All of the empirical results presented in this paper are, therefore, consistent with the interpretation that the redenomination risk in French CDS around the presidential elections in 2017 was deemed contagious by market participants, while the risk measured from Italian CDS immediately after the French election, ahead of the Italian elections in March 2018, and particularly following the formation of the coalition government in May 2018, was not expected to spill over into other Eurozone countries. Interpreting the exposures of sovereign yields to French redenomination risk as indicators of the strength of each national shadow currency, I next relate these coefficients to fundamental country-level variables.

4.3 National shadow currencies

Which factors explain the cross-section of sovereign yield reactions to contagious redenomination risk? In the simple model set-up, this reaction is pinned down by paramenter δ_J, the new national currency's depreciation relative to the euro (or relative to the new national currencies of other currency union members). To be more precise, the change in bond prices reflects the change in expected losses or gains from currency redenomination. This expectation is the product of the probability of redenomination in country B, conditional on redenomination in country A (= 1 in the contagion case of the model), and the expected depreciation of country B's national currency after redenomination ($= \delta_B$). It is natural to ask which factors determine the heterogeneity in δ, that is heterogeneity in national exchange rates immediately following the break-up of the currency union.[18] In line with the evidence and interpretation presented above, suppose that the time series for French redenomination risk reflects the risk of a Eurozone break-up. This simplifying assumption echoes the contagion case of the model, such that for all countries the probability of redenomination conditional on redenomination in France is equal to 1, and the cross-sectional heterogeneity in yield responses to French redenomination risk is driven by heterogeneity in δ_J across countries, that is, heterogeneity in the performance of the different national currencies immediately following the dissolution of the currency union.

Consider the β_{FRA}-estimates in Table 7 (from refRegCSCR Regression (9), which controls directly for credit risk): German and Austrian yields have the most negative coefficients, followed by Danish and Dutch yields. As in the baseline Regression (2),

[18]As outlined in Subsection 1.1, losses from redenomination may stem from an increase in credit risk premia for the respective country outside of the Eurozone, alongside the depreciation of the new numéraire. Without imposing strong further assumptions on these only indirectly observable quantities, it is impossible to disentangle the different sources of redenomination losses.

Portuguese and French yields have significantly positive β_{FRA}-estimates. Dropping the Italian regressors, the β_{FRA}-estimate for Italy jumps to 0.71. If these coefficients reflect an expected appreciation of, say, a new German currency or of a de-pegged Danish krone relative to a new Italian or Portuguese currency, then what is it about Germany or Denmark (Italy or Portugal) that promises a strong (weak) national currency after the break-down of the peg enforced by the currency union?

To relate the regression coefficients to country-fundamentals, I run univariate cross-sectional regressions of the β_{FRA} coefficients from Regression (9) on the (i) debt-to-GDP ratio, (ii) budget surplus/deficit, (iii) labor productivity, and (iv) current account balance. Data on all four variables are obtained from the OECD. Debt-to-GDP ratios and labor productivity data (GDP per hour worked) are as of 2016, due to incomplete data for 2017. All other data are for 2017. Budget surplus, and current account balance are expressed as a percentage of GDP.

For each country, Figure 14 plots the point estimates for $\beta_{FRA,j}$ from Regression (9) against each of the five fundamental variables, along with the univariate R^2 of the respective cross-sectional regression. Sovereign debt and the 2017 budget surplus (all scaled by GDP) each linearly account for large shares of the cross-country variation in β_{FRA}: 0.66, and 0.72, respectively. (These two fundamental variables are also strongly correlated across countries.) Labor productivity and the current account balance deliver univariate R^2 of 0.25 and 0.32, respectively. Since a negative β_{FRA} suggests a strong national currency, it is not surprising that the only variable that is positively related to the coefficient is the debt-to-GDP ratio. A strong link between a country's fiscal position and the value of its currency is in line with the long literature on the fiscal theory of the price level (e.g., Sargent and Wallace (1984) and Sims (1994), or—in more recent applications—Jiang (2018) and Bolton and Huang (2017)), and the high univariate R^2 are consistent with the interpretation of β_{FRA} as a weakness-gauge for the national shadow currencies of Eurozone members.

Taking the interpretations from Subsection 4.2 at face value, I now proceed to a back-of-the-envelope calculation of the fiscal costs to different national treasuries that are attributable to the periods of heightened redenomination risk in France and Italy.

4.4 Fiscal contagion or 'exorbitant' privilege?

The quantitative measure of redenomination risk can be used to estimate the overall fiscal cost of French and Italian redenomination risk on these two countries as well as the cost of spillovers on other Eurozone members. As discussed above, the sign of yield spillovers varies by country, such that German taxpayers benefit from the risk of redenomination in France, while sovereign yields for most other Eurozone member countries rise. As the de facto provider of safe assets for the Eurozone, the German treasury collects insurance premia in the form of interest savings on newly issued debt. The role of Germany as an insurance provider against redenomination risk can be viewed in analogy to the role of the United States as a provider of safe assets and the US dollar as the reserve currency within the global financial system, which has been described as an "exorbitant privilege" by French then-Minister of Finance, Valéry Giscard d'Estaing in the 1960s, and is interpreted as that of an insurance provider by Gourinchas et al. (2010).

To quantify the impact of—positive and negative—spillovers on yields, I compute counterfactual yield curves for each sample country on each day from 2017 until the end of the sample period in June 2018 as if redenomination spreads of France and Italy were zero throughout. I restrict attention to the sample period with most of the time-variation in redenomination risk. Specifically, I compute the counterfactual yield $\tilde{y}_{j,T,t} = \hat{\alpha}_{j,T,t} + \hat{\gamma}_{j,T,t} OIS_{€,T,t} + \hat{\varepsilon}_{j,T,t}$ using estimates from rolling-window regression analogous to Regression (2) for maturities $T = \{1, 2, 3, 5, 10, 30\}$ years. Estimating rolling coefficients allows for time-variation in the sensitivity of bond yields to redenomination risk. I choose a window-length of 250 daily observations up to and including observation t. I then compute the estimated spillover costs (or cost savings, if negative) as $c_{j,T,t} = y_{j,T,t} - \tilde{y}_{j,T,t} = \hat{\beta}_{FRA,j,T,t} RS_{FRA,t} + \hat{\beta}_{ITA,j,T,t} RS_{ITA,t}$, which reflects an estimate of the yield component that is due to French and Italian redenomination risk. For each bond issuance, I then multiply $c_{j,T,t}$ by the issuance volume, $v_{j,T,t}$ and capitalize the differential interest costs over the maturity of the bond with an annuity factor to obtain $C_{j,T,t} = c_{j,T,t} \cdot v_{j,T,t} \cdot a(T, y_{j,T,t})$. Since the coefficients are estimated for nominal yields, I exclude inflation-linked bond issuances.

Crucially, this exercise assumes that the (plausibly endogenous) choice of issuance volume and maturity is fixed. If national treasuries adjust issuance volume and/or maturity to changes in yields, my back-of-the-envelope cost estimate will be biased downwards, since the unobservable counterfactual issuance choice would have resulted in higher interest costs than the observable optimized issuance. Given the high frequency of changes in redenomination risk, which is characterized by sudden jumps and few periods of sustained elevated levels over the sample period, an adjustment of issuance by national treasuries would have to occur rather quickly. The idea that issuance volumes are chosen in response to changes in redenomination risk is also at odds with the overall low amount of issuance by the German treasury, which benefits most from redenomination risk in this sample. Figure 15 plots these costs for each bond auction of France (Panel A), Italy (B), Spain (C), and Germany (D). To visualize the time-variation in the intensity of redenomination risk, I include the two redenomination spreads in each plot. The aggregate measure can be decomposed into a French and an Italian component, $C_j = C_j^{FRA} + C_j^{ITA}$.

The result of this back-of-the-envelope calculation is that, from 2017 until June 2018, French taxpayers incur a substantial fiscal cost from redenomination risk: the risk surrounding the presidential election in 2017 resulted in substantially increased interest costs of around €400m. However, these costs to taxpayers are more than offset by the benefits newly issued French bonds have subsequently reaped as a substitute to Italian bonds during periods of Italian redenomination risk. The net benefit estimate to French taxpayers from redenomination risk in 2017-2018 amounts to €858m.

With the exception of a few very short-term issuances, Italian debt issues carried higher interest rates over the period, both during the tumultuous run-up to the French election in March/April 2017, but particularly following the Italian elections in March 2018 that led to the formation of the coalition between the far-left Five Star Movement and the far-right League in late May 2018. The estimated interest cost from redenomination risk to Italian taxpayers totals €3.5bn.

Spain is a net beneficiary over the period, despite negative spillovers and higher yields ahead of the French election (with costs totaling around €40m). Following the Italian elections, Spanish yields were negatively correlated with rising Italian redenomination risk, leading "cheap" debt issuances and an estimated net fiscal benefit of €499m over the entire period.

As a provider of 'safe' assets, the German treasury benefitted sizeably from the risks surrounding the French election, with interest savings of around €280m in early 2017.

The total estimated net benefit to German taxpayers over the period from January 2017 through June 2018 amounts to €565m. To put this number into perspective, I note that nominal bond issuance by the German treasury over those 18 months totaled €205bn. It is important to note that the direct fiscal costs, which may appear minuscule in relation to the trillions of euros of outstanding sovereign debt, are computed on the basis of newly issued debt only. At the same time, the risks measured over the sample period suggest event probabilities of a few (single-digit) percentage points, under the risk-neutral measure (i.e., an upper bound on the true, physical probability). The fact that such small probabilities have consequences of economically meaningful magnitude highlights the need for investors, policy makers, and electorates alike to understand the full ramifications a Eurozone exit, not to mention a break-up of the currency union.

Next, I discuss potential empirical concerns with the difference-in-difference approach used to quantify redenomination risk.

5 Concerns in measuring redenomination risk

The difference-in-difference measure of redenomination risk is obtained from the relative behavior of CDS contracts based on differing definitions of credit events. The most pressing concern when comparing new contracts to old ones is one of liquidity differences: similar to on-the-run/off-the-run premia in the US Treasury market, the potential lack of liquidity for off-the-run CDS contracts may result in different CDS spreads and the consistently positive difference between CDS spreads for the largely unaffected issuers in the control group, suggests that such a liquidity component exists. I also describe the other important contract change that applies to sovereign CDS and why my approach deals with it successfully.

5.1 Liquidity

The diff-in-diff will account for liquidity-driven differences between old and new contracts, as long as such differences are common across treatment and control groups. Liquidity differences are likely to be more severe in smaller markets. Since both France and especially Italy are among the largest European CDS markets, the control group is more likely to overstate the correction due to market-size driven liquidity.

However, the additional distinction between the two types in treated issuers may create clientele effects that generate price differences between CR and CR14 contracts as some investors shift holdings from CR to CR14 contracts and the market for CR adjusts to the new clientele. Such adjustments in market clientele are not purely driven by an on-the-run versus off-the-run phenomenon, and would, therefore, be systematically different between treatment and control groups. However, such adjustments are also likely to be temporary, if the launch of CR14 contracts was widely anticipated. Transitory price effects driven by the adjustment of market clientele to the newly bifurcated market may be responsible for the elevated Italian redenomination spread in October to November 2014 following the introduction of CR14 contracts. The spread then goes back to hover around zero.

Anticipation plays a problematic role in the interpretation of many difference-in-difference measures. In this case, however, anticipation does not threaten the validity of the diff-in-diff, since both treated and untreated variables are observed simultaneously (i.e. the diff-in-diff is not across time). On the contrary, for my diff-in-diff measure to reveal redenomination risk, it is necessary that market participants are immediately and fully aware of the differences between the two contract types and price them accordingly. To show that this was likely the case, I briefly summarize the timeline of the revision process.

ISDA began the revision of its CDS definitions in May 2012, following the restructuring credit event in Greece. In November 2013, ISDA published a draft of the revised definitions to review comments from market participants ahead of the final release of the new definitions on February 21st, 2014. Trading in the new contracts began 7 months later on September 22nd.[19] The release of the new definitions in February also announced the implementation process for the new set of definitions. For the vast majority of reference entities, the changes were retroactively applied to existing contracts on October 6th, but due to the expected pricing impact of the sovereign-specific changes (see also Subsection 5.2), most sovereign issuers were excluded from this adjustment such that CR contracts remained widely outstanding alongside the newly issued CR14 contracts. Among sovereign issuers, existing contracts were only migrated to the new 2014 definitions for emerging market sovereign issuers because ISDA was concerned

[19] see ISDA release dated February 21st, 2014 and June 30th, 2014, respectively, here and here.

that the resulting lack of liquidity in legacy CR contracts would be insufficient to support efficient trading in a bifurcated market (Simmons & Simmons, 2016). At the same time, there were no such liquidity concerns for developed-market sovereign issuers, including all Eurozone countries studied in this paper. Due to the broad consultation of market participants in the revision process and the long lead time between release of the final new definitions and the beginning of trading, it is reasonable to assume that, at the time, the CR14 contracts were launched, market participants were immediately and fully aware of the differences and prices reflect these differences throughout my sample period. ISDA's decision to exclude most sovereign reference entities from a retroactive activation of the new definitions suggests that market liquidity in the remaining CR contracts was viewed as sufficient for price discovery in both markets.

This view is consistent with the market depth of available quotes for both contract types: Table 12 reports the market 'depth' as the number of quote submissions from dealers used in Markit's computation of the consensus quote. Differences in market depth between the two contracts are small for all countries: for the average country, 4.90 CR14 quotes are reported on the average day, versus 5.05 for the older CR contracts—the older contract type receives slightly *more* quotes on average. Excluding Portugal, for which this difference is the largest in favor of the older CR contracts, the remaining average difference is zero. Similarly, the volatility, maxima, and minima of market depth are comparable across both contract types for all countries. The absolute market depth of around five intermediary submissions is consistent with the large concentration of these OTC markets among a few dealers (Giglio, 2014; Siriwardane, forthcoming).

5.2 Asset package delivery

A second change in the CR14 restructuring clause relative to the CR clause that relates particularly to sovereign issuers is the introduction of 'asset package delivery' (APD). This reform in the calculation of the recovery value is a direct response to the Greek debt restructuring of 2012. When Greece restructured its debt in 2012, existing bonds with 1€ in face value were exchanged into a *package* of new securities: (i) 15 cents of face value in short-term notes to be repaid by the European Financial Stability Facility (EFSF), (ii) 46.5 cents of face value in new Greek bonds with 30 years to maturity and a coupon rate of 2%, and (iii) detachable GDP-warrants which pay a capped amount if Greek GDP growth exceeds certain projections. Greek CDS payouts were triggered, but since old bonds were exchanged, the recovery had to be determined in an auction of the new 30 year bonds, which traded at approximately 30% of par value. As Duffie and Thukral (2012) outline, the *true* recovery is derived from the value (relative to the face value of the original bond) of the total asset package that is received in exchange for the original bonds rather than the value of just the single security, which is determined to be the 'deliverable obligation' and auctioned by ISDA. The APD clause addresses this flaw in the original CDS terms and specifies that recovery be based on the market value of the full asset package. Since the APD clause may impact the recovery offset against the CDS payout, the change in this clause potentially introduces another difference between CR and CR14 CDS spreads. As seen in equation (1), the recovery value interacts with the default probability in determining the fair insurance premium. If the APD term is responsible for differences between CR and CR14 spreads, this difference should therefore scale with the level of the spread. Table 1 shows that, in the control group, this is true in the cross-section: countries with higher average CR14 spreads show a larger difference between CR14 and CR spreads. However, this correlation does not show up within-country. The correlation is negative and/or close to zero for all sampled countries, indicating that the ISDA basis is unlikely to stem from the presence of the APD clause in CR14 contracts. Nonetheless, while necessary, the difference-in-difference method, is well-suited to eliminate APD-driven pricing effects, since the introduction of APD in the CR14 relative to the CR restructuring clause applies to all sovereign issuers regardless of G-7 membership.

6 Conclusion

This paper presents a directly observable quantitative measure of redenomination risk in French, Italian, and German government bonds. The measure uses CDS spreads on contracts, which, respectively, do and do not cover bondholders' losses from a redenomination into a newly issued French, Italian, or German national currency. I construct a difference-in-difference measure to account for potential liquidity differences and other contractual discrepancies between the two CDS types.

French redenomination risk is economically large before the 2017 presidential elections, when it accounts for 40% of the total French CDS spread. Italian redenomination risk is elevated around and immediately following the French presidential election, and spikes to 80 basis points (close to one third of the total CDS spread) during coalition negotiations in late May 2018. German redenomination risk is close to zero throughout the sample period, consistent with the interpretation that a redenomination into a new German currency (i) does not cause losses for bondholders, and/or (ii) is very unlikely.

French redenomination risk is associated with a statistically and economically significant drop in yields on German and Austrian government bonds, while many other sovereign Eurozone yields rise—particularly those on Portuguese debt. The German Bund response to French risk is similar to that of US Treasuries. In contrast, all Eurozone sovereign yields other than Italian yields are negatively correlated with Italian redenomination risk: higher redenomination risk in Italy is associated with lower sovereign yields elsewhere. I do not find a similar association with Italian redenomination risk for dollar-denominated US Treasuries.

Sovereign yields for most European countries, European corporate credit spreads, US Treasury yields, and the euro exchange rate react differently to French and Italian redenomination risk changes. French redenomination risk appears to have heterogeneous spillover effects on Eurozone assets, while Italian redenomination risk is associated with homogeneously lower yields on most other euro-denominated assets. This discrepancy is consistent with the interpretation that a French exit from the Eurozone is expected to lead to further redenominations in other European countries. In contrast, an Italian exit is expected to remain isolated, and benefits other euro-denominated sovereign and corporate debt, which serve as substitutes to Italian bonds.

I relate the co-movement of Eurozone yields with the presumably contagious French risk to fundamental variables. I find that the heterogeneity lines up with cross-sectional variation in the countries' fiscal positions, trade balances, and labor productivities.

I do not address the question why a French exit is associated with a Eurozone break-up, while an Italian exit is not. I leave it to further research to uncover the political, macroeconomic, and/or financial channels which may or may not generate a 'contagious' cross-country correlation in withdrawals from the Eurozone.

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A Tables

Table 1: Summary statistics – CDS spreads

This table reports the summary statistics of CDS spreads collected from Markit for a cross-section of Eurozone countries. The maturity in each case is five years, which is typically the most liquid maturity in CDS markets. CDS spreads for contracts under, respectively, 2003 and 2014 ISDA definitions are denoted by CR and $CR14$. The daily data run from September 22nd, 2014 to June 19th, 2018. CDS spreads are annualized and reported in basis points. Rows with $\mu(\cdot)$, $\sigma(\cdot)$, and $\rho(\cdot,\cdot)$ report, respectively, the mean, standard deviation, and correlation.

Country	FRA	ITA	GER	AUT	BEL	ESP	IRE	NED	POR
$\mu(CR14)$	32.69	132.26	15.95	23.79	34.52	81.03	48.60	20.17	195.36
$\sigma(CR14)$	11.38	26.95	3.79	5.80	12.54	19.08	14.66	5.28	70.39
$\mu(CR)$	27.57	106.91	14.21	21.61	30.89	68.25	42.83	18.55	172.90
$\sigma(CR)$	10.53	23.52	3.94	6.28	12.73	22.07	16.05	5.51	71.37
$\rho(CR14, CR)$	0.88	0.74	0.97	0.99	0.99	0.97	0.99	0.98	0.99
$\mu(CR14 - CR)$	5.10	26.30	1.81	2.27	3.65	13.04	5.86	1.67	22.71
$\sigma(CR14 - CR)$	5.41	18.43	0.92	1.01	1.28	6.34	2.60	1.03	9.14
$\rho(CR14 - CR, CR14)$	0.39	0.52	-0.05	-0.41	-0.09	-0.36	-0.47	-0.13	-0.04

Table 2: Summary statistics – Redenomination spreads

This table reports the summary statistics of the French, Italian, and German redenomination spreads (RS) constructed as a difference-in-difference measure: $RS_{i,t} = CR14_{i,t} - CR_{i,t} - (CR14_{s(i),t} - CR_{s(i),t})$, where $s(i)$ denotes variables relating to a synthetic control country constructed to match country i. The daily data run from September 22nd, 2014 to June 19th, 2018. Redenomination spreads are annualized and reported in basis points. Rows denoted by $\mu(\cdot)$, $\sigma(\cdot)$, $\rho(\cdot,\cdot)$, and Max$(\cdot)$ report, respectively, mean, standard deviation, correlation and maximum.

Country	FRA	ITA	GER
$\rho(RS, CR)$	-0.03	-0.01	0.08
$\mu(RS)$	1.46	8.23	0.10
$\sigma(RS)$	3.99	10.81	0.99
$\mu(RS/CR14)$	0.04	0.06	0.00
Max$(RS/CR14)$	0.40	0.32	0.42

Table 3: Regression of Eurozone sovereign yields on redenomination spreads

This table reports the results for time-series regressions of Eurozone (plus Denmark) government bond yields on French and Italian redenomination spreads, controlling for €-denominated overnight swap rates (OIS).

$$y_{j,T,t} - OIS_{€,T,t} = \alpha_{j,T} + \beta_{FRA,j,T} RS_{FRA,t} + \beta_{ITA,j,T} RS_{ITA,t} + \varepsilon_{j,T,t}, \quad (2)$$

for maturity $T = 5$ years. Newey–West standard errors are reported in parentheses. The daily data run from September 2014 to June 2018. Yields, swap rates, and redenomination spreads are measured in %-points.

Country	GER	AUT	DEN†	NED	IRE	BEL	ESP	ITA	FRA	POR
RS_{FRA}	-0.965	-0.939	-0.613	-0.210	0.514	0.042	0.805	0.365	1.230	5.410
	(0.434)	(0.221)	(0.249)	(0.335)	(0.364)	(0.216)	(0.520)	(0.522)	(0.210)	(0.757)
RS_{ITA}	-1.316	-0.441	-0.590	-0.770	-1.109	-0.433	-1.357	1.213	-0.678	-1.898
	(0.356)	(0.165)	(0.181)	(0.268)	(0.294)	(0.169)	(0.389)	(0.331)	(0.152)	(0.414)
Intercept	-0.390	-0.058	-0.033	-0.094	0.205	-0.021	0.612	0.615	0.045	1.479
	(0.028)	(0.013)	(0.024)	(0.020)	(0.025)	(0.015)	(0.031)	(0.026)	(0.012)	(0.077)
R^2	0.386	0.370	0.173	0.267	0.351	0.149	0.263	0.319	0.359	0.116
Obs.	967	965	967	965	818	967	966	967	967	967

†: included as a quasi-Eurozone member.

Table 4: Regression of € and $ FX rates on French and Italian redenomination spreads

This table reports the results for time-series regressions of exchange rate variables on French and Italian redenomination spreads, controlling for overnight swap rates.

$$e_{€,t} = \alpha + \beta_{FRA} RS_{FRA,t} + \beta_{ITA} RS_{ITA,t} + \gamma_{€} OIS_{€,t} + \varepsilon_t, \tag{11}$$

$$e_{\$/€,t} = \alpha + \beta_{FRA} RS_{FRA,t} + \beta_{ITA} RS_{ITA,t} + \gamma_{€} OIS_{€,t} + \gamma_{\$} OIS_{\$,t} + \varepsilon_t, \tag{12}$$

$$e_{\$,t} = \alpha + \beta_{FRA} RS_{FRA,t} + \beta_{ITA} RS_{ITA,t} + \gamma_{\$} OIS_{\$,t} + \varepsilon_t. \tag{13}$$

where $e_{€,t}$, $e_{\$/€,t}$, and $e_{\$,t}$ denote, respectively, the natural logarithms of the Bloomberg euro spot index, the euro-dollar exchange rate, and the ICE US-dollar spot index. The euro-dollar exchange rate is defined such that an increase reflects an appreciation of the euro against the dollar. For the two indices, an increase in e reflects an appreciation of the respective currency against a trade- and liquidity-weighted basket of other currencies. Newey–West standard errors (max. 10 lags) are reported in parentheses. The daily data run from September 2014 to June 2018. Redenomination spreads are measured in basis points.

Currency	EUR index	EURUSD	USD index
RS_{FRA}	−0.003	−0.005	0.004
	(0.000)	(0.000)	(0.000)
RS_{ITA}	0.001	0.000	0.000
	(0.000)	(0.000)	(0.000)
$OIS_{€}$	0.069	0.053	
	(0.015)	(0.044)	
$OIS_{\$}$		0.036	−0.036
		(0.019)	(0.006)
Intercept	6.770	0.081	4.601
	(0.005)	(0.027)	(0.008)
R^2	0.307	0.347	0.255
Obs.	969	969	972

Table 5: Regression of German and US government bond yields on RS

This table reports the results for time-series regressions of German (Panel A) and US (Panel B) government bond yields on French and Italian redenomination spreads, controlling for both €- and \$-denominated overnight swap rates.

$$y_{GER,T,t} = \alpha + \beta_{FRA,T} RS_{FRA,t} + \beta_{ITA,T} RS_{ITA,t} + \gamma_T OIS_{€,T,t} + \varepsilon_{i,T,t}, \quad (2)$$

$$y_{US,T,t} = \alpha + \beta_{FRA,T} RS_{FRA,t} + \beta_{ITA,T} RS_{ITA,t} + \gamma_T OIS_{\$,T,t} + \varepsilon_{i,T,t}, \quad (6)$$

for maturities $T = \{1, 2, 3, 5, 10\}$ years. Newey–West standard errors (max. 10 lags) are reported in parentheses. The daily data run from September 2014 to June 2018. Yields, swap rates, and redenomination spreads are measured in percentage points.

Maturity	1y	2y	3y	5y	10y
		Panel A: Bund yield, FRA			
RS_{FRA}	−1.266	−1.321	−1.087	−1.234	−0.186
	(0.182)	(0.251)	(0.269)	(0.401)	(0.154)
RS_{ITA}	−0.369	−0.612	−0.725	−1.101	−0.507
	(0.142)	(0.190)	(0.195)	(0.329)	(0.099)
OIS EUR	1.535	1.355	1.181	0.467	1.024
	(0.070)	(0.083)	(0.069)	(0.076)	(0.028)
Intercept	−0.013	−0.065	−0.124	−0.410	−0.115
	(0.012)	(0.018)	(0.020)	(0.027)	(0.011)
R^2	0.853	0.789	0.753	0.445	0.897
Obs	970	970	969	967	970
		Panel B: US Treasury yield, FRA			
RS_{FRA}	−0.723	−0.616	−0.490	-0.146	0.183
	(0.126)	(0.122)	(0.116)	(0.104)	(0.146)
RS_{ITA}	−0.073	−0.002	0.117	0.283	0.487
	(0.096)	(0.090)	(0.083)	(0.089)	(0.120)
OIS USD	1.070	1.007	0.959	0.892	0.768
	(0.011)	(0.017)	(0.021)	(0.025)	(0.026)
Intercept	−0.038	0.056	0.158	0.374	0.735
	(0.010)	(0.022)	(0.027)	(0.034)	(0.041)
R^2	0.989	0.975	0.966	0.952	0.913
Obs	970	970	970	970	970

Table 6: Regression of corporate CDS spreads on French and Italian redenomination spreads

This table reports the results for time-series regressions of corporate CDS spreads on French and Italian redenomination spreads, controlling for overnight swap rates.

$$S_t = \alpha + \beta_{FRA} RS_{FRA,t} + \beta_{ITA} RS_{ITA,t} + \gamma OIS_{€,t} + \varepsilon_t. \tag{14}$$

where S_t denotes the spread of different equally weighted portfolios of corporate CDS contracts: The first portfolio contains CDS written on the senior debt of the 125 investment grade corporates included in the iTraxx Europe CDS Index. The second and third portfolios contain, respectively, senior and subordinated CDS contracts for 30 investment grade financial companies (i.e., banks and insurance companies). The next ten portfolios split the original set of 125 CDS by industry into financial and non-financial companies, and by country into the five Eurozone countries with at least one financial company (Germany, the Netherlands, Italy, Spain, and France). Newey–West standard errors (max. 10 lags) are reported in parentheses. The row entitled $\mu(S_t)$ reports the time-series averages of the credit spreads in the respective portfolio. The daily data run from September 2014 to June 2018. All variables are measured in percentage points.

	All	Financials		GER		NED		ITA		ESP		FRA	
	Senior	Senior	Subord.	Fin.	Non-F.	Fin.	Non-F.	Fin.	Non-F.	Fin.	Non-F.	Fin.	Non-F.
RS_{FRA}	0.357	0.705	1.640	0.300	−0.012	1.229	0.297	1.510	0.179	0.794	0.017	1.475	0.460
	(0.183)	(0.266)	(0.465)	(0.209)	(0.254)	(0.217)	(0.119)	(0.358)	(0.192)	(0.588)	(0.484)	(0.357)	(0.166)
RS_{ITA}	−0.157	−0.157	−0.138	−0.071	−0.431	−0.514	−0.192	0.337	0.112	−0.750	−0.720	−0.705	−0.208
	(0.144)	(0.222)	(0.365)	(0.166)	(0.198)	(0.182)	(0.091)	(0.298)	(0.141)	(0.455)	(0.355)	(0.300)	(0.123)
$OIS_€$	−0.310	−0.638	−1.621	−0.724	−0.336	−0.505	−0.103	−1.421	−0.557	−1.177	−0.873	−0.428	−0.317
	(0.058)	(0.068)	(0.140)	(0.058)	(0.074)	(0.069)	(0.040)	(0.119)	(0.072)	(0.121)	(0.146)	(0.079)	(0.051)
Interc.	0.669	0.749	1.625	0.648	0.712	0.637	0.536	1.128	0.740	0.995	0.989	0.655	0.609
	0.0157	(0.020)	(0.038)	(0.017)	(0.020)	(0.019)	(0.010)	(0.034)	(0.016)	(0.040)	(0.039)	(0.023)	(0.014)
R^2	0.255	0.469	0.557	0.569	0.273	0.473	0.146	0.575	0.427	0.479	0.336	0.379	0.312
$\mu(S_t)$	0.664	0.753	1.656	0.655	0.679	0.618	0.525	1.193	0.758	0.957	0.939	0.622	0.602
Comp.	125	30	30	5	16	3	8	4	3	2	4	4	22
Obs..	967	967	967	967	967	967	967	967	967	967	967	967	967

Table 7: Regression of Eurozone sovereign yields on RS and CR CDS spreads

This table reports the results for time-series regressions of Eurozone (plus Denmark) net government bond yields on French and Italian redenomination risk, controlling for credit risk through CR CDS spreads.

$$y_{j,T,t} - OIS_{€,T,t} = \alpha_{j,T} + \beta_{FRA,j,T} RS_{FRA,t} + \beta_{ITA,j,T} RS_{ITA,t} + \\ + \psi_{FRA,j,T} CR_{FRA,t} + \psi_{ITA,j,T} CR_{ITA,t} + \varepsilon_{j,T,t}, \quad (9)$$

for maturity $T = 5$ years. Newey–West standard errors are reported in parentheses. The daily data run from September 2014 to June 2018. Yields, swap rates, and CDS spreads are measured in %-points.

Country	GER	AUT	DEN†	NED	IRE	BEL	ESP	ITA	FRA	POR
RS_{FRA}	-1.650	-1.103	-0.916	-0.773	-0.243	-0.087	-0.024	-0.710	0.874	1.399
	(0.325)	(0.166)	(0.223)	(0.201)	(0.192)	(0.157)	(0.332)	(0.406)	(0.086)	(0.853)
RS_{ITA}	-0.596	-0.103	-0.413	-0.187	-0.478	0.009	-0.541	1.735	-0.284	-1.397
	(0.178)	(0.104)	(0.142)	(0.116)	(0.108)	(0.101)	(0.170)	(0.155)	(0.055)	(0.513)
CR_{FRA}	1.579	0.805	0.333	1.273	1.363	1.090	1.768	0.909	0.870	-0.350
	(0.176)	(0.088)	(0.248)	(0.107)	(0.120)	(0.094)	(0.144)	(0.152)	(0.085)	(0.452)
CR_{ITA}	-0.001	-0.108	0.092	0.007	0.069	-0.201	0.036	0.397	-0.013	2.428
	(0.114)	(0.046)	(0.092)	(0.005)	(0.070)	(0.047)	(0.099)	(0.065)	(0.035)	(0.194)
Intercept	-0.875	-0.190	-0.234	-0.492	-0.277	-0.143	0.030	-0.088	-0.209	-1.004
	(0.088)	(0.042)	(0.069)	(0.046)	(0.047)	(0.047)	(0.089)	(0.051)	(0.020)	(0.151)
R^2	0.718	0.637	0.243	0.792	0.871	0.563	0.690	0.771	0.840	0.723
Obs.	967	965	967	965	818	967	966	967	967	967

†: included as a quasi-Eurozone member.

Table 8: Decomposition of Eurozone-G7 sovereign yields

This table reports the results for time-series regressions of five-year Eurozone sovereign yields on redenomination risk, credit risk (CR CDS spread), and five-year swap rates.

$$y_{j,t} = \alpha_j + \beta_j RS_{j,t} + \psi_j CR_{j,t} + \gamma_j OIS_{€,t} + \varepsilon_{j,t}, \tag{8}$$

for $j = \{FRA, ITA, GER\}$. The right panel uses the redenomination spreads of France and Italy as regressors, instead of the German redenomination spread. Newey–West standard errors are reported in parentheses. The daily data run from September 2014 to June 2018. Yields, swap rates, and CDS spreads are measured in %-points. The bottom panel reports t-statistics for the null hypothesis that the two β-coefficients are equal to one.

Country	FRA		ITA	GER
Subsample	full	02/17-06/18	full	full
RS_{FRA}	0.552	0.856		−1.827
	(0.091)	(0.128)		(0.412)
RS_{ITA}			1.128	−0.797
			(0.155)	(0.285)
CR_j	0.976	0.952	0.852	3.041
	(0.046)	(0.122)	(0.068)	(0.682)
$OIS_€$	1.021	1.110	1.447	0.803
	(0.029)	(0.062)	(0.067)	(0.080)
Intercept	−0.270	−0.302	−0.279	−0.855
	(0.013)	(0.023)	(0.071)	(0.097)
R^2	0.930	0.867	0.855	0.592
Obs.	967	351	969	966
t-stat: $\beta^{RS} = 1$	-4.92	-1.13	0.82	
t-stat: $\beta^{CR} = 1$	-0.53	-0.39	-2.19	2.99

Table 9: Subsample regression of Eurozone sovereign yields – 01/2017 to 06/2018

This table reports the results for time-series regressions of Eurozone (plus Denmark) sovereign bond yields on French and Italian redenomination risk, for the subsample January 2017 to June 2018 (controlling for French and Italian credit risk, Regression (9)). Newey–West standard errors are reported in parentheses. The daily data run from January 2017 to June 2018. Yields, swap rates, and CDS spreads are measured in %-points.

Country	GER	AUT	DEN†	NED	IRE	BEL	ESP	ITA	FRA	POR
					Panel B: Regression (9)					
RS_{FRA}	-0.742	-0.558	-0.089	-0.271	0.370	0.243	1.165	-0.444	0.870	2.822
	(0.175)	(0.076)	(0.188)	(0.080)	(0.077)	(0.187)	(0.177)	(0.287)	(0.075)	(0.722)
RS_{ITA}	-0.339	0.357	0.387	0.044	-0.218	0.459	-0.507	1.141	-0.265	-1.650
	(0.090)	(0.071)	(0.131)	(0.047)	(0.054)	(0.106)	(0.106)	(0.131)	(0.052)	(0.535)
CR_{FRA}	-0.696	0.934	1.920	0.249	0.708	1.583	-1.674	-2.533	0.802	-2.139
	(0.280)	(0.295)	(0.529)	(0.193)	(0.183)	(0.375)	(0.284)	(0.486)	(0.166)	(1.466)
CR_{ITA}	0.520	-0.337	-0.639	0.220	0.103	-0.459	0.902	1.468	0.046	2.729
	(0.099)	(0.104)	(0.159)	(0.057)	(0.062)	(0.137)	(0.100)	(0.157)	(0.060)	(0.459)
Intercept	-1.090	-0.121	-0.039	-0.602	-0.286	-0.098	-0.270	-0.391	-0.262	-1.017
	(0.047)	(0.046)	(0.055)	(0.022)	(0.018)	(0.067)	(0.051)	(0.064)	(0.023)	(0.193)
R^2	0.566	0.409	0.262	0.780	0.887	0.330	0.798	0.932	0.913	0.813
Obs.	373	373	373	373	364	373	373	373	373	373

†: included as a quasi-Eurozone member.

Table 10: Regression of Eurozone sovereign CDS spreads on redenomination spreads

This table reports the results for time-series regressions of Eurozone sovereign CDS spreads on French and Italian redenomination risk.

$$CR14_{j,t} = \alpha_j + \beta_{FRA,j} RS_{FRA,t} + \beta_{ITA,j} RS_{ITA,t} + \varepsilon_{j,t}, \tag{10}$$

Newey–West standard errors are reported in parentheses. The daily data run from September 2014 to June 2018. CDS spreads are measured in basis points.

	5-year CR14 CDS spreads						
Country	GER	AUT	NED	IRE	BEL	ESP	POR
RS_{FRA}	0.317	0.285	0.491	1.043	0.151	0.296	5.619
	(0.058)	(0.090)	(0.068)	(0.249)	(0.246)	(0.368)	(0.760)
RS_{ITA}	−0.103	−0.278	−0.145	−0.615	−0.601	−0.835	−2.002
	(0.022)	(0.062)	(0.026)	(0.158)	(0.188)	(0.297)	(0.423)
Intercept	16.35	25.68	33.39	52.18	39.31	87.53	203.74
	(0.403)	(0.600)	(1.214)	(1.627)	(1.508)	(2.267)	(7.975)
R^2	0.118	0.223	0.136	0.181	0.249	0.202	0.116
Obs.	970	970	970	970	970	970	970

Table 11: Bank-sovereign home bias

This table reports the relative exposures of banks to different sovereign issuers within liquid asset holdings. I consider net direct exposures in assets held as *available-for-sale (AFS)*, *held-for-trading (HFT)*, and *held-to-maturity (HTM)*. The data refer to balance sheet exposures as of December 31st, 2015, and are obtained from the European Banking Authority (EBA) and its reports on the stress tests conducted in 2016.

	Bank Country												
Sovereign	AUT	BEL	DEN	ESP	FRA	GER	IRE	ITA	NED	NOR	POL	SWE	UK
AUT	**20.1**	0.9	4.3	0.0	2.1	2.1	0.1	3.5	4.0	0.0	0.0	1.2	0.5
BEL	0.4	**40.9**	5.5	0.1	8.0	2.4	2.1	0.5	8.8	0.0	0.0	3.7	0.9
DEN	0.0	0.0	**12.2**	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	5.6	0.5
ESP	0.3	5.2	6.3	**50.5**	3.8	3.2	7.5	7.8	2.5	0.0	0.0	0.0	0.5
FRA	1.3	9.0	12.8	0.7	**38.8**	4.5	6.1	3.7	11.3	0.0	0.0	8.3	4.0
GER	1.8	0.3	10.2	0.0	5.3	**44.4**	1.0	3.9	14.6	5.5	0.0	19.1	6.7
IRE	0.0	1.8	3.1	0.0	0.5	0.8	**67.6**	0.1	0.0	0.0	0.0	0.1	0.2
ITA	1.3	10.2	4.8	9.0	8.3	4.6	7.4	**65.8**	3.0	0.0	0.0	0.3	1.3
NED	1.1	0.5	6.3	0.2	2.6	4.2	2.0	0.4	**29.4**	0.0	0.0	3.9	1.6
NOR	0.0	0.0	0.4	0.1	0.0	0.0	0.0	0.1	0.0	**63.2**	0.0	4.9	0.1
POL	5.5	1.8	0.0	2.0	0.9	3.8	0.6	2.6	3.9	0.0	**98.8**	0.0	0.2
SWE	0.2	0.0	7.9	0.0	0.1	0.3	0.0	0.2	0.6	7.0	0.0	**18.0**	0.4
UK	0.0	0.0	13.1	2.4	1.7	1.4	4.0	0.1	0.2	0.0	0.0	0.0	**26.8**
POR†	0.0	0.5	1.0	3.7	0.7	0.5	0.7	0.1	0.0	0.0	0.0	0.0	0.1
US	2.7	1.0	0.0	5.4	10.9	12.5	0.0	1.0	5.8	1.6	0.0	20.8	24.8
CH	0.0	0.0	0.0	0.0	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.5
CAN	0.0	0.5	0.0	0.0	1.3	0.7	0.0	0.3	0.7	20.7	0.0	0.9	2.5
Others	65.2	27.5	12.1	25.9	14.6	13.8	0.8	10.0	15.0	2.1	1.2	13.1	28.4

†: No Portuguese banks were included in the 2016 EBA stress test, due to a size threshold.

Table 12: Summary statistics – Market depth

This table reports the market depth by contract type as the number of quote submissions from financial intermediaries to Markit. Rows denoted by $\mu(\cdot)$, $\sigma(\cdot)$, $\rho(\cdot,\cdot)$, Max$(\cdot)$, and Min$(\cdot)$ report, respectively, the mean, standard deviation, correlation, maximum, and minimum of the respective variables.

Country	FRA	ITA	GER	AUT	BEL	ESP	IRE	NED	POR
μ(Depth CR14)	4.74	6.32	4.29	4.48	4.50	5.93	4.44	3.77	5.63
μ(Depth CR)	4.60	5.62	4.16	5.04	4.30	5.84	4.91	4.11	6.90
Min(Depth CR14)	2.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00
Min(Depth CR)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Max(Depth CR14)	10.00	12.00	9.00	9.00	8.00	11.00	10.00	11.00	11.00
Max(Depth CR)	10.00	12.00	9.00	9.00	8.00	11.00	10.00	11.00	11.00
σ(Depth CR14)	1.48	1.62	1.23	1.24	1.15	1.90	1.28	1.33	2.03
σ(Depth CR)	1.46	2.21	1.33	1.24	1.23	1.97	1.14	1.29	1.54
ρ(Depth CR14, Depth CR)	0.86	0.79	0.87	0.62	0.76	0.94	0.77	0.86	0.63

B Figures

Figure 1: Aggregate outstanding notionals by country in $bn from swapsinfo.org.

Panel A: Net *Panel B: Gross*

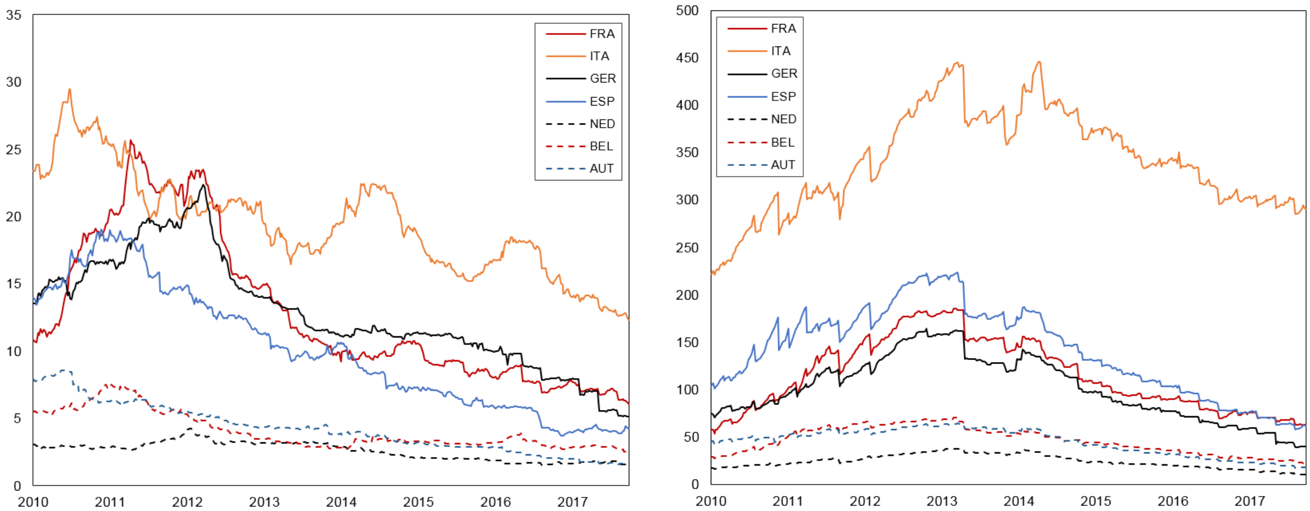


Figure 2: CDS spreads (in bps) under 2003- and 2014 ISDA definitions for the control group.

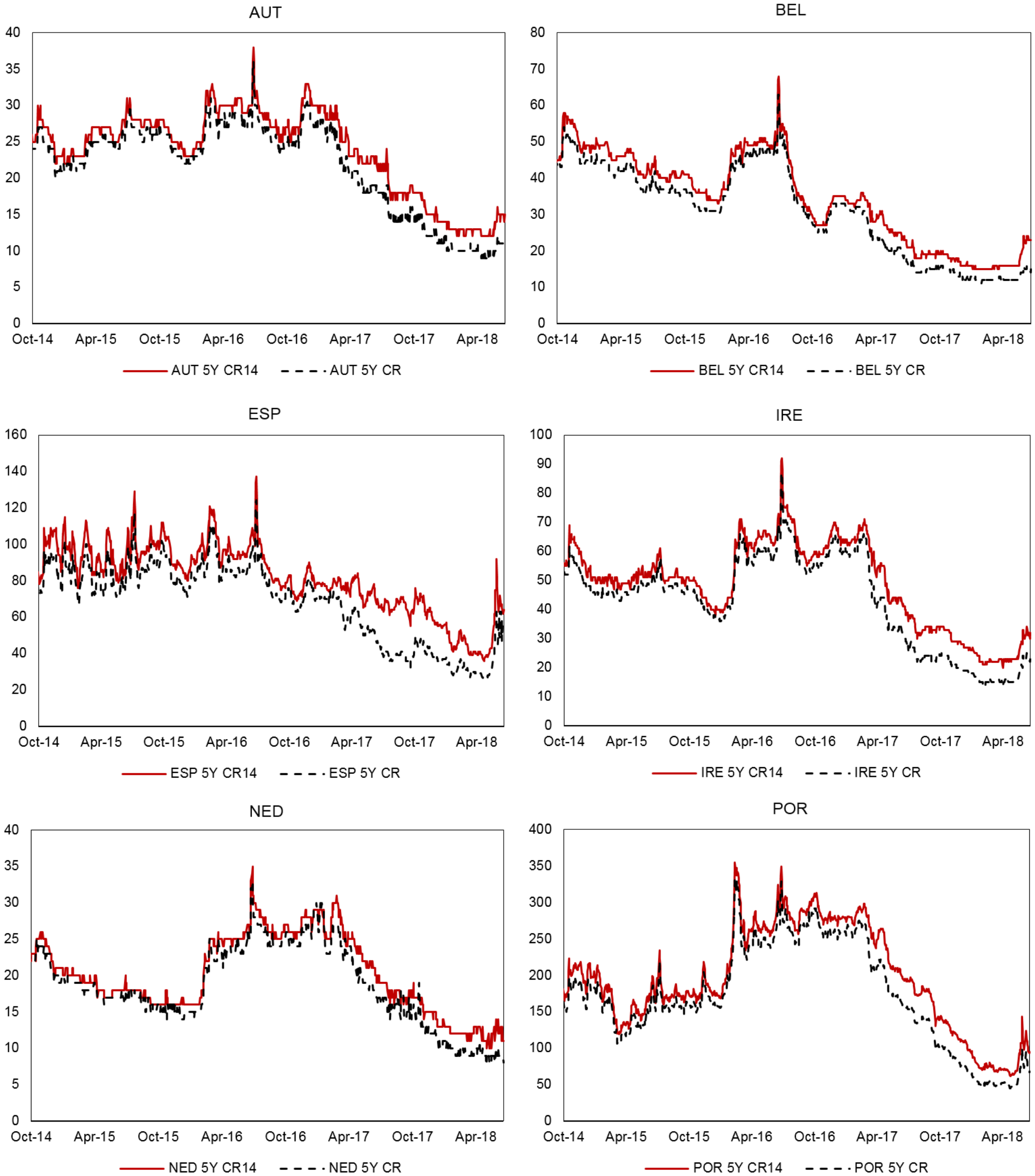


Figure 3: CDS spreads (in bps) under 2003- and 2014 ISDA definitions for FRA, ITA, and GER.

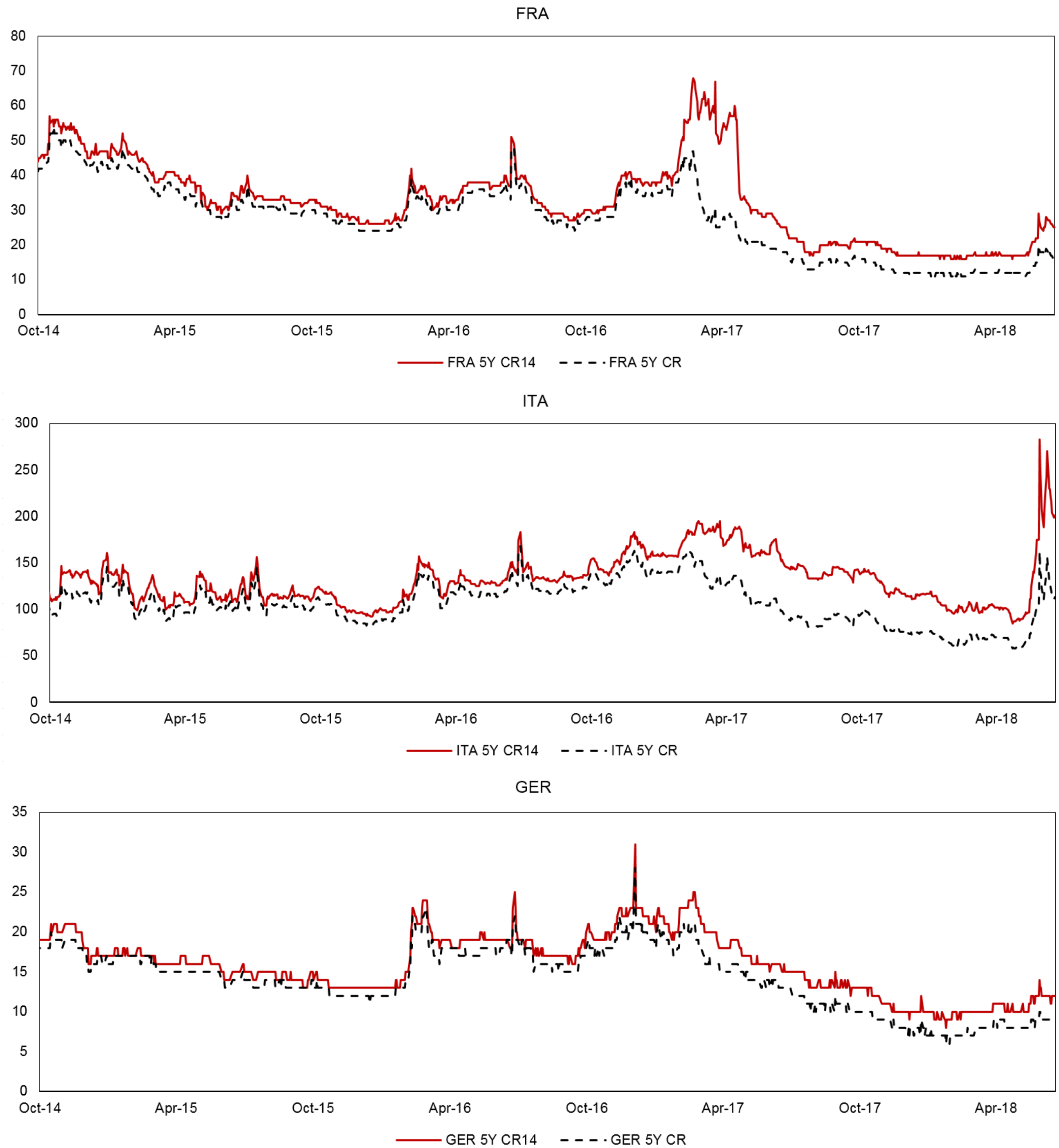


Figure 4: Synthetic control — observed (solid, blue) versus synthetically constructed (dashed, red) CR spread for Belgium (top), Spain (middle), and Ireland (bottom).

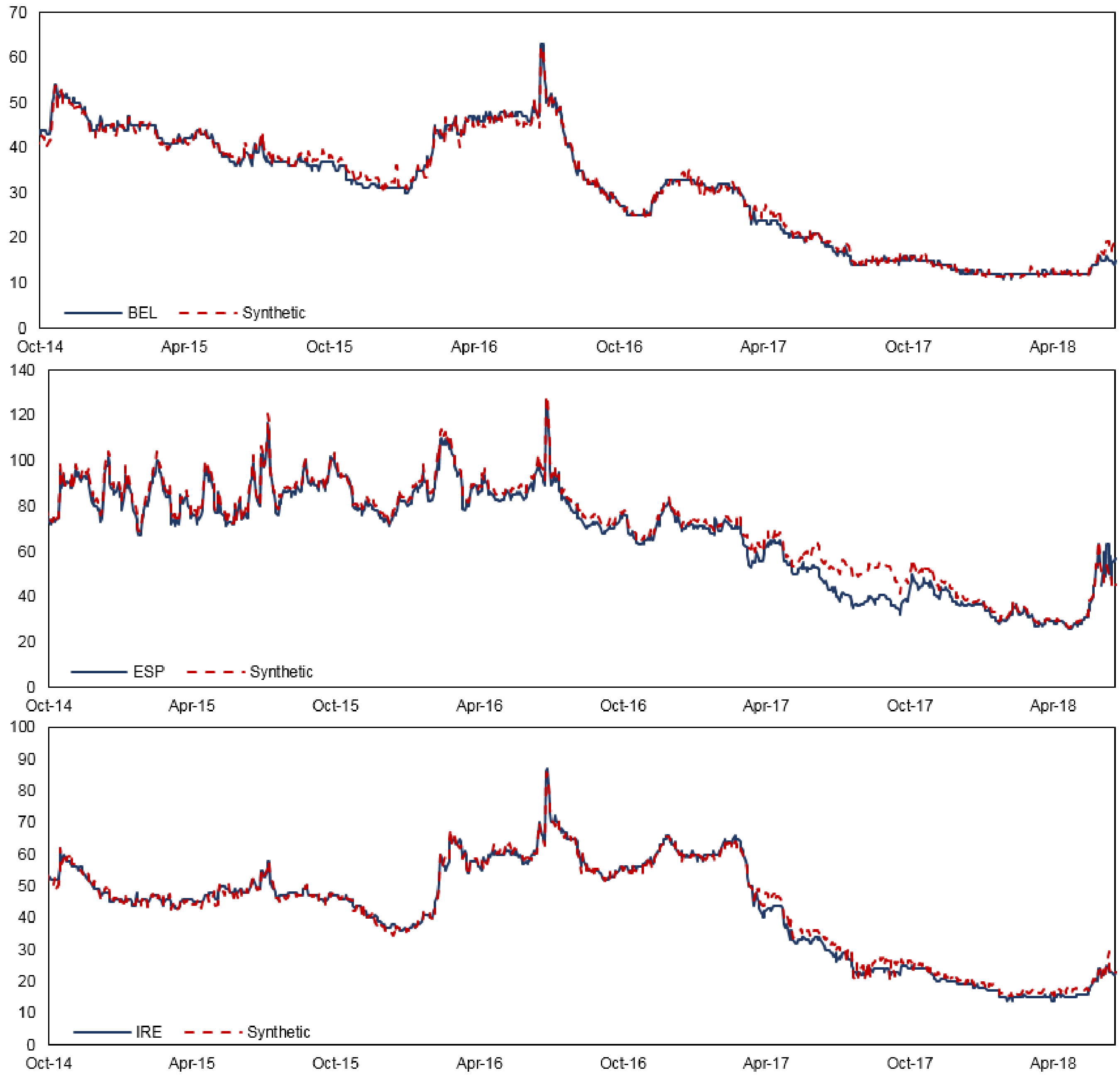
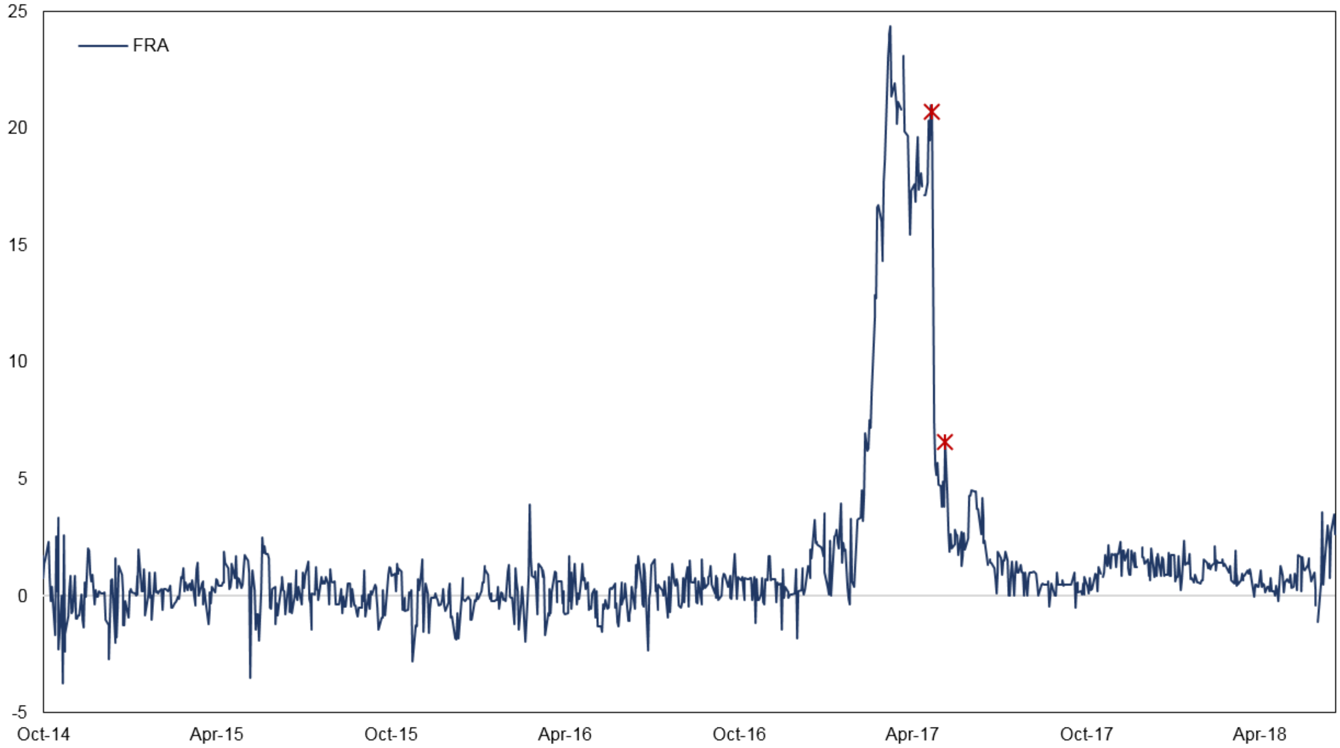


Figure 5: Redenomination spreads for France and Germany (bottom). Asterisks denote major plebiscites: 1st and 2nd round of the French presidential elections on April 23rd and May 7th, 2017. In each case, the asterisk marks the observation for the Friday preceding the Sunday plebiscite.



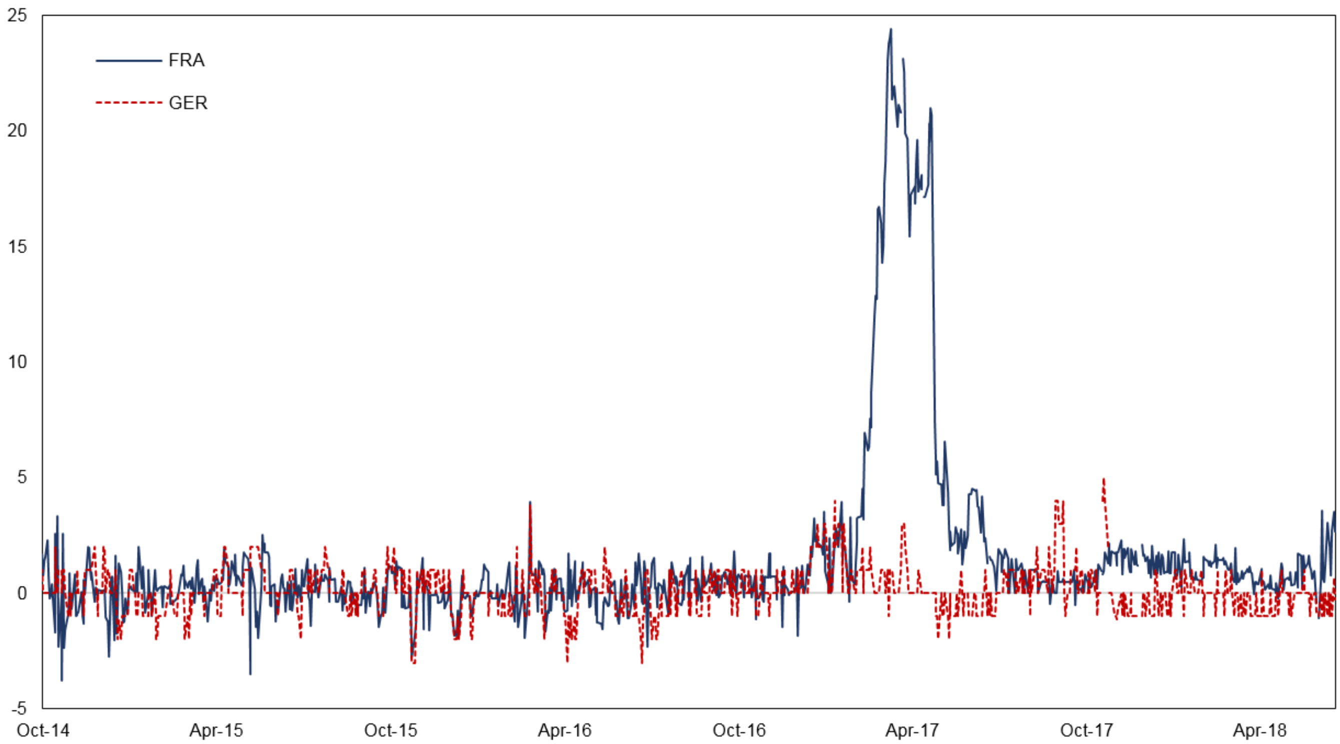


Figure 6: RS_{FRA} (LHS) and combined poll share of J.-L. Mélenchon & M. Le Pen (RHS)

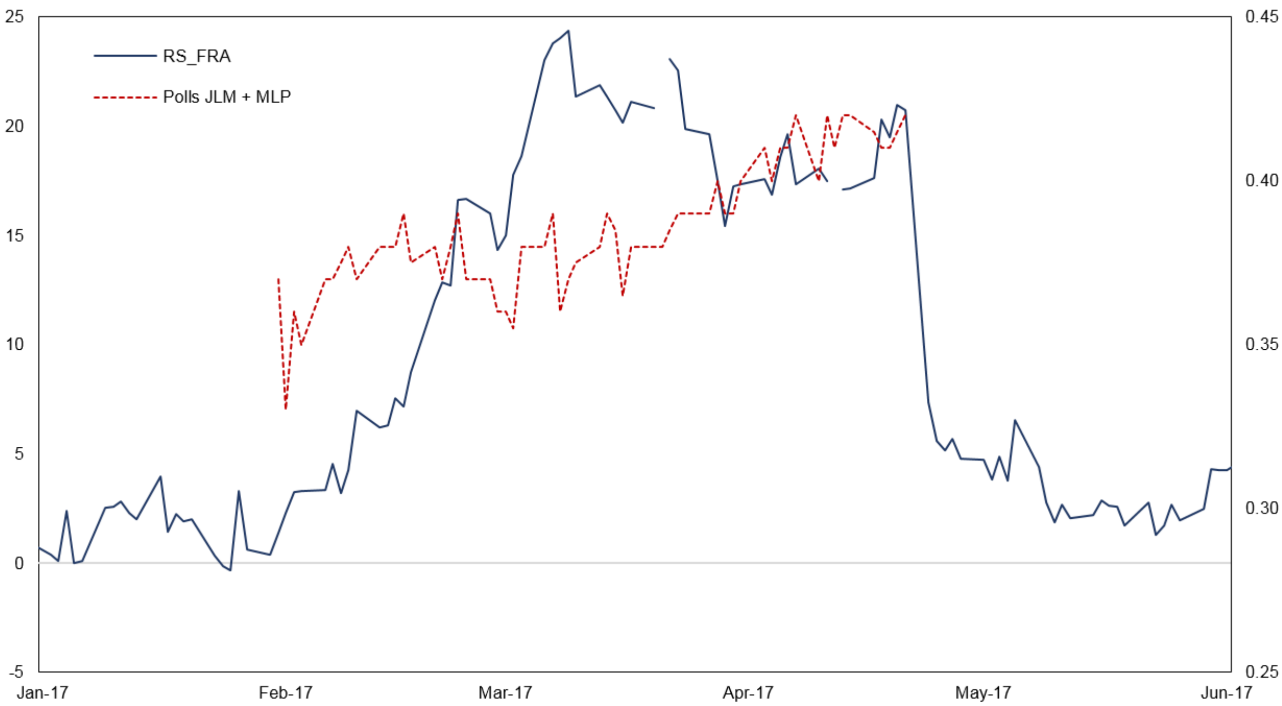


Figure 7: Redenomination spread for Italy. Asterisks denote major plebiscites: the constitutional referendum in Italy, held on December 4th, 2016, as well as the general elections on March 4th, 2018.

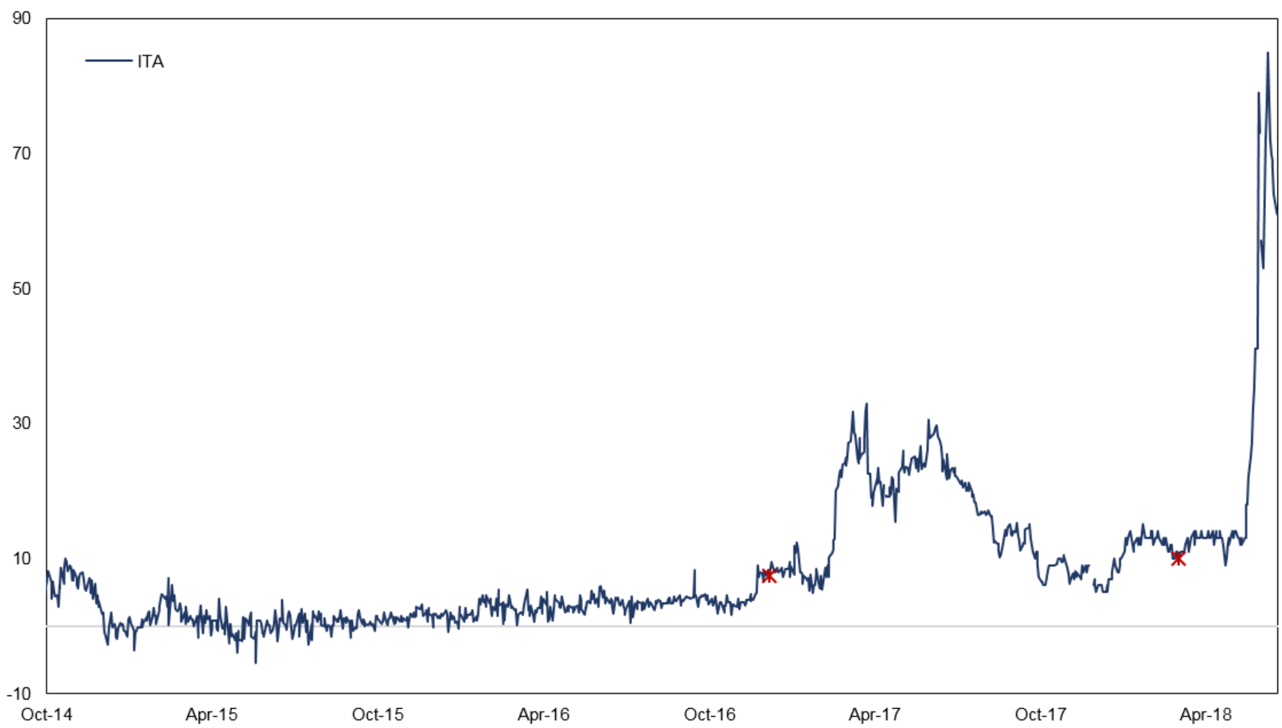


Figure 8: Redenomination spreads for France and Italy, as a fraction of the CR14 CDS spread.

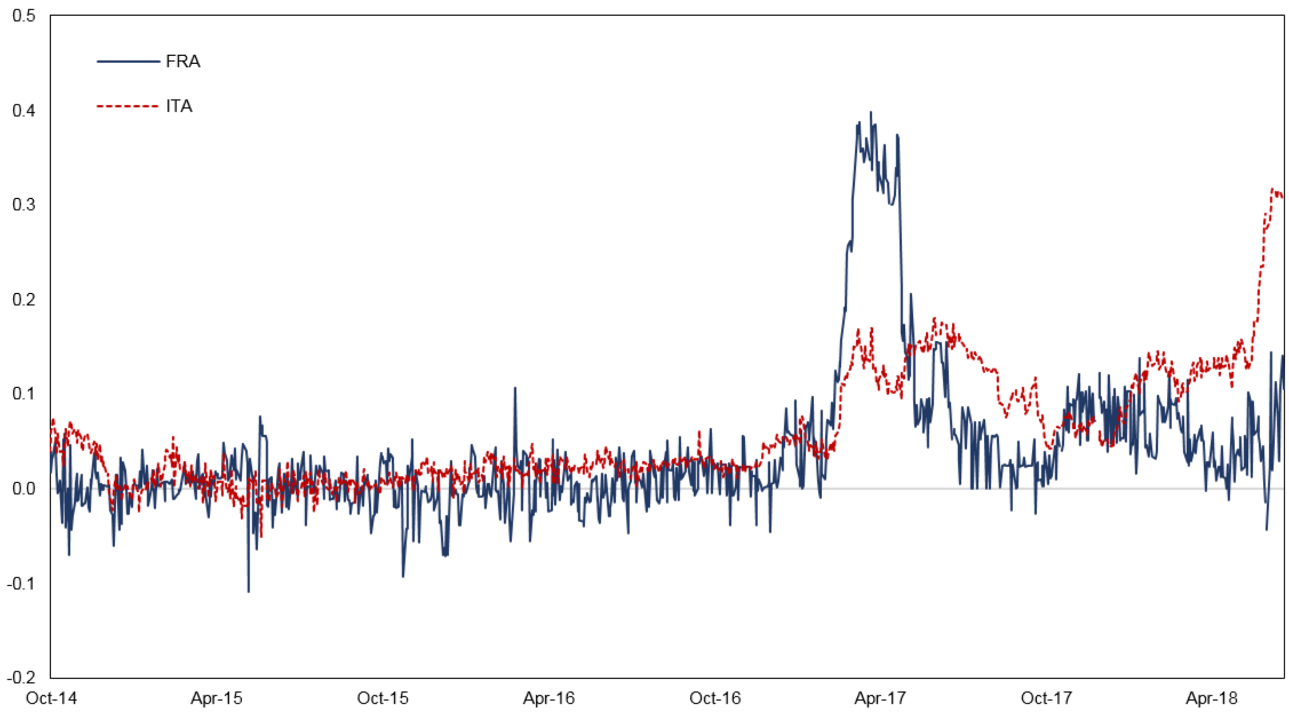


Figure 9: Slope coefficients from Regression (2) of Eurozone government bond yields with maturity of five years on French (left) and Italian (right) redenomination spreads. The 95% confidence bars are based on Newey–West standard errors. As a robustness check, the middle panels show the same coefficients from Regression (9), which controls for French and Italian credit risk. The lower panels plot the coefficients on credit risk. The triangular marker in the left-hand side panels indicates the β_{FRA} estimate for Italian yields, once RS_{ITA} is dropped from the regressors.

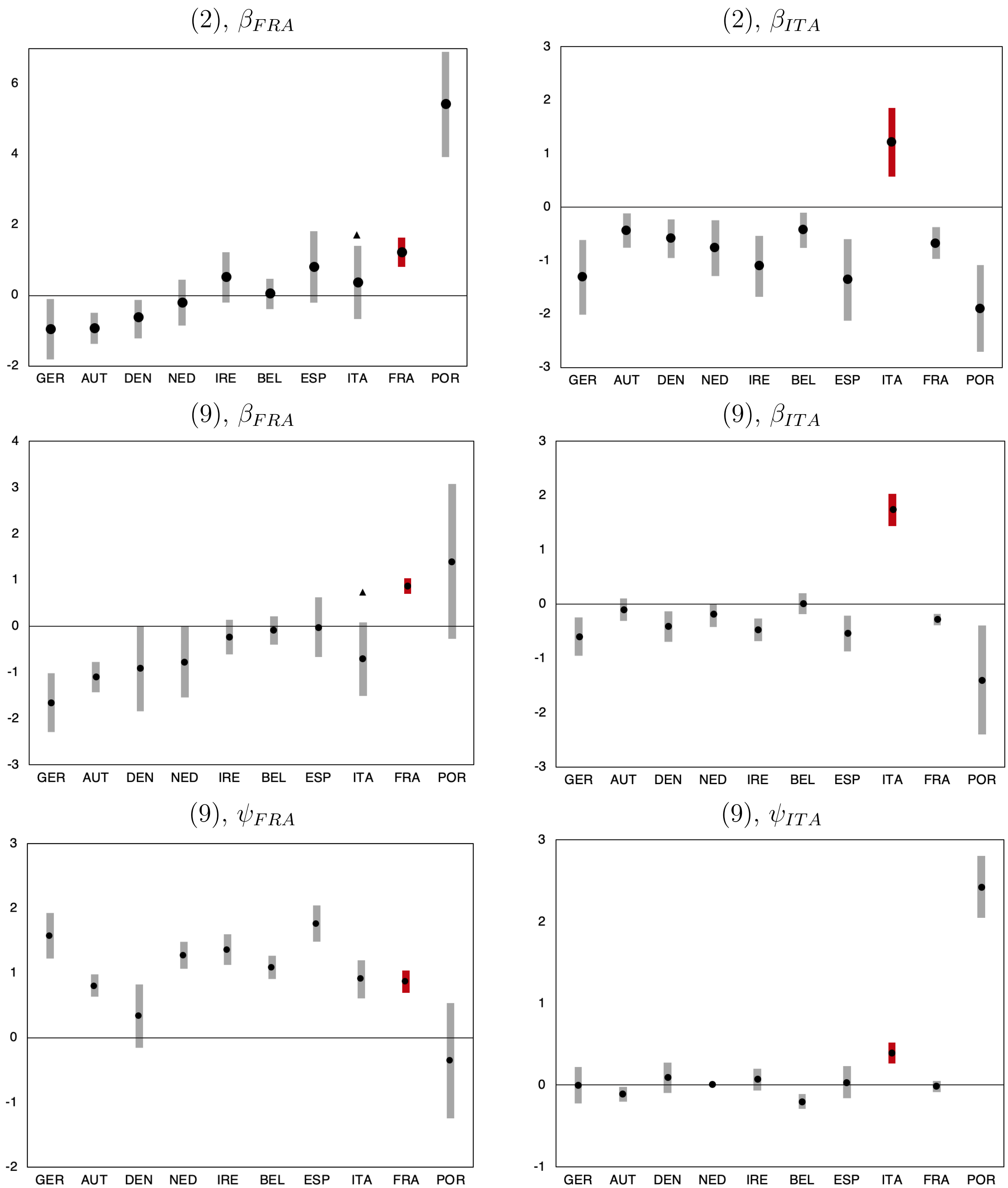


Figure 10: Slope coefficients of German and US government bond yields on RS from Table 5.

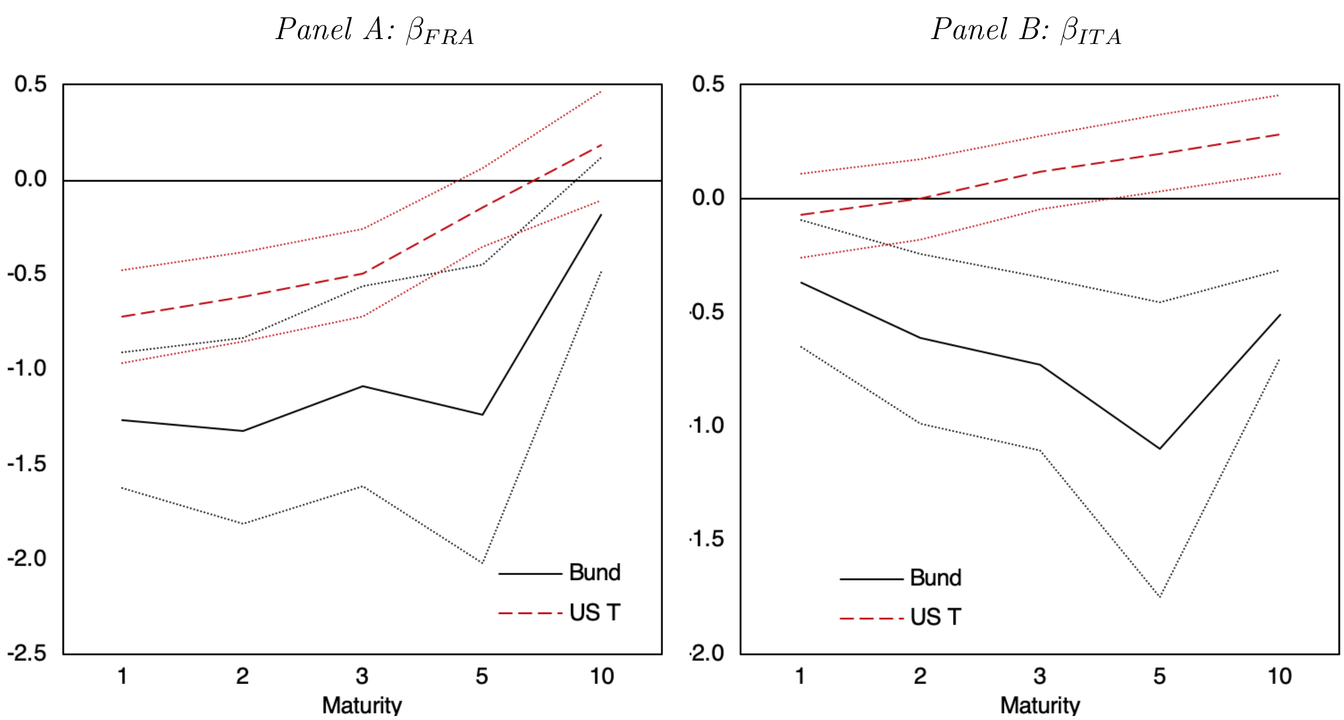
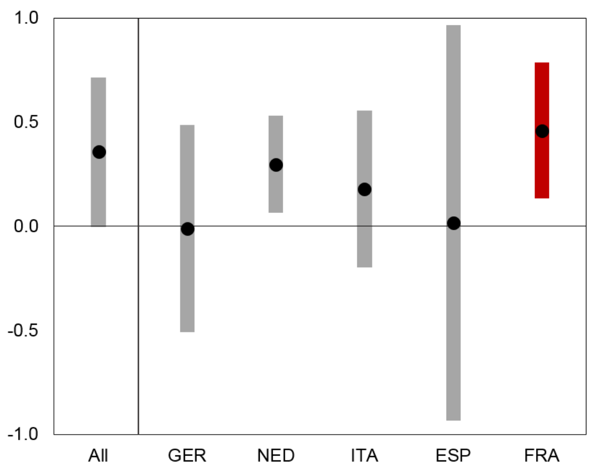
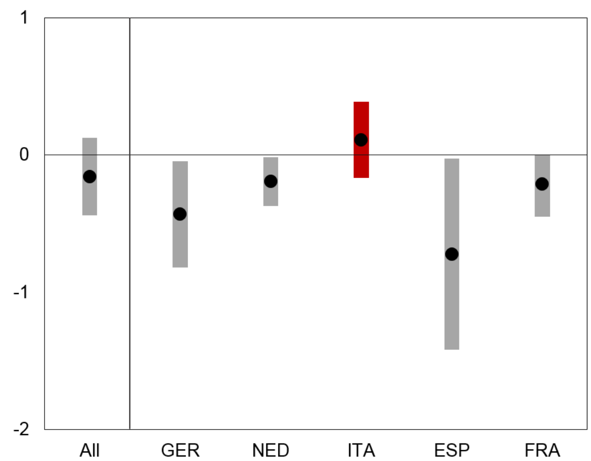


Figure 11: Slope coefficients from Regression (14) of Corporate five-year CDS spreads on French (left) and Italian (right) redenomination spreads with 95% confidence bars (Newey–West s. e.).

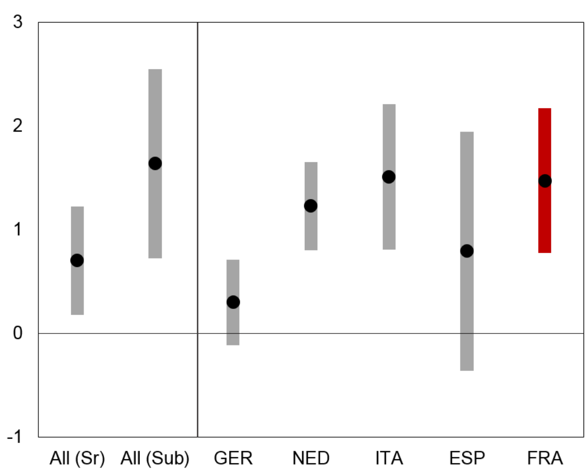
Panel A: β_{FRA}, all / non-financial



Panel B: β_{ITA}, all / non-financial



Panel A: β_{FRA}, financial



Panel B: β_{ITA}, financial

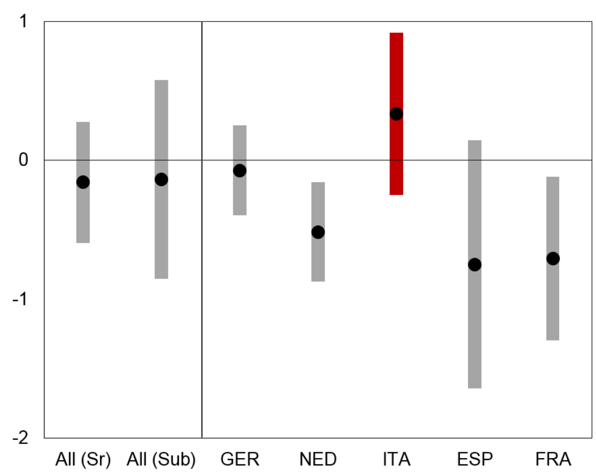


Figure 12: Slope coefficients from Regressions (2) and (10) of, respectively, five-year Eurozone sovereign bond yields and 5-year CR14 CDS spreads on French (left) and Italian (right) redenomination risk. I omit confidence bars in the interest of readability.

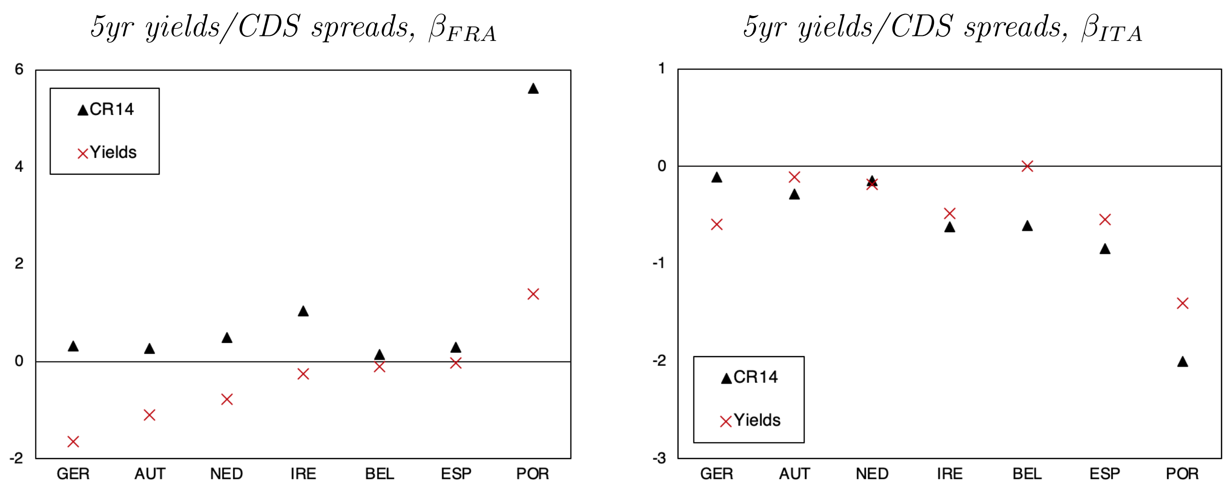
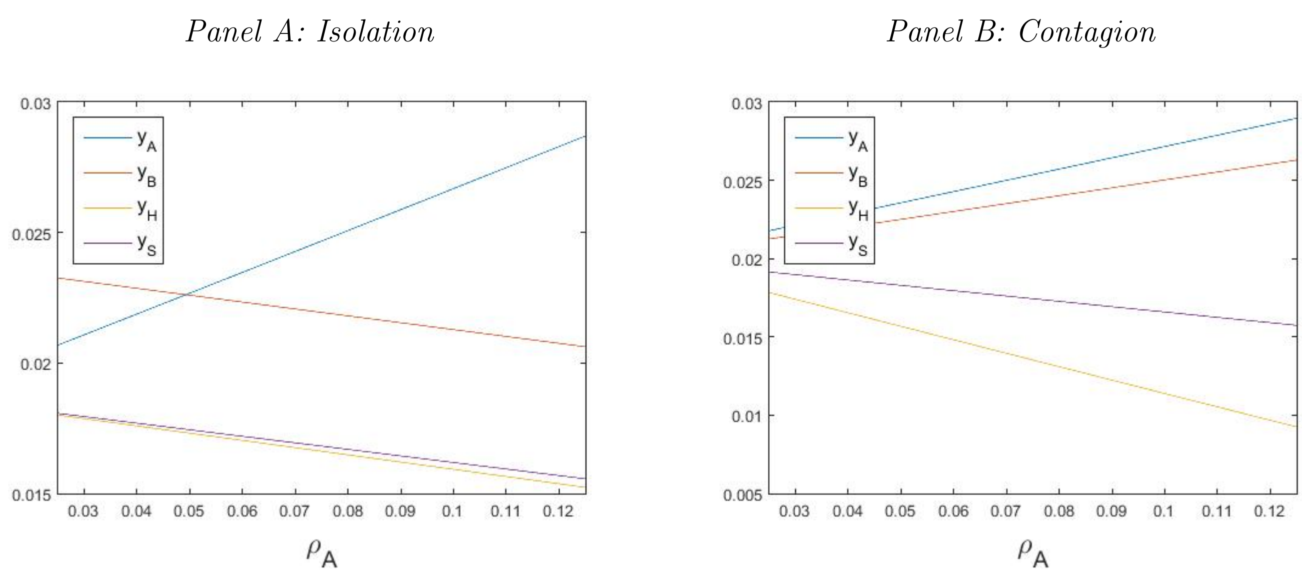


Figure 13: Comparative statics of risky bond investments by banks a and b, and (net) bond yields with respect to redenomination probability in country A.



Parameters: $d^a = d^b = 0.02$, $\rho_B = 0.05$, $\delta_A = 0.1$, $\delta_B = 0.08$, $\sigma_A = \sigma_B = \sigma_H = \sigma_S = 0.51$.

Figure 14: Regression coefficients $\beta_{FRA,j}$ from Regression (9) (horizontal axis) against fundamental variables (vertical axis, obtained from OECD) by country, with univariate R^2.

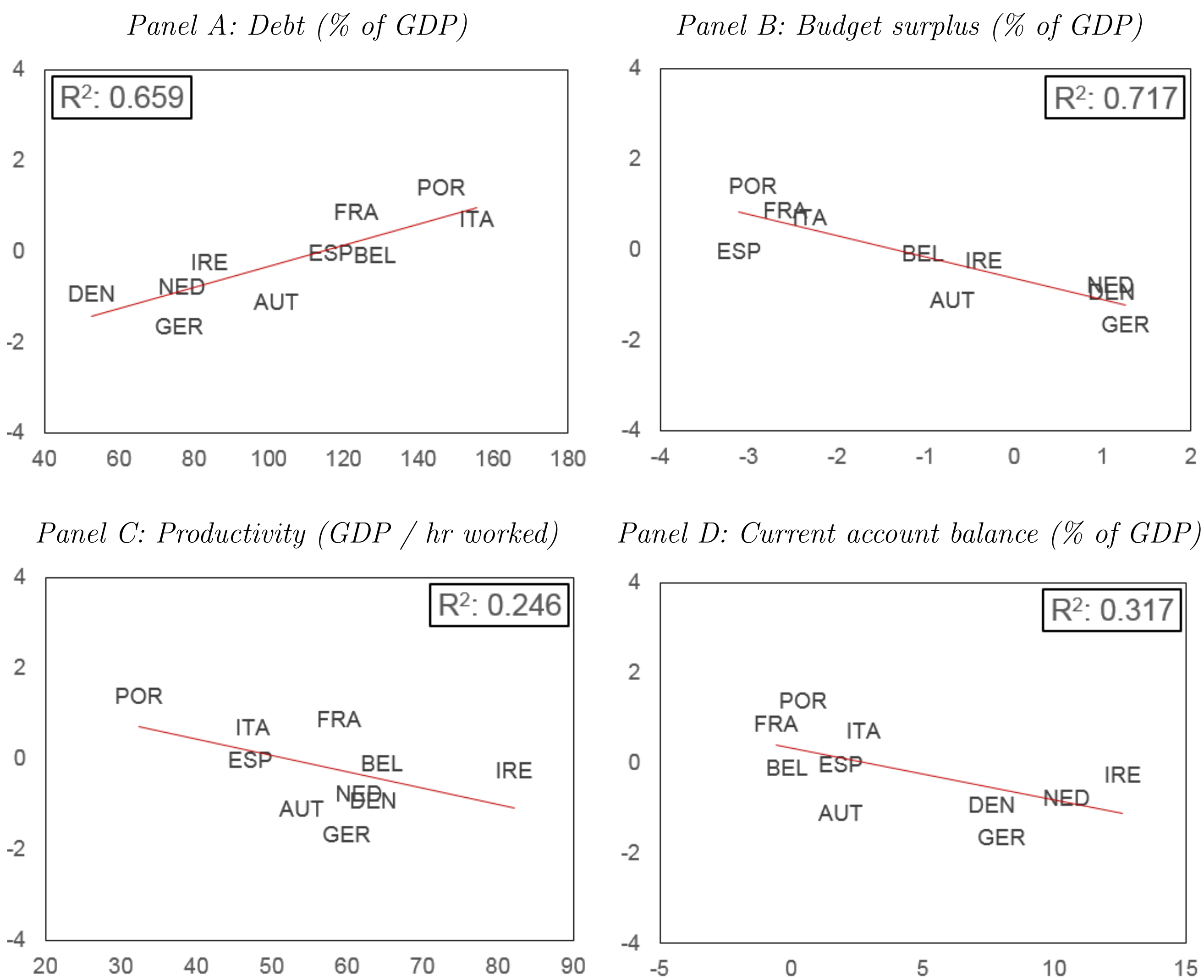
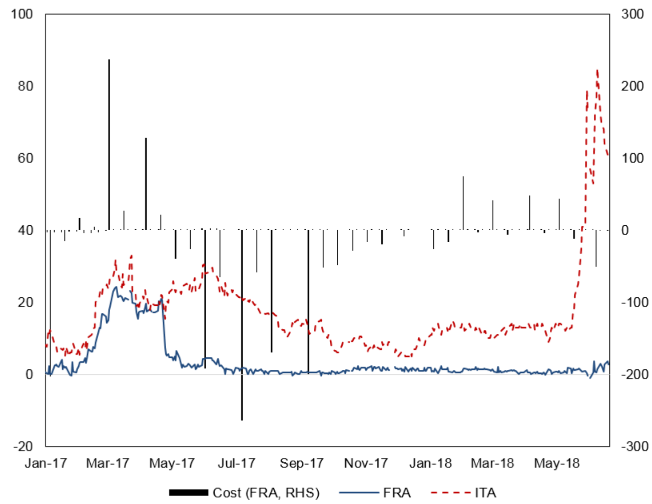
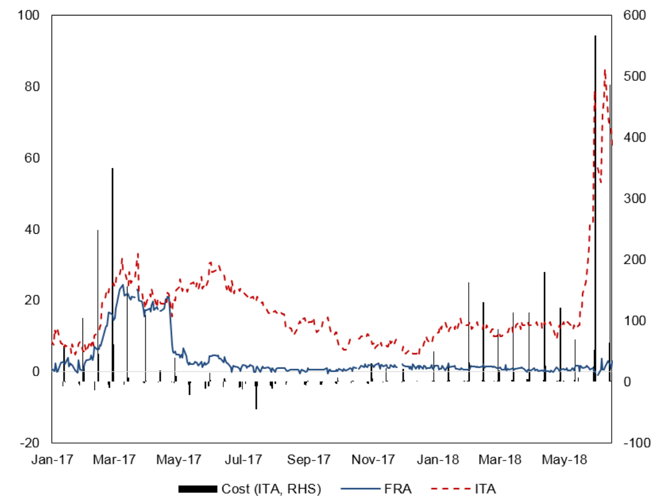


Figure 15: Cost of redenomination risk – additional funding cost attributable to French and Italian redenomination risk on debt issued between January 2017 and June 2018. Differential interest rates on the issuance by country j on date t are computed as $c_{j,t} = \hat{\beta}_{j,t}^{FRA} RS_{FRA,t} + \hat{\beta}_{j,t}^{ITA} RS_{ITA,t}$, using 250-trading-day rolling windows up to date t. Differential interest rates are then multiplied by the observed issuance volume, $v_{j,t}$, capitalized with annuity factor $a(T, y_{j,t,T})$ as $C_{j,t} = c_{j,t} \cdot v_{j,t} \cdot a(T, y_{j,t,T})$, and plotted on the RHS axes, in €m.

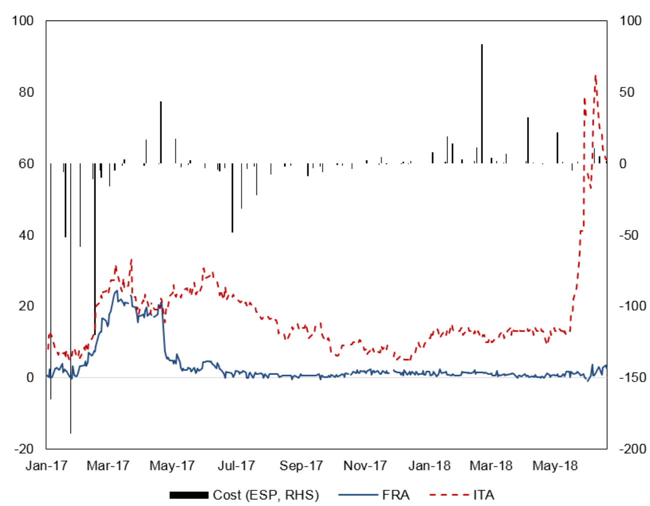
Panel A: France



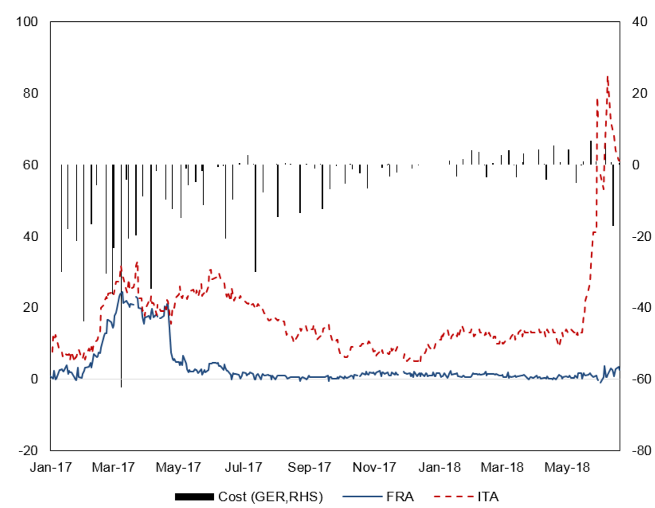
Panel B: Italy



Panel C: Spain



Panel D: Germany



C Proofs

In the interest of parsimony, I omit the bulky closed-form expressions for equilibrium yields and comparative statics w.r.t. ρ_A. Instead, Figure 13 provides a visual exposition of the different spillover effects in the isolation and contagion cases. The equilibrium objects, i.e., four bond yields and six portfolio weights, are determined by the four market clearing conditions and six first-order conditions w.r.t. bond investments:

$$\begin{aligned}
\sigma_J =&(w_J^a + w_J^b) \cdot y_J && \text{for } J = \{A, B, S, H\} \\
0 =& \left(\frac{p_1}{e_1^i} + \frac{p_3}{e_3^i}\right)(y_A - y_S) + \left(\frac{p_2}{e_2^i} + \frac{p_4}{e_4^i}\right)(y_A(1-\delta^A) - y_S) && \text{for } i = \{a, b\} \\
0 =& \left(\frac{p_1}{e_1^i} + \frac{p_2}{e_2^i}\right)(y_B - y_S) + \left(\frac{p_3}{e_3^i} + \frac{p_4}{e_4^i}\right)(y_B(1-\delta^B) - y_S) && \text{for } i = \{a, b\} \\
0 =& \left(\frac{p_1}{e_1^i} + \frac{p_2}{e_2^i} + \frac{p_3}{e_3^i}\right)(y_H - y_S) + \frac{p_4}{e_4^i}(y_H(1-\delta^H) - y_S) && \text{for } i = \{a, b\}
\end{aligned}$$

Due to market completeness, the equilibrium can be determined alternatively based on the prices for the four Arrow-Debreu securities. I go on to prove the two remaining effects, namely home bias in redenominatable sovereign bond holdings and the sub-zero lower bound of redenominatable haven bond yields.

Home bias: $w_A^a > w_A^b$ and $w_B^a < w_B^b$.

Proof. With four linearly independent assets, and four states of the world, markets are complete. Due to market completeness, marginal utilities (and hence equity values) are equalized state-by-state across agents in equilibrium: $u'(e_s^a) = u'(e_s^b) \Leftrightarrow e_s^a = e_s^b \; \forall s$.

$$\begin{aligned}
e_1^a = e_1^b \Leftrightarrow & w_A^a y_A + w_B^a y_B + w_S^a y_S + w_H^a y_H - d^a \\
=& w_A^b y_A + w_B^b y_B + w_S^b y_S + w_H^b y_H - d^b && (15) \\
e_2^a = e_2^b \Leftrightarrow & w_A^a y_A(1-\delta_A) + w_B^a y_B + w_S^a y_S + w_H^a y_H - d^a(1-\delta_A) \\
=& w_A^b y_A(1-\delta_A) + w_B^b y_B + w_S^b y_S + w_H^b y_H - d^b && (16) \\
e_3^a = e_3^b \Leftrightarrow & w_A^a y_A + w_B^a y_B(1-\delta_B) + w_S^a y_S + w_H^a y_H - d^a \\
=& w_A^b y_A + w_B^b y_B(1-\delta_B) + w_S^b y_S + w_H^b y_H - d^b(1-\delta_B) && (17) \\
e_4^a = e_4^b \Leftrightarrow & w_A^a y_A(1-\delta_A) + w_B^a y_B(1-\delta_B) + w_S^a y_S + w_H^a y_H(1-\delta_H) - d^a(1-\delta_A) \\
=& w_A^b y_A(1-\delta_A) + w_B^b y_B(1-\delta_B) + w_S^b y_S + w_H^b y_H(1-\delta_H) - d^b(1-\delta_B) && (18)
\end{aligned}$$

Combining (15)–(17) yields $w_A^a - w_A^b = d^a/y_A > 0$ and $w_B^b - w_B^a = d^b/y_B > 0$. Home bias, i.e., the difference between risky bond holdings by the domestic and the foreign bank, is positive and proportional to the domestic bank's redenominatable deposits. □

Note that this proof does not cover the extreme case of perfectly correlated redenominations, where states 2 and 3 have probability 0. In this case, bond payoffs A, B, and H are no longer linearly independent and the bond holdings are indeterminate. Assigning $\varepsilon > 0$ probability to states 2 and 3 restores the proof.

Sub-zero lower-bound: $y_H - y_S < 0$.

Proof. By each bank's Euler equation, the price of an asset with payoff X is given by $\mathbb{E}(y_S^{-1} u'(e^i) X)$. The Arrow-Debreu security that pays off in state (4) consists of $-\delta_H^{-1}$ units of bond H, and δ_H^{-1} units of bond S. Bond prices are y_H^{-1} and y_S^{-1} , respectively, and therefore

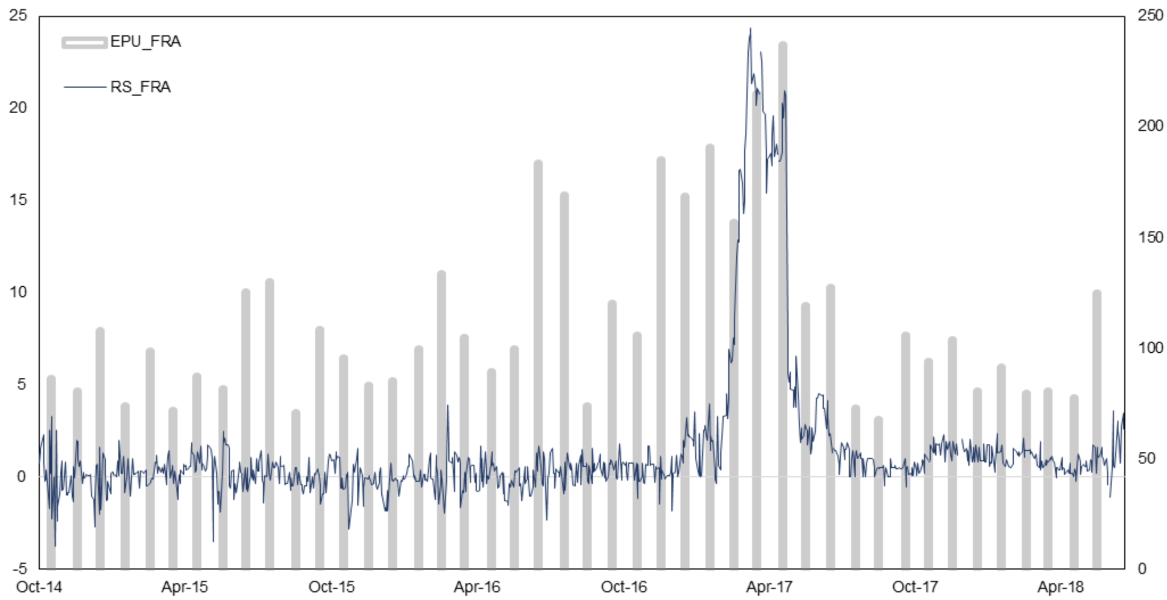
$$\begin{aligned} \delta_H^{-1}(y_S^{-1} - y_H^{-1}) &= \frac{1}{y_S} \cdot \frac{p_4}{e_4^i} \\ \Rightarrow \delta_H^{-1}(1 - y_S/y_H) &= \frac{p_4}{e_4^i} \end{aligned} \tag{19}$$

Equity is strictly positive by assumption and $p_4 \in (0,1)$. The RHS of (19) is therefore strictly positive, which, together with $\delta_H < 0$, implies that $y_H < y_S$. □

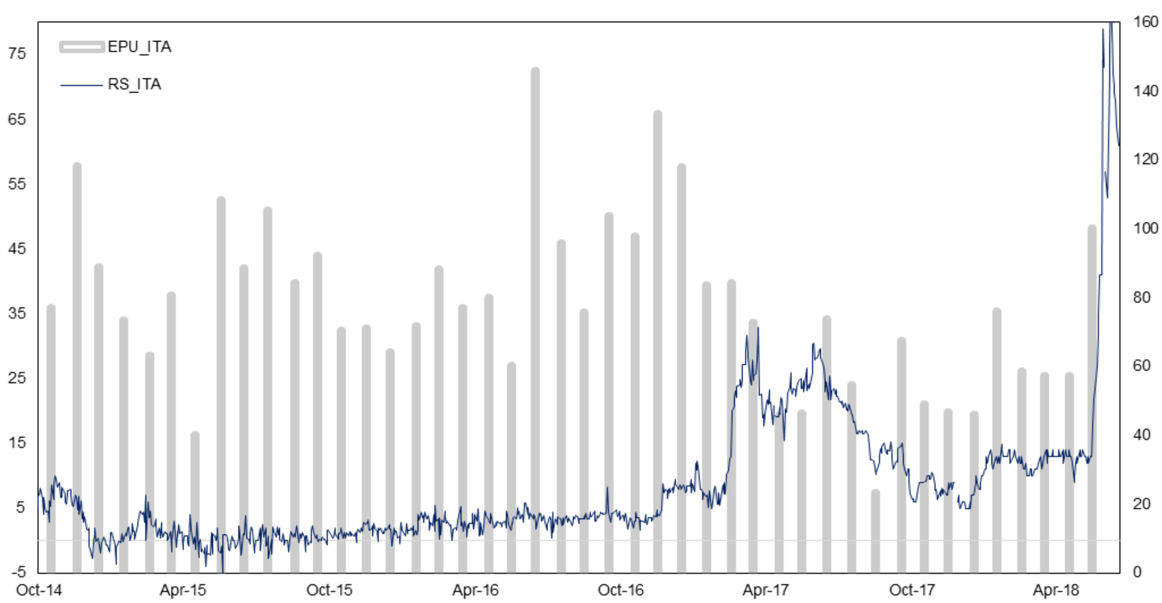
D Supplementary Tables and Figures

Figure 16: Redenomination risk and *Economic Policy Uncertainty* (Baker et al., 2016) (RHS)

Panel A: France



Panel B: Italy



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