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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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# Euro area sovereign risk spillovers before and after the ECB's OMT announcement*

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**Abstract**

We study the dynamics of sovereign risk spillovers from (and between) Spain and Italy, before and after the ECB's announcement of the OMT program. We identify domestic Italian and Spanish sovereign risk shocks through an intraday event study. The shocks are used as external instruments in bilateral, daily, local projection regressions. Prior to the announcement of the OMT, changes in the Spanish and, to a lesser extent, Italian spread spilled over to many other euro area member states, and also affected the euro-dollar exchange rate. Peak effects generally materialized after 2-3 days. Since the OMT announcement, spillovers to non-crisis, non-safe haven countries have disappeared. Some spillovers among crisis countries persist, but are smaller and shorter-lived than before. Overall, our results are consistent with the view that the OMT, through eliminating equilibrium multiplicity, has largely stopped contagion.

**Keywords**: Sovereign risk; contagion; narrative identification; local projections; OMT
**JEL classifications**: C53; E44; F36; G01; G15

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# 1 Introduction

During the sovereign debt crisis in the euro area, many member states faced steeply rising sovereign yields. By and large, these reflected increasing risk premia, with risk-free benchmark rates remaining flat or even falling. The increase in perceived riskiness of European sovereign debt was not a phenomenon limited to a few crisis countries. The Belgian spread vis-à-vis Germany, for instance, peaked above 3 percentage points, while Austrian and French spreads shortly approached 2 percentage points. The escalating crisis led ECB President Mario Draghi to announce on July 26 2012 that, within its mandate, the ECB would do "whatever it takes" to save the euro. In September 2012, this was followed up by the ECB formally announcing the Outright Monetary Transactions (OMT) program, a potentially unlimited bond buying scheme. Through the announcement of the OMT, the ECB signaled that − under conditions − it was willing to act as lender of last resort for sovereigns. While the OMT has as of yet never been activated, the immediate effect of its announcement was a reduction of sovereign spreads across the eurozone (Szczerbowicz, 2015; Altavilla et al., 2016). Yet, little is known about its longer-term effects on the stability of the euro area sovereign bond market.

In this paper, we study the effects of the OMT on the cross-border transmission of sovereign risk. We focus on spillovers from Italy and Spain. To overcome the identification challenge associated with separating country-specific shocks from common shocks, we first document the response of Italian and Spanish sovereign yields to domestic events, in a tight window around their first publication. Recognizing that this only yields an approximation of the 'true' shocks, we use the narratively identified shocks as external instruments for the daily change in Italian and Spanish spreads in bilateral local projections - instrumental variable (LP-IV) regressions. Prior to the OMT, we document significant sovereign risk spillovers between Spain and Italy, and from (in particular) Spain to the rest of the euro area. Peak effects are generally reached after 2-3 days. We also find spillovers to the financial sector and global financial markets. Post-OMT, some spillovers among the most vulnerable countries remain, but in a significantly more muted form. Spillovers from Spain and Italy to the rest of the euro area disappear or become marginally negative. Likewise, global financial markets no longer respond much to shocks to Italian or Spanish spreads. These findings are robust to using our full, 2009-2016, sample, as well as to using shorter intervals around the announcement of the OMT. They indicate that the OMT has largely broken the negative feedback loop between member states.

Our paper builds on an extensive literature studying cause and effect of surging spreads in the euro area. Elevated risk premia have been shown to hamper financial intermediation and depress the real economy (Bocola, 2016; Altavilla et al., 2017; Bahaj, 2019). They have been caused, at least in part, by investors reopening their eyes to fiscal fundamentals (Von Hagen et al., 2011). There is also evidence that, at the height of the crisis, spreads had increased by more than could be explained by fundamentals (e.g. Aizenman et al., 2013; De Haan et al., 2014; Dewachter et al., 2015). It has been argued that this reflected self-fulfilling expectations about default, euro exit, or both (e.g. De Grauwe and Ji, 2013; De Santis, 2015). However, as the non-fundamental part of spreads can generally only be identified as the remaining residual after controlling for fundamental drivers, no consensus exists about the size or relevance of this effect.

The debate on self-fulfilling dynamics is closely linked with the one on contagion. As argued by Masson (1998), the presence of multiple equilibria is a necessary condition for 'pure' contagion – a country-specific shock directly affecting another country's sovereign spread, without changes in the fundamentals of the latter – to take place. The OMT has been explicitly aimed at ruling out equilibrium multiplicity[1] and should therefore also have stopped pure contagion. Most related to this paper, Saka et al. (2015) reverse this logic, noting that if it can be shown that the mere announcement of the OMT has reduced spillovers, this would indicate that they (previously) contained a non-fundamental, contagious, component. As part of an eclectic study into the European sovereign bond market[2] the authors conduct an event study, in which they show that pre-OMT news from Spain significantly affected Italian, French, Belgian and Austrian yields. Post-OMT, such effects are no longer visible.

Event studies like Saka et al. (2015) arguably offer the cleanest and most transparent way of identifying spillovers. It is clear what the shocks are and events of direct relevance for multiple countries (e.g. news about the bail-out regime) can be separated from country-specific news (see also Mink and De Haan, 2013). A before/after comparison using an event study is, however, challenging. In a pure event study, events are captured by dummies and lack a scale. If, after the OMT, events in country A have a smaller effect on country B than before, this could reflect both a weaker shock transmission or less exciting events. To identify the magnitude of spillovers, events thus need to be scaled. This induces measurement error, that might not be constant over time, again complicating statements about the strength of transmission. As event studies are also limited to studying impact effects, a more muted post-OMT response of spreads could both reflect a weaker or slower cross-border transmission or a worse measurement of events.

The main contribution of this paper is to retain the clean identification of event studies, while being able to trace out the dynamics of sovereign risk spillovers and to formally test whether they differ before and after the OMT. This is the result of using an LP-IV approach that accounts for the fact that the measured market reaction to news only captures part of the total shock, and typically does so with error. In contrast to some of the VAR-based approaches to measuring spillovers, the LP-IV approach does require the ex-ante identification of shocks. A secondary contribution of this paper lies in the precision and the time-span of the news database constructed for this purpose. Our tick sovereign yield data and a timed-to-the-minute database of eurozone news (extending the database of Bahaj, 2019) permits cleaner identification than in the existing literature, which by and large uses daily data, and covers a longer timespan.

The remainder of this paper is organized as follows. Section 2 discusses the theoretical relation between the OMT and sovereign risk spillovers and formulates hypotheses. Section 3 discusses the related empirical literature. Section 4 presents our method and data, while sections 5 and 6 present our main findings and discuss their sensitivity. Finally, section 7 concludes.

[1] In the press conference following the official announcement of the OMT program, Draghi stated that the OMT was needed because large parts of the euro area were in "a bad equilibrium" with "self-fulfilling expectations that feed upon themselves".

[2] The authors also conduct a principal component analysis of government CDS spreads and conduct a herding contagion analysis.

# 2 OMT and spillovers

## 2.1 The vulnerability of euro area sovereigns

Much like banks, governments face a maturity mismatch between their assets and liabilities (Buiter and Rahbari, 2012). The government's main asset, the net present value of future tax income, is intangible and illiquid. In contrast, the government debt needs to be rolled over regularly. A loss of confidence in a government's capacity to repay can therefore trigger a vicious cycle, with higher interest rates aggravating fiscal worries, which in turn pushes up yields further.

Not all governments are vulnerable to liquidity crises. When debt is low, investors are aware that – even at sharply higher interest rates – it is cheaper for the government to repay than to default.[3] In that case, there will be no run. Beyond a certain threshold, however, the government's willingness (or ability) to repay depends on the level of the interest rate. For this range of intermediate debt levels – dubbed the 'crisis zone' by Cole and Kehoe (2000) – a loss of confidence can push a nation from the safe to the crisis equilibrium. This can lead to a roll-over crisis triggering immediate default or, as in Lorenzoni and Werning (2018), a slow-moving crisis in which debt accumulates gradually but at an ever increasing pace.

A central bank (CB) can help avert self-fulfilling debt crises in two ways. First, it can lower the real value of debt through creating surprise inflation, thereby increasing the threshold above which such crises are possible. The effectiveness of this policy depends on, amongst others, the maturity structure of government debt. Generally, however, as shown by Bacchetta et al. (2018), the scope for this type of policy is limited. Corsetti and Dedola (2016) highlight a potentially more effective way of eradicating multiplicity. CBs can (threaten to) directly take government debt onto their balance sheets. Seen from the perspective of the consolidated balance sheet of the government and the (national) central bank, this amounts to a swap of potentially risky government bonds for monetary liabilities that are subject only to inflation risk. This eliminates credit risk and lowers financing costs for the consolidated government. If the CB is willing to purchase a sufficient chunk of the debt, falling interest costs will reduce the government debt's riskiness, pushing down yields on the privately held share of the debt. By serving as lender of last resort for governments,[4] the CB can therefore eradicate self-fulfilling crises. If the central bank is fully credible, the mere threat of buying suffices.

There are few countries in which a CB explicitly commits itself to being a backstop for governments. However, as argued by De Grauwe (2012, 2013), investors know that when push comes to shove, countries with a flexible exchange rate and their own central bank will always have access to their central banks' balance sheet.[5] In the euro area, no individual government has control over the ECB, and government bail-outs are explicitly ruled out by the Treaty. As such, it was long far from evident that the ECB would intervene in case investors lost trust in a

[3] In the theoretical literature, this is often the result of the assumption that the cost of default is fixed or at least has a fixed component, such as the loss of market access. See e.g. Corsetti and Dedola (2016).

[4] As lending to governments typically involves buying their bonds, this role is sometimes also referred to as 'buyer of last resort'. See e.g. Acharya et al. (2018).

[5] To some observers, engaging in Quantitative Easing is a way of signaling that the CB is prepared to buy government debt in case of need.

country's public finances, rendering member states more vulnerable to this type of self-fulfilling crises than countries issuing their own currencies.

The vulnerability of euro area member states to self-fulfilling crises is aggravated by the fact that membership of a monetary union might not be irreversible (Kriwoluzky et al., 2015; Eijffinger et al., 2018). Instead, or on top, of explicitly defaulting on its obligations a country could exit EMU and redenominate its debt into a (devalued) new currency. To the extent that fears about one country leaving the eurozone lead to questions about the future of the euro itself, redenomination risk could prove particularly contagious. More broadly speaking, the potential presence of multiple equilibria, driven by fear of default, redenomination or both, implies that a foreign shock with relatively small direct effects on another country's fiscal outlook could still have large effects on its interest rate, by acting as a 'sunspot' variable pushing the country towards the bad equilibrium. The presence of multiple equilibria thus opens the door to contagion.

## 2.2 OMT and hypotheses

The declaration on July 26, 2012, by ECB President Mario Draghi that within its mandate, the ECB would do "whatever it takes" to preserve the euro, is widely seen as the first reference to what would become known as the OMT. The official announcement followed on August 2. Pointing to "severe malfunctioning in the price formation process in the bond markets of euro area countries", the ECB announced that it might undertake outright open market purchases of sovereign bonds. Purchases would be conditional on the adherence of governments to the conditionality set by emergency funds European Financial Stability Facility (EFSF) and European Stability Mechanism (ESM). The exact parameters of the OMT program were announced on September 6, 2012.

Technically, the OMT is a promise to engage in the potentially unlimited buying of sovereign bonds of countries that are subject to an adjustment program. Purchases would be made in secondary sovereign bond markets, would be sterilized, and would concentrate on bonds with remaining maturities of up to three years. Three important differences with previous ECB initiatives, such as the Securities Markets Program (SMP), are that i) OMT interventions are in principle unlimited, ii) that they do not enjoy privileged creditor status, and iii) are explicitly conditional on sound domestic policies.

Through the OMT the ECB, under conditions, took up the role of backstop in the market for sovereign bonds. Solvent governments willing to accept policy conditionality were offered an escape route in case of self-fulfilling default or redenomination fears. As such, if the OMT were fully credible, it would have eliminated the possibility of self-fulfilling crises in fundamentally healthy members of the eurozone. Because of the link with an ESM program, the OMT can however not rule out fundamental defaults (and is not intended to do so). An insolvent country seeking ESM support, would need to restructure its debt before it would receive emergency loans.

Based on the above, we hypothesize that i) through ruling out equilibrium multiplicity, the

OMT should have stopped the more extreme forms of contagion, while ii) fundamental spillovers might persist, especially to weaker member states.

## 3 Empirical literature

This paper builds on a large literature investigating the drivers of yield differentials in EMU.[6] This literature can roughly be split into three parts. A first strand studies domestic economic and financial drivers of yield spreads, focusing on the early convergence of yields, and more recently, the renewed divergence during the crisis. A second strand, starting around 2011, focuses on spillovers or contagion during the crisis. Finally, a third strand focuses on the direct effects of the OMT on the pricing of sovereign bonds.

Typically, sovereign bond spreads reflect credit, liquidity, exchange rate and redenomination risk, as well as general risk aversion and differences in tax treatment. In the run-up to the introduction of the euro, both exchange rate risk and differences in tax treatment were largely eliminated, resulting in a significant convergence of interest rates (Codogno et al., 2003; Gomez-Puig, 2006). As spreads fell, their responsiveness to country-specific risk factors became more muted. Liquidity risk premia fell significantly (Bernoth et al., 2012; Favero et al., 2010), though there is no consensus on their elimination (Gomez-Puig, 2006). The small spreads did still, to some extent, reflect differences in fiscal fundamentals (Bernoth et al., 2012; Bernoth and Erdogan, 2012). Increasingly, however, yield differentials were driven by a common risk factor, typically identified as international risk aversion (Codogno et al., 2003; Favero et al., 2010; Bernoth and Erdogan, 2012; Pozzi and Wolswijk, 2012).

The European sovereign debt crisis sparked a repricing of sovereign bonds. Spreads became more sensitive both to fiscal fundamentals and to developments in the banking sector (Von Hagen et al., 2011; De Grauwe and Ji, 2013). This reflected the implicit guarantee provided by government to 'too big to fail' financial institutions. At the same time, there also is increasing evidence that economic and financial fundamentals did no longer fully explain spread movements (Aizenman et al., 2013; De Grauwe and Ji, 2013; De Haan et al., 2014; Dewachter et al., 2015). Overall, the new bond pricing regime differed so starkly from the pre-crisis one that it led D'Agostino and Ehrmann (2014) to conclude that markets were either under-pricing risk prior to the crisis, over-pricing it afterwards, or were pricing in catastrophic events like the break-up of the euro. Others explicitly questioned the rationality of the new regime, pointing out that EMU member states paid far higher interest rates than European non-member states with similar fundamentals (De Grauwe and Ji, 2013).

A related literature examines to what extent the re-pricing of sovereign bonds during the euro crisis was driven by spillovers from other member states. Various authors find evidence that negative events in individual EMU members states contributed to an increase in risk aversion and a stronger reaction of spreads to fiscal fundamentals (Beirne and Fratzscher, 2013; Giordano et al., 2013). This type of indirect spillovers – a repricing of an unchanged set of fundamentals in

[6] From a methodological viewpoint, our paper is also indebted to the literature on the high-frequency identification of monetary policy shocks using external instruments, chiefly Gertler and Karadi (2015).

reaction to a negative shock in a foreign country – is often referred to as 'wake-up call contagion' (e.g. Mink and De Haan, 2013; Bekaert et al., 2014).

'Pure' contagion – where country-specific negative shocks directly affect spreads in other countries – is more contentious. Empirical evidence for pure contagion during the euro crisis is found by Metiu (2012) and Ludwig (2014), who both apply augmented versions of the Pesaran and Pick (2007) framework. In an event study focusing specifically on contagion from Spain, Saka et al. (2015) also find evidence for pure contagion. Claeys and Vašíček (2014), using a FAVAR framework, find sizable spillovers from Spain, Italy and Belgium, but conclude that most of this is driven by larger shocks rather than a stronger transmission. They find pure contagion limited to a few specific events related to bail-outs. Ehrmann and Fratzscher (2017), based on identification through heteroskedasticity, do not find contagion and instead highlight the increased fragmentation of the sovereign bond market during the early years of the crisis.

De Santis (2014) refrains from using the term 'contagion', but does document sizable spillovers from Greece to Ireland, Portugal, Italy, Spain, Belgium, France and Austria. Focusing on CDS spreads, Alter and Beyer (2014) find sizable spillovers between euro area sovereigns, banks, and between banks and sovereigns. The latter part – the 'doom loop' – gets stronger over the sample period, which ends just before the OMT announcement. Beetsma et al. (2013) find that, since September 2009, an increase in the number of news messages dealing with the euro area crisis countries increases both the interest spread of the country in question, as well as that of the other crisis countries. The size of the cross-border effect is related to cross-border bank holdings. Brutti and Sauré (2015) also find cross-border bank exposure to sovereign debt to be an important transmission mechanism of sovereign spillovers between eurozone members.

Our analysis finally builds on the literature studying the wider effects of the OMT on the pricing of sovereign bonds. Delatte et al. (2017) find that the OMT has restored the pre-crisis bond pricing regime, while Afonso et al. (2018) conclude that in the post-OMT regime some residual redenomination risk remains. Acharya et al. (2018) document that the OMT has increased the market prices of sovereign bonds and limited the bank-sovereign nexus. Krishnamurthy et al. (2017) find that the OMT, like the earlier Securities Markets Program (SMP), has been successful in reducing market segmentation, redenomination risk and default risk in the crisis countries, while also leading to positive macro-economic spillovers to the rest of the eurozone.

# 4 Method and data

We aim to identify the dynamics of sovereign risk spillovers from and between Spain and Italy, two countries that have been singled out as important sources of contagion and that, importantly for identification purposes, also had functioning sovereign bond markets throughout the crisis.

Throughout the analysis, we will focus on the spreads of 10-year benchmark sovereign bonds vis-à-vis the 10 year Overnight Index Swap (OIS) rate. Longer term bonds offer a comprehensive indicator of a government's solvency position, and the market for 10-year bonds is one of the most liquid. We look at spreads relative to the OIS rate, because this offers the arguably cleanest indicator of the risk-free rate. It is almost completely free from counterparty risk and as a swap cannot be used as store of value, also hardly contains 'convenience' or inverse safety premiums.[7]

The identification of spillovers poses a challenge, as spreads in the various euro area countries are potentially driven by common shocks, and causality between changing spreads in different countries could run both ways. We therefore first set out to identify domestically originated interest rate shocks in Italy and Spain. We do this by capturing the variation in Italian and Spanish yields caused by purely domestic news in an intraday event study. The resulting shock series are then used as instruments in daily bilateral LP-IV regressions.

### 4.1 Identification of domestic interest rate shocks

To construct a series of domestically originated interest sovereign risk shocks, we use the news database put together by Bahaj (2019) and extend it by three and a half years.[8] The extended news database covers July 2009 through June 2016 and contains news messages about the six euro area crisis countries: Greece, Cyprus, Portugal, Ireland, Italy and Spain. The database is based on the daily EuroIntelligence news briefing. This briefing, released each morning, contains a selection of 8-12 news stories related to the euro area, of which a single one is designated the 'headline' story. All events that can be timed using the Bloomberg newswire and that relate to a single crisis-hit country are included in the database. This excludes data releases, because in the eurozone statistical data is often released in multiple countries more or less simultaneously. Events are classified either as domestic events or as foreign interventions (generally, statements or actions about the respective country by international organizations or foreign governments). When constructing our shock series, we exclude foreign interventions as these often concern 'bail-out' related statements that could be of direct relevance to other EMU member states and are thus not suitable to identify purely domestic shocks.

To identify the effect of the events on the *domestic* interest rate, we conduct an event study. We first source raw intraday sovereign yield bid and ask quotes at tick frequency from the Thomson Reuters Tick History Database. After checking for evidently 'wrong' quotes (see Annex A.1), we take the middle of 10 year bid and ask yields to maturity, and compute one-minute averages. This reduces the number of observations by a factor of 30 to 35 for both countries and thus smooths any remaining spikes. Only data between 7:30 and 16:30 London time (GMT in winter, BST in summer), the time at which the London market is open, is used, with ticks outside this window being too infrequent. For Italy and Spain, occasional minutes for which no ticks are available have been interpolated (see also Annex A.1). For Greece, Ireland, Cyprus, and to a lesser extent Portugal, debt markets at the height of the crisis were so illiquid, that too much data is missing to include these countries in our baseline event study. We however keep these countries in our database to be able to rule out overlapping events.

Using the sovereign yields and the timed events, for Italy and Spain, we compute the change

[7]In contrast, the yield on German government bonds – the most common alternative indicator of the risk free rate – at times did include an inverse safety or redenomination premium. It is of course possible to redo our analysis using spreads vis-à-vis the Bund. Other than that this requires us to drop Germany itself from the analysis, it does not significantly alter our analysis. Results are available on request.

[8]Data collection benefited from research assistance by Minke van der Heijden. An untimed version of the news database is used in Van der Heijden et al. (2018).

in the interest rate in a window around the event.[9] In our baseline specification, we use an 80 minute window: from 40 minutes before the event was first mentioned on Bloomberg, until 40 minutes thereafter. Window length is a compromise between maximizing the chance that the yield change during the window is *only* driven by the event under study, and giving markets some time to incorporate the effect of the announcement. An 80-minute window is a bit longer than in most intraday event studies, but far shorter than in most event studies of the euro crisis, which tend to use daily data.[10] We choose 80 minute windows because the timing of our events is not exact: some events might have appeared slightly earlier in other news sources than on Bloomberg, and some events (like speeches) might have lasted until after the first Bloomberg headline appeared. Additionally, in contrast to, for example, monetary policy announcements, news about the crisis countries did not appear at pre-announced and regular intervals, and might take longer for markets to be picked up.

A challenge with the intraday approach is that a significant share of events occurs outside trading hours, or too close to market opening / closing to compute our regular windows. To keep as many events as possible in our dataset, we adjust our regular windows for events occurring at least 15 minutes before (after) market close (open).[11] All events occurring between market close and 7:45 are treated as 'overnight' events. These pose the greatest challenge: on the one hand, given the European tendency towards late-night crisis meetings, they contain some of the most relevant crisis events. On the other hand, any 'overnight' window is inevitably long, and the risk looms large that our identified event is not the only driver of the overnight change in the spread. In our baseline specification, we follow Bahaj (2019) and include those overnight events that are featured as the *headline* story in next morning's EuroIntelligence news briefing. This implies that the story was deemed the most important overnight event by EuroIntelligence's editors. We argue that for these major events, it is likely that they are the main driver of the overnight change in the respective sovereign spreads. For these events, we use a window running from 16:15 to 8:30 on the next trading day.[12] In a sensitivity analysis, we exclude all overnight events.

To make sure to the greatest extent possible that the interest rate reaction during the various windows is only driven by the event in question, we exclude all events where the window overlaps with another event in our database (which for this purpose also includes the events in Ireland,

[9]We conduct our event study using sovereign yields, while we will use the resulting shock series as instrument for the change in spreads. This inconsistency arises from the fact that we only have high-frequency data for the OIS rate available from mid-2011 onwards. To the extent that, within a short window around a country-specific event the OIS rate would not be expected to move much, changes in yields and spreads should be the same, and in any case we treat our shock series as an imperfectly measured proxy. As a robustness check, we have also computed windows using spreads from the moment the data high-frequency OIS data is available. The correlation between windows computed using spreads ands those computed using yields is 0.96, confirming that within our event window movements in the OIS rate play little role.

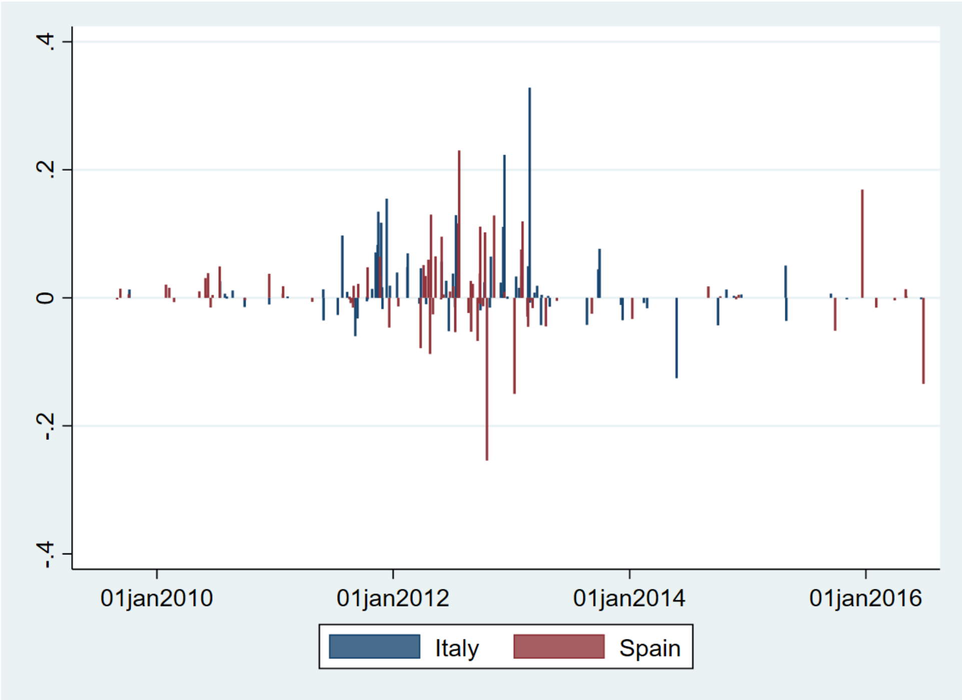
[10]See Gürkaynak and Wright (2013) for a discussion of window length in event studies, and Aizenman et al. (2016), Mink and De Haan (2013), Falagiarda and Reitz (2015) and Saka et al. (2015) for examples of event studies focusing on the euro crisis, all using daily data.

[11]For events occurring between 7:45 and 8:10, we use a 7:30 - 8:50 window. Similarly, for all events occurring between 15 and 45 minutes from market closing, we use a 15:10 - 16:30 window.

[12]This window avoids the less liquid 7:30 - 8:30 interval and also makes sure that all events treated as 'overnight' occur within the overnight window.

Cyprus, Portugal and Greece, and bail-out related news) or ECB announcements.[13]

Figure 1: Events




Note: The figure shows the (domestic) market reactions to events in Italy and Spain, in 80 minute windows around the event. The data has been aggregated to the daily level.

We finally aggregate the data to the daily level. This implies that if, for a given country, multiple events occur on the same day, we take the sum of the observed market reactions. The resulting daily shock series are displayed in figure 1. Shocks are most frequent, and largest, from 2011 to 2014. However, in both countries shocks do occur throughout the sample period. In total, the database contains 84 days with Spanish news and 78 days with Italian news. For both countries, the pre/post-OMT split is close to 50-50, with slightly more news pre-OMT.

## 4.2 Other data

We focus on the 12 initial members of the euro area. For Greece, Ireland and Luxembourg there are too many days with missing sovereign yield data, leaving a sample of nine countries for our main analysis. To obtain daily data, we use the mid-yield to maturity at market closing.[14] We then subtract the 10-year euro OIS closing rate, and finally compute daily changes.

All variables included in our analysis are first-differenced and stationary. In most countries, the mean change in sovereign spreads is marginally negative after the OMT, resembling that

[13]We exclude all events occurring between 13:15 and 15:30 on ECB meeting days, capturing both the publication of the monetary policy decisions, as well as the entire press conference. Additionally, we exclude all events that occur on the same day as any ECB announcement relating to any form of sovereign bond purchases.

[14]London market closing is at 16:30, though in some markets trading goes on longer. If there are no quotes available at 16:30, we first check for quotes between 16:30 and 17:00, and take the first available one. If this fails, we look if there are quotes available between 15:30 and 16:30, and take the last available one.

over the post-OMT period the level of spreads has on average been falling. Pre-OMT, the spread on average increased in 5 out of 9 countries, most notably in Portugal, Spain and Italy.

Portuguese data contains some notable spikes, with occasional days in which the daily change in the spread approaches 2 percentage points. In Spain and Italy, the largest daily increase in the spread is around 0.6 percentage point, while in both cases the largest fall is slightly larger (see table A.1 in the Annex.) For all other countries, the largest absolute changes in the spread are below 0.5 percentage point. The number of observations per country lies around 1785, with a small number of non-synchronized gaps: for the Netherlands, for instance, the series is generally of high quality, but the number of observations is somewhat pushed down by a gap in July 2010.

End-of-day bid-ask spreads are computed using our intraday sovereign yield data. The other variables used in our analysis are sourced at a daily frequency from Thomson Reuters Eikon. These include the VIX index, the Dow Jones index, the euro-dollar exchange rate, the 10 year euro OIS swap rate, the Euro Stoxx index, a CDS index for the 35 largest European banks, and national sovereign CDS and stock market indices for all individual countries. Summary statistics are presented in table A.1 in the Annex.

### 4.3 Local projections

To estimate the sovereign spread spillovers, we employ the LP-IV method pioneered by Jordà et al. (2015) and Ramey and Zubairy (2018). Local projections (Jordà, 2005) are an increasingly popular method to compute impulse responses without constraining the shape of the impulse response function. For each horizon, a separate forecast is constructed, so that there is no 'rolling over' of forecast errors, as in (S)VARs. This makes them less vulnerable to misspecification and better able to capture non-linearities (see Ramey, 2016, for a discussion). Important for our application, their flexibility also makes it straightforward to test for state dependency or structural breaks. The flipside of the unconstrained nature of the estimation procedure is that impulse responses can be erratic, and estimation is generally a bit less efficient than in VARs. Teulings and Zubanov (2014) moreover note that because local projections do not incorporate shocks occurring after time $t$, longer-term forecasts can be biased downwards. As in our analysis shocks are both negative and positive this is unlikely to be a major issue. We return to this topic, and the solution proposed by Teulings and Zubanov (2014), in section 6.

Defining $\Delta y_{i,t+h}$ as the change in the country $i$ sovereign spread between time $t-1$ and time $t+h$, local projections, in their simplest form, consist of a series of ordinary least squares regressions for each forecast horizon of $\Delta y_{i,t+h}$ on the shock series of interest (here, labeled $shock_{s,t}$) and past changes of $y_i$:

$$\Delta y_{i,t+h} = \beta_h shock_{s,t} + \sum_{q=1}^{Q} \theta_{h,q} \Delta y_{i,t-q} + v_{t+h} \tag{1}$$

Here, $\beta_h$ gives the change in variable $y_{t+h}$ in response to the shock at time $t$ from country $s$ and $Q$ defines the number of lags included in the regression. The impulse response function is directly given by plotting the set of coefficients $\{\beta_h\}_{h=0}^{H}$.

Our shocks – domestic Spanish and Italian events, scaled by their impact on the domestic yield – are, however, imperfectly measured. Similar to most shocks identified using a narrative approach, they only pick up part of the shock. Any anticipated effect of a shock, or any effect that materializes after the end of our window, is not taken into account. This makes the scaling of the shocks, to a certain extent, arbitrary, as a longer window would typically imply larger 'shocks'. To the extent that, over time, the speed with which markets process shocks differs (for instance, due to markets being less liquid at the height of the crisis), comparisons of the effects of the shocks over time could also be misleading. This comes on top of the fact that our list of events will by definition be incomplete. Gertler and Karadi (2015) and Stock and Watson (2018) therefore argue that this type of shocks can better be thought of as instruments for the true shocks than as the true shocks themselves.[15]

To use our shock series as an instrument, we need to be explicit about the endogenous series of interest. Throughout our analysis, these will be daily changes in the Spanish and Italian sovereign spreads. We will study bilateral spread spillovers from Italy and Spain, to the other euro area countries:

$$\Delta y_{i,t+h} = \beta_h \Delta y_{s,t} + \sum_{q=1}^{Q} \theta_{h,q} \Delta y_{i,t-q} + v_{t+h} \tag{2}$$

Here, subscripts $i$ and $s$ refer to the country pair under consideration and $v_{t+h}$ depends on the entire history of structural shocks: $v_{t+h} = \epsilon_{t+h} + \Gamma_1 \epsilon_{t+h-1} + \Gamma_2 \epsilon_{t+h-2} + .... + \Gamma_h \epsilon_{h-1} \epsilon_{t+1}$.

In order for our shock series (from here on denoted $z_{s,t}$) to be a valid instrument in a LP-IV setting, it needs to fulfill the usual IV criteria of relevance and (contemporaneous) exogeneity. Due to the local projection dynamics – the dependent variable depends on the entire history of shocks up to $t + h$ – it also needs to meet an additional 'lead / lag' exogeneity requirement.

Table 1 shows that for both countries, both before and after the introduction of the OMT, our instrument is relevant. Bivariate regressions of the daily change in the domestic sovereign spread on the relevant shock series give (robust) F-statistics ranging from 18 to 286. At the same time, the coefficient in most cases differs significantly from one and also differs pre- and post-OMT, highlighting that it would not have been appropriate to directly include the shock series as regressor.

Lead / lag exogeneity requires that the instrument is uncorrelated with all past or future shocks hitting a country's spread that are not captured by the control variables. Lead exogeneity is relatively unrestrictive: structural shocks occurring between time $t$ and time $t + h$ are by definition uncorrelated with any information available at time $t$; as such lead exogeneity is satisfied as long as the instrument is constructed using information available at or before time $t$. Lag exogeneity is a potentially more restrictive assumption. Strictly speaking, it requires that

[15] Hebous and Zimmermann (2016) show that the common approach of including a narrative shock directly in the regression can be interpreted as the reduced form of an IV regression, but only if the instrument is correlated exactly 1-to-1 with the endogenous series of interest.

Table 1: Instrument relevance: pre- and post OMT

| $\Delta spread_{i,t}$ | (1) ES pre-OMT | (2) ES post-OMT | (3) IT pre-OMT | (4) IT post-OMT |
|---|---|---|---|---|
| Domestic shock series | 1.64*** | 1.36*** | 1.31*** | 1.50*** |
| | (0.33) | (0.22) | (0.31) | (0.09) |
| Observations | 806 | 991 | 806 | 991 |
| R-squared | 0.04 | 0.07 | 0.02 | 0.10 |
| F-statistic | 25.19 | 38.42 | 18.00 | 286.33 |

Note: OLS estimation. HAC robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Sample period: 2009M6 - 2016M6.

$z_{s,t}$ is not linearly predictable by past values of $\epsilon$ (see Stock and Watson, 2018). In our set-up, this implies that it should not be possible to predict our instrument using lags of $\Delta y_i$. This is indeed not the case.[16]

Contemporaneous exogeneity requires that our instrument is uncorrelated with other structural shocks to the dependent variable. While this cannot be tested directly,[17] our relatively tight windows, the exclusion of all events with potential direct ramifications for the eurozone (in particular, news related to bail-outs or monetary policy), and the care taken to avoid all overlapping events (such as data releases occurring in multiple countries simultaneously) from the shock series all serve to increase the plausibility of this assumption. In line with a.o. Metiu (2012) and Ludwig (2014), in our baseline specification, we will furthermore control for a number of variables that have been identified as fundamental drivers of sovereign spreads in the euro area. These include lagged changes in worldwide, euro area, and domestic economic and financial conditions. This serves both to increase the plausibility of our instruments and to enhance estimation efficiency.[18] We estimate the following local projection model:

$$\begin{aligned}\Delta y_{i,t+h} = \alpha + \beta_h \Delta y_{s,t} + \sum_{q=1}^{Q} \eta_{h,q} \Delta y_{i,t-q} + \gamma_h^{'} \Delta X_{t-1} + OMT(\alpha^{OMT} \\ + \beta_h^{OMT} \Delta y_{s,t} + \sum_{q=1}^{Q} \eta_{h,q}^{OMT} \Delta y_{i,t-q} + \gamma_h^{OMT'} \Delta X_{t-1}) + v_{t+h} \qquad (3)\end{aligned}$$

Here, $\Delta y_{i,t+h}$ is the change in the 10 year yield spread of country $i$ between time $t+h$ and time $t-1$ and $\Delta y_{s,t}$ is the change in the 10 year spread of country $s$ between day $t$ and day $t-1$, which we will instrument with our narrative shock series. $OMT$ is a dummy equal to one from the OMT's first informal announcement (Draghi's 'whatever it takes' speech) onwards. The regression furthermore contains lagged changes of the home yield spread ($\Delta y_i$). Vector $\Delta X$

[16]For each country in the sample, we have run regressions of the instrument on 10 lags of their spread. Only very occasionally a significant coefficient shows up, and in none of these regressions the R-squared exceeds 0.01.

[17]We return to this issue in section 6, where we create additional instruments, using shorter windows and excluding overnight events, to conduct tests of overidentifying restrictions.

[18]In section 6.2 we show that results our robust to excluding, or expanding, the set of lagged controls.

contains the lagged change of the foreign spread ($\Delta y_{s,t-1}$) and a set of lagged and first differenced global, European and domestic control variables. In our baseline specification this contains the (log) Chicago Board Options Exchange Volatility Index (VIX), which serves as a proxy for uncertainty in global financial markets (see e.g. Dewachter et al., 2015; Afonso et al., 2018), the (log) Euro Stoxx stock market index to capture changes in European economic sentiment, the 10-year OIS rate, the risk-free benchmark that also serves to pick up monetary policy, the (log) bank CDS index that aims to pick up part of the 'doom loop', and finally the domestic bid-ask spread to capture liquidity conditions in the home sovereign bond market.

In our baseline specification, we include five lags of the home yield spread, ($Q = 5$), one lag of the foreign spread, and one lag of all other controls. The five lags of the home spread serve to capture autocorrelation, as well as day-of-week effects. The lagged foreign spread is included to make sure that our estimate of the transmission of foreign shocks does not pick up any delayed effects of past shocks. Finally, the controls are lagged one day to avoid simultaneity (for the European and domestic controls) as well as to account for the different zones (for the global variables, which are in US time).

We estimate the regressions separately for each country pair $i$ and $s$, using 2SLS. For all horizons $h > 0$, local projections induce autocorrelation in the error term. To correct for this, as well as for any residual autocorrelation in the epsilons themselves, we use Newey-West standard errors that are robust to heteroskedasticity and autocorrelation.[19]

In our baseline estimations, we use our full dataset. This implies that the pre-OMT period spans 3 years (July 2009 through 25 July 2012, with Draghi's whatever-it-takes speech taken as the de-facto introduction of the OMT), while the post-OMT period spans 4 years (26 July 2012 through 1 July 2016). In robustness checks we will consider symmetric one- and two-year intervals around the OMT, that exclude, amongst others, the later QE episode.

# 5 Results

We first discuss spillovers from Spain and Italy to the other members of the eurozone. Thereafter, to provide some context to these results, we also touch upon spillovers to pan-European and global financial variables.

## 5.1 Spain

Figure 2 displays the spillovers resulting from a 100 bps shock to the Spanish spread (note that actual shocks are smaller, with the largest shock being 70 bps). Table 2 provides further background information, detailing the significance of the difference between pre- and post-OMT estimates of spillovers and the effects of the main control variables. It also provides tests for under and weak identification for the $h = 0$ regressions.

[19]To correct for the autocorrelation induced by the LP-IV structure, a correction for autocorrelation of up to $h + 1$ lags is customary. To err on the side of caution, and because we for consistency apply the same model and lag structure to all country-pairs in our analysis, we use errors robust to autocorrelation of up to $h + 10$ lags throughout the analysis.

Prior to the introduction of the OMT, shocks to the Spanish spread have sizable effects on other countries. On impact, the effect is largest in Italy, with a 100 bps increase in the Spanish spread leading to a 79 bps increase in the Italian spread. Austrian, Belgian, French and Italian spreads are notably affected too. For none of the countries, the impact effect is the peak effect, which is generally only reached after 2-3 working days. In the Italian case, the spread has by then increased by more than the size of the original Spanish shock. For Belgium, at the peak, the shock spills over one-to-one, in Austria and France a 100 bps shock leads to a maximum spillover of 50-60 bps. The relative vulnerability of Belgium to external shocks is in line with findings by Metiu (2012) and De Santis (2012). It is, nevertheless, not the hardest hit country, as the most extreme spillovers are visible in Portugal. Here, the dynamics are most consistent with a badly functioning market: compared to other countries, the transmission of the shock is slow.[20] The peak effect, reached after 3 days and maintained up to 8 days after the shock, is however very large: the Portuguese spread has on average increased by three times the size of the original Spanish shock before it starts falling.

Prior to the OMT, Dutch and – to a lesser extent – Finnish spreads vis-à-vis the OIS rate increase a bit in response to Spanish shocks. Somewhat remarkably, the spread between the German Bund and the OIS rate also marginally increases, though it takes a bit longer than in most countries. It reaches its peak 4 days after the initial shock, when spreads in other countries have already started falling. The combination of a small increase in the German spread with falling spreads elsewhere, might reflect a positively received policy response to the initial shock or the expectation that Germany would bear the brunt of the cost of a rescue operation. Alternatively, the small increase in German spreads vis-à-vis the pure risk-free rate could also simply reflect that Germany, having a less than fully healthy banking system, was not always 100% isolated from Spanish turmoil.[21]

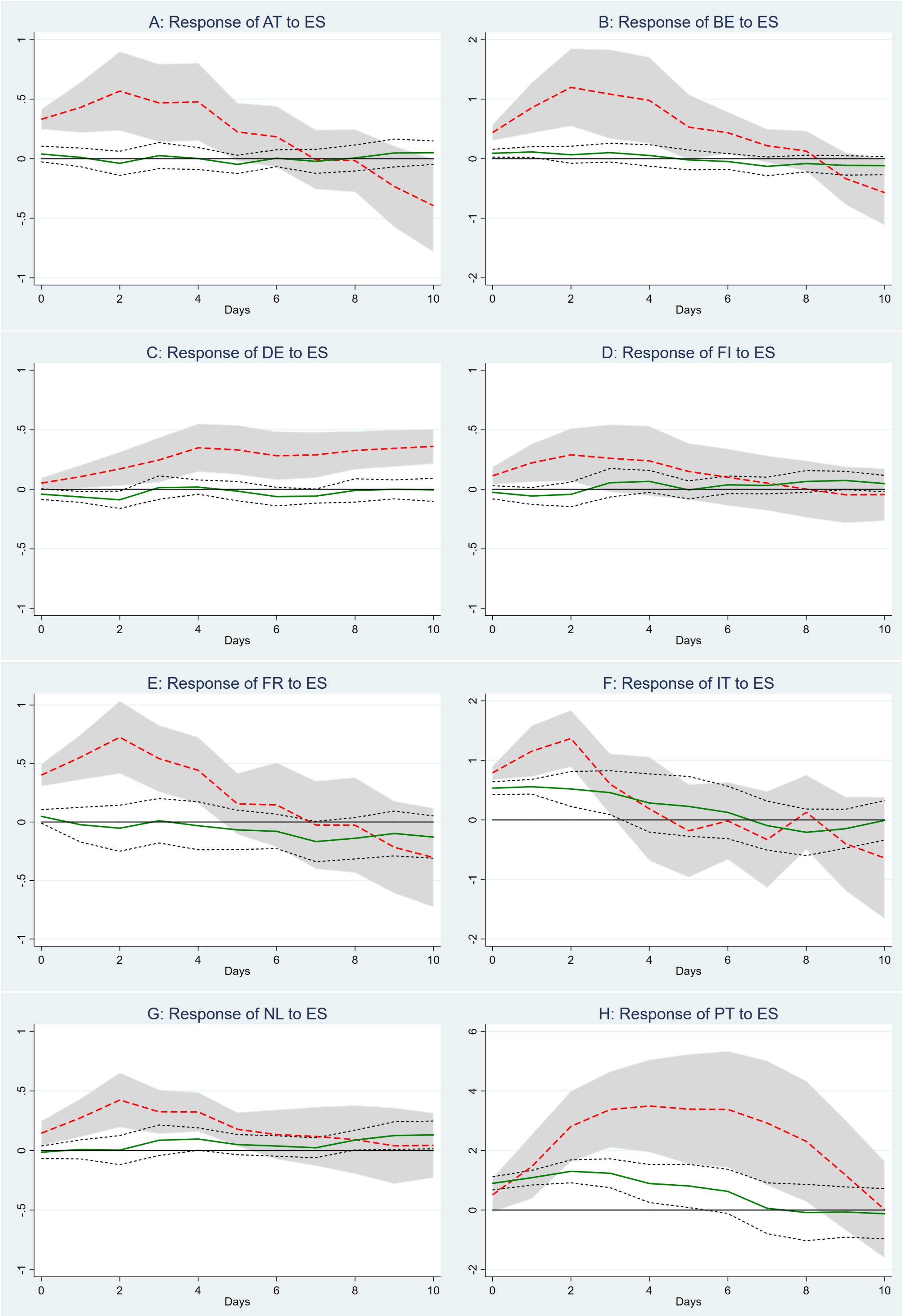
In most countries, the shock fades out between 5-10 working days after the shock. Given the action-reaction nature of the European policy response to the crisis, one way to interpret this is that the shock has been contained after 1-2 weeks. Since the introduction of the OMT, the picture is markedly different. Spillovers from Spain still exist, but now only to Italy and Portugal. Peak effects are now also reached much sooner, after which the effect of the shock monotonically fades away. Table 2 sheds more light on the extent to which pre- and post-OMT effects statistically differ from each other, which on impact is the case for all countries bar Portugal (for which, however, the longer-run effect is significantly smaller than before).

Table 2 also displays the coefficients on the control variables. Interestingly, in the 'safe' euro area countries – Germany, Finland and the Netherlands – the coefficient on the lagged change of the own spread is negative. That is, the spread is mean reverting. For Belgium, Italy, and Portugal, the spread is more persistent, as is evident from the positive and statistically significant lag of the change of the own spread. Austria and France are intermediate cases, with coefficients

[20]This might also explain why Saka et al. (2015), focusing only on impact effects, somewhat counter-intuitively did not find any spillovers from Spain to Portugal.

[21]The German response is not simply a quirk of the Bund-OIS spread. German CDS also marginally increase in response to Spanish shocks. The (limited) responsiveness of German CDS to turmoil in the periphery is consistent with the fact that German CDS were higher during 2011/2012 than before or after this period.

Figure 2: Yield spillovers from Spain




Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Spanish spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6. The range of the y-axis in figures B, F and H differs from that in the other figures.

Table 2: Yield spillovers from Spain

| $\Delta$ $Spread_{i,t+h}$ | (1) AT | (2) BE | (3) DE | (4) FI | (5) FR | (6) IT | (7) NL | (8) PT |
|---|---|---|---|---|---|---|---|---|
| *h = 0* | | | | | | | | |
| $\Delta$ $Spread_{ES,t}$ | 0.33*** | 0.44*** | 0.05* | 0.11** | 0.40*** | 0.79*** | 0.15** | 0.51 |
| | (0.05) | (0.08) | (0.03) | (0.05) | (0.06) | (0.07) | (0.06) | (0.35) |
| $\Delta$ $Spread_{ES,t}$ * OMT$_t$ | -0.29*** | -0.35*** | -0.09** | -0.14** | -0.35*** | -0.26*** | -0.16** | 0.39 |
| | (0.07) | (0.09) | (0.04) | (0.06) | (0.07) | (0.10) | (0.07) | (0.37) |
| *h = 1* | | | | | | | | |
| $\Delta$ $Spread_{ES,t}$ | 0.43*** | 0.86*** | 0.11* | 0.22** | 0.55*** | 1.15*** | 0.27*** | 1.46** |
| | (0.13) | (0.26) | (0.06) | (0.10) | (0.12) | (0.26) | (0.10) | (0.66) |
| $\Delta$ $Spread_{ES,t}$ * OMT$_t$ | -0.42*** | -0.74*** | -0.17*** | -0.28*** | -0.58*** | -0.60** | -0.27** | -0.37 |
| | (0.14) | (0.27) | (0.07) | (0.11) | (0.15) | (0.27) | (0.11) | (0.67) |
| *h = 3* | | | | | | | | |
| $\Delta$ $Spread_{ES,t}$ | 0.47** | 1.08** | 0.25** | 0.26 | 0.15 | 0.60* | 0.33*** | 3.38*** |
| | (0.20) | (0.46) | (0.12) | (0.17) | (0.22) | (0.31) | (0.11) | (0.78) |
| $\Delta$ $Spread_{ES,t}$ * OMT$_t$ | -0.44** | -0.98** | -0.23* | -0.21 | -0.23 | -0.14 | -0.24* | -2.14*** |
| | (0.21) | (0.47) | (0.13) | (0.19) | (0.24) | (0.38) | (0.14) | (0.83) |
| *h = 6* | | | | | | | | |
| $\Delta$ $Spread_{ES,t}$ | 0.18 | 0.44** | 0.28** | 0.10 | 0.15 | -0.02 | 0.13 | 3.38*** |
| | (0.16) | (0.21) | (0.12) | (0.15) | (0.22) | (0.40) | (0.13) | (1.19) |
| $\Delta$ $Spread_{ES,t}$ * OMT$_t$ | -0.18 | -0.48** | -0.34*** | -0.06 | -0.23 | 0.14 | -0.10 | -2.75** |
| | (0.16) | (0.23) | (0.13) | (0.15) | (0.24) | (0.47) | (0.14) | (1.27) |
| *h = 0* | | | | | | | | |
| $\Delta$ $Spread_{i,t-1}$ | 0.06 | 0.24*** | -0.10 | -0.17* | 0.05 | 0.21*** | -0.17*** | 0.27*** |
| | (0.05) | (0.09) | (0.08) | (0.09) | (0.06) | (0.07) | (0.05) | (0.08) |
| $\Delta$ $Spread_{i,t-1}$ * OMT$_t$ | -0.22*** | -0.31*** | -0.28*** | -0.02 | -0.17** | -0.18** | -0.05 | -0.16* |
| | (0.07) | (0.10) | (0.10) | (0.10) | (0.08) | (0.08) | (0.07) | (0.09) |
| $\Delta$ OIS10$_{t-1}$ | 0.11* | 0.15** | 0.13*** | 0.11** | 0.11 | 0.05 | 0.14*** | 0.16 |
| | (0.06) | (0.07) | (0.04) | (0.04) | (0.07) | (0.06) | (0.03) | (0.22) |
| $\Delta$ OIS10$_{t-1}$ * OMT$_t$ | -0.00 | -0.01 | -0.05 | -0.02 | -0.00 | 0.01 | -0.03 | -0.12 |
| | (0.06) | (0.07) | (0.04) | (0.05) | (0.08) | (0.07) | (0.04) | (0.23) |
| $\Delta$ VIX$_{t-1}$ | 0.04 | 0.01 | -0.00 | -0.00 | 0.07** | -0.00 | 0.02 | -0.08 |
| | (0.03) | (0.03) | (0.02) | (0.03) | (0.03) | (0.05) | (0.03) | (0.12) |
| $\Delta$ VIX$_{t-1}$ * OMT$_t$ | -0.04 | -0.02 | -0.00 | -0.01 | -0.08** | 0.06 | -0.03 | 0.12 |
| | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) | (0.06) | (0.03) | (0.13) |
| $\Delta$ Euro Stoxx$_{t-1}$ | -0.50*** | -0.64*** | -0.24 | -0.37** | -0.44** | -0.17 | -0.19 | -0.77 |
| | (0.19) | (0.19) | (0.16) | (0.17) | (0.21) | (0.18) | (0.13) | (0.67) |
| $\Delta$ Euro Stoxx$_{t-1}$ * OMT$_t$ | 0.23 | 0.41* | 0.16 | 0.09 | 0.24 | 0.34 | -0.04 | 0.87 |
| | (0.20) | (0.21) | (0.17) | (0.20) | (0.23) | (0.24) | (0.15) | (0.73) |
| $\Delta$ Bank CDS$_{t-1}$ | 0.04 | -0.03 | -0.01 | -0.01 | 0.03 | 0.11 | 0.05 | 0.49 |
| | (0.06) | (0.09) | (0.05) | (0.04) | (0.06) | (0.08) | (0.04) | (0.31) |
| $\Delta$ Bank CDS$_{t-1}$ * OMT$_t$ | -0.02 | 0.04 | 0.01 | 0.04 | -0.02 | -0.09 | -0.04 | -0.46 |
| | (0.06) | (0.09) | (0.05) | (0.04) | (0.06) | (0.08) | (0.04) | (0.31) |
| $\Delta$ BA spread$_{t-1}$ | -0.05 | -0.08 | -0.25* | -0.05 | -0.28*** | 0.13 | -0.02 | 0.34*** |
| | (0.07) | (0.09) | (0.13) | (0.05) | (0.07) | (0.16) | (0.07) | (0.11) |
| $\Delta$ BA spread$_{t-1}$ * OMT$_t$ | 0.05 | -0.05 | 0.15 | -0.06 | 0.29* | -0.34 | -0.18 | -0.28** |
| | (0.09) | (0.13) | (0.30) | (0.14) | (0.17) | (0.53) | (0.26) | (0.13) |
| Observations | 1,787 | 1,791 | 1,790 | 1,788 | 1,788 | 1,792 | 1,782 | 1,788 |
| Kleibergen-Paap underid p | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 |
| Kleibergen-Paap weak ID F | 10.10 | 8.72 | 9.39 | 9.49 | 10.49 | 8.60 | 9.40 | 10.41 |

Note: dependent variable: change in the spread between day $t + h$ and day $t - 1$ of the country listed in the top row. The change in the Spanish spread is instrumented with the shock series documented in section 4.1. All regressions include five lags of the own spread, one lag of the Spanish spread, and a pre- and post-OMT constant (see equation 3). HAC robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. See figure 2 for the corresponding IRFs.

that are close to zero. After the introduction of the OMT, spreads become mean-reverting in all countries with the exception of Portugal, where persistence nevertheless falls significantly.

Consistent with the results of Manganelli and Wolswijk (2009) and in line with the risk-taking channel of monetary policy, an increase in the risk free rate increases spreads in all euro area countries (statistically significant in six out of eight cases). This is the case both before and after the introduction of the OMT.

Prior to the OMT, an increase in the Euro Stoxx index leads to lower spreads across the board. Non-crisis, non-safe haven countries Austria, Belgium, and France are most sensitive to changes in this stock market index. The relation between spreads and the Euro Stoxx index gets weaker post-OMT. Changes in the VIX index have fewer effects. Only in France, prior to the OMT, do we find a significant positive relation with spreads.

The effect of the lagged change in the bid-ask spread is somewhat difficult to interpret, as this series is strongly mean reverting: days with increases in the bid-ask spread are followed by days of falling bid-ask spreads. The effect of using one-day lagged as opposed to contemporaneous BA spreads is thus to switch the sign of the coefficient. The positive pre-OMT coefficient for Portugal is best (cautiously) interpreted as less liquid markets being associated with falling spreads, while the opposite effect in France and Germany suggests a 'scarcity' premium which might be expected for Germany but which, given the other results, is somewhat surprising for France.

In the reported $h = 0$ regressions, the aggregate bank CDS index does not significantly affect the spread of any of the countries in the analysis, presumably because the index is too wide. At longer horizons, we do find an effect in the Netherlands, with its big and internationally active banking sector. This effect disappears after the announcement of the OMT.

## 5.2 Italy

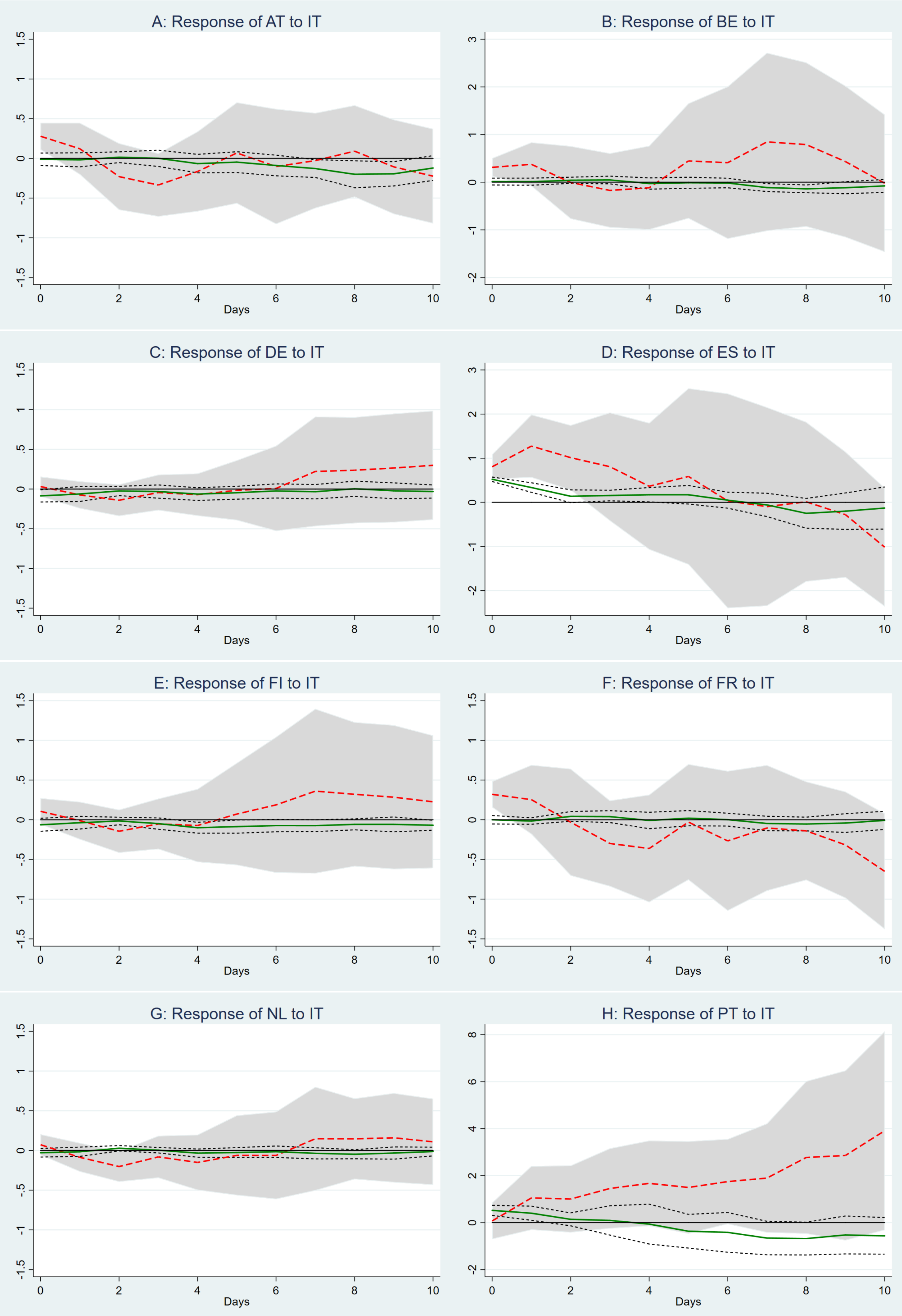
Figure 3 and table 3 display the results for Italy. Prior to the introduction of the OMT, shocks to the Italian spread induce significant spillovers to Austria, Belgium, France and Spain. Both on impact and overall, Spain is most heavily affected: a shock to the Italian spread spills over for 81% on impact, and over one-to-one after one day. The reaction of Spain to Italy largely resembles the reaction of Italy to Spain, highlighting their interconnectedness.

Like in the Spanish case, the Portuguese spread is slow to respond: it takes 12 days before the peak effect is reached (not shown), though confidence intervals are very large.

Overall, spillovers from Italy are mostly smaller and shorter lived than those originating in Spain, but also less precisely estimated. More than in the case of Spain, there is evidence of a negative response of Dutch, Finnish and German spreads, though prior to the OMT this response is never statistically significant.

The coefficients on the control variables are as before. Spain joins the club of vulnerable countries in terms of the persistence of its spread movements. As in the Portuguese case, some persistence remains even after the introduction of the OMT, though notably less than before.

Figure 3: Yield spillovers from Italy




Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Italian spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6. The range of the y-axis in figures B, D and H differs from that in the other figures.

Table 3: Yield spillovers from Italy

| $\Delta$ $Spread_{i,t+h}$ | (1) AT | (2) BE | (3) DE | (4) ES | (5) FI | (6) FR | (7) NL | (8) PT |
|---|---|---|---|---|---|---|---|---|
| *h = 0* | | | | | | | | |
| $\Delta$ $Spread_{IT,t}$ | 0.28*** | 0.31*** | 0.03 | 0.81*** | 0.11 | 0.29** | 0.07 | 0.07 |
| | (0.10) | (0.12) | (0.08) | (0.17) | (0.10) | (0.12) | (0.08) | (0.47) |
| $\Delta$ $Spread_{IT,t}$ * $\text{OMT}_t$ | -0.29** | -0.30** | -0.12 | -0.28 | -0.17 | -0.29** | -0.10 | 0.45 |
| | (0.11) | (0.13) | (0.09) | (0.17) | (0.11) | (0.13) | (0.09) | (0.49) |
| *h = 1* | | | | | | | | |
| $\Delta$ $Spread_{IT,t}$ | 0.12 | 0.38 | -0.07 | 1.27*** | -0.01 | 0.23 | -0.11 | 1.05 |
| | (0.20) | (0.28) | (0.10) | (0.43) | (0.14) | (0.28) | (0.11) | (0.83) |
| $\Delta$ $Spread_{IT,t}$ * $\text{OMT}_t$ | -0.14 | -0.36 | 0.01 | -0.94** | -0.03 | -0.24 | 0.09 | -0.65 |
| | (0.21) | (0.28) | (0.12) | (0.44) | (0.15) | (0.29) | (0.12) | (0.85) |
| *h = 3* | | | | | | | | |
| $\Delta$ $Spread_{IT,t}$ | -0.34 | -0.17 | -0.04 | 0.81 | -0.05 | -0.34 | -0.10 | 1.45 |
| | (0.24) | (0.47) | (0.14) | (0.75) | (0.19) | (0.38) | (0.17) | (1.04) |
| $\Delta$ $Spread_{IT,t}$ * $\text{OMT}_t$ | 0.34 | 0.22 | 0.01 | -0.65 | 0.00 | 0.38 | 0.10 | -1.36 |
| | (0.25) | (0.48) | (0.15) | (0.75) | (0.20) | (0.38) | (0.17) | (1.11) |
| *h = 6* | | | | | | | | |
| $\Delta$ $Spread_{IT,t}$ | -0.10 | 0.41 | 0.01 | 0.03 | 0.19 | -0.27 | -0.07 | 1.75 |
| | (0.44) | (0.97) | (0.33) | (1.48) | (0.52) | (0.57) | (0.35) | (1.10) |
| $\Delta$ $Spread_{IT,t}$ * $\text{OMT}_t$ | 0.01 | -0.43 | -0.03 | 0.02 | -0.26 | 0.27 | 0.05 | -2.16* |
| | (0.45) | (0.97) | (0.33) | (1.48) | (0.52) | (0.57) | (0.35) | (1.22) |
| *h = 0* | | | | | | | | |
| $\Delta$ $Spread_{i,t-1}$ | 0.09 | 0.21** | -0.10 | 0.30*** | -0.17* | 0.04 | -0.17*** | 0.26*** |
| | (0.07) | (0.10) | (0.08) | (0.04) | (0.09) | (0.07) | (0.05) | (0.08) |
| $\Delta$ $Spread_{i,t-1}$*$\text{OMT}_t$ | -0.24*** | -0.27** | -0.28*** | -0.16* | -0.02 | -0.15 | -0.05 | -0.19** |
| | (0.09) | (0.11) | (0.10) | (0.08) | (0.02) | (0.10) | (0.08) | (0.09) |
| $\Delta$ $\text{OIS10}_{t-1}$ | 0.12*** | 0.15** | 0.12*** | -0.02 | 0.10** | 0.13** | 0.13*** | 0.20 |
| | (0.05) | (0.07) | (0.04) | (0.08) | (0.05) | (0.05) | (0.03) | (0.23) |
| $\Delta$ $\text{OIS10}_{t-1}$ * $\text{OMT}_t$ | -0.02 | -0.01 | -0.04 | 0.02 | -0.01 | -0.03 | -0.01 | -0.16 |
| | (0.05) | (0.07) | (0.05) | (0.09) | (0.05) | (0.06) | (0.04) | (0.25) |
| $\Delta$ $\text{VIX}_{t-1}$ | 0.02 | -0.03 | -0.01 | -0.06 | -0.01 | 0.04 | -0.00 | -0.18 |
| | (0.03) | (0.04) | (0.03) | (0.06) | (0.03) | (0.04) | (0.02) | (0.16) |
| $\Delta$ $\text{VIX}_{t-1}$*$\text{OMT}_t$ | -0.02 | 0.02 | 0.01 | 0.05 | 0.00 | -0.04 | -0.01 | 0.22 |
| | (0.04) | (0.04) | (0.03) | (0.06) | (0.03) | (0.04) | (0.03) | (0.16) |
| $\Delta$ Euro $\text{Stoxx}_{t-1}$ | -0.46*** | -0.61*** | -0.25* | 0.15 | -0.36** | -0.36 | -0.20* | -0.80 |
| | (0.18) | (0.23) | (0.14) | (0.22) | (0.17) | (0.22) | (0.12) | (0.70) |
| $\Delta$ Euro $\text{Stoxx}_{t-1}$ * $\text{OMT}_t$ | 0.18 | 0.36 | 0.16 | -0.23 | 0.10 | 0.14 | -0.02 | 0.93 |
| | (0.20) | (0.25) | (0.16) | (0.27) | (0.19) | (0.24) | (0.14) | (0.76) |
| $\Delta$ Bank $\text{CDS}_{t-1}$ | -0.00 | -0.04 | -0.01 | -0.04 | -0.02 | -0.01 | 0.05 | 0.49 |
| | (0.06) | (0.08) | (0.04) | (0.09) | (0.04) | (0.05) | (0.04) | (0.32) |
| $\Delta$ Bank $\text{CDS}_{t-1}$ * $\text{OMT}_t$ | 0.02 | 0.05 | 0.02 | 0.04 | 0.05 | 0.02 | -0.04 | -0.46 |
| | (0.06) | (0.09) | (0.04) | (0.09) | (0.04) | (0.05) | (0.04) | (0.32) |
| $\Delta$ BA $\text{spread}_{t-1}$ | -0.09 | -0.08 | -0.27* | 0.06 | -0.04 | -0.23*** | 0.01 | 0.33*** |
| | (0.07) | (0.09) | (0.14) | (0.11) | (0.05) | (0.07) | (0.07) | (0.11) |
| $\Delta$ BA $\text{spread}_{t-1}$ * $\text{OMT}_t$ | 0.11 | -0.03 | 0.18 | -0.07 | -0.07 | 0.21 | -0.21 | -0.28** |
| | (0.09) | (0.14) | (0.31) | (0.25) | (0.15) | (0.17) | (0.27) | (0.13) |
| Observations | 1,787 | 1,791 | 1,790 | 1,792 | 1,788 | 1,788 | 1,782 | 1,788 |
| Kleibergen-Paap underid p | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.00 | 0.02 | 0.01 |
| Kleibergen-Paap weak ID F | 13.24 | 11.84 | 7.74 | 9.72 | 8.60 | 8.74 | 8.56 | 8.22 |

Dependent variable: change in the spread between day $t+h$ and day $t-1$ of the country listed in the top row. The change in the Italian spread is instrumented with the shock series documented in section 4.1. All regressions include five lags of the own spread, one lag of the Italian spread and a pre- and post-OMT constant (see equation 3). HAC robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

### 5.3 Response of pan-European variables

So far, we have established sizable sovereign risk spillovers from Spain and, to a lesser extent, Italy to large parts of the eurozone. This suggests that a response might also be visible in pan-European financial variables, which could provide some context to our earlier results.

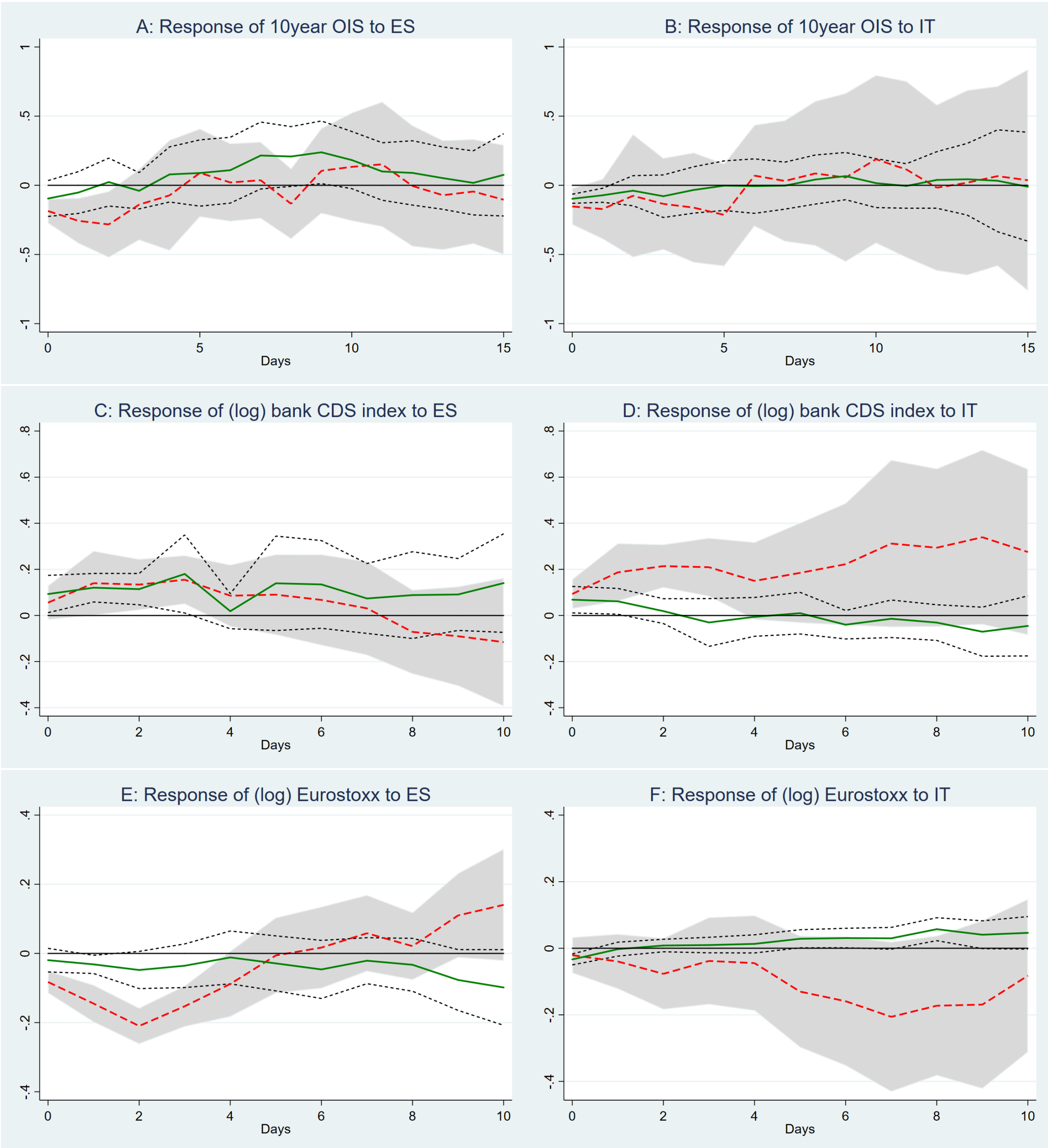
To this end, figures 4A and 4B report the response of our measure of the risk-free rate itself. On impact, prior to the OMT, the 10 year OIS rate marginally falls in response to increases in either the Spanish or the Italian spread. A 100 bps shock to the Italian spread on impact pushes the OIS rate down by 15 bps, an equivalent shock to the Spanish spread has an effect of -18 bps. From $h = 2$ onward, the response is never significantly different from zero, although point estimates move around a little. After the OMT, dynamics are similar, but the impact effect of Spanish shocks loses significance.

A first thing to take away from this is that the fall of the OIS rate resulting from a shock in Spain is similar in magnitude to the increase in Dutch and Finnish spreads reported earlier. Thus, Dutch and Finnish *yields* do not move much in response to a shock in Spain. For Germany, the net effect is that on impact its yield falls in response to both Spanish or Italian shocks. A second thing to note is that the point estimates of the effect on the OIS rate fluctuate somewhat – within relatively wide confidence bands. This serves as a reminder that with the LP-IV approach, small day-to-day variations should not be over-interpreted. Specifically, when looking at spillovers from Spain to the other euro area countries, the fact that spillovers turn somewhat negative at $h = 10$ largely seems to reflect a small upward movement of the OIS rate. As figure 4A illustrates, this is a bleep, with the coefficient falling back to zero in the following days.

An important element of the euro crisis has been the so-called 'doom loop' between banks and sovereigns. For this reason, we have included (the log of) the lagged change of the aggregate European banking CDS index as control in all regressions. In figures 4C and 4D, we instead plot the contemporaneous *response* of this bank CDS index to shocks to the Italian and Spanish sovereign spreads. We find that, prior to the OMT, the CDS index increases in reaction to increases in both Spanish and Italian spreads. Post-OMT, we still find an impact effect, but especially in Italy it dies out quicker than before. In Spain, there is no notable difference pre- and post-OMT. This conclusion does somewhat depend on the use of the natural logarithm of the index, however: in absolute terms, the reaction was a bit stronger prior to the OMT. The sensitivity of the estimation to this choice reflects that the index was generally at a far higher level in the pre-OMT period.

The response of the Euro Stoxx stock market index is also in line with earlier findings. Prior to the OMT, Spain appears a bigger risk for the European economy than Italy: changes in the Spanish spread have a larger (as well as more precisely estimated) effect on the stock index than changes in the Italian spread. The pre- / post-OMT split is also notably clearer in the Spanish case.

Figure 4: Response of pan-European variables




Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Spanish spread (figures A, C and E) or the Italian spread (figures B, D and F), instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6.

### 5.4 External effects

When the euro area as a whole is perceived to be at risk, this might well have global effects. Investigating these effects in an event study, Stracca (2015) find that during 2010-2012 crisis-related events in the euro area contribute to a rise in global risk aversion (as captured by the VIX index), a small fall in interest rates of other 'safe' countries, and a depreciation of the euro. In the following, we build on this by testing whether an increase in the Spanish or Italian sovereign spread affects the the VIX index, the yield on 10 year US sovereign bonds, and the euro-dollar exchange rate, and if this changed after the OMT. The methodology is similar as before, though we now add the (lagged) Dow Jones index and US interest rate to the set of controls.

We find that prior to the OMT, the US interest rate falls in response to upward changes in the Spanish and Italian yield spreads (see figure 5A and 5B). The strength of the spillover is similar in both countries, though, as before, the estimate for Italy is less precise. After the announcement of the OMT, this effect disappears.

The downward movement of US rates in response to an intensification of the euro crisis could reflect its global safe haven status, in which case we would also expect to see an increase in global risk aversion following Spanish and Italian shocks. To this end, figure 5C and 5D display the response of the VIX index. Prior to the OMT, it indeed increases in response to both Spanish and Italian shocks, though only significantly so for the former. Post-OMT, this effect disappears.

Prior to the OMT, we also document a consistent downward effect of changes in the Spanish and Italian spread on the euro-dollar exchange rate. In terms of size, the effect is actually slightly bigger for Italy, though the Italian impulse response function is a bit erratic (due to a spike at $h = 4$). Post-OMT, this effect is smaller and shorter lived than before, but it does not disappear completely.

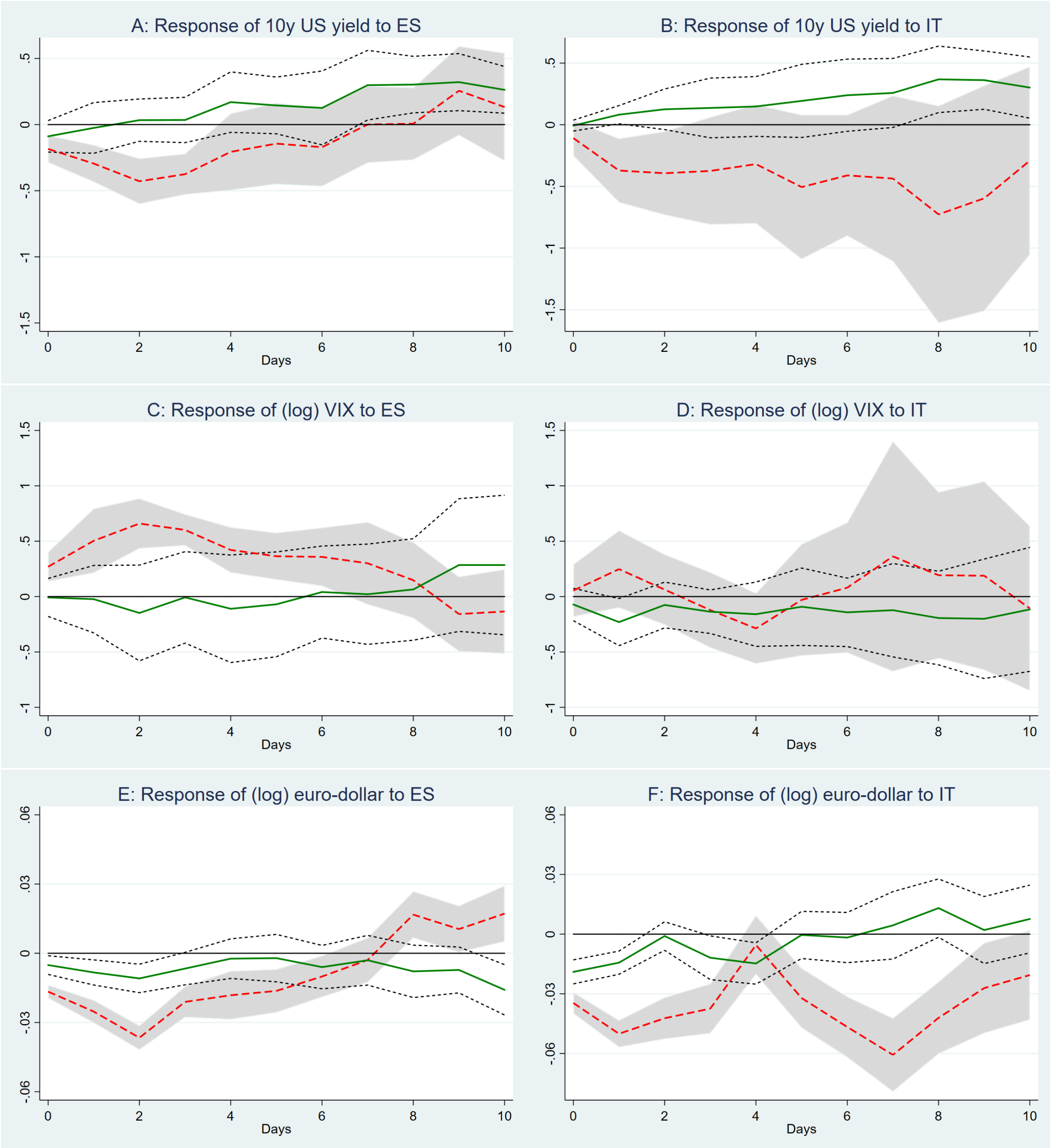
## 6 Sensitivity

### 6.1 Shorter and symmetric intervals around OMT

In our main analysis, our pre-OMT period covers June 1, 2009 until June 25, 2012. Our post-OMT period is a bit longer, covering June 26, 2012 through June 30, 2016. We believe this entire period to be of interest, as it, for instance, allows us to show that the OMT opened the door to a *durable* new regime. Additionally, identification is supported by having more data.

At the same time, however, more things happened in this period than just the announcement of the OMT. In the years prior to the introduction of the OMT, cross-border banking exposures have been gradually reduced. It is possible, therefore, that cross-border sovereign risk spillovers had already been gradually falling before the OMT. In the years after the OMT, many other policy initiatives were taken that might plausibly have affected spillovers in sovereign debt markets. On 9 March 2015, for instance, the ECB launched its quantitative easing program (dubbed Asset Purchase Program, or APP) and started buying substantial amounts of euro area sovereign debt. It is possible that part of the more muted post-OMT sovereign risk spillovers are in fact the consequence of such later interventions.

Figure 5: External effects




Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Spanish spread (figures A, C and E) or the Italian spread (figures B, D and F), instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6.

To isolate the effects of the OMT, we therefore now shrink our sample period. We rerun our regressions for symmetric two year (one year before the OMT, until one year after) and one year samples. Shortening the sample period puts an increasing amount of strain on our identification strategy. However, as much news was concentrated in 2012 / 2013, identification is generally still acceptable.[22] For the two-year window, results are very similar to those reported before, confirming the break taking place around the OMT, and ruling out alternative explanations like the APP. See Figure A.1 and A.2 in the Annex.

For the one-year window, where identification is more challenging, main results are confirmed too, with a few minor but interesting deviations (see figure A.3 and A.4 in the Annex). Germany's pre-OMT response to Spain is more muted, and its response to Italy more notably negative, than when using longer samples, suggesting that any small upward movements of the German spread took place early in the crisis. The pre-OMT Belgian response to Spain remains notable, but falls somewhat compared to earlier estimates. This could reflect that Belgian vulnerability had already been falling somewhat prior to the OMT.[23] Yet, the break around the OMT remains extremely clear also in this short sample. For all other countries spillovers are as before, with the caveat that the confidence intervals for spillovers from Italy widen further.

### 6.2 Specification of the LP model

In our baseline model, we have opted for a relatively parsimonious specification, only including the most commonly used control variables and a limited number of lags. This makes for a more transparent regression and facilitates presentation and interpretation of the control variables. As discussed in section 4, there are also advantages to richer specifications, amongst which the fact that assumptions for IV exogeneity become less stringent. In contrast, if one takes our identification strategy at face value but instead doubts the exogeneity of some of the (lagged) control variables, an even leaner model can also be argued for.

To test the sensitivity of our results to the exact version chosen, we have estimated two more specifications: a full model, and an extremely lean model. The full model includes additional (lagged and first differenced) variables controlling for the domestic and European economic situation: the domestic stock market index, the CITI group economic surprise index, the VSTOXX index (the European equivalent of the VIX), the euro-dollar exchange rate, and the short-term EONIA interest rate. To capture any residual autocorrelation we now also include 10 lags of the own spread, as well as 5 lags of all control variables and the lagged Spanish and Italian interest rates. The lean model, on the other hand, excludes all control variables other than the lagged changes of the own and foreign yield spread.

Results are presented in in figures A.5-A.8 in the Annex. As to the full model, spillovers are very similar to those presented before, with confidence intervals shrinking slightly. None of

[22]Even when using the one year sample, it always remains possible to reject underidentification at the 5% level. For Spain, values for the Kleibergen-Paap rk Wald F statistic generally remain close to 10, for Italy, values fall more notably, especially when using the one-year interval.

[23]This is confirmed by a casual inspection of spread levels. Whereas Spanish and Italian sovereign spreads peaked right around the announcement of the OMT, Belgian spreads peaked in November 2011.

the additional controls has significant effects across the board, though for individual countries occasionally one of the longer lags of the own spread and/or the new controls (mostly lags of the euro-dollar, the CITI surprise index, or the EONIA) have a significant impact. As to the lean model, results are qualitatively unchanged, but estimated spillovers increase somewhat, and confidence intervals marginally widen, compared to the baseline results presented earlier.

### 6.3 Including leads and lags of instruments

Given the assumption of lead/lag exogeneity, Stock and Watson (2018) note that in an LP-IV framework it is theoretically possible to include both leads and lags of the instrument as control variables in order to enhance estimation efficiency. Controlling for lags of the instrument has the additional advantage that, in case of serial correlation in the shock series, it makes sure that the instrument only picks up the effect of the time $t$ shock.

Including leads of the instrument helps to deal with the issue highlighted by Teulings and Zubanov (2014) that, at longer horizons, local projection estimates might be biased because in the estimation process shocks occurring between time $t$ and $t + h$ are ignored. As a pragmatic solution, they suggest to directly include these shocks in the regression.

We have therefore re-estimated the model including 2 lags and 10 leads (i.e. covering the entire forecast horizon) of the instruments. Results are presented in figures A.9 and A.10 in the Annex. For Italy, point estimates are similar as before, while the efficiency gain results in somewhat smaller confidence intervals. As a result, we now do find statistically significant spillovers from Italy to Portugal (still taking 12 days to reach its peak).

Regarding spillovers from Spain, controlling for lagged values of the instrument proves more relevant, with 'peak' estimates of spillovers falling a little.[24] This is most visible for countries where spillovers are largest: for Belgium the peak spillover effect falls from a slightly larger than one-to-one effect, to a slightly smaller effect. Most notably, for Portugal, the maximum spillover effect falls by about 60 bps. The exact size of the (quite extreme and imprecisely estimated) spillover effect to Portugal should be interpreted with some caution. Overall however, results are similar to those presented in the main text, both in terms of the size and persistence of pre-OMT spillovers, as well as in terms of the clear break around the OMT announcement.

### 6.4 Instrument validity

The exogeneity of our instrument largely hinges on our use of high-frequency data. The arguably most contentious part of our shock series concerns the market reaction to overnight events, for which it is much harder to ascertain that no other events interfere. We take two approaches to make sure that this does not unduly affect our results. First, we generate an additional instrument: the market reaction in a very short window around the event (15 minutes before until 15 minutes after), only for events occurring during trading hours. Including this additional,

[24] Further inspection indeed suggests (minor) serial correlation in the Spanish shock series, with a regression of the shock on its lag giving a coefficient of 0.11.

and more evidently exogenous, instrument in our regressions allows us to conduct tests of over-identifying restrictions. We obtain separate P-values for the Hansen test for each forecast lead of every bilateral regression, providing us with a distribution of P-values ranging from 0.04 to 0.99. Out of the 160 tests done, the null hypothesis of exogeneity is only rejected thrice at the 10% level and once at the 5% level. Overall therefore, the Hansen-test does not point to an endogeneity problem.

As a second and more rigorous approach, we exclude all overnight events. This reduces the number of event days in our dataset by about a quarter (to 66 for Spain and 55 for Italy). It weakens identification, particularly post-OMT, and more so for Italy than for Spain. However, while Italian post-OMT confidence intervals widen as a result, our results are otherwise confirmed (see figures A.11 and A.12). Qualitatively most affected is, again, the estimated spillover effect from Spain to Portugal: the peak effect of a 100 bps shock to the Spanish spread on the Portuguese spread falls from around 340 bps, to around 240 bps. Our baseline estimate was thus to a considerable degree driven by overnight events. This serves as a second reminder that the point estimates for spillovers to Portugal should be interpreted with some caution.

# 7 Concluding remarks

Sovereign risk spillovers are often dubbed contagion when they have substantially increased vis-à-vis a certain 'quiet' baseline period. In this paper, we adopt a reverse logic, comparing sovereign risk spillovers at the peak of the crisis with those after the announcement of the ECB's OMT program.

During 2009-2012, we document sizable yield spillovers between Italy and Spain, from Spain to Portugal, and from Spain and Italy to non-crisis, non-safe haven countries such as Belgium, France and Austria. During this period, we find spillovers from Spain to be more persistent than those from Italy, and also to have larger external effects on global financial variables such as the VIX index. During this period, developments in both countries also significantly affect the euro-dollar index and risk-free interest rates in the US. After the announcement of the OMT, spillovers to non-crisis, non-safe haven countries disappear almost completely, as do most spillovers to global financial markets. Some effect on the exchange rate, however, persists, as do limited spillovers between Italy, Spain and Portugal.

The sharp break around the OMT holds both for the full, 2009-2016, sample, as well as for symmetric, shorter windows around Mario Draghi's initial 'whatever it takes' speech. As such, we can rule out that the reduction in spillovers is driven by later developments, such as the ECB's Asset Purchase Program. Nevertheless, the announcement of the OMT was not a standalone event. It has even been suggested that other improvements to the EMU's institutional framework, such as the Banking Union, were seen by the ECB as prerequisites for the OMT (see e.g. Hartmann and Smets, 2018). These more gradual steps might very well have contributed to a reduction of spillovers. Yet, the sharp break around the announcement of the OMT even in short samples suggests that it, at the very least, has been an important factor in limiting contagion.

That the mere announcement of the OMT so drastically reduced sovereign risk spillovers suggests that at the height of the crisis, spillovers had a significant non-fundamental component. While the terminology is contentious, referring to this as contagion does not appear to be much of a stretch. Our analysis also provides evidence for the incredible effectiveness of the OMT announcement. While ECB-President Draghi has, because of his 'whatever it takes' speech, frequently been hailed as savior of the Eurozone, actual evidence on the effectiveness of the OMT beyond its short-term effects on spreads has been fairly scarce. Our results suggest that, due to the OMT, problems in even large individual member states remain much more contained, greatly enhancing the stability of the eurozone as a whole.

## References

Acharya, V. V., Pierret, D., and Steffen, S. (2018). Lender of Last Resort, Buyer of Last Resort, and a Fear of Fire Sales in the Sovereign Bond Market. *ZEW - Centre for European Economic Research Discussion Paper*, 16(9).

Afonso, A., Arghyrou, M. G., Gadea, M. D., and Kontonikas, A. (2018). "Whatever it takes" to resolve the European sovereign debt crisis? Bond pricing regime switches and monetary policy effects. *Journal of International Money and Finance*, 86:1–30.

Aizenman, J., Hutchison, M., and Jinjarak, Y. (2013). What is the risk of European sovereign debt defaults? Fiscal space, CDS spreads and market pricing of risk. *Journal of International Money and Finance*, 34:37–59.

Aizenman, J., Jinjarak, Y., Lee, M., and Park, D. (2016). Developing countries' financial vulnerability to the eurozone crisis: an event study of equity and bond markets. *Journal of Economic Policy Reform*, 19(1):1–19.

Altavilla, C., Giannone, D., and Lenza, M. (2016). The financial and macroeconomic effects of OMT announcements. *International Journal of Central Banking*, 12(3).

Altavilla, C., Pagano, M., and Simonelli, S. (2017). Bank exposures and sovereign stress transmission. *Review of Finance*, 21(6):2103–2139.

Alter, A. and Beyer, A. (2014). The dynamics of spillover effects during the European sovereign debt turmoil. *Journal of Banking & Finance*, 42:134–153.

Bacchetta, P., Perazzi, E., and van Wincoop, E. (2018). Self-fulfilling debt crises: What can monetary policy do? *Journal of International Economics*, 110:119–134.

Bahaj, S. (2019). Sovereign spreads in the euro area: Cross border transmission and macroeconomic implications. *Forthcoming, Journal of Monetary Economics.*

Beetsma, R., Giuliodori, M., De Jong, F., and Widijanto, D. (2013). Spread the news: The impact of news on the European sovereign bond markets during the crisis. *Journal of International Money and Finance*, 34:83–101.

Beirne, J. and Fratzscher, M. (2013). The pricing of sovereign risk and contagion during the European sovereign debt crisis. *Journal of International Money and Finance*, 34:60–82.

Bekaert, G., Ehrmann, M., Fratzscher, M., and Mehl, A. (2014). The global crisis and equity market contagion. *The Journal of Finance*, 69(6):2597–2649.

Bernoth, K. and Erdogan, B. (2012). Sovereign bond yield spreads: A time-varying coefficient approach. *Journal of International Money and Finance*, 31(3):639–656.

Bernoth, K., Von Hagen, J., and Schuknecht, L. (2012). Sovereign risk premiums in the European government bond market. *Journal of International Money and Finance*, 31(5):975–995.

Bocola, L. (2016). The pass-through of sovereign risk. *Journal of Political Economy*, 124(4):879–926.

Brutti, F. and Sauré, P. (2015). Transmission of sovereign risk in the euro crisis. *Journal of International Economics*, 97(2):231–248.

Buiter, W. and Rahbari, E. (2012). The European Central Bank as lender of last resort for sovereigns in the Eurozone. *JCMS: Journal of Common Market Studies*, 50(S2):6–35.

Claeys, P. and Vašíček, B. (2014). Measuring bilateral spillover and testing contagion on sovereign bond markets in Europe. *Journal of Banking & Finance*, 46:151–165.

Codogno, L., Favero, C., and Missale, A. (2003). Yield spreads on EMU government bonds. *Economic Policy*, 18(37):503–532.

Cole, H. L. and Kehoe, T. J. (2000). Self-fulfilling debt crises. *The Review of Economic Studies*, 67(1):91–116.

Corsetti, G. and Dedola, L. (2016). The Mystery of the Printing Press: Monetary Policy and Self-Fulfilling Debt Crises. *Journal of the European Economic Association*, 14(6):1329–1371.

D'Agostino, A. and Ehrmann, M. (2014). The pricing of G7 sovereign bond spreads–The times, they are a-changin. *Journal of Banking & Finance*, 47:155–176.

De Grauwe, P. (2012). The governance of a fragile Eurozone. *Australian Economic Review*, 45(3):255–268.

De Grauwe, P. (2013). The European Central Bank as lender of last resort in the government bond markets. *CESifo Economic Studies*, 59(3):520–535.

De Grauwe, P. and Ji, Y. (2013). Self-fulfilling crises in the Eurozone: An empirical test. *Journal of International Money and Finance*, 34:15–36.

De Haan, L., Hessel, J., and van den End, J. W. (2014). Are European sovereign bonds fairly priced? The role of modelling uncertainty. *Journal of International Money and Finance*, 47:239–267.

De Santis, R. (2012). The euro area sovereign debt crisis: safe haven, credit rating agencies and the spread of the fever from greece, ireland and portugal. *ECB Working Paper Series*, 1419.

De Santis, R. A. (2014). The euro area sovereign debt crisis: Identifying flight-to-liquidity and the spillover mechanisms. *Journal of Empirical Finance*, 26:150–170.

De Santis, R. A. (2015). A measure of redenomination risk. *ECB Working Paper Series*, 1785.

Delatte, A.-L., Fouquau, J., and Portes, R. (2017). Regime-dependent sovereign risk pricing during the euro crisis. *Review of Finance*, 21(1):363–385.

Dewachter, H., Iania, L., Lyrio, M., and de Sola Perea, M. (2015). A macro-financial analysis of the euro area sovereign bond market. *Journal of Banking & Finance*, 50:308–325.

Ehrmann, M. and Fratzscher, M. (2017). Euro area government bonds – Fragmentation and contagion during the sovereign debt crisis. *Journal of International Money and Finance*, 70:26–44.

Eijffinger, S. C., Kobielarz, M. L., and Uras, B. R. (2018). Sovereign default, exit and contagion in a monetary union. *Journal of International Economics*, 113:1–19.

Falagiarda, M. and Reitz, S. (2015). Announcements of ECB unconventional programs: Implications for the sovereign spreads of stressed euro area countries. *Journal of International Money and Finance*, 53:276–295.

Favero, C., Pagano, M., and Von Thadden, E. L. (2010). How does liquidity affect government bond yields? *Journal of Financial and Quantitative Analysis*, 45(1):107–134.

Gertler, M. and Karadi, P. (2015). Monetary policy surprises, credit costs, and economic activity. *American Economic Journal: Macroeconomics*, 7(1):44–76.

Giordano, R., Pericoli, M., and Tommasino, P. (2013). Pure or wake-up-call contagion? Another look at the EMU sovereign debt crisis. *International Finance*, 16(2):131–160.

Gomez-Puig, M. (2006). Size matters for liquidity: Evidence from EMU sovereign yield spreads. *Economics Letters*, 90(2):156–162.

Gürkaynak, R. S. and Wright, J. H. (2013). Identification and inference using event studies. *The Manchester School*, 81(S1):48–65.

Hartmann, P. and Smets, F. (2018). The first twenty years of the European Central Bank: Monetary policy. *ECB Working Paper Series 2219*.

Hebous, S. and Zimmermann, T. (2016). Revisiting the narrative approach of estimating tax multipliers. *The Scandinavian Journal of Economics*, 120(2):428–439.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American Economic Review*, 95(1):161–182.

Jordà, Ò., Schularick, M., and Taylor, A. M. (2015). Betting the house. *Journal of International Economics*, 96(S1):S2–S18.

Krishnamurthy, A., Nagel, S., and Vissing-Jorgensen, A. (2017). ECB policies involving government bond purchases: Impact and channels. *Review of Finance*, 22(1):1–44.

Kriwoluzky, A., Müller, G., and Wolf, M. (2015). Exit expectations and debt crises in currency unions. *CEPR Discussion Papers*, 10817.

Lorenzoni, G. and Werning, I. (2018). Slow moving debt crises. Mimeo, Norhtwestern University, July 11 2018.

Ludwig, A. (2014). A unified approach to investigate pure and wake-up-call contagion: Evidence from the Eurozone's first financial crisis. *Journal of International Money and Finance*, 48:125–146.

Manganelli, S. and Wolswijk, G. (2009). What drives spreads in the euro area government bond market? *Economic Policy*, 24(58):191–240.

Masson, P. R. (1998). Contagion: Monsoonal effects, spillovers, and jumps between multiple equilibria. *IMF Working Papers*, 98(142).

Metiu, N. (2012). Sovereign risk contagion in the eurozone. *Economics Letters*, 117(1):35–38.

Mink, M. and De Haan, J. (2013). Contagion during the Greek sovereign debt crisis. *Journal of International Money and Finance*, 34:102–113.

Pesaran, M. H. and Pick, A. (2007). Econometric issues in the analysis of contagion. *Journal of Economic Dynamics and Control*, 31(4):1245–1277.

Pozzi, L. and Wolswijk, G. (2012). The time-varying integration of euro area government bond markets. *European Economic Review*, 56(1):36–53.

Ramey, V. A. (2016). Macroeconomic shocks and their propagation. In Taylor, J. and Uhlig, H., editors, *Handbook of Macroeconomics*, volume 2, pages 71–162. Elsevier.

Ramey, V. A. and Zubairy, S. (2018). Government Spending Multipliers in Good Times and in Bad: Evidence from US Historical Data. *Journal of Political Economy*, 126(2):850–901.

Saka, O., Fuertes, A.-M., and Kalotychou, E. (2015). ECB policy and Eurozone fragility: Was De Grauwe right? *Journal of International Money and Finance*, 54:168–185.

Stock, J. H. and Watson, M. W. (2018). Identification and Estimation of Dynamic Causal Effects in Macroeconomics Using External Instruments. *The Economic Journal*, 128(610):917–948.

Stracca, L. (2015). Our currency, your problem? The global effects of the euro debt crisis. *European Economic Review*, 74:1–13.

Szczerbowicz, U. (2015). The ECB Unconventional Monetary Policies: Have They Lowered Market Borrowing Costs for Banks and Governments? *International Journal of Central Banking*, 11(4):91–127.

Teulings, C. N. and Zubanov, N. (2014). Is economic recovery a myth? Robust estimation of impulse responses. *Journal of Applied Econometrics*, 29(3):497–514.

Van der Heijden, M., Beetsma, R., and Romp, W. (2018). 'Whatever it takes' and the role of Eurozone news. *Applied Economics Letters*, 25(16):1166–1169.

Von Hagen, J., Schuknecht, L., and Wolswijk, G. (2011). Government bond risk premiums in the EU revisited: The impact of the financial crisis. *European Journal of Political Economy*, 27(1):36–43.

# A Annex

## A.1 Outliers

Outlier checks have been performed by inspecting the (tick-to-tick) changes in ask, bid and mid yields, as well as by checking bid-ask spreads.

Data quality generally appeared to be high. Two types of data errors were noted. Firstly, large jumps in both bid and ask yields that were driven by a comma in the wrong place (i.e. a yield jumping from 0.85% to 8.5%). These were corrected. Secondly, some zero bid or ask spreads were noted. When both bid and ask yields were equal te zero, the observation was dropped. When one of the two was exactly zero, and the absolute bid-ask spread was larger than 0.5%, the observation was dropped as well. All cases in which bid and ask spreads were closer together, but where one of them was exactly equal to zero, were inspected manually to see if they fitted within the pattern of the data.

Though the number of ticks per minute is generally high (on average 30-35 for both countries), they are not distributed uniformly over the day nor the sample period. Occasional missing minutes do exist. Often this is really an individual missing minute, sometimes the market in a specific country opened later than usual, or the market is truly illiquid. As a first step, all single missing minutes are interpolated. If more than one minute is missing in succession and this results in it being not possible to compute the market reaction to a news story, the data is checked manually. In three cases this has resulted in gaps from 2 to 5 minutes being interpolated.

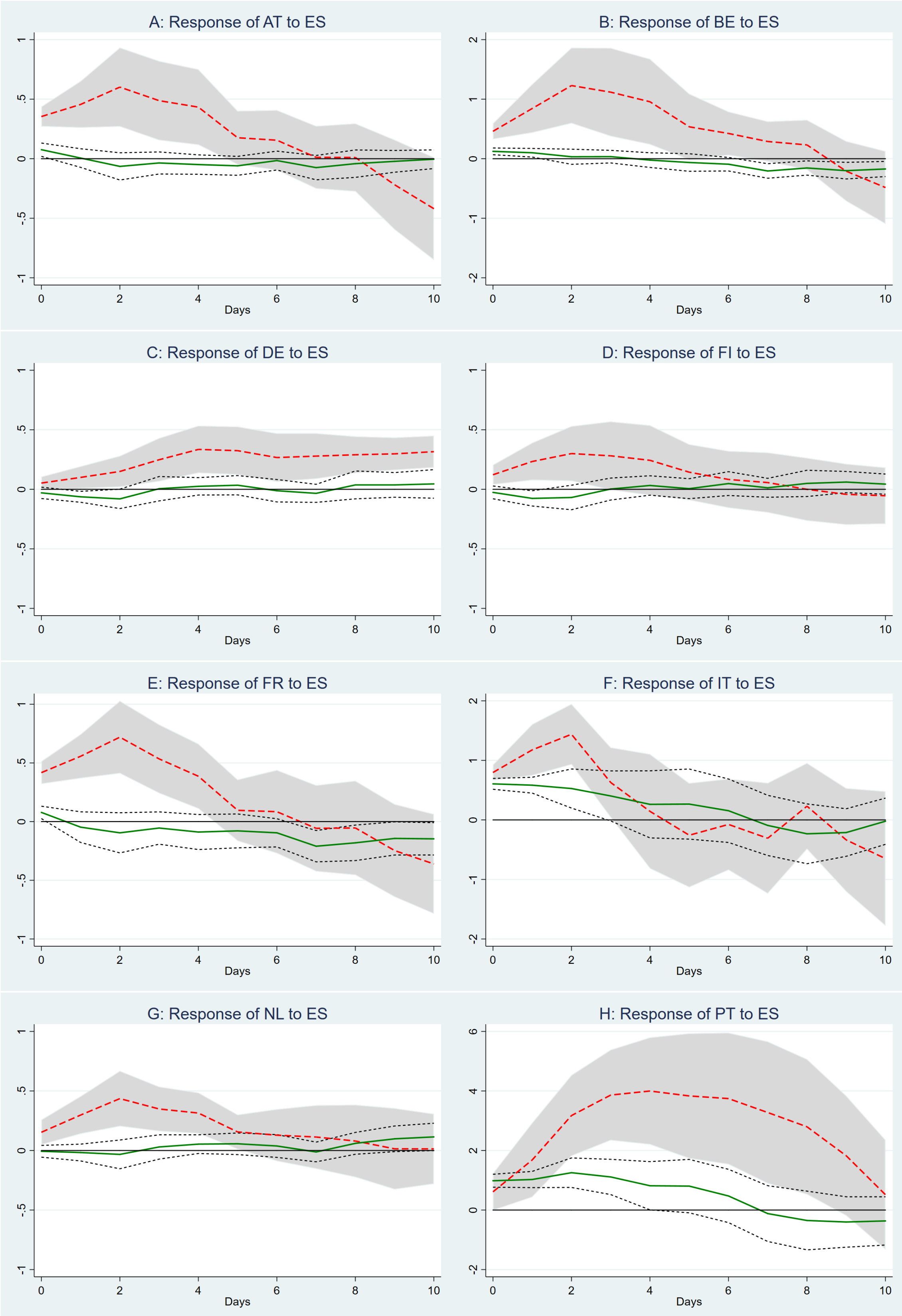
## A.2 Summary statistics

Table A.1: Summary statistics

| | Obs | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| *OMT = 0* | | | | | |
| Δ Spread AT | 804 | 0.000 | 0.048 | -0.294 | 0.277 |
| Δ Spread BE | 806 | 0.001 | 0.070 | -0.382 | 0.367 |
| Δ Spread DE | 804 | 0.000 | 0.030 | -0.234 | 0.167 |
| Δ Spread ES | 806 | 0.006 | 0.112 | -0.665 | 0.531 |
| Δ Spread FI | 802 | -0.001 | 0.037 | -0.215 | 0.186 |
| Δ Spread FR | 801 | 0.000 | 0.050 | -0.258 | 0.284 |
| Δ Spread IT | 806 | 0.005 | 0.111 | -0.854 | 0.629 |
| Δ Spread NL | 791 | 0.000 | 0.033 | -0.207 | 0.210 |
| Δ Spread PT | 800 | 0.012 | 0.217 | -1.724 | 1.923 |
| | | | | | |
| Δ OIS10 | 806 | -0.003 | 0.048 | -0.213 | 0.190 |
| Δ Yield US | 806 | -0.003 | 0.063 | -0.200 | 0.200 |
| Δ ln(VIX) | 806 | -0.001 | 0.070 | -0.351 | 0.405 |
| Δ ln(Euro Stoxx) | 806 | 0.000 | 0.016 | -0.063 | 0.098 |
| Δ ln(bank CDS index) | 806 | 0.001 | 0.028 | -0.149 | 0.154 |
| Δ ln(eurodollar) | 806 | 0.000 | 0.007 | -0.027 | 0.018 |
| | | | | | |
| Event series ES | 807 | 0.001 | 0.013 | -0.088 | 0.230 |
| Event series IT | 807 | 0.001 | 0.012 | -0.060 | 0.155 |
| | | | | | |
| *OMT = 1* | | | | | |
| Δ Spread AT | 983 | -0.001 | 0.025 | -0.099 | 0.189 |
| Δ Spread BE | 989 | -0.001 | 0.028 | -0.170 | 0.211 |
| Δ Spread DE | 989 | 0.000 | 0.020 | -0.096 | 0.129 |
| Δ Spread ES | 991 | -0.005 | 0.078 | -0.509 | 0.556 |
| Δ Spread FI | 989 | 0.000 | 0.022 | -0.082 | 0.227 |
| Δ Spread FR | 989 | -0.001 | 0.025 | -0.113 | 0.153 |
| Δ Spread IT | 991 | -0.004 | 0.070 | -0.437 | 0.527 |
| Δ Spread NL | 989 | 0.000 | 0.022 | -0.081 | 0.154 |
| Δ Spread PT | 989 | -0.007 | 0.112 | -0.583 | 0.864 |
| | | | | | |
| Δ OIS10 | 991 | -0.001 | 0.037 | -0.121 | 0.162 |
| Δ Yield US | 991 | 0.000 | 0.047 | -0.170 | 0.210 |
| Δ ln(VIX) | 991 | 0.000 | 0.076 | -0.437 | 0.401 |
| Δ ln(Euro Stoxx) | 991 | 0.000 | 0.013 | -0.090 | 0.047 |
| Δ ln(bank CDS index) | 991 | -0.001 | 0.071 | -0.714 | 0.707 |
| Δ ln(eurodollar) | 991 | -0.000 | 0.006 | -0.037 | 0.025 |
| | | | | | |
| Event series ES | 991 | 0.000 | 0.015 | -0.254 | 0.169 |
| Eevent series IT | 991 | 0.001 | 0.015 | -0.126 | 0.328 |

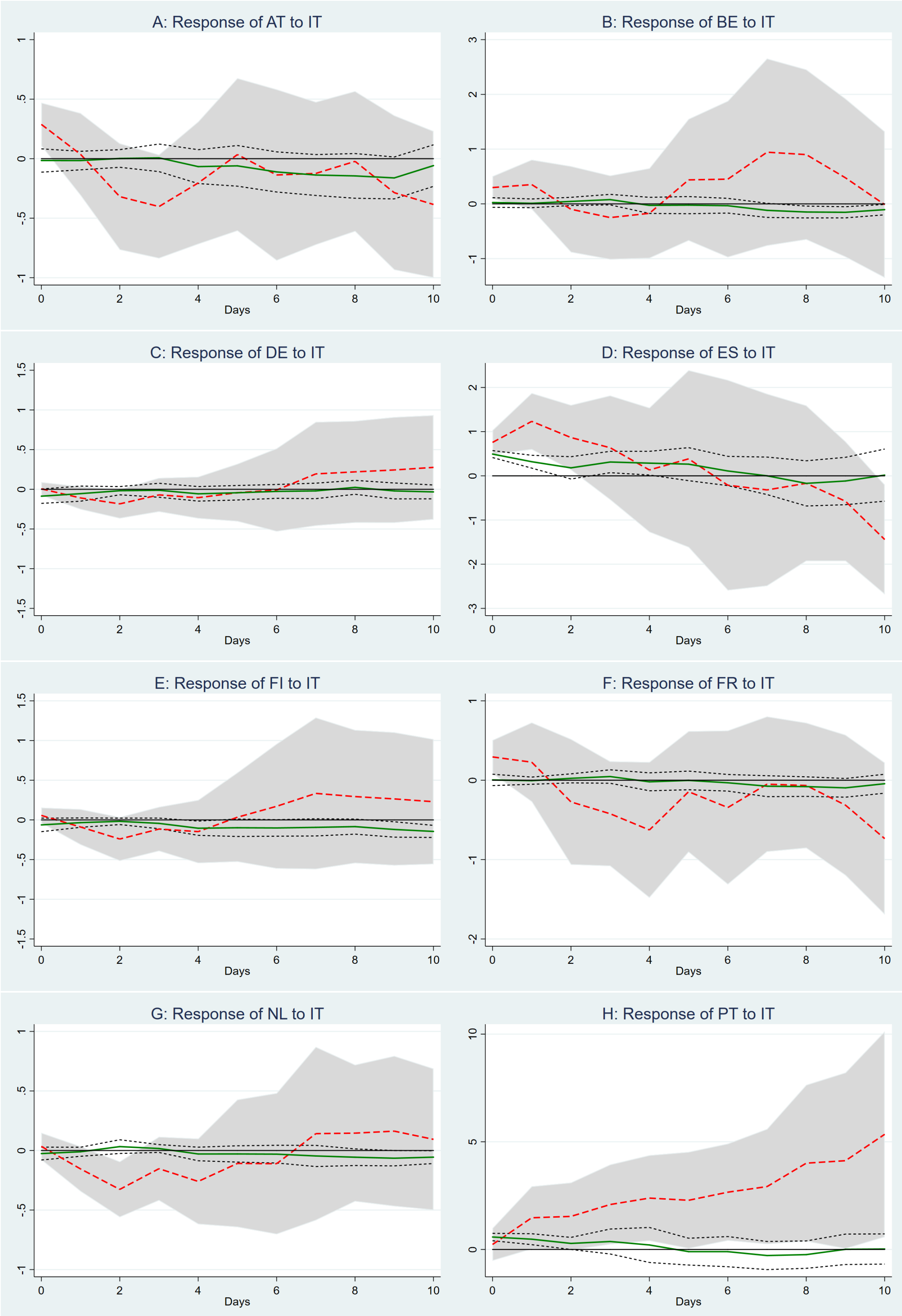
## A.3 Sensitivity

Figure A.1: Yield spillovers from Spain - two year interval around OMT announcement



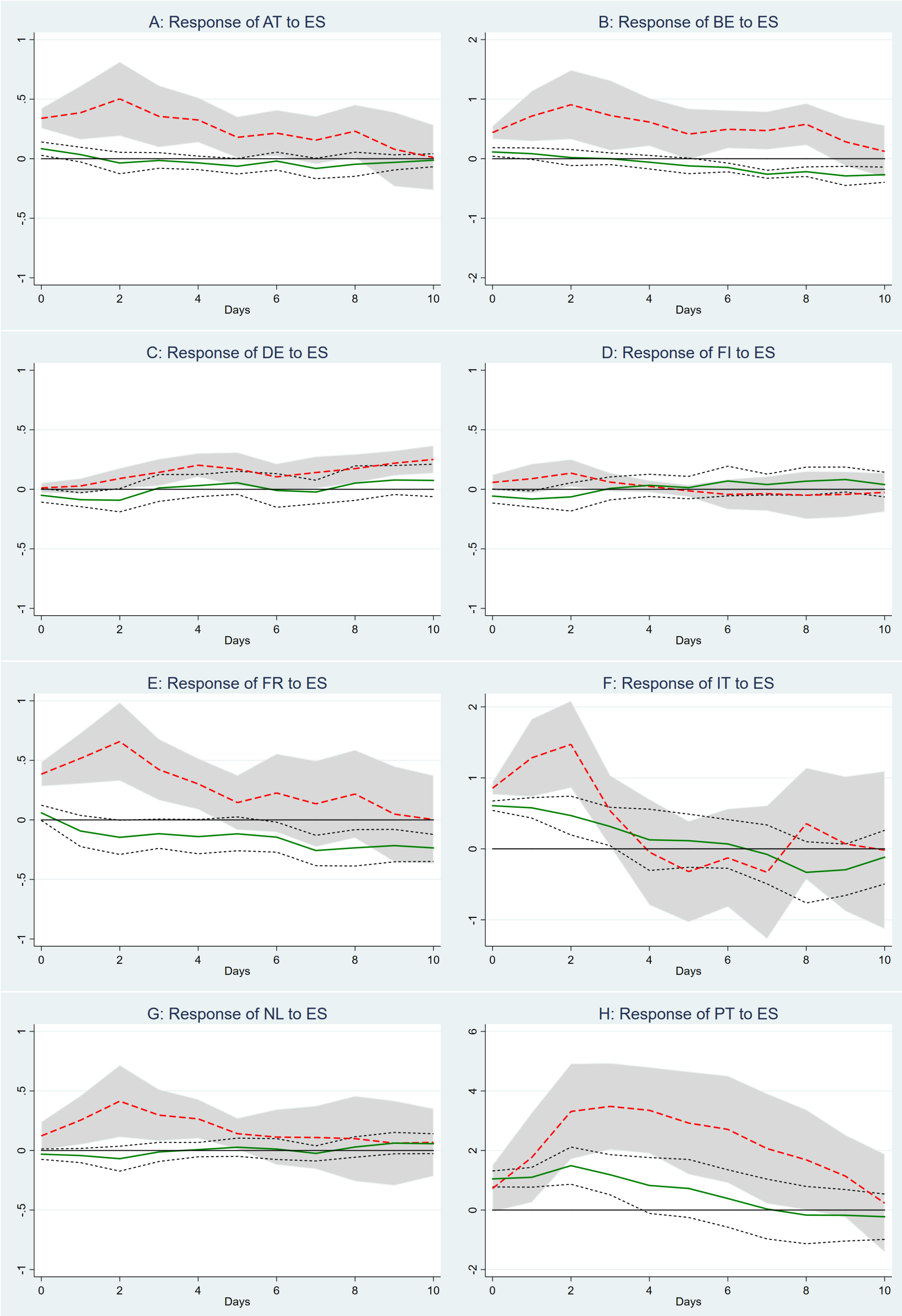

Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Spanish spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2011M7 - 2013M7.

Figure A.2: Yield spillovers from Italy - two year interval around OMT announcement



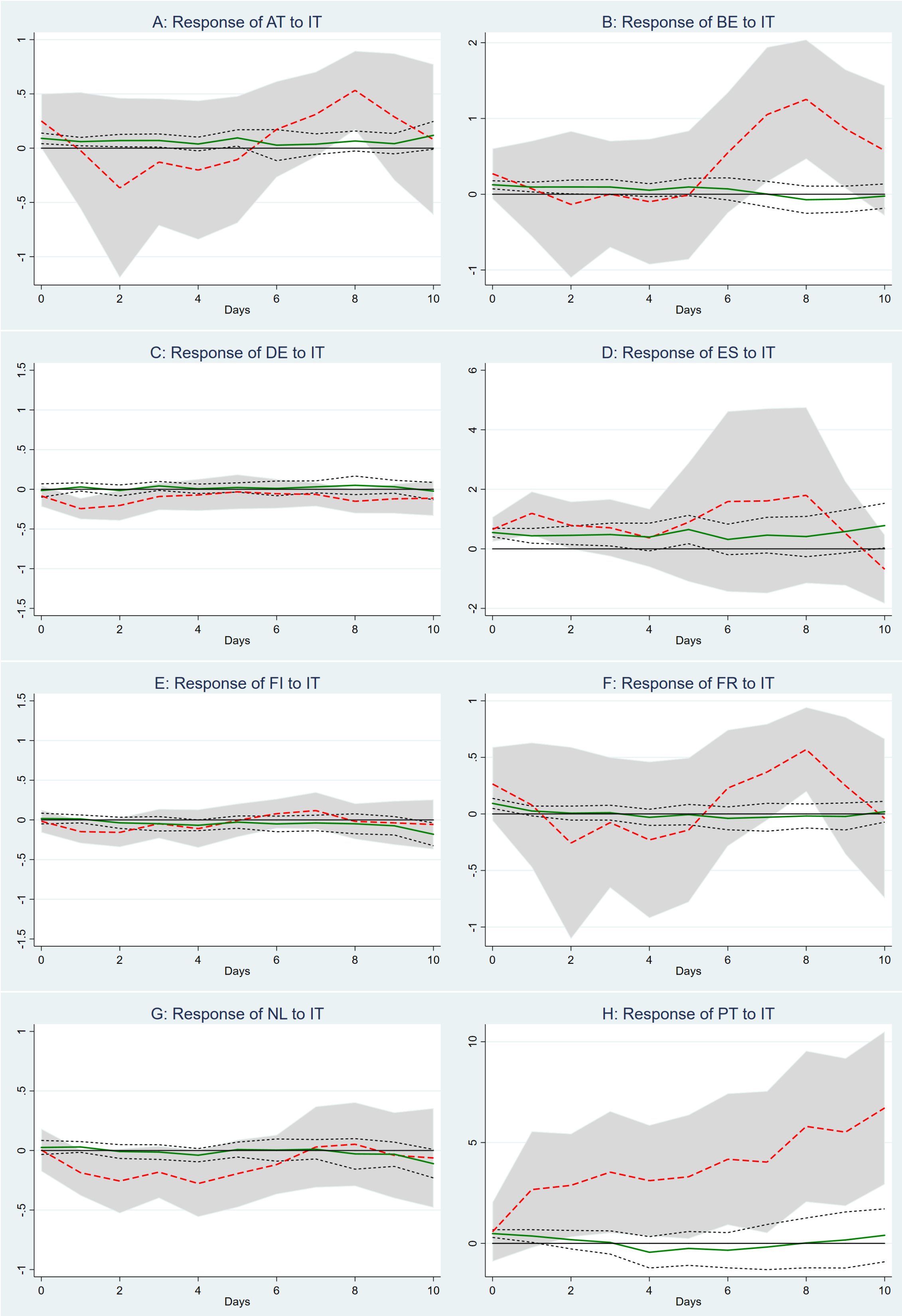

Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Italian spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2011M7 - 2013M7.

Figure A.3: Yield spillovers from Spain - one year interval around OMT announcement



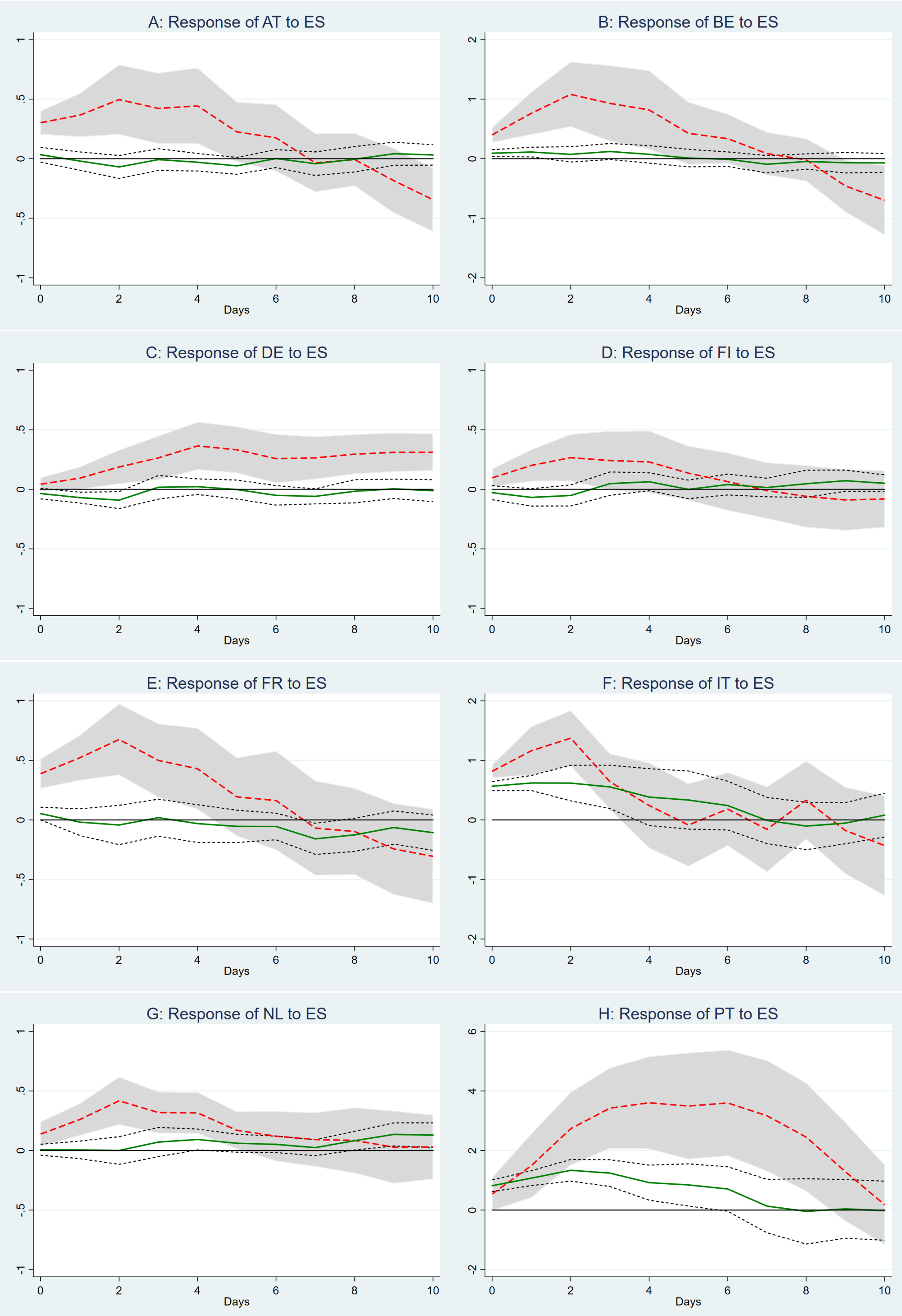

Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Spanish spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 20121M1 - 2013M1.

Figure A.4: Yield spillovers from Italy - one year interval around OMT announcement



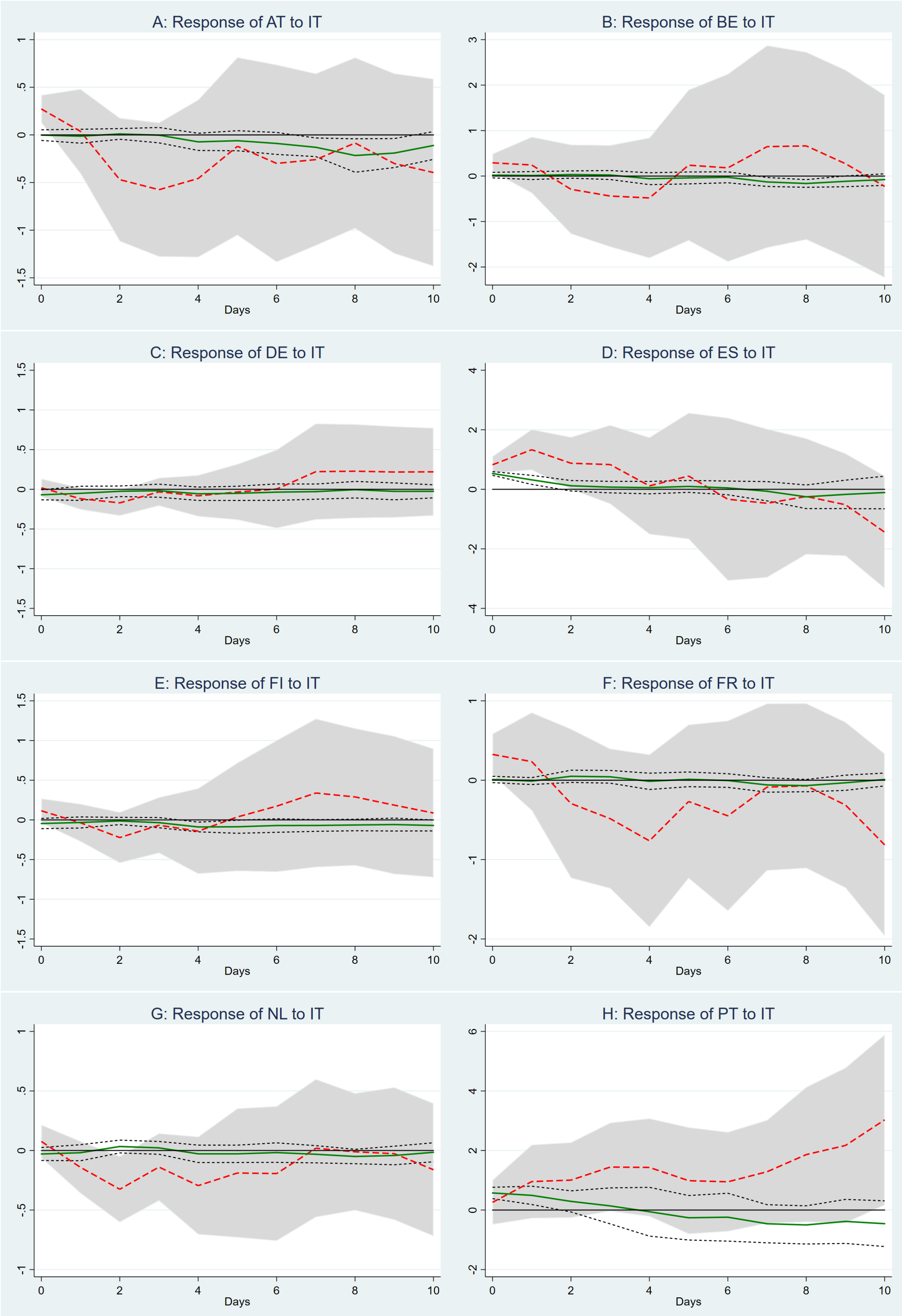

Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Italian spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2012M1 - 2013M1.

Figure A.5: Yield spillovers from Spain - full set of controls



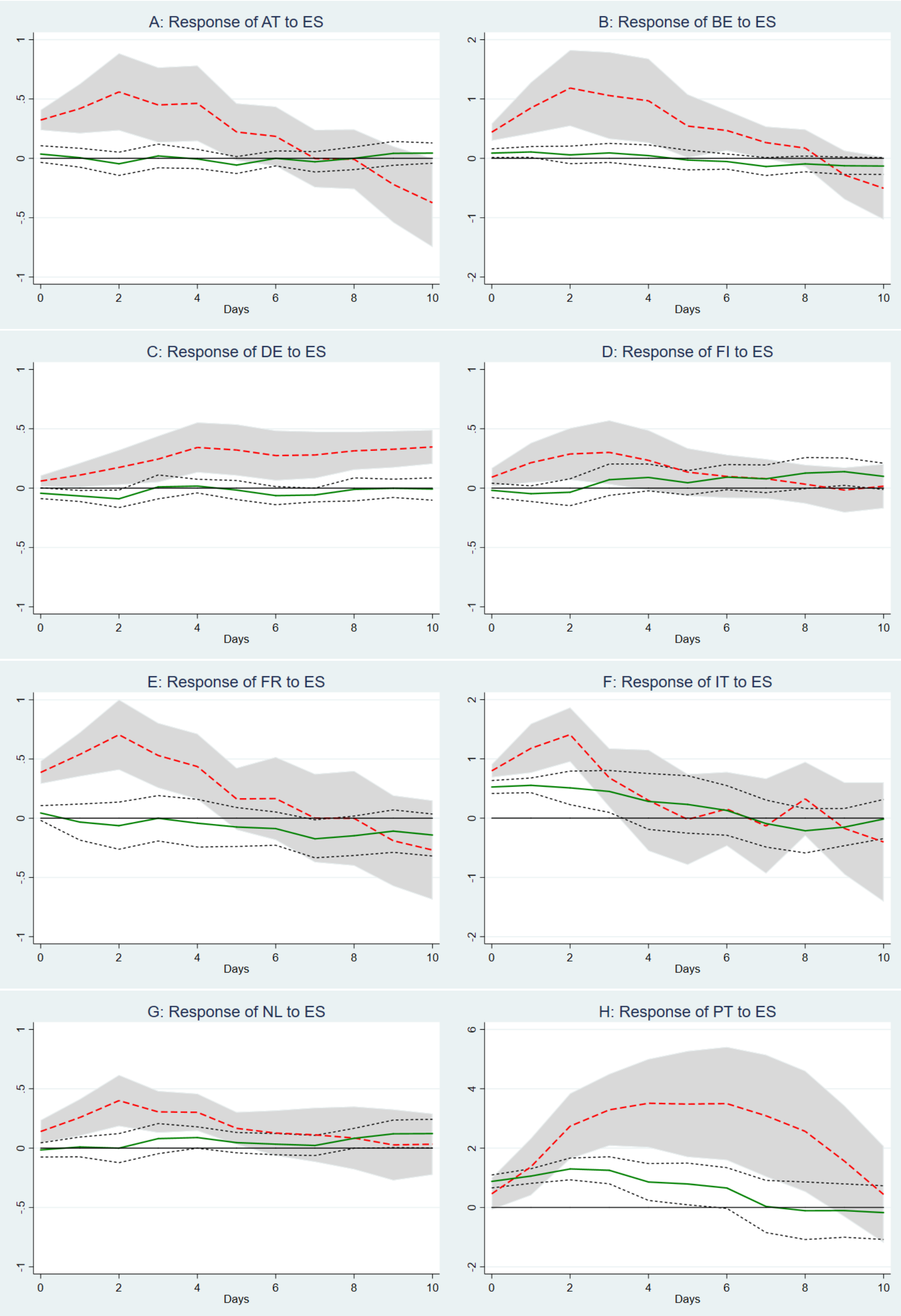

Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Spanish spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6. All regressions contain the expanded set of (lagged) controls described in section 6.2.

Figure A.6: Yield spillovers from Italy - full set of controls



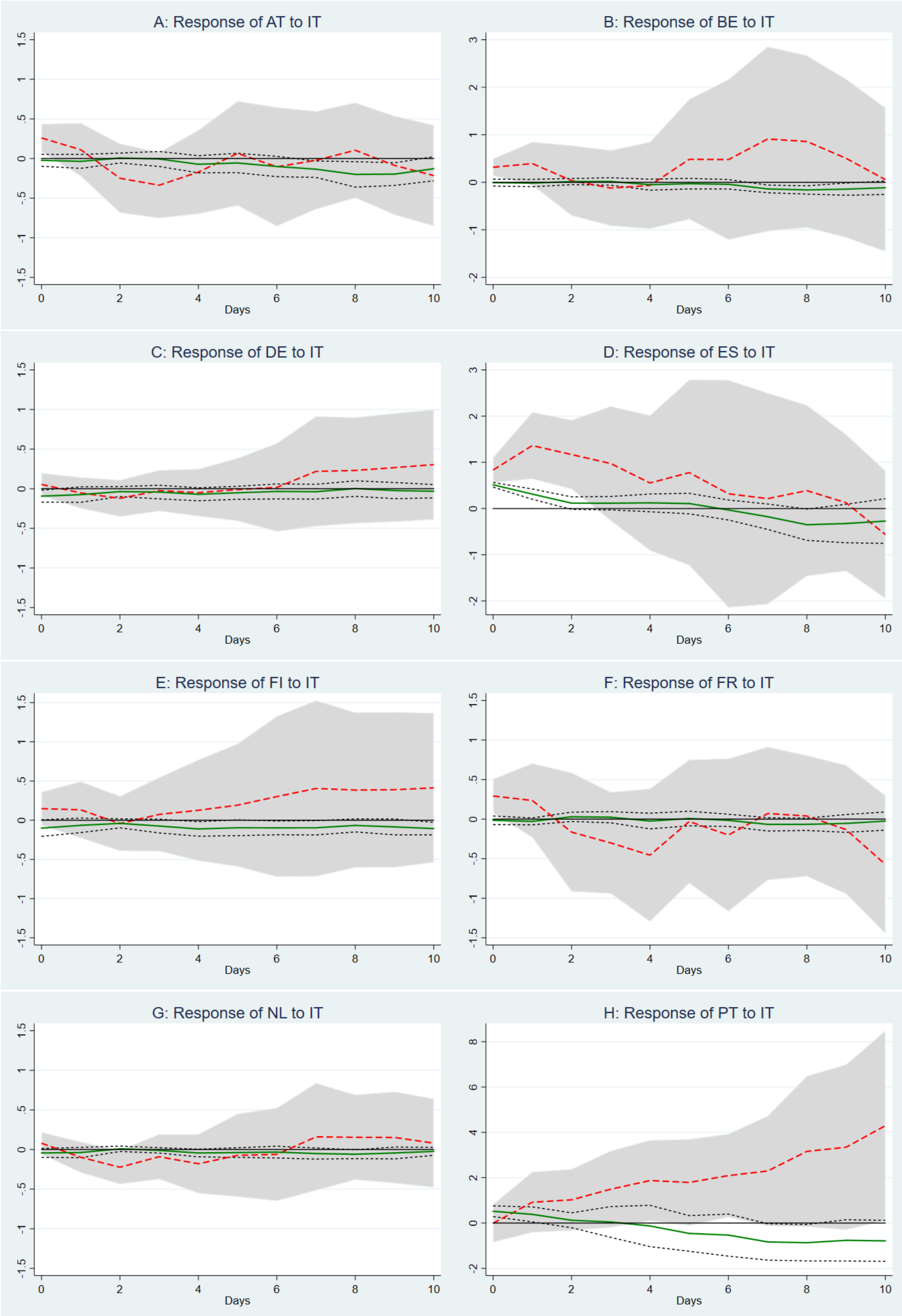

Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Italian spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. Sample period: 2009M6 - 2016M6. All regressions contain the expanded set of (lagged) controls described in section 6.2.

Figure A.7: Yield spillovers from Spain - no control variables



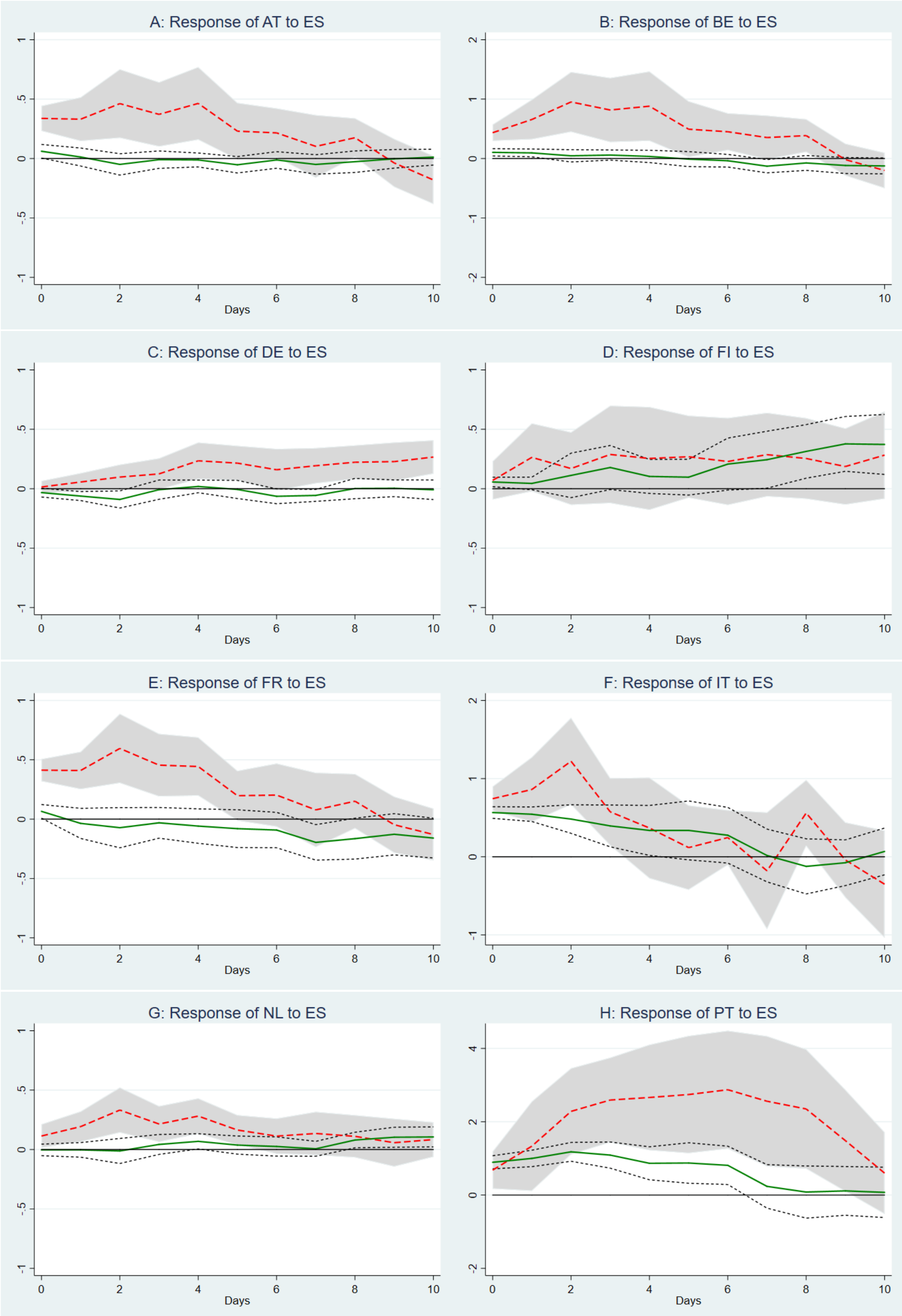

Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Spanish spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6. Regressions contain no control variables other than 5 lags of the home spread and 1 lag of the Spanish spread.

Figure A.8: Yield spillovers from Italy - no control variables



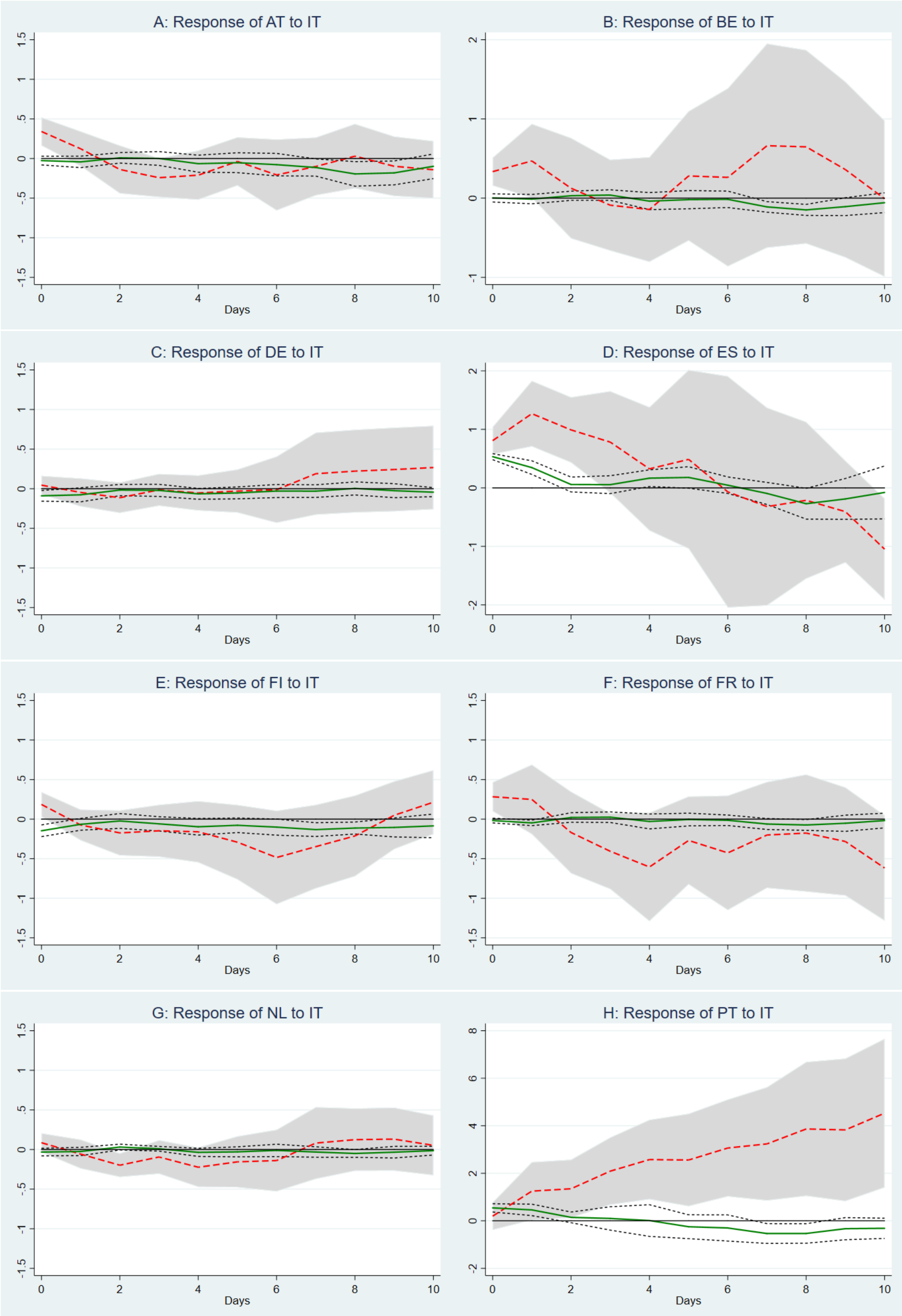

Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Italian spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6. Regressions contain no control variables other than 5 lags of the home spread and 1 lag of the Italian spread.

Figure A.9: Yield spillovers from Spain - including leads and lags of the instruments



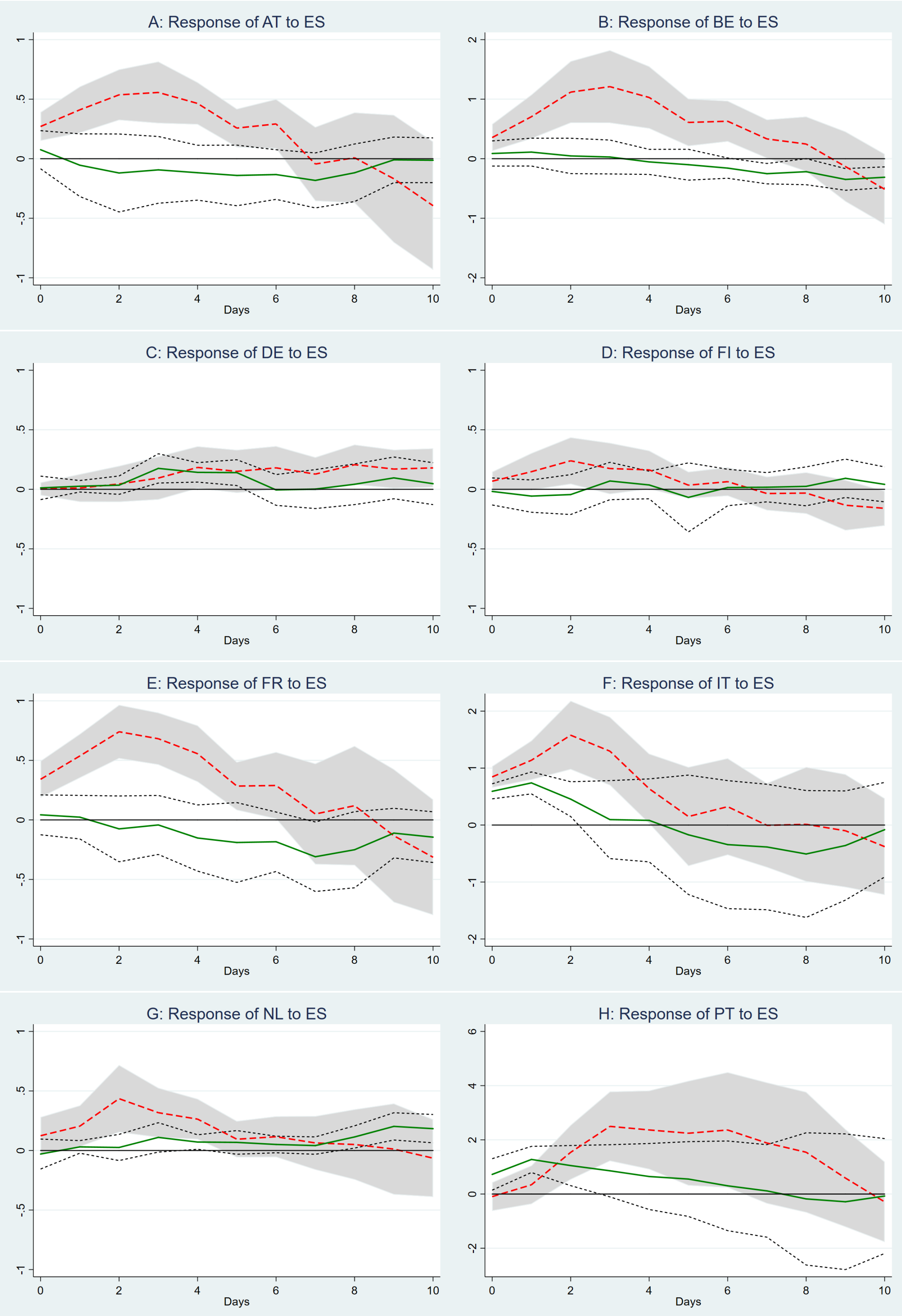

Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Spanish spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6. All regressions contain two lags and 10 leads of the instruments as additional controls.

Figure A.10: Yield spillovers from Italy - including leads and lags of the instruments



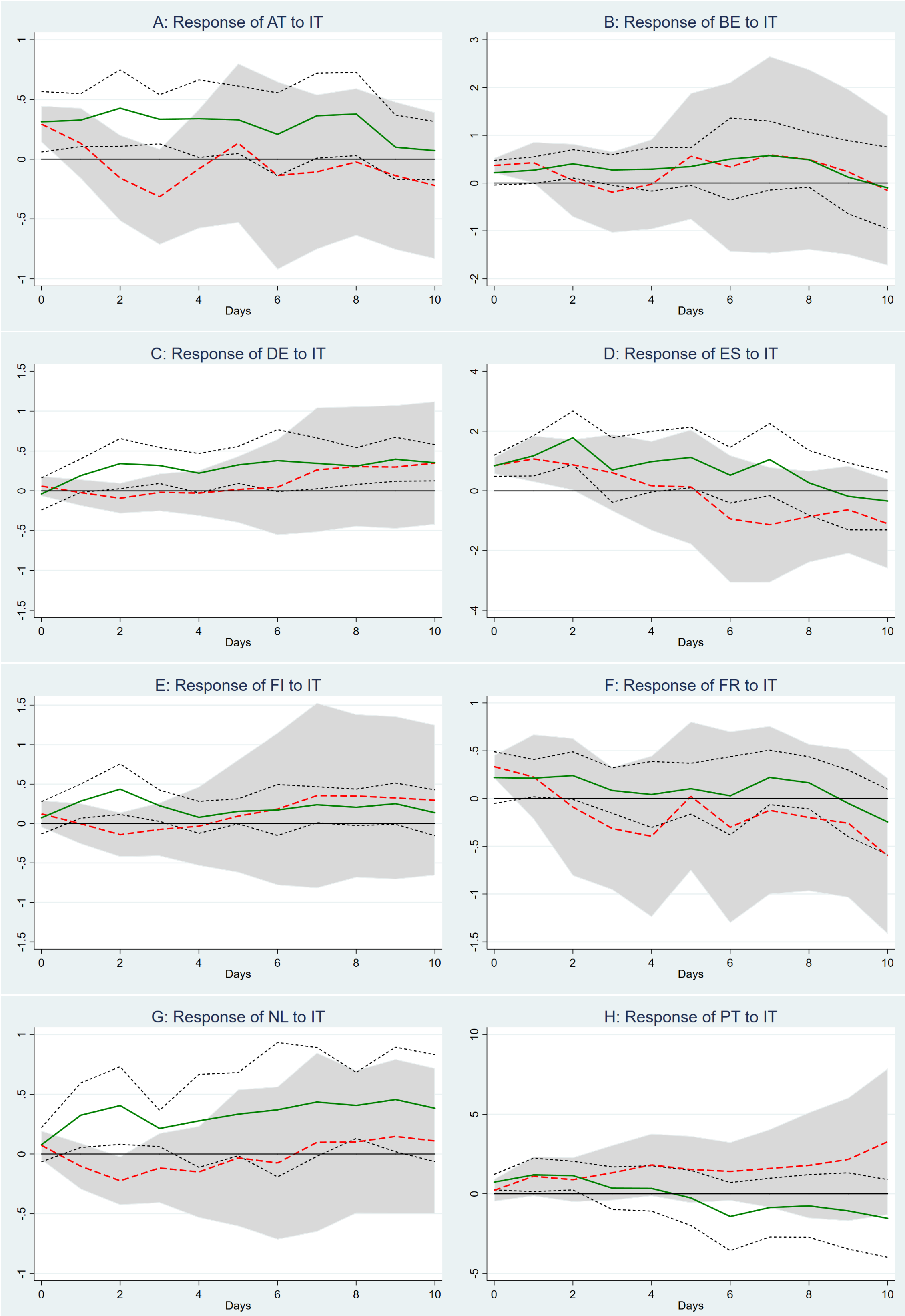

Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Italian spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6. All regressions contain two lags and 10 leads of the instruments as additional controls.

Figure A.11: Yield spillovers from Spain - excluding overnight events




Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Spanish spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6. The instrument set for the Spanish spread only contains timeable events that took place when markets were open.

Figure A.12: Yield spillovers from Italy - excluding overnight events




Note: the red dashed line displays the pre-OMT IRF to a 100 bps positive shock to the Italian spread, instrumented with our narrative shock series (see equation 3). The green solid line displays the post-OMT IRF. 90% confidence bands are calculated using HAC robust standard errors. Sample period: 2009M6 - 2016M6. The instrument set for the Italian spread only contains timeable events that took place when markets were open.

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