Domestic and Cross-Border Auction Cycle Effects of Sovereign Bond Issuance in the Euro Area[1]

Roel Beetsma,[2] Massimo Giuliodori,[3] Jesper Hanson,[4] Frank de Jong[5]

Version: 29 December 2015

(Please do not circulate without the permission of the authors)

Abstract

This paper provides evidence of spillovers from foreign primary public debt issues into domestic secondary market auction cycles in the euro area. It also confirms the presence of such auction cycles in response to domestic debt issues. These results are consistent with the theory of primary dealers' limited risk-bearing capacity. Also consistent with the theory, domestic auction cycles in response to new debt issues are stronger during the crisis period, while the cross-border effects tend to be stronger in the pre-crisis period, possibly as a result of diminished financial market integration in euro-zone sovereign bond markets during the crisis. Very long maturity Spanish auctions form an exception to this weakening of the cross-border effects.

Date: December 2015

Keywords: auctions, auction cycles, cross-border effects, public debt, crisis, primary dealers, limited risk-bearing capacity.

JEL codes: G12, G18.

[1] We thank Arie Guzluklu, Dmitry Yakovlev and participants in workshops and seminars at the IMF, Brunel University, the European University Institute in Florence and the University of Amsterdam for helpful comments.

[2] MN Chair in Pension Economics, University of Amsterdam; CEPR; CESifo; Netspar; Tinbergen Institute. Address: Department of Economics and Econometrics, University of Amsterdam, P.O. Box 15867, 1001 NJ Amsterdam, The Netherlands; phone: +31.20.5255280; e-mail: r.m.w.j.beetsma@uva.nl.

[3] University of Amsterdam; Tinbergen Institute. Address: Department of Economics and Econometrics, University of Amsterdam, P.O. Box 15867, 1001 NJ Amsterdam, The Netherlands; phone: +31.20.5254011; e-mail: m.giuliodori@uva.nl.

[4] Dutch Ministry of Finance; and Department of Economics and Econometrics, University of Amsterdam, P.O. Box 15867, 1001 NJ Amsterdam, The Netherlands; e-mail: hansonjesper@gmail.com.

[5] Department of Finance, Tilburg University, P.O. Box 90153, 5000 LE Tilburg, The Netherlands; phone: +31.13.4668040; fax: +31.13.4662875; e-mail: f.dejong@tilburguniversity.edu.

1. Introduction

Budgetary policy in the Euro area faced severe challenges during the sovereign debt crisis. Fiscal stimulus and interventions in the financial sector caused high budget deficits, resulting in large amounts of newly-issued debt. In turn, these deteriorating fiscal positions, in combination with weak growth, caused risk premia on sovereign debt to rise to dangerously high levels in some instances. Further challenges were posed by fears of cross-country contagion of the financial market reactions to the budgetary difficulties plaguing Euro-area member states.

In this paper we study how secondary markets for sovereign debt react to domestic and foreign issues of new public debt in the Eurozone. We do this for the full sample period since the inception of the euro in 1999 and the pre- and post-crisis sub-periods. In particular, we are interested whether primary issues cause “auction cycles”, whereby secondary market yields rise in anticipation of the auction and fall thereafter. Studying potential auction cycles is important, because they affect the cost of the auctions in the primary market and they may provide an indication of the potential roll-over risk associated with the public debt. Moreover, such a study may provide leads for improvements in the design of the auction mechanism and the timing of auctions. For example, if auction cycles are larger in more turbulent periods, governments may want to consider increasing the flexibility of auction calendars to be able to concentrate new debt issues in tranquil periods, when the upward pressure on yields in anticipation of the auction is smaller. The possibility of spill-overs of domestic debt issues into foreign auction cycles raises a set of new issues, such as the potential need to coordinate auction activity at the euro-zone level and the potential desirability to reschedule or scale down an auction when a recent foreign auction has failed.

The specific contributions of the current paper are the following. First, we explore the presence of domestic auction cycles for a new and broader country sample than studied before in the literature. Second, and most importantly, thanks to this broader country sample, this is (to the best of our knowledge) the first paper to explicitly address the cross-country spill-over effects of domestic debt issues on foreign auction cycles. For this purpose, we also present a theoretical framework of primary dealers’ limited risk-bearing capacity in an international setting with partially-segmented markets. The model encompasses other models in the literature. We also explore how the spill-over effects differ during the periods before and after the recent financial crisis. Regarding the latter, it is not a priori clear from the theoretical model whether the spill-overs should have increased or decreased as a result of the crisis. On the one hand, increased risk aversion and market volatility would suggest a strengthening of the spill-overs. Indeed, we have witnessed a number of occasions when unrest in the financial markets spread across large parts of the Eurozone, suggesting that uncertainty about the success of a debt auction in one country could spill-over into nervousness about sovereign debt market conditions of other countries. On the other hand, the theoretical model distinguishes between changes in “economic integration”, as captured by the correlations between the fundamentals of the sovereign bonds, and changes in “financial market integration”, as captured by the extent to which primary dealers are internationally active. While a crisis likely undermines financial market integration, it is not a priori clear how it would affect economic integration.

Our main results are in line with our theoretical framework. First, we find systematic evidence of a domestic auction cycle in response to new debt issues. The domestic auction cycle tends to be larger during the crisis than before the crisis. The sum of the up and down movements in the secondary market over the full cycle can be quite substantial and exceed 10 basis points during the crisis period. Second, we find systematic evidence of foreign secondary market yield responses to new domestic debt issues. While the domestic cycle tends to be larger than the foreign cycle, the latter can still reach be quite substantial and reach a size of around 5 basis points. The spill-over effects tend to be more prevalent before the crisis than during the crisis, suggesting a dominating effect of the reduction in financial market integration. In other words, the magnitude of the foreign auction cycles relative to the domestic auction cycle has shrunk.

The analysis in this paper connects to different strands in the literature. First, there is a limited literature that has explored the interplay between domestic primary and secondary public debt markets. Fleming and Rosenberg (2007) and Lou *et al*. (2013) find evidence of an auction cycle for the U.S., while Beetsma *et al*. (2015) find similar evidence for Italian public debt auctions, but only limited evidence German debt auctions.[6] Moreover, they find that the Italian auction cycle is larger in the period since the onset of the crisis in 2007 than before the crisis.

Second, a substantial literature has emerged on sovereign bond markets in the euro area. Several studies analyze the determinants of sovereign yields in the euro area during the crisis, with a particular focus on country risk and liquidity. Examples are Beber *et al*. (2009), Favero *et al*. (2010), Von Hagen *et al*. (2011), Montfort and Renne (2011), Ejsing *et al.* (2012), Mohl and Sondermann (2013) and De Santis (2014). Other papers, such as Pozzi and Wolswijk (2012), Christiansen (2014) and Cipollini *et al*. (2015), study the integration of these markets after the introduction of the euro in 1999. Focusing on the returns in sovereign bond markets,[7] these papers find a reversal of the high degree of integration of these markets in the euro area after the onset of the financial crisis in 2007. Indeed, the divergence in sovereign spreads reported in the abovementioned papers after 2007 is an important indicator of the decline in integration of euro area sovereign bond markets.

While bond market integration has decreased during the crisis, the risk of contagion has increased. Several articles, such as Ang and Longstaff (2013) and Battistini *et al.* (2014), explore the relationship between sovereign risk and common risk factors in the euro area. Linkages between sovereigns and the banking sector are seen as an important source of cross-country contagion effects – see Acharya *et al.* (2011), Kallestrup *et al*. (2012), De Bruyckere *et al*. (2013), Brutti and Sauré (2013) and Claeys and Vasicek (2014). Several papers investigate the role of news in generating spill-over effects. Examples are Bhanot *et al.* (2012) and Beetsma *et al*. (2013). The latter paper demonstrates the adverse spillover effects of negative domestic news on sovereign interest spreads among the crisis countries. It finds that those effects are stronger when foreign banks have a larger stake in the domestic economy. By contrast, as Baele *et al*. (2013) demonstrate, countries with solid macroeconomic fundamentals appeared to benefit from 'flight-to-safety' effects.

The remainder of this article is structured as follows. Section 2 provides some institutional background information on the auction mechanisms employed in our sample countries. This section

[6] These type of auction cycles may also occur in other markets, such in equity markets and corporate debt markets (e.g., see Duffie, 2012).

[7] These papers do not explicitly distinguish between changes in economic versus financial market integration. Correlations between returns, especially over shorter periods, can fall because of reduced correlations between the fundamentals, but also because there is less cross-border primary dealer activity.

also presents a simple model of the price-setting behavior of primary dealers with limited risk-bearing capacity and limited market segmentation between domestic and foreign bond markets.[8] Section 3 describes the data set and discusses some key summary statistics of the data. Section 4 analyses the presence of domestic auction cycles using an event study and regression analysis in the vein of Lou *et al*. (2013) and Beetsma *et al*. (2015). Section 5 explores the presence and magnitude of foreign spill-overs of domestic primary debt issues. Section 6 estimates the implications for the cost of new debt issuance of the detected auction cycles in response to both domestic and foreign auctions. Section 7 concludes the main body of this paper.

2. Institutional background information and theoretical framework

In this section we first provide some institutional background information for public debt auctions of the countries in our sample, Belgium, France, Germany, Italy, The Netherlands and Spain. These are the six countries with the largest nominal stock of general government debt in the euro area. Together these countries accounted for almost 90% of the total stock of outstanding euro area sovereign debt in 2013.[9] Because primary dealers play a key role during auctions, we formulate a simple theoretical model of both domestic and foreign price formation around auction dates in which the behavior of primary dealers with limited risk-bearing capacity features prominently. An upcoming debt auction induces the primary dealers to make room for the new issue in their asset portfolio, implying selling pressure on closely substitutable assets. Hence, their yield goes up in the run-up to the auction, while yields falls in the days after the auction as the primary dealers unload their inventory of the newly

[8] Our empirical results are strongly in line with this model. In Beetsma *et al.* (2015) we also discuss a number of alternative hypotheses for yield movements in the secondary market around primary issues and provide references to the relevant literature. One alternative is that new debt issues affect the supply of debt. However, relative to the existing debt stock the supply effect of a new issue is likely to be limited (although 'local supply effects' for specific maturities may still be relevant), while we expect movements in secondary market yields to be asymmetric before and after the auction if the supply changes. A second hypothesis concerns the possibility that on the issuance date the current 'on-the-run' issue switches to 'off-the-run' status, which makes it less attractive for repo transactions (e.g., see Sundaresan, 1994). For the US, Krishnamurthy (2002) shows that the on-the-run premium is highest directly after an auction. However, the 'on-the-run/off-the-run' spread seems less relevant here, as most of the countries in our sample use auctions to reopen previously issued series, while new series of bonds are typically issued via syndications.

[9] The total stock of government debt in the euro area amounted to 9007.7 billion euros in 2013, of which 2159.5 billion euros consisted of debt from Germany (24.0%), 2069.8 billion euros from Italy (23.0%), 1949.5 billion euros from France (21.6%), 966.2 billion euros from Spain (10.7%), 441.0 billion euros from The Netherlands (4.9%) and 413.2 billion euro from Belgium (4.6%). Source: Eurostat.

issued asset. The risk that primary dealers run and that they want to be compensated for are the fluctuations in the value of the new issue during the period that is on their books.

2.1 Auction mechanisms for euro area public debt

Euro area treasuries fulfill the largest part of their annual debt issuance requirements through public auctions. Auctions are announced in an annual auction calendar. Hence, market participants know well in advance at which date auctions take place. Germany, The Netherlands and Italy also publish a quarterly calendar in which they provide more information about the bonds to be issued at each auction in the upcoming quarter.[10] Details of an upcoming auction, such as the maturity and an indication of the targeted volume, are typically announced five or six working days before the auction takes place. In other words, detailed information about the auction is typically known before the start of the relevant (for our analysis) event window around the auction.

Table A.1 in Appendix A (not for publication) provides a brief overview of the auction procedures in our sample countries. Belgium, France and Germany use multiple-price auctions, where bids above a certain cut-off price are allotted in full at the submitted price. Italy uses a single-price auction, in which all bidders pay the same cut-off price. Spain employs a mixture of a single-price and a multiple-price auction and the Netherlands uses a so-called tap auction in which the treasury agency can adjust prices during the auction. The allotments for the single- and multiple-price auctions in Belgium, France, Germany Italy and Spain take place after the auction. This contrasts with the tap auction in The Netherlands where a trade is made immediately when a primary dealer hits the quoted price.

Participation in public debt auctions is limited to designated banks, the so-called primary dealers. Primary dealers absorb the debt issuance on the day of a public debt auction, while they sell the newly-issued bonds to end-users in the days after an auction. Primary dealers are typically bound to a minimum participation requirement on the primary market. Table A.1 shows that this minimum

[10] Concretely, France publishes a monthly calendar that only states dates; Italy publishes quarterly updates of minimum amounts for re-openings and coupons for new issues; The Netherlands and Germany mention the specific bond, the date and an indicative amount; Belgium and Spain only publish an annual calendar. These calendars are published on the website of the treasury agencies.

requirement varies from a minimum purchase requirement of 0.05% of the total amount issued in Germany to a minimum bidding requirement of 3% of all bids per auction in Spain.

Table 1 lists the primary dealers for the year 2014. Importantly, we see a high degree of cross-country overlap in primary dealerships. As the model presented below suggests, this overlap should be conducive to spill-overs of auctions in one country to other countries. All 14 primary dealers for The Netherlands and all 19 primary dealers for France, for instance, hold a primary dealership for Germany as well. In addition, six banks (Barclays, Commerzbank, Deutsche Bank, HSBC, Nomura and Société Générale) hold a primary dealership in all countries in our dataset.

Germany, The Netherlands, France, Italy and Spain publish annual rankings of primary dealer performance. Table 1 also shows the top-5 primary dealers for each of these countries in 2014. Private conversation with primary dealers reveals that they perceive several advantages of being high in the ranking. Examples are enhanced exposure to the outside world, better chances to be selected as a trading partner in other assets, for syndications to place public debt and to carry out government transactions and, due to the signaling value, as a partner to other financial institutions. Five banks hold a top 5 position in two or more countries (Barclays, Citigroup, Commerzbank, Crédit Agricole and HSBC). The rankings also show the importance of domestic primary dealers. For each country, the top-5 contains at least two domestic banks. Although their relative importance may change over time, generally the set of primary dealers tends to be stable over time for a given country.

Finally, there is quite substantial evidence from the literature that the European debt crisis has reduced the integration of European bond markets (e.g., see Pozzi and Wolswijk, 2012, Christiansen, 2014, and Cipollini *et al*., 2015). The next sub-section will distinguish two aspects of integration and give our precise definitions of these aspects. One concerns what we call "economic integration", which refers to the correlation between economic fundamentals, while the other is "financial market integration", which refers to the cross-border activities of the traders in assets. To form an impression of how the crisis affected the latter, Figure 1 depicts for the countries in our sample the total exposure of the domestic primary dealers in the European Banking Authority (EBA) dataset to the sovereign, divided by the total exposure of all primary dealers in the EBA dataset to the sovereign. The exposures were published by the EBA in the context of the stress tests it has conducted on the

European banks. Note that these exposures are not only associated with the banks acting as primary dealers. The EBA defines them as the gross long positions held in the different books (trading, banking) net of cash short positions, ordinarily held in the trading book. Unfortunately, primary dealers from outside the EU were not included in the total, because they were not subject to the European stress tests, while the first observation moment already falls well into the crisis period. Further, in many instances the domestic primary dealers are also primary dealer for other foreign governments, in contrast to the theoretical model presented below. Nevertheless, the figure is indicative of a retrenchment of financial integration of the European bond markets as captured by the reduced activity of foreign primary dealers in the domestic markets: four of the six countries exhibit an increase in the relative role of domestic primary dealers, which in the case of Spain rises to well over 80%.

2.2 A model of auction cycles and cross-country auction spillovers

The description of the auction mechanisms in the previous subsection suggests a key role for the primary dealers in a model describing the price formation of public debt around dates at which new debt is issued. We present such a model below. Our model is in particular also relevant for price formation in the secondary market, as the group of dealers in this market largely coincides with the group of primary dealers.

In view of the ensuing empirical analysis, we want our model to capture the domestic and cross-border secondary market effects of primary sovereign debt issues. In addition, we want it to account for how these effects change as a result of a crisis like the one that the Eurozone experienced recently. This can be achieved if we introduce partially segmented markets into our model and allow for the degree of segmentation to change as a result of the crisis. Such partial segmentation is a realistic feature for the euro-zone. For example, although legally the euro-zone is characterized by perfect capital mobility and cross-border asset trading is voluminous, there remains a substantial home bias in asset holdings. Figure 1, which showed that disproportionate shares of the public debt are held by domestic primary dealers, is highly suggestive of this bias.

Our model is based on Stoll (1978), as worked out in De Jong and Rindi (2009, Chapter 2), and extends Beetsma *et al*. (2015) into three directions: (i) we make aggregate risk aversion a function of the size of the market; (ii) we allow for primary dealers to hold debt from multiple countries; (iii) and we distinguish between local and global primary dealers as investors in sovereign debt. Local primary dealers trade only in debt issued in their own country, while global primary dealers trade in debt issued by all countries. This distinction produces the aforementioned partially-segmented market for domestic and foreign public debt. The partial segmentation allows the domestic and cross-border secondary market effects of a new debt issue to differ in size and allows to capture the effects a change in both financial market integration and economic integration.

We consider two countries, Home (*h*) and a Foreign (*f*), which makes up the rest of the euro-zone. Each country features a vector of bonds with normally-distributed payoff values $\tilde{F}_h$ and $\tilde{F}_f$, respectively. The variance-covariance matrix of the pay-off vector $\tilde{F} \equiv \left(\tilde{F}_h', \tilde{F}_f'\right)'$ is

$$\Sigma = \begin{bmatrix} \Sigma_{hh} & \Sigma_{hf} \\ \Sigma_{fh} & \Sigma_{ff} \end{bmatrix},$$

where Σ_{hh} and Σ_{ff} are the variance-covariance matrices of $\tilde{F}_h$ and $\tilde{F}_f$, respectively, and Σ_{hf} and Σ_{fh} contain the (suitably organized) co-variances of the elements of $\tilde{F}_h$ with those of $\tilde{F}_f$. Later we will specialize the set-up to some specific cases that fit our ensuing empirical set-up.

We also allow for two types of dealers, purely local dealers who only trade in the bonds of their own country and global dealers who trade in the bonds of both countries. Under the assumption that all primary dealers feature exponential (i.e., constant absolute risk aversion) utility and identical relative risk aversion ρ, the demand functions of the local and global primary dealers are given by their respective first-order conditions (see De Jong and Rindi, 2009, Chapter 2):

$$P_c = \mathrm{E}\left[\tilde{F}_c\right] - \rho W_c^{-1} \Sigma_{cc} x_c, \text{ where } c \in \{h, f\},$$

$$P = \mathrm{E}\left[\tilde{F}\right] - \rho W_g^{-1} \Sigma x_g ,$$

where $P = \left(P_h', P_f'\right)'$ is the vector of prices of all bonds, P_h and P_f are the vectors of prices of the Home and Foreign bonds, respectively, x_g and x_c are the amounts demanded by the global primary dealers and the local primary dealers of country *c*, respectively, and W_g and W_c are aggregate wealth of the global and local primary dealers of country *c*, respectively. Aggregating the demands, equalizing them to the aggregate supply $X = \left(X_h', X_f'\right)'$, and solving yields the following price formula for Home bonds:[11]

$$P_h = \mathrm{E}\left[\tilde{F}_h\right] - \rho\left[W_g I + W_h\left(I - \theta_f R\right)\right]^{-1}\left[\left(I - \theta_f R\right)\Sigma_{hh} X_h + \left(I - \theta_f\right)\Sigma_{hf} X_f\right], \qquad (1)$$

where I is the identity matrix (of appropriate dimensions), $\theta_f = W_f / \left(W_f + W_g\right)$ and $R \equiv \left(\Sigma_{hf}\Sigma_{ff}^{-1}\Sigma_{fh}\right)\Sigma_{hh}^{-1}$ is the multivariate *R*-squared of a regression of $\tilde{F}_h$ on $\tilde{F}_f$. It is difficult, if not impossible, to derive a full set of analytical results from this general pricing formula. However, we can do so for some special cases that fit our empirical set up.

2.2.1. Special case: two Home bonds and no Foreign bonds

This case allows us to explore the consequences of a new Home bond issue on the secondary market prices of existing Home bonds. Hence, we assume an "old" Home bond that we distinguish by subscript "*o*" and a newly-issued bond denoted by subscript "*n*". Hence, the price vector of Home bonds is $P_h = \left(P_{h,n}, P_{h,o}\right)'$, while the vector of supplies is given by $X_h = \left(X_{h,n}, X_{h,o}\right)'$. Because Foreign bonds are absent, $X_f = 0$ and $\theta_f = 0$. Hence, all primary dealer wealth, now given by $W_d + W_g$, is

[11] The algebra is cumbersome (see Appendix B – not for publication). Of course, a "symmetric" expression is obtained for Foreign's price vector. However, we present only Home's price vector, because this suffices for our exposition below.

concentrated on Home bonds. From the expression for the price of the old Home bond (see Appendix B – not for publication), we can immediately derive the effect of the issue of a new Home debt instrument:

$$\frac{\partial P_{h,o}}{\partial X_{h,n}} = -\rho \frac{1}{W_h + W_g} Cov\left(\tilde{F}_{h,o}, \tilde{F}_{h,n}\right) = -\rho \frac{1}{W_h + W_g} r_{o,n} \sigma_0 \sigma_n , \tag{2}$$

where σ_o and σ_n are the standard deviations of $\tilde{F}_o$, respectively $\tilde{F}_n$, and $r_{o,n}$ is the correlation between $\tilde{F}_o$ and $\tilde{F}_n$. This expression leads to a number of empirical predictions:

i. If the pay-offs of the two bonds have a positive co-variance, an upcoming auction of the new bond, by leading to a positive inventory of the primary dealers in this asset, pushes down the price of the old bond. This is the hypothesis of the domestic auction cycle.

ii. The domestic auction cycle will be larger, the larger is the size of the auction.

iii. It will also be larger, the more closely substitutable the two assets are as measured by the correlation between their pay-offs. A higher correlation causes a stronger pressure to sell the existing security when a new security is brought on the market. Hence, the expected return on the existing security has to rise more to keep it in the portfolio. This implies a larger price drop.

iv. Finally, it will also be larger if the aggregate amount of primary dealer wealth $W_h + W_g$ is smaller. The reason is that there is less capital available to bear the additional risks associated with absorbing the new issue. Since we would expect aggregate primary dealer wealth to be smaller for small countries than for large countries, we would also expect a new debt issue of a *given* size to produce a larger auction cycle in a small country than in a large country.

The model also has predictions for how a financial crisis influences the domestic auction cycle:

i. The crisis may suppress the risk tolerance of the primary dealers, i.e. $\rho/\left(W_h+W_g\right)$ rises, implying a stronger negative response of the price of the old bond to the new debt issue. Such a change in risk tolerance could come about by a change in fundamental risk preferences, i.e. ρ, or because the amount of capital allocated to primary dealer activity shrinks, *ceteris paribus*.

ii. A crisis may lead to an increase in the uncertainty σ_o and σ_n about the pay-offs of the instruments, thereby amplifying the price effect of the new debt issue. It may also affect the correlation between the pay-offs, although a priori we cannot think of a likely direction in which the correlation changes.

2.2.2. Special case: one Home and one Foreign bond

To analyse the spill-overs of a Foreign bond issue on Home secondary bond market prices, we now explore the case of a single Home and a single Foreign bond. Some algebra shows that the formula for the Home bond price simplifies to:

$$P_h = \mathrm{E}\left[\tilde{F}_h\right]-\frac{\rho}{\hat{W}}\left\{\left[1+\left(1-r_{h,f}^2\right)W_f/W_g\right]Var\left(\tilde{F}_h\right)X_h+Cov\left(\tilde{F}_h,\tilde{F}_f\right)X_f\right\}. \tag{3}$$

where

$$\hat{W}\equiv W_h+W_f+W_g+\left(1-r_{h,f}^2\right)W_hW_f/W_g,$$

and where $r_{h,f}$ is the correlation between $\tilde{F}_h$ and $\tilde{F}_f$. Hence,

$$\frac{\partial P_h}{\partial X_f}=-\frac{\rho}{\hat{W}}r_{h,f}\sigma_h\sigma_f\,. \tag{4}$$

Hence, fully analogous to the predictions a new Home bond issue studied above, we obtain predictions for the effect of a Foreign debt issue on the Home bond price:

i. If the pay-offs between the Home and Foreign bond have a positive co-variance, a new Foreign bond issue pushes down the price of the Home bond.
ii. The effect will be larger, the larger is the size of the auction.
iii. It will also be larger, the more closely substitutable the two bonds are as measured by their correlation.
iv. Finally, it will also be larger when our "adjusted" measure of aggregate primary dealer wealth $\hat{W}$ is smaller.

We are particularly interested in how a financial crisis may affect the spill-over. We can distinguish various effects:

i. The crisis may cause an increase in the market volatilities σ_o and σ_f, thereby strengthening the spill-over.
ii. The degree of economic integration, which we capture by the correlation $r_{h,f}$ between $\tilde{F}_h$ and $\tilde{F}_f$, may change as a result of the crisis. However, a priori there is no specific direction in which we would expect the correlation to change.
iii. The degree of financial integration may fall. We formally define this as a shift in capital from the global primary dealers to the local primary dealers, holding total primary dealer capital, $W_h + W_f + W_g$, constant. Hence, W_g shrinks, while W_h and/or W_f increases. We see immediately that, if the correlation between $\tilde{F}_h$ and $\tilde{F}_f$ is positive, such a shift dampens the price spill-over of a foreign debt auction.

2.2.3. Reinterpretation: partially-segmented Home bond markets

The special case in the previous subsection can be directly translated to a setting of partially-segmented Home bond markets. This translation is relevant, because there is empirical evidence that debt of different maturities tends to attract different clienteles (e.g., see Greenwood and Vayanos, 2008, 2010). Some primary dealers may cater to some clienteles more than to others and, therefore, trade more in some maturities than in others, while other primary dealers have no preference for trading one maturity or another.

In terms of model specialization in the previous subsection, the Home and Foreign bonds now become Home bonds of different maturities, while the "local" primary dealers are primary dealers who tend to specialize in bonds of a specific maturity. The "global" primary dealers are unspecialized primary dealers. From the price formula, we observe that if the market for some specific maturity is smaller, as captured by a reduction in W_h, then the price effect of a new issue of this maturity is larger. From the ensuing empirical analysis we can see whether this prediction is borne out by the data. The market for 30-year debt is typically smaller than that for 5- or 10-year debt, hence on the basis of this alternative model interpretation we expect a new issue of 30-year debt to produce a larger auction cycle in its own segment than does a new issue of 5- or 10-year debt.

2.2.4. Special case: three assets and no Foreign local primary dealers

It seems reasonable that the effect on the price of an existing Home bond is larger for a new Home bond issue than for a new Foreign bond issue. To see whether this prediction is indeed borne out by our model, we need a version of the model with two Home bonds, where we again denote the existing Home bond by "*o*" and the new Home bond by "*n*", as well as one Foreign bond. Deriving analytical results in this case is generally very cumbersome. However, in the special case in which there are no Foreign local primary dealers, we find the following expression for the price effect of a new Foreign debt issue relative to a new Home debt issue:

$$\frac{\partial P_{h,o} / \partial X_f}{\partial P_{h,o} / \partial X_{h,n}} = \frac{r_{o,f}\sigma_f}{r_{o,n}\sigma_n}. \tag{5}$$

If the Home and Foreign market volatilities are of the same order of magnitude, then a new Home issue has a larger effect than a new Foreign issue if, as seems plausible, the correlation $r_{o,n}$ between the pay-offs of the two Home bonds is larger than the correlation $r_{o,f}$ between the old Home bond and the Foreign bond.

3. Data description and key statistics

We use data from the primary and secondary markets for sovereign bonds of Belgium, France, Germany, Italy, The Netherlands and Spain in the period from 1 January 1999 until 31 July 2014. We collect primary market data from Bloomberg for the 5-, 10- and 30-year maturity segment. These are the only three maturities for which all countries in our sample performed auctions both in the period before the crisis (January 1, 1999 until June 30, 2007) and the period since the start of the crisis (July 1, 2007 until July 31, 2014). For each auction, Bloomberg reports the auction date, the maturity of the new issue, the total amount bid, the total amount allotted and the average accepted yield or the marginal yield. We cross-check the data from Bloomberg with data from the countries' debt management agencies. We also retrieve end-of-day secondary market yields from Bloomberg and calculate the daily yield changes in basis points for the 5-, 10- and 30-year maturity segment.

Beetsma *et al.* (2015) also report results for 2-year auctions. However, for Belgium, Spain and The Netherlands there are too few 2-year auctions as these countries are more active in issuing 3-year debt. We prefer to refrain from combining the 2- and 3-year maturities in our analysis and limit ourselves to the 5-, 10- and 30-year maturities.

Figure 2 shows the secondary market yields in the 5-, 10- and 30-year maturity segment. The figure shows that the secondary market yields are highly correlated across countries in our sample between 1999 and mid-2007. Yields diverge during the crisis. Spain and Italy experience an increase in yields, whereas the yields on German, French and Dutch debt decrease. Belgium presents an in-between case, with yields rising between 2010 and 2012 and converging to French yields from early 2012 and on. Spanish and Italian yields start falling from July 2012 onward, when the ECB announced the OMT-program and ECB-president Draghi stated that the ECB would do "whatever it takes" to preserve the euro.

Table 2 reports summary statistics for the secondary market yields. The table shows the means and standard deviations for both the pre-crisis and post-crisis period. Generally, the standard deviation of daily yield changes is inversely related to the length of the maturity. The pre-crisis period shows limited cross-country variation in standard deviations. In the post-crisis period, we see an increase in the standard deviation for each country-maturity combination. For Belgium, France, Germany and the Netherlands, the average increase equals 1 basis point, whereas Italy and Spain witness an average rise of, respectively, 4 and 5 basis points. As a result, the cross-country variation in the standard deviations increases in the post-crisis period compared to the pre-crisis period.

The lower diagonal of Table 3 reports the co-variances of the secondary market yields between each country pair in the 5-, 10- and 30-year maturity segment for both the pre-crisis and the post-crisis period, while the upper diagonal of Table 3 does the same for the corresponding correlations. All entries in the table are positive. Our model of primary dealers' limited risk-bearing capacity and partial segmentation suggests that the cross-country spillovers of auctions are stronger when the co-variance between yields of different countries is high. The co-variances of Dutch and German yields with yields of Italy and Spain exhibit a substantial fall when going from the pre- to post-crisis period, while the other co-variances do not change materially or they even increase. In fact, the covariance between Italian and Spanish yields increases very substantially. Correlations exhibit a much more consistent pattern of change. While correlations are always 0.9 or higher before the crisis, going from the pre- to the post-crisis period, each correlation, except for one, falls. In some instances, such as between Germany and the Netherlands and between Italy and Spain, the fall is only limited, while in other instances, in particular between Germany or the Netherlands and Italy or Spain, the fall is very substantial.

Table 4 reports key statistics for the sovereign bond auctions. For each country, the frequency of auctions with a 5-year and 10-year maturity is higher than that of 30-year auctions. For example, Germany records 107 five-year auctions and 122 ten-year auctions, versus only 36 thirty-year auctions. The table also shows that the size is on average larger for the 5- and 10-year auctions than for the 30-year auctions. The total amount of 30-year debt issued over all auctions in our dataset equals 397 billion euro, while the total amounts of 5- and 10-year debt issued are 1,778 and 2,050 billion euros, respectively. For all countries, except Spain, the size of the average allotment is highest for auctions of 10-year bonds.

Comparing across countries, we observe that the frequency of auctions is highest for Italy, France and Spain. Germany issues new debt at a lower frequency, but the size of its auctions is largest, ranging between 3.1 and 5.0 billion euros, whereas the average auction size is lowest in Spain and Belgium, with a range between 0.7 and 1.6 billion euros. Belgium and The Netherlands have comparable nominal stocks of general government debt, which are the lowest in the sample. However, their auction practices differ. The Netherlands issues relatively large amounts per auction at a low frequency of auctions, whereas Belgium issues smaller amounts at a higher frequency. These patterns may be interesting in and of themselves, because it suggests that the traditionally "more vulnerable" countries tend to opt for more frequent, but smaller, auctions, possibly as a way to reduce the risk of an auction going awry.

Auction yields increase with the length of the maturity. Italy, for example, shows for the full sample an average yield increase from 3.8% for the 5-year maturity to 4.6% for the 10-year maturity and 5.4% for the 30-year maturity. The cross-country sample consists of three pairs of countries with comparable yields. Italy and Spain have the highest average yields, respectively 5.4% and 5.1% for 30-year auctions. France and Belgium show slightly lower average yields, at levels of respectively 4.6% and 4.5% for 30-year auctions. Germany and the Netherlands have the lowest average yields, respectively 3.8% and 3.6% for 30-year auctions.

Table A.2 in Appendix A (not for publication) shows that the number of auctions of different countries coinciding on the same day is limited. France and Spain are the exception to this regularity. Our dataset contains 22 cases of coinciding 5-year auctions in France and Spain (respectively 13.5% and 16.5% of the total numbers of auctions) and 43 cases of coinciding 10-year auctions (respectively 28.5% and 34.6% of the total numbers of auctions). However, the number of auctions of different countries within a 10-day window (5 days before and after an auction) is substantial. The upper diagonal of Table A.2 for instance shows 126 instances of 5-year auctions in Italy and France within a 10-day window from each other (respectively 64.0% and 77.3% of the total number of auctions).

4. Evidence of domestic auction cycles

As a logical step before the study of cross-border auction cycle spill-overs we explore the presence of domestic auction cycles. We start with an event study analysis of secondary market movements around auction dates. After this we provide evidence from a regression analysis.

4.1. The event study

The methodology in our event study is similar to that in Lou *et al.* (2013) and Beetsma *et al.* (2015). Lou *et al.* (2013) find evidence for the United States that secondary market yields tend to increase in the run-up to an auction and fall back once the auction has taken place. Beetsma *et al.* (2015) find similar auction cycles for Germany and Italy, with the cycle being more significant and larger for the latter country.

For the five trading days before and after an auction of a particular maturity, we show the development of the average secondary market yields of the same maturity. In particular, we report the average of the yield movement between the end of day t and the end of the auction day (indicated by subscript 0), $y_t - y_0$, together with the 90%-confidence band around this movement.

We consider the 5-, 10- and 30-year auctions of the six countries in our sample, resulting in 18 country-maturity pairs. Figure 3 shows the secondary-market yield movements around auction date in basis points for all country-maturity pairs in our sample. In line with the results of Beetsma *et al.* (2015), the figure shows clear and highly significant auction cycles for Italy and smaller and less significant cycles for Germany. Belgium has somewhat smaller auction cycles than Italy and the confidence bands are wider. France also exhibits some indications of auction cycles, with a particularly pronounced yield increase in the 5 days before a 30-year auction. For Spain we can only detect a significant auction cycle around issues of 30-year debt. This auction cycle is of the order of magnitude of that for Italy. Finally, there is not much indication of auction cycles for The

Netherlands, although secondary market yields on 5- and 30-year auctions exhibit some upward movement prior to an auction.

4.2. Regression evidence of domestic auction cycles

The event study in the previous subsection provides strong suggestive evidence of auction cycles in response to domestic public debt auctions in the Euro area. We now turn to a regression analysis in which we link secondary-market yield movements around auction date to the auction event. The regression analysis in this subsection allows us to estimate the size and significance of the domestic cycle and provides a stepping stone for the extended model below in which we also capture the role of foreign auctions in order to account for cross-border spill-over effects of auctions. We will perform regressions for the full sample period as well as for the pre- and post-crisis periods separately.

Although information on the auction size is available, in our regressions we choose to use only dummy variables for the auctions. Below we briefly describe the results of regressions based on the auction size. The reason is for using the auction dummies is that, while the auction dates are fixed in advance and thus can be taken as exogenous, the auction size may be endogenous. In particular, prior to the auction, the debt management agency announces a target volume or a volume range. However, if demand at the auction turns out to be lower than anticipated, it may choose to issue at the lower end of this target range, because issuing a higher volume would require a higher auction yield.

In our most basic regression we estimate the following equation for maturity *m* of country *j*:

$$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \varepsilon_t^{j,m}, \tag{6}$$

where $c_0^{j,m}$ is a constant and $AUC_t^{j,m}$ is a dummy that takes a value of 1 if an auction of a bond with maturity m takes place in country *j* at time *t*, and a value of zero otherwise. Further, $\varepsilon_t^{j,m}$ is a disturbance term. Hence, equation (6) estimates the effect of an auction on the secondary market yield for that particular maturity in the four days before the auction ($4 \geq l > 0$), the day of the auction ($l=0$) and the five days after an auction ($-5 \leq l < 0$). We estimate this equation for each of our six countries for 5-year, 10-year and 30-year maturities.

There is evidence of an auction cycle if the secondary market yield increases in the 5 days prior to (and including) the auction day $\left(\sum_{l=4}^{0}\alpha_l > 0\right)$ and decreases in the 5 days after an auction $\left(\sum_{l=-1}^{-5}\alpha_l < 0\right)$.[12] The formal null hypothesis of no auction cycle is formulated as:

$$H_0^{\alpha}:\ AC \equiv \left(\sum_{l=4}^{0}\alpha_l\right) - \left(\sum_{l=-1}^{-5}\alpha_l\right) \leq 0\,,$$

for which we use an F-test. An auction cycle is symmetric, if, in addition to $AC > 0$, we have that $\left(\sum_{l=-1}^{-5}\alpha_l\right) = -\left(\sum_{l=4}^{0}\alpha_l\right)$.

Table 5 reports the OLS estimates of AC for the full, pre-crisis and post-crisis sample periods in basis points. The standard errors are Newey-West adjusted. The auction cycle estimates are consistent with the results from the event study, and for Germany and Italy they are consistent with Beetsma *et al*. (2015). For Italy, in line with our theoretical model, we find a highly significant auction cycle for all three maturities. For Germany and Belgium we find evidence of an auction cycle for the 5- and 10-year maturities and for France for the 5- and 30-year maturities. Spain exhibits an auction cycle for the 10- and 30-year maturity segment, while no evidence of auction cycles is found for the Netherlands.

There is rather substantial cross-country variation in the size of the auction cycle. The size of the Italian cycle is 6 – 7 basis points, which is more than double that of Germany. The size of the auction cycle of Belgium in the 5- and 10-year segment is comparable to that for Italy and the sizes of the French and Spanish auction cycles in the 30-year segment are also broadly comparable to the size of the Italian cycle in this segment.

Beetsma *et al.* (2015) find that Italian auction cycles are more significant and larger in the post-crisis period than in the pre-crisis period. Here, we explore the potential difference between the two sub-periods again to check if this sample split is also relevant for our broader set of Euro countries. Hence, Table 5 also reports the auction cycles based on the estimation of equation (6) for

[12] Note that $\left(\sum_{l=4}^{0}\alpha_l > 0\right)$ also includes the movement of the yield during the auction day. If anything, this biases the results against finding an auction cycle, because it possible that between the end of the auction and the end of the trading day primary dealers have already started off-loading their inventory of the new debt issue.

the two sub-periods. For Belgium, Italy and Spain there is rather limited evidence of auctions cycles before the crisis and substantial evidence of auction cycles in the post-crisis period. The size of the cycles in the post-crisis period is also substantially larger than what was estimated for the full sample period. In particular, for the Belgian 30-year segment we estimate an auction cycle of over 20 basis points. In the context of our theoretical framework, these findings are consistent with the higher market volatility during the post-crisis period for all three countries. Quite remarkably, however, France exhibits strong evidence of auction cycles in all segments before the crisis and no evidence at all after the start of the crisis. Finally, the behavior of Germany and the Netherlands is rather similar in the pre- and post-crisis periods.

We finally test also for the symmetry of secondary yield movements around auctions (see Appendix C – not for publication). While we saw from the event study that the increase in yields prior to an auction is sometimes larger than the decrease afterwards, the hypothesis that $\left(\sum_{l=4}^{0} \alpha_l\right) = -\left(\sum_{l=-1}^{-5} \alpha_l\right)$ cannot be rejected in most cases. This lends further credence to our model of auction cycles caused by primary dealer activity, while it suggests that the supply effect does not play a large role (recall Footnote 8).

Our theoretical framework suggests that the size of the auction cycle is positively related to the size of a debt issue, as the primary dealers have to hold a larger inventory if the issue size increases. It is interesting to see whether this is indeed borne out by the data. Hence, Appendix D (not for publication) repeats the regression in (6) with the issue size replacing the auction dummy *AUC*. We find that all country-maturity combinations that are significant in Table 5 continue to be significant. However, the new regressions are of separate interest, because they quantify the effect of a given increase in the size of an auction on the magnitude of the cycle. We observe that this effect is larger for 30-year debt than for shorter debt, while it is also larger for Belgium than for Italy or Spain. For example, an increase in a Belgian 30-year debt issue by one billion increases the auction cycle by more than 12 basis points, almost double the effect of a one-billion increase in a Belgian 5-year issue and three times larger than a one-billion increase in an Italian 30-year issue. From the perspective of our theoretical model these findings may not be surprising given that an increase in the issue size by one billion constitutes a larger fraction of the outstanding stock of 30-year debt than for the other maturities, while it also constitutes a larger fraction of the outstanding stock of 30-year Belgian debt than of the Italian or Spanish 30-year debt.

5. Evidence of auction cycles caused by foreign debt issues

This section explores the presence of cross-border spill-overs from new debt issues. Again we start with an event study, which is then followed by formal econometric evidence.

5.1. The event study

The event study is similar to the one in the previous section used to detect domestic auction cycles. Now, we are interested in the effect of a foreign public debt auction of a particular maturity in one of the other countries in our sample on domestic secondary market yields. For example, we are interested in how the 5-year secondary market yield for German debt moves around 5-year auctions in any of the other countries in our sample.

For each given country Figure 4 reports the average of y_t - y_0, where y_t and y_0 are the secondary market yields on the country's debt, while subscript 0 refers to the auction dates of the other countries in the sample. We average over all foreign auctions of the same maturity. Overall, the figure is strongly suggestive of the presence of auction cycles around foreign auctions. The evidence is particularly suggestive for 30-year foreign auctions. For Germany, The Netherlands, Belgium and France, we find an increase in the secondary-market yield by 2 basis points or more in the 5 days before an auction, as well as a consistent, though somewhat smaller, decline in the yield after the auction. Also for the other two countries this event study suggests evidence of domestic cycles around foreign auctions, in particular in the 30-year segment. This evidence is consistent with our theoretical framework and the positive co-variances between the pairs of same-maturity debt instruments reported in Table 3.

5.2. Regression evidence of cross-border spillovers

In this subsection we extend our baseline regression framework for the detection of domestic auction cycles to also allow for cross-border auction cycle effects of primary debt issues. This way we can estimate the size of the potential spillover effects of foreign auctions and compare these with the size of the domestic cycles. Moreover, if the timing of the domestic and foreign auctions is correlated, including foreign auctions in the regressions allows us to avoid potential biases due to overlapping windows around auction dates in the estimates of the α_l coefficients in equation (6).

We explore first the effect of aggregate foreign auction activity. Hence, we estimate the following generalization of equation (6):

$$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{l=4}^{-5} \gamma_l \sum_{i(\neq j)} AUC_{\ t+l}^{i,m} + \varepsilon_t^{j,m}, \tag{7}$$

where $\sum_{i(\neq j)} AUC_{\ t+l}^{i,m}$ is the number of maturity-*m* auctions by sample countries other than *j* on date *t*. The size of the auction cycle in response to foreign auction activity is given by $AC\_F \equiv \left(\sum_{l=4}^{0} \gamma_l\right) - \left(\sum_{l=-1}^{-5} \gamma_l\right)$.

Table 6 reports the results of OLS estimation of (7). First, the estimates of the auction cycles generated by domestic issues are virtually unaffected in size and significance by including the foreign auction dummies (compare with Table 7). All the estimates of *AC* that were significant in Table 5 are also significant in Table 6, except for the estimates for 5-year auctions in France and 10-year auctions in Spain. Second, in line with our theory there is strong evidence of domestic auction cycles arising from foreign auction activity. For the full sample, we find a (highly) significant auction cycle in each country in the 30-year segment in response to foreign auction activity, while for the 10-year segment we find the same result for all countries except for Germany. The evidence of cross-border spill-overs is slightly weaker for the 5-year markets. Still, also in this segment, foreign auction activity generates auction cycles in the secondary debt markets of Germany, France and the Netherlands, despite the absence of cycles in response to domestic auctions for the latter two countries. In all the cases where the cycles in response to domestic and foreign auctions are both significant, the former are larger than the latter, which is in line with the theory – see equation (5). The maximum cycle in response to domestic auctions is about 7 basis points, while the maximum cycle in response to foreign auctions is about 4.5 basis points. Finally, for each country, and also in line with our theoretical framework that predicts larger effects of an auction of given size in a smaller market, the maximum spill-over effect is always found for the 30-year auctions. This result is even more salient, because the regressions estimate the response to an auction event, while the magnitudes of the 30-year auctions are systematically smaller than those of the other two maturities.

The two lower panels of Table 6 report the corresponding results for the pre- and post-crisis period. The second panel of Table 6 shows that the effect of foreign auction activity on the domestic cycle is (highly) significant for all country – maturity combinations in our sample. In fact, for the 30-year maturity, significance is always at the 1%-level. By contrast, for the post-crisis period there is much less evidence of cross-border spill-overs and, in particular, we observe no cross-border spill-overs of foreign auctions to Belgium, Italy and Spain. Evidence of spill-overs is completely absent for the 5-year segment and only present for France and Italy in the 10-year segment. There is more evidence of spill-overs in the 30-year segment. The reduced spill-overs going from the pre- to the post-crisis period would in the context of our theoretical partial-segmentation framework be consistent with the evidence in the literature on a reduction in the degree of European bond market integration, which in turn is consistent with an increase in domestic primary dealer activity relative to international primary dealer activity. Other potential reasons for finding less evidence of spill-overs in the second part of the sample could be a smaller number of auctions during the second sub-period, the reduced precision of the estimates due to the higher yield volatility (in all instances we find that the standard deviation associated with the estimated spill-overs has become higher than in the first sub-period) and a reduced average size of the auction. However, the total number of auctions has hardly fallen between the two periods (see Table 4), although there is some variation in this respect across the countries and maturities. Also, except for Germany and the Netherlands the average auction size has increased for all other countries and each maturity, which in terms of our model would suggest increased spill-overs. The standard deviations of the coefficient estimates have indeed increased. Hence, the most likely explanations for the observed reduction in spill-overs during the crisis period are the combination of reduced estimation precision and, in line with our theoretical framework, a decline in euro-area bond market integration that has dominated the increase in market volatility that seems to drive the increase in yield co-variances between most country pairs (recall Table 3).

5.3. Bilateral spill-over effects of foreign debt issues

To dig further into the determinants of the cross-border spillovers reported earlier, we estimate the bilateral cross-country auction cycle effects using the specification:

$$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{i \neq j} \sum_{l=4}^{-5} \gamma_{i,l} AUC_{t+l}^{i,m} + \varepsilon_t^{j,m} \quad (8)$$

This way we can, within a single regression, estimate the size of the domestic auction cycle in country *j*, as well as the auction cycle in country *j*'s secondary market caused by spill-overs from the auctions in each of the other countries $i \neq j$. The size of the auction cycle in response to auction activity in foreign country *i* is given by $AC\_i \equiv \left(\sum_{l=4}^{0} \gamma_{i,l}\right) - \left(\sum_{l=-1}^{-5} \gamma_{i,l}\right)$.

Table 7 reports for each country *j* the estimates of the auction cycles caused by the domestic and foreign auctions. It shows that the pattern of spill-overs is rather diverse. Obviously, given the rather limited number of auctions at the individual country level, it is harder to detect spill-overs for country pairs than for aggregate foreign issuance activity. In this extended regression framework, we observe domestic cycles in the 5-year segment for Germany, Belgium and Italy, and in the 10-year segment in addition for Spain. In the 30-year segment we observe domestic cycles for France, Italy and Spain. Spill-overs in the 5-year segment are observed from the Netherlands to France, Italy and Spain, and from Belgium to the Netherlands, France and Italy. In the 10-year segment we observe them from Germany to all other countries, except for the Netherlands, and from Spain to all other countries, except for Italy. Finally, in the 30-year segment, we detect spill-overs from France to Germany, the Netherlands and Belgium, and from Italy and Spain to all other countries in the system. The latter result is quite intuitive given that Italy and Spain are generally seen as rather vulnerable, while the 30-year market is the smallest market.

Table 8 reports the results for a split of the sample into the pre- and post-crisis period. In line with the theory, which predicts larger domestic auction cycles in the presence of a crisis, we indeed observe that the number of significant domestic cycles has increased from four before the crisis to nine post-crisis. Moreover, the significant post-crisis cycles are on average also larger than the significant before-crisis cycles. However, the transmission across borders of the auction cycle has been affected negatively, likely due to the reduction in market integration and diminished precision of the estimates. The number of significant spill-overs in the pre-crisis period (24 cases) is substantially higher than that in the post-crisis period (12 cases), although in the 30-year segment there appear to be spill-overs from Spanish auctions onto all the other countries in the system, except Belgium. This confirms the worries during the crisis that the precarious financial situation of Spain would spill over to the other countries in the Eurozone.

5.4. Robustness

The analysis in Subsection 5.1 presented evidence of cross-border spill-overs of public debt auctions. The evidence was particularly strong for the pre-crisis period. In this subsection we explore the robustness of these results.

Our first robustness test excludes those *individual* auctions that cause an exceptionally large (in absolute magnitude) domestic cycle $(y_{i,0} - y_{i,-5}) - (y_{i,5} - y_{i,0})$, where, again, y_{it} is the end-of-day t secondary market yield on a bond of given maturity, where t=0 refers to the day of the individual auction by country i. The idea is that those exceptional cases may have been caused by extreme events that are not captured by our theoretical framework. Examples might be the sudden loss of confidence in the survival of the euro or an unexpected downgrade by a credit rating agency. To determine the set of auctions to be excluded, we compare the magnitudes of the individual domestic cycles with the distribution of the other domestic cycles for the same country-maturity combination. There are ten such cases in which individual cycles are far larger in size than the other cycles. In some instances, but not in all, we can detect the likely reason for the extreme yield movements in the secondary market. Reassuringly, the estimates (and their significance) of the domestic and foreign auction cycles associated with the "non-extreme" auctions tend to be close to the corresponding estimates in Table 6 (see Table D.1 in Appendix E – not for publication). In view of this finding we do not pursue other, more formal strategies for the exclusion of observations.

The next robustness test is based on the observation that the Netherlands and Belgium are the relatively smaller economies, so that the spill-overs from these countries onto the other countries may be expected to be rather small a priori, while in the case of the Netherlands the number of 30-year auctions has been rather low. Hence, Table 9 reports the results from the estimation of (7) while leaving out the Belgian and Dutch auctions from the second term on its right-hand side. The estimates, both in terms of magnitude and in terms of significance are very much in line with the original results reported in Table 6. Hence, there continues to be substantial evidence for the existence of cross-country spill-overs from auctions, while this evidence remains substantially stronger for the pre-crisis period than for the crisis period.

As a third robustness test, we add control variables to equation (7) to test whether our results are driven by confounding factors. First, we want to exclude that the observed fluctuations in sovereign yields around auctions are the result of changes in domestic solvency risk around auction dates. In Table 10, we therefore control for the lagged first difference of the 5-year sovereign CDS spread. We take the lag to rule out potential feedback effects, although estimation with the contemporaneous difference yields very similar results. Due to data availability, we only estimate this regression for the post-crisis period. The size and significance of the auction cycle are similar to the original results in Table 6. Except in one instance, the auction cycle estimates are always significant when they were significant before. Secondly, we want to exclude the possibility of yield movements around auctions being driven by fluctuations in market conditions around the auction dates. In Table 11, we therefore control for the lagged first differences of the Euro Stoxx Bank Index to measure developments in the European banking sector, the Euro Stoxx Index to capture developments in the European equity markets, the CBOE volatility index (VIX) to control for market volatility and the Euro Overnight Index Average (EONIA) to control for interbank funding conditions. As before, we take lags to rule out feedback effects. However, using contemporaneous values would again yield very similar results. The results of the estimations in Table 11 are similar to those in Table 6, providing further support for the hypothesis that the observed auction cycles are associated only with the auctions themselves. The evidence in favor of cross-border spill-overs of auctions remains strong, and it is again stronger for the pre-crisis than for the post-crisis period.

5.5. Evidence from rolling regressions

In the previous sections we applied a sample split between the pre- and post-crisis periods. To more carefully analyze the development of the cross-country spillovers over time, we perform rolling regressions on the basis of equation (7). Figure 5 shows the rolling estimates of the cross-country spillover, $AC\_F \equiv \left(\sum_{l=4}^{0} \gamma_l\right) - \left(\sum_{l=-1}^{-5} \gamma_l\right)$. The first estimated window is equal to the pre-crisis period from 1 January 1999 to 31 June 2007, while we consecutively shift the window in steps of 30 days keeping the window length constant.

The results in Figure 5 show that our estimates of the cross-country spillovers generally tend to move in a rather smooth way, indicating that our earlier estimates of the spill-overs are not dominated by a few very specific events. The lines for the 30-year auction are obviously less smooth than the other two, because of the lower number of 30-year debt issues. For the 5-year maturities there is a tendency for the spill-over effect to fall as the window rolls further into the crisis period. A similar, but weaker, tendency is observed for the 10-year auctions, except for Italy and Spain, where the spillover-effect from the 10-year auctions increases between 2010 and 2014. For the 30-year auctions, all countries show an increase in the size of the spillovers caused by foreign auctions during the crisis in 2011 and 2012. After 2012, this increase is partly reversed in most countries. Apparently, when the crisis becomes rather acute and the market segment is relative small, the rise in the co-variance between the cross-border yields dominates the reduced bond market integration, implying a net positive effect on the spillovers. This hypothesis is confirmed by rolling co-variances between the cross-border yields on 30-year debt that at a few instances in 2011 and 2012 peak at very high levels relative to the remainder of the sample (see Appendix F – not for publication). High peaks are observed especially for the co-variances between Belgian, Italian and Spanish yields.

6. Debt issuance costs

The increase in yields in the days before an auction raises debt issuance costs for the government. Following Lou *et al.* (2013) and Beetsma *et al.* (2015) we can use our results to calculate the additional costs associated with the domestic auction cycle. In addition, our estimates of the cross-country secondary market effects allow us to calculate the additional costs of issuing debt within the event window of a foreign issue. If the latter are substantial, then the obvious policy implication would be for treasury agencies to coordinate their auction calendars.

We calculate the average yield increase prior to an auction as half the estimated size of the auction cycle generated by domestic debt issues, i.e. $\left(\sum_{l=4}^{0} \alpha_l\right) - \left(\sum_{l=-1}^{-5} \alpha_l\right)$ based on equation (6) and Table 5, or by foreign debt issues, where we focus on examples of spill-overs from specific individual countries, i.e. $\left(\sum_{l=4}^{0} \gamma_{i,l}\right) - \left(\sum_{l=-1}^{-5} \gamma_{i,l}\right)$ in equation (8) and reported in Table 7**.** We multiply the resulting numbers by the average amount allotted as reported in Table 4 to calculate the average additional issuance costs as additional (annual) interest payments.

We illustrate the calculations for 30-year auctions by Italy and Spain. The estimate of half the domestic auction cycle size is 3.40 basis points for Italy and 2.75 basis points for Spain, while the average allotment per auction equals 1,549 million euros for Italy and 1,039 million euros for Spain. Hence, the additional annual interest cost associated with a new 30-year issue is approximately 527,000 euros for Italy and 286,000 euros for Spain. To obtain the additional issuance costs over the full length of an issue, we can multiply this amount by the duration of the issue. The duration of a bond is calculated as a function of the length of the period between settlement and maturity date, the coupon dates, the coupon rate, the frequency of the coupon payments and the average accepted yield at the auction date. For both countries, we take the average duration over three randomly chosen 30-year auctions in 2006 and three randomly chosen 30-year auctions in 2013 and 2014.[13] The average durations equal 16.36 years for Italy and 15.85 years for Spain. Hence, the total additional issuance costs associated with the auction cycle amount to 8.6 million and 4.5 million euros for Italy and Spain, respectively.

[13] Spain only has two 30-year auctions in 2013, so for Spain we use one auction from 2014.

Similar calculations for the effect of Italian auctions on issuance costs in Spain, and vice versa, result in an average annual interest payment of about 199.000 euros for Spain in case of an Italian auction and of about 332.000 euros for Italy in case of a Spanish auction. These additional costs over the full length of an issue are about 3.2 million euros for Spain and 5.4 million euros for Italy.

In the post crisis period, we observe an increase in the size of domestic auction cycles and the size of cross-country spillovers between Italy and Spain, implying larger increases in issuance costs resulting from the auction cycles. In addition, Table 4 reveals an increase in the average allotment in Spain in the post-crisis period, implying a further increase in the costs associated with a given debt issue. For the post-crisis period, the total additional interest cost associated with the cycle for a domestic issue rises to 11.7 million euros for Italy and 13.1 million euros for Spain, while based on Table 8 we now calculate the additional cost to Italy (Spain) of auctioning a new issue within the event window of a Spanish (Italian) issue at 6.9 million (6.8 million) euros over the length of an issue.

7. Concluding remarks

This paper has provided evidence of auction cycles in secondary public debt markets of the euro area in response to domestic and foreign primary debt auctions. To this end we construct a unique dataset of primary auctions covering Belgium, France, Germany, Italy, the Netherlands and Spain. Together, these countries account for around 90% of the outstanding public debt of the Eurozone. We focus on the period since the inception of the Eurozone and study both the full sample period and the pre- and post-crisis sub-periods. To the best of our knowledge, this is the first paper to study domestic and cross-border spillover effects of sovereign bond auctions in the euro area for an extended set of countries.

Except for the Netherlands, for the full sample all countries exhibit an auction cycle in response to domestic debt issues. Inspecting the sub-samples, the evidence is strongest for the post-crisis period and it is strongest for the 30-year maturity, for which we find a cycle of up to 20 basis points during the crisis period. All these results are strongly in line with our theoretical framework, which emphasizes the role of the primary dealers with limited risk-bearing capacity. Also in line with our theoretical framework, we also find strong evidence of a transmission of foreign auctions into domestic auction cycles. These spill-overs can amount to a cycle of about 5 basis points. The evidence for spill-overs appears to be stronger in the pre-crisis period than during the post-crisis period. Also this is consistent with our theoretical framework, which allows for partial market segmentation. If the effect of increased segmentation driven by reduced financial market or economic integration during a crisis dominates the increase in market volatility, then cross-border auction spill-overs weaken. However, there is also evidence that spill-overs from Spain, which was particularly vulnerable during the crisis, increased during this period, suggesting that in this case the effect of higher market volatility dominated the reduction in market integration.

We found that the presence of auction cycles may seriously impact the costs of debt issuance. For example, for the post-crisis period, the total additional interest cost for a domestic 30-year debt issue is estimated at 12 and 13 million euros for Italy and Spain, respectively, while the additional cost to Italy (Spain) of a new issue within the event window of a Spanish (Italian) issue is estimated at roughly 7 million euros over the full length of an issue.

Our results are relevant for Treasuries issuing new debt. The sensitivity of the auction cycles to turbulence in the financial markets suggests that retaining flexibility on the timing of the debt auctions could limit debt issuance costs and reduce the risk of roll-over crises. Moreover, the finding of, sometimes strong, spillovers of foreign auctions indicates that proper coordination of the auction calendars among Eurozone countries may also limit issuance costs. Further research into the role of the auction design and macroeconomic fundamentals for the emergence of auction cycles would be highly desirable.

References

Acharya, V., I. Drechsler, and P. Schnabl. "A pyrrhic victory? - Bank bailouts and sovereign credit risk." *Journal of Finance* 69, no. 9 (2014): 2689-2739.

AFME. "European Primary Dealers Handbook, London/Brussels. <http://www.afme.eu>." 2014.

Ang, A., and F.A. Longstaff. "Systemic sovereign credit risk: Lessons from the U.S. and Europe." *Journal of Monetary Economics* 45, no. 1 (2013): 493-510.

Baele, L., G. Bekaert, K. Inghelbrecht, and M. Wei. "Flights to safety." *National Bank of Belgium Working Paper No. 230*, 2014.

Battistini, N., M. Pagano, and S. Simonelli. "Systemic risk, sovereing yields and bank exposures in the euro crisis." *Economic Policy* 29, no. 78 (2014): 203-251.

Beber, A., M.W. Brandt, and K. Kavayecz. "Flight-to-Quality of Flight-to-Liquidity? Evidence from the Euro-Area Bond Market." *Review of Financial Studies* 22 (2009): 925-957.

Beetsma, R., M. Giuliodori, F. De Jong, and D. Widijanto. "Price effects of sovereign debt auctions in the euro-zone: The role of the crisis." *Journal of Financial Intermediation*, 2015.

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

Bhanot, K., N. Burns, D. Hunter, and M. Williams. "Was there contagion in eurozone sovereign bond markets during the Greek debt crisis?" *Working Paper No. 006FIN-73-2012*, 2012.

Brutti, F., and P. Sauré. "Transmission of sovereign risk in the euro crisis." *mimeo, Study Center Gerzensee and Swiss National Bank*, 2013.

Bruyckere De, V., M. Gerhardt, G. Schepens, and R. Vander Vennet. "Bank/sovereign risk spillovers in the European debt crisis." *Journal of Banking and Finance* 37 (2013): 4793-4809.

Christiansen, C. "Integration of European bond markets." *Journal of Banking & Finance* 42, no. C (2014): 191-198.

Cipollini, A, J. Coakley, and H. Lee. "The European sovereign debt market: from integration to segmentation." *The European Journal of Finance* 21, no. 2 (2015): 111-128.

Claeys, P., and B. Vasicek. "Measuring bilateral spillover and testing contagion on sovereign bond markets in Europe." *ECB Working Paper No. 1666*, 2014.

De Santis, R.A. "The euro area sovereign debt crisis: Identifying flight-to-liquidity and the spillover mechanisms." *Journal of Empirical Finance* 37 (2014): 150-170.

Ejsing, J., M. Grothe, and O. Grothe. "Liquidity and credit risk premiums in government bond yields." *ECB Working Paper No 1440*, 2012.

Eurostat. *General government gross debt.* 2015. http://ec.europa.eu/eurostat/data/database.

Favero, C., M. Pagano, and E.L. Von Thadden. "How does liquidity affect government bond yields?" *Journal of Financial and Quantitative Analysis* 45, no. 1 (2010): 107-134.

Fleming, M.J., and J.V. Rosenberg. "What moves the bond market?" *Federal Reserve Bank of New York Economic Policy Review*, 2007: 31-50.

Greenwood, R, and D Vayanos. "Bond Supply and Excess Bond Returns." *NBER Working Paper No. 13806*, 2008.

Greenwood, R, and D Vayanos. "Price Pressure in the Government Bond Market." *American Economic Review: Papers and Proceedings* 100 (2010): 585-90.

Kallestrup, R., D. Lando, and A. Murgoci. "Financial sector linkages and the dynamics of bank and sovereign credit spreads." *Available at SSRN: http://ssrn.com/abstract=2023635*, 2012.

Lou, D., H. Yan, and J. Zhang. "Anticipated and repeated shocks in liquid markets." *Review of Financial Studies* 26, no. 8 (2013): 1891-1912.

Mohl, P., and D. Sondermann. "Has political communication during the crisis impacted sovereign bond spreads in the euro area?" *Applied Economic Letters* 20, no. 1 (2013): 48-61.

Montfort, A., and J.-P. Renne. "Credit and liquidity risks in euro area sovereign yield curves." *Banque de France Working Paper No. 352*, 2011.

Pozzi, L., and G. Wolswijk. "The time-varying integration of euro area government bond markets." *European Economic Review* 56, no. 1 (2012): 36-53.

Von Hagen, J., L. Schuknecht, and G. Wolswijk. "Government bond risk premiums in the EU revisisted: The impact of the financial crisis." *European Journal of Political Economy* 27, no. 1 (2011): 36-43.

Tables

Table 1: Overview of primary dealers in 2014

	Germany	Netherlands	France	Belgium*	Italy	Spain**
ABN AMRO	X	X		X^r		
Bankinter						X
Banca IMI	X				X	
Bankhaus Lampe KG	X					
Bankia						X
Bank of America Merrill Lynch	X		X		X	
Barclays	X	X	X: 2	X	X: 5	X: 2
Bayerische Landesbank	X					
BBVA	X			X^r		X: 3
Belfius				X^r		
BHF-Bank Aktiengesellschaft	X					
BNP Paribas	X: 4		X: 1	X	X	X
Caixa Bank						X: 4
Citigroup	X	X	X	X	X: 4	X: 1
Commerzbank	X: 1	X: 2	X	X^r	X	X
Confederación Esp. De Cajas de Ahorros						X
Crédit Agricole	X: 5		X: 4	X	X	X
Credit Suisse	X		X		X	X
Danske Bank A/S	X					
Dekabank	X					
Deutsche Bank	X: 2	X	X	X	X	X

DZ Bank	X					
Goldman Sachs	X		X	X^r	X	X
HSBC	X: 3	X: 5	X: 5	X	X	X: 5
ING	X	X: 1		X	X	
Jefferies	X	X		X^r		
JP Morgan	X		X	X	X: 3	X
KBC				X		
Landesbank Baden-Wurttemberg	X					
Landesbank Hessen-Thuringen Girozentrale	X					
Mihuzo	X					
Monte Paschi di Siena					X: 1	
Morgan Stanley	X		X	X	X	X
Natixis	X	X	X	X		X
Nomura	X	X: 4	X	X	X	X
Norddeutsche Landesbank Girozentrale	X					
Nordea	X			X^r		
Rabobank	X	X: 3				
Royal Bank of Scotland	X	X	X	X	X	
Santander	X	X	X	X		X
Scotiabank Europe	X		X	X^r		
Société Générale	X	X	X: 3	X	X	X
UBS	X		X	X	X	
Unicredit	X				X: 2	
Total	37	14	19	24	20	20

Notes: Germany, Italy, Spain, France and The Netherlands publish primary dealer rankings. The numbers depict the top 5 in the ranking for 2014. For France and Italy, the rankings for 2013 are shown.
(*) Belgium has primary dealers and recognized dealers. Primary dealers have more duties and obligations than recognized dealers, such as access to non-competitive subscriptions and an obligation to participate in auctions. Recognized dealers are denoted with a superscript r.
(**) Spain has a separate list of primary dealers for T-bills and government bonds. The table shows the list for government bonds.

Table 2: Means and standard deviations of daily yield changes

			5-year	10-year	30-year
Belgium	Mean	Full sample	-0.08	-0.06	-0.07
	(in basis points)	Pre-crisis	0.04	0.03	-0.02
		Post-crisis	-0.23	-0.17	-0.12
	Standard deviation	Full sample	5.44	4.65	4.31
	(in basis points)	Pre-crisis	4.57	3.94	3.77
		Post-crisis	6.32	5.39	4.88
Italy	Mean	Full sample	-0.05	-0.03	-0.02
	(in basis points)	Pre-crisis	0.07	0.05	0.02
		Post-crisis	-0.18	-0.11	-0.06
	Standard deviation	Full sample	7.37	5.95	4.82
	(in basis points)	Pre-crisis	4.36	3.90	3.64
		Post-crisis	9.83	7.72	5.93
France	Mean	Full sample	-0.07	-0.06	-0.05
	(in basis points)	Pre-crisis	0.06	0.03	0.00
		Post-crisis	-0.22	-0.17	-0.12
	Standard deviation	Full sample	4.92	4.37	4.18
	(in basis points)	Pre-crisis	4.39	3.99	3.70
		Post-crisis	5.48	4.79	4.71
Spain	Mean	Full sample	-0.10	-0.07	-0.05
	(in basis points)	Pre-crisis	-0.01	-0.03	-0.05
		Pre-crisis	-0.19	-0.12	-0.05
	Standard deviation	Full sample	7.65	6.38	5.58
	(in basis points)	Pre-crisis	4.35	3.77	3.57
		Pre-crisis	10.07	8.32	7.14
Germany	Mean	Full sample	-0.07	-0.07	-0.07
	(in basis points)	Pre-crisis	0.05	0.03	0.00
		Pre-crisis	-0.23	-0.18	-0.14
	Standard deviation	Full sample	4.85	4.41	4.26
	(in basis points)	Pre-crisis	4.37	3.85	3.70
		Pre-crisis	5.37	5.01	4.85
Netherlands	Mean	Full sample	-0.08	-0.06	-0.07
	(in basis points)	Pre-crisis	0.05	0.03	0.00

	Pre-crisis	-0.23	-0.18	-0.14
Standard deviation	Full sample	4.83	4.31	4.21
(in basis points)	Pre-crisis	4.48	3.93	3.69
	Post-crisis	5.21	4.72	4.76

Notes: Sub-period "Pre-crisis" ranges from 1 January 1999 until 31 June 2007, while sub-period "Post-crisis" ranges from 1 July 2007 until 31 July 2014.

Table 3: Covariances and correlations of daily yield changes

Upper diagonal: correlation $r_{j,i}$.

Lower diagonal: covariance $Cov(R_j, R_i)$.

5-year maturity	Pre-crisis (1-1-1999 – 31-6-2007)						Post-crisis (1-7-2007 – 31-7-2014)					
$i\downarrow$ $j\rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain	Germany	Netherlands	France	Belgium	Italy	Spain
Germany		0.94	0.96	0.90	0.93	0.93		0.89	0.76	0.49	0.06	0.10
Netherlands	18.44		0.95	0.91	0.92	0.93	24.80		0.83	0.62	0.19	0.21
France	18.33	18.61		0.92	0.93	0.94	22.50	23.68		0.73	0.34	0.33
Belgium	18.05	18.75	18.53		0.90	0.92	16.64	20.55	25.40		0.51	0.50
Italy	17.62	17.99	17.82	18.00		0.93	2.94	9.85	18.07	31.69		0.78
Spain	17.17	17.66	17.41	17.61	17.04		5.31	11.27	18.39	31.51	77.47	
10-year maturity	Pre-crisis (1-1-1999 – 31-6-2007)						Post-crisis (1-7-2007 – 31-7-2014)					
$i\downarrow$ $j\rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain	Germany	Netherlands	France	Belgium	Italy	Spain
Germany		0.98	0.98	0.96	0.95	0.98		0.91	0.75	0.50	0.02	0.06
Netherlands	14.85		0.98	0.96	0.95	0.98	21.52		0.82	0.61	0.15	0.17
France	15.02	15.32		0.96	0.95	0.98	17.95	18.46		0.76	0.37	0.34
Belgium	14.47	14.73	15.01		0.94	0.97	13.50	15.57	19.66		0.54	0.51
Italy	14.26	14.54	14.75	14.47		0.97	0.89	5.36	13.59	22.33		0.79
Spain	13.79	14.03	14.22	14.04	13.73		2.45	6.75	13.54	22.91	51.02	
30-year maturity	Pre-crisis (1-1-1999 – 31-6-2007)						Post-crisis (1-7-2007 – 31-7-2014)					
$i\downarrow$ $j\rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain	Germany	Netherlands	France	Belgium	Italy	Spain
Germany		0.98	0.98	0.95	0.92	0.98		0.98	0.82	0.68	0.11	0.15
Netherlands	13.35		0.98	0.96	0.92	0.98	22.54		0.84	0.71	0.15	0.18
France	13.38	13.35		0.96	0.93	0.98	18.70	18.83		0.87	0.36	0.38
Belgium	13.28	13.31	13.41		0.91	0.97	16.09	16.50	19.97		0.50	0.51
Italy	12.40	12.36	12.44	12.48		0.95	3.03	4.25	10.08	14.57		0.78
Spain	12.58	12.56	12.63	12.58	11.90		5.04	6.13	12.76	17.64	32.77	

Table 4: Summary statistics of auctions

		Full sample			Pre-crisis period			Post-crisis period		
		5Y	10Y	30Y	5Y	10Y	30Y	5Y	10Y	30Y
Belgium	Number of auctions	63	87	27	26	38	15	37	49	12
	Av. amount allotted (mln. eur)	887	1188	714	886	1208	589	888	1172	872
	Av. accepted yield (%)	3.2	3.9	4.5	4.2	4.5	4.9	2.5	3.4	4.1
France	Number of auctions	163	151	63	81	83	37	82	68	26
	Av. amount allotted (mln. eur)	2918	3459	1433	2694	3115	1385	3140	3880	1502
	Av. accepted yield (%)	2.8	3.9	4.6	3.9	4.3	5.0	1.6	3.3	4.0
Germany	Number of auctions	107	122	36	43	52	14	64	70	22
	Av. amount allotted (mln. eur)	4571	5032	3094	5353	6208	4450	4045	4157	2231
	Av. accepted yield (%)	2.5	3.3	3.8	3.7	4.3	4.7	1.6	2.5	3.2
Italy	Number of auctions	197	182	73	109	95	51	88	87	22
	Av. amount allotted (mln. eur)	2471	2753	1549	2148	2490	1539	2872	3041	1570
	Av. accepted yield (%)	3.8	4.6	5.4	4.0	4.6	5.5	3.6	4.6	5.1
Netherlands	Number of auctions	29	57	11	6	30	4	23	27	7

	Av. amount allotted (mln. eur)	1808	2245	1603	1915	2393	2013	1781	2081	1369
	Av. accepted yield (%)	2.0	3.8	3.6	3.3	4.5	4.7	1.7	2.9	3.0
Spain	Number of auctions	133	123	57	60	69	37	73	54	22
	Av. amount allotted (mln. eur)	1643	1479	787	1206	1104	599	2002	1960	1086
	Av. accepted yield (%)	3.8	4.7	5.1	4.1	4.7	5.1	3.5	4.7	5.1

Notes: See Notes to Table 2.

Table 5: Testing for the presence of domestic auction cycles

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \varepsilon_t^{j,m}$

$AC = (\sum_{l=4}^{0} \alpha_l) - (\sum_{l=-1}^{-5} \alpha_l)$

		Germany	Netherlands	France	Belgium	Italy	Spain
Full sample							
5-year	*AC*	3.12**	3.54	2.43*	7.35***	6.82***	0.34
10-year	*AC*	2.75**	0.80	1.15	6.19***	5.81***	3.89*
30-year	*AC*	2.92	4.76	5.27***	7.94	6.80***	5.50**
Pre-crisis period							
		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	-0.31	5.15*	3.71***	5.25*	1.43	0.97
10-year	*AC*	4.61***	1.92	3.18**	0.60	0.70	2.64
30-year	*AC*	1.40	5.63*	4.94***	-2.60	5.60***	0.32
Post-crisis period							
		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	5.43***	3.14	1.15	8.84**	13.43***	-0.12
10-year	*AC*	1.35	-0.43	-1.33	10.52***	11.34***	5.24
30-year	*AC*	3.89	4.27	5.71	20.58**	9.62***	12.49***

Notes: Estimation method is Ordinary Least Squares with Newey-West adjusted standard errors.
*, ** and *** denote significance at the 10%-, 5%- and 1%-levels, respectively.

Table 6: Testing for cross-country spillovers

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{l=4}^{-5} \gamma_l \sum_{i(\neq j)} AUC_{t+l}^{i,m} + \varepsilon_t^{j,m}$

$AC = (\sum_{l=4}^{0} \alpha_l) - (\sum_{l=-1}^{-5} \alpha_l)$ and $AC\_F = (\sum_{l=4}^{0} \gamma_l) - (\sum_{l=-1}^{-5} \gamma_l)$

		Germany	Netherlands	France	Belgium	Italy	Spain
Full sample							
5-year	*AC*	3.05**	3.12	2.18	6.96***	6.95***	0.19
	AC_F	1.85***	1.39**	1.61**	0.94	-0.08	1.46
10-year	*AC*	2.76**	0.63	1.13	6.06**	6.94***	3.61
	AC_F	1.03	1.43***	2.35***	1.71***	2.54***	2.40**
30-year	*AC*	2.96	4.99	6.07***	7.92	7.21***	5.77**
	AC_F	4.45***	4.04***	3.71***	3.95***	2.63**	3.65**
Pre-crisis period							
		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	-0.63	5.89**	2.64*	5.39*	2.01	1.77
	AC_F	3.19***	2.07***	2.18**	2.03**	1.94**	1.79**
10-year	*AC*	5.01***	1.32	2.46*	-0.20	1.49	1.94
	AC_F	1.86**	2.19***	2.41***	2.43***	2.02**	1.93**
30-year	*AC*	1.59	5.76	5.38***	-2.33	5.57***	0.85
	AC_F	3.86***	3.31***	3.09***	4.18***	2.73***	3.41***
Post-crisis period							
		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	5.39***	2.59	1.11	8.16**	12.90***	-0.65
	AC_F	0.79	0.82	0.93	-0.24	-0.64	1.05
10-year	*AC*	1.26	-0.87	-0.64	11.14***	12.22***	4.87
	AC_F	0.08	0.65	2.03**	0.76	2.77*	2.77
30-year	*AC*	3.82	4.78	6.83*	20.37**	10.20***	13.72***
	AC_F	5.39***	5.17***	4.56***	3.04	2.54	4.76

Notes: See Notes to Table 5.

Table 7: Estimates of bilateral auction cycle spillovers

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{i \neq j} \sum_{l=4}^{-5} \gamma_{i,l} AUC_{t+l}^{i,m} + \varepsilon_t^{j,m}$, where $AC\_i \equiv \left(\sum_{l=4}^{0} \gamma_{i,l}\right) - \left(\sum_{l=-1}^{-5} \gamma_{i,l}\right)$.

5-year maturity						
$i \downarrow \quad j \rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain
AC_DE	3.03*	0.56	0.45	0.79	-4.07	-2.26
AC_NL	2.55	3.10	4.69*	4.27	7.01*	9.11**
AC_FR	2.03	2.04	1.77	1.28	-2.15	3.16
AC_BE	3.21	4.08*	4.44**	6.63**	6.01*	-0.73
AC_IT	1.44	0.63	1.37	1.18	7.11***	2.04
AC_ES	2.10	1.10	0.70	0.22	1.09	0.11
10-year maturity						
$i \downarrow \quad j \rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain
AC_DE	2.80**	1.95	3.57***	3.97**	3.65**	5.34***
AC_NL	0.48	0.24	-0.61	-1.85	2.10	-0.19
AC_FR	0.78	0.53	0.42	0.93	0.96	-0.64
AC_BE	-0.22	0.89	2.09	5.62***	4.53	2.88
AC_IT	0.55	0.72	0.75	0.17	5.32***	1.46
AC_ES	3.02**	3.60***	4.16***	2.77*	2.84	4.06*
30-year maturity						
$i \downarrow \quad j \rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain
AC_DE	2.99	3.48	1.94	2.18	1.73	1.07
AC_NL	5.18	4.88	3.24	1.96	-1.77	3.42
AC_FR	5.24***	5.06***	6.37***	4.50***	1.53	2.16
AC_BE	0.07	-0.13	2.15	7.78	4.01	8.01
AC_IT	3.97***	3.52***	3.94***	4.05***	6.34***	3.83**
AC_ES	5.21**	5.22**	4.75**	4.64**	4.29**	5.16**

Notes: See Notes to Table 5.

Table 8: Estimates of bilateral auction cycle spillovers – split between the pre- and post-crisis period

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{i \neq j} \sum_{l=4}^{-5} \gamma_{i,l} AUC_{t+l}^{i,m} + \varepsilon_t^{j,m}$, where $AC\_i \equiv \left(\sum_{l=4}^{0} \gamma_{i,l}\right) - \left(\sum_{l=-1}^{-5} \gamma_{i,l}\right)$.

5-year maturity	Pre-crisis						Post-crisis					
$i \downarrow \quad j \rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain	Germany	Netherlands	France	Belgium	Italy	Spain
AC_DE	-0.51	-0.08	-0.77	-0.39	-0.63	-2.27	5.77***	1.71	1.79	2.37	-5.04	-1.66
AC_NL	4.89	6.75**	8.53***	5.97*	5.61*	6.30**	1.02	1.49	3.29	3.41	6.69	10.19*
AC_FR	2.33	0.93	2.39	2.66	1.38	3.70**	2.62	3.65*	2.05	0.84	-4.84	1.88
AC_BE	4.58	2.90	4.31	5.02	3.76	0.47	1.74	4.23	3.92	7.34*	6.95	-1.80
AC_IT	2.22	1.85	1.91	1.31	1.74	1.68	0.39	-1.22	0.41	0.43	12.44***	1.46
AC_ES	3.51*	3.46*	3.55*	3.92*	3.10	2.04	-0.07	-2.03	-2.40	-3.01	1.30	-1.22
10-year maturity	Pre-crisis						Post-crisis					
$i \downarrow \quad j \rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain	Germany	Netherlands	France	Belgium	Italy	Spain
AC_DE	4.89***	4.50***	5.14***	5.42***	4.16***	4.58***	1.51	0.28	2.66	3.22	2.81	5.51*
AC_NL	1.89	1.23	2.10	0.26	0.28	1.53	-1.46	-1.25	-3.68	-4.55	4.25	-0.34
AC_FR	2.60	2.53	2.96	2.88	2.55	2.69	-0.89	-1.10	-1.70	-0.44	-0.59	-3.20
AC_BE	-0.27	-0.56	0.04	-0.05	-0.25	-0.76	-0.55	1.61	3.51	10.07***	8.64**	5.31
AC_IT	0.68	0.82	0.90	0.64	0.99	0.68	0.74	1.25	1.15	0.11	9.39***	1.96
AC_ES	2.36	2.15	2.13	2.16	2.20	1.30	3.29	4.57*	5.86***	2.38	1.63	5.67
30-year maturity	Pre-crisis						Post-crisis					
$i \downarrow \quad j \rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain	Germany	Netherlands	France	Belgium	Italy	Spain
AC_DE	2.11	2.66	2.48	2.57	3.00	2.26	3.43	3.88	1.49	1.68	0.98	0.68
AC_NL	5.88	5.73	5.84	5.21	5.45	3.45	4.03	3.35	1.36	-1.02	-6.65	2.00
AC_FR	5.95***	5.73***	6.11***	5.61***	4.00**	5.71***	4.55	4.50	7.07**	3.32	-1.84	-1.30
AC_BE	-2.03	-1.67	-1.47	-2.17	-1.43	-0.05	2.81	2.01	6.87*	20.47**	11.57*	16.05
AC_IT	4.27***	4.22***	4.15***	4.61***	4.90***	3.50**	2.89	1.57	2.32	1.56	8.40***	6.50
AC_ES	2.74	2.13	2.43	3.04	3.24	0.60	9.27**	10.27**	8.54**	6.96	5.63*	12.36***

Notes: See Notes to Table 5.

Table 9: Testing cross-country spillovers – excluding Belgian and Dutch auctions

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{l=4}^{-5} \gamma_l \sum_{i(\neq j)} AUC_{t+l}^{i,m} + \varepsilon_t^{j,m}$

$AC = (\sum_{l=4}^{0} \alpha_l) - (\sum_{l=-1}^{-5} \alpha_l)$ and $AC\_F = (\sum_{l=4}^{0} \gamma_l) - (\sum_{l=-1}^{-5} \gamma_l)$

Full sample							
		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	2.99*	3.30	2.09	6.87***	6.39***	0.50
	AC_F	1.59**	1.05	0.95	0.78	-1.78	1.13
10-year	*AC*	2.80**	0.59	1.02	5.98**	7.03***	3.76*
	AC_F	1.30*	1.52***	2.94***	2.03***	2.33***	2.54**
30-year	*AC*	3.16	4.74	6.17***	8.01	7.00***	5.65**
	AC_F	5.09***	4.60***	4.10***	4.12***	2.63**	2.83
Pre-crisis period							
		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	-0.72	5.91**	2.46*	5.24*	1.97	2.06
	AC_F	2.95***	1.90**	1.71	1.98**	1.49	1.71*
10-year	*AC*	4.85***	1.51	2.44*	-0.31	1.70	1.92
	AC_F	2.13***	2.62***	2.96***	2.62***	2.70***	2.48***
30-year	*AC*	1.53	5.32	5.43***	-2.32	5.75***	0.74
	AC_F	4.66***	4.01***	3.84***	4.18***	3.33***	4.12***
Post-crisis period							
		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	5.30***	2.69	1.13	8.12**	11.16***	-0.19
	AC_F	0.32	0.25	0.01	-0.60	-2.96	0.16
10-year	*AC*	1.35	-0.92	-0.75	11.04***	12.17***	5.37
	AC_F	0.12	0.32	2.57**	1.31	1.56	2.46
30-year	*AC*	4.29	4.58	6.95*	20.48**	9.99***	12.88***
	AC_F	5.92***	5.59***	4.52**	3.46*	1.68	2.31

Notes: See Notes to Table 5.

Table 10: Regressions controlling for CDS spreads

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{l=4}^{-5} \gamma_l \sum_{i(\neq j)} AUC_{t+l}^{i,m} + \delta \Delta CDS_{t-1}^{j} + \varepsilon_t^{j,m}$

$AC = (\sum_{l=4}^{0} \alpha_l) - (\sum_{l=-1}^{-5} \alpha_l)$ and $AC\_F = (\sum_{l=4}^{0} \gamma_l) - (\sum_{l=-1}^{-5} \gamma_l)$

CDS_{t-1}^{j} is the 5-year CDS-spread of country *j*

Post-crisis period

		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	5.06***	1.76	1.28	6.52*	12.56***	0.24
	AC_F	0.97	0.65	1.06	0.13	-0.47	1.26
10-year	*AC*	0.75	-0.15	-0.12	9.72***	11.82***	5.82
	AC_F	-0.06	0.21	1.81**	0.67	2.64*	2.20
30-year	*AC*	2.81	4.74	7.58**	16.26**	10.42***	13.75***
	AC_F	5.19***	5.72***	4.58***	3.70*	2.35	4.51

Notes: See Notes to Table 5.

Table 11: Controlling for market conditions

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{l=4}^{-5} \gamma_l \sum_{i(\neq j)} AUC_{t+l}^{i,m} + \delta \Delta X_{t-1} + \varepsilon_t^{j,m}$

$AC = (\sum_{l=4}^{0} \alpha_l) - (\sum_{l=-1}^{-5} \alpha_l)$ and $AC\_F = (\sum_{l=4}^{0} \gamma_l) - (\sum_{l=-1}^{-5} \gamma_l)$

X_{t-1} is a vector containing variables measuring market conditions: the Euro Stoxx Bank Index, the Euro Stoxx Index, the CBOE Volatility Index (VIX) and the Euro Overnight Index Average (EONIA).

Full sample

		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	2.40	3.28	2.72*	6.36**	6.71***	0.45
	AC_F	1.88***	1.20*	1.34*	0.84	-0.04	1.33
10-year	*AC*	2.80**	0.28	1.03	5.62**	6.04***	3.58
	AC_F	0.90	1.36**	2.23***	1.55**	2.45***	2.04*
30-year	*AC*	3.01	3.49	5.66***	8.01	7.43***	5.55**
	AC_F	4.13***	3.97***	3.50***	3.97***	2.45**	3.14*

Pre-crisis period

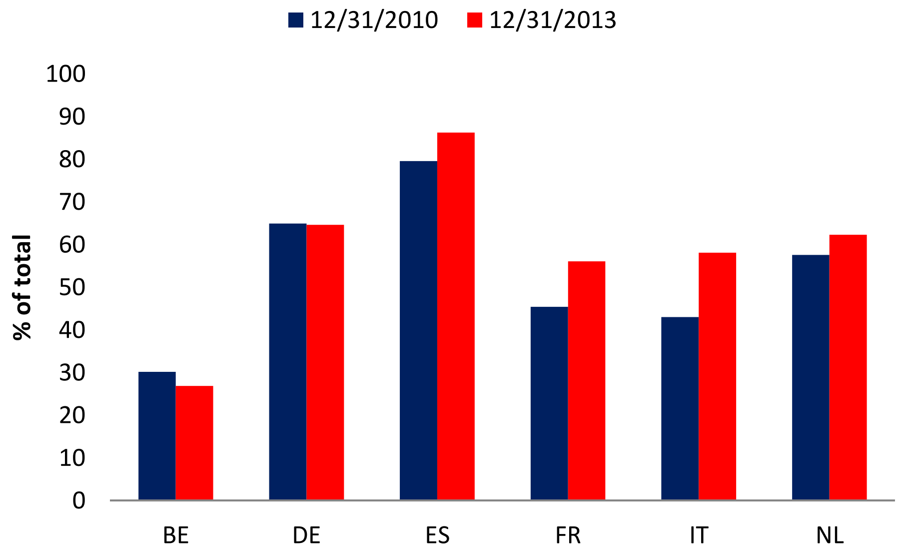
		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	-0.73	5.61*	2.83*	5.81*	2.38*	1.03
	AC_F	3.11***	1.96**	2.16**	1.92**	1.59*	1.69*
10-year	*AC*	4.94***	0.85	2.07	-0.93	1.53	2.11
	AC_F	1.62**	2.02***	2.22**	2.20***	1.80**	1.55*
30-year	*AC*	1.93	4.69	4.75***	-2.11	5.62***	-0.46
	AC_F	3.53***	3.16***	2.65**	4.02***	2.24*	2.98***

Post-crisis period

		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	4.12**	2.62	2.11	7.32*	12.22***	0.21
	AC_F	1.06	0.64	0.54	-0.28	-0.52	0.88
10-year	*AC*	1.44	-1.10	-0.34	10.99***	10.36***	4.57
	AC_F	0.10	0.74	2.04**	0.75	2.86*	2.41
30-year	*AC*	3.52	3.61	6.67*	22.00*	11.37***	13.81***
	AC_F	5.12***	5.27***	4.47**	3.47*	2.72	4.23

Notes: See Notes to Table 5.

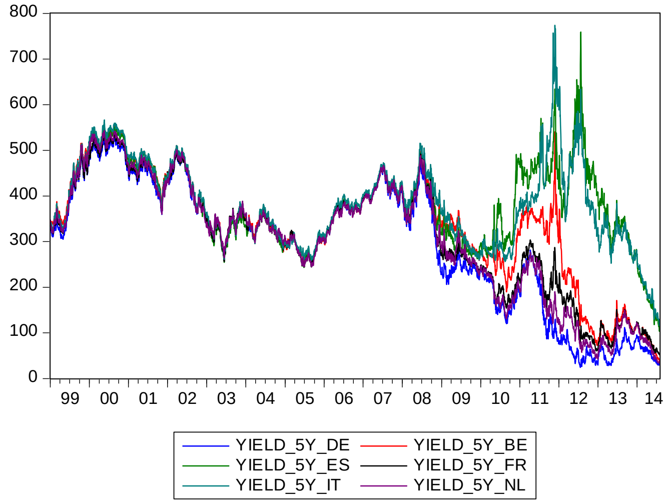
Figure 1: Share of domestic primary dealer exposure to sovereign



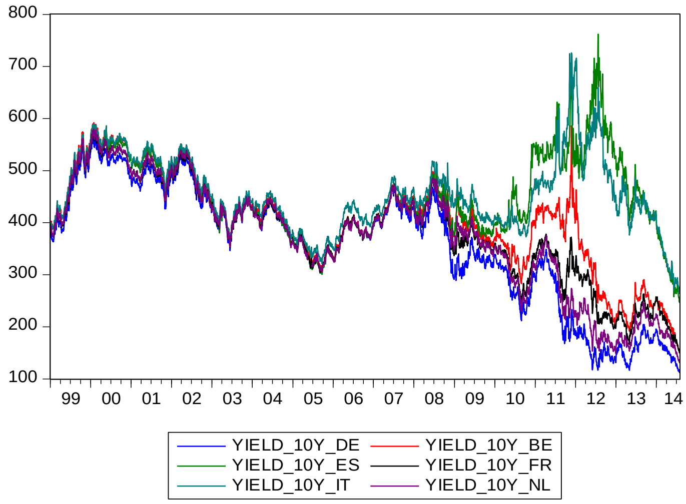
Note: The bars represent total bond holdings by national primary dealers included in the EBA-data divided by total bond holdings by all (domestic and foreign) primary dealers included in the EBA-data.

Figure 2: Secondary market yields

(a) 5-year maturity



(b) 10-year maturity



(c) 30-year maturity

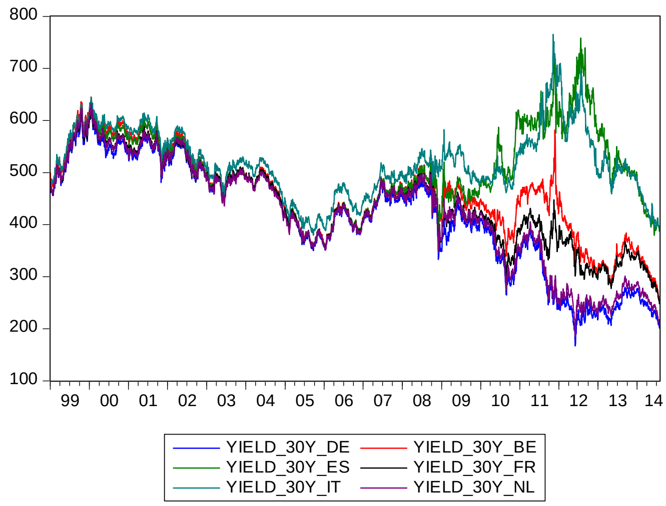
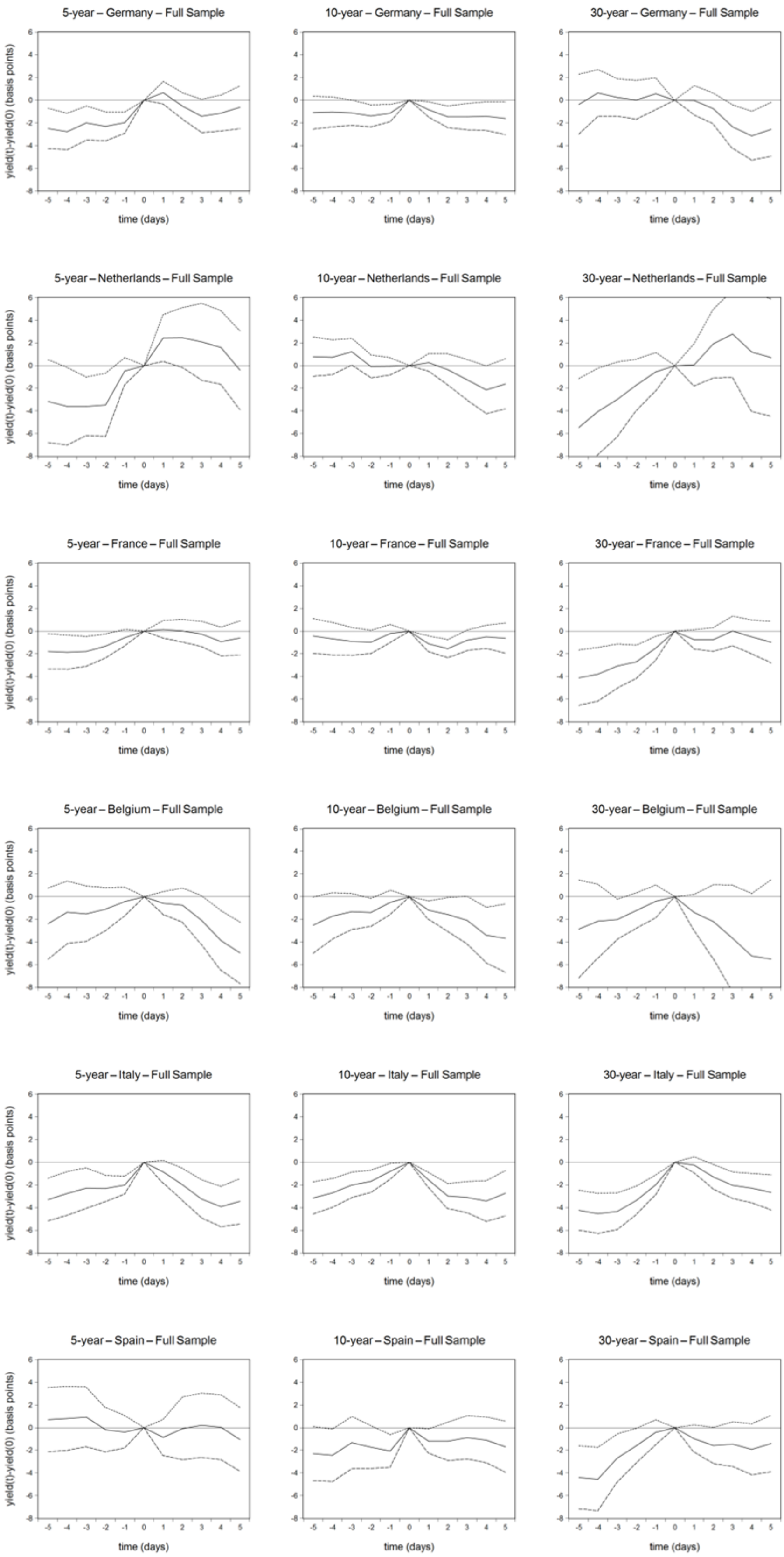
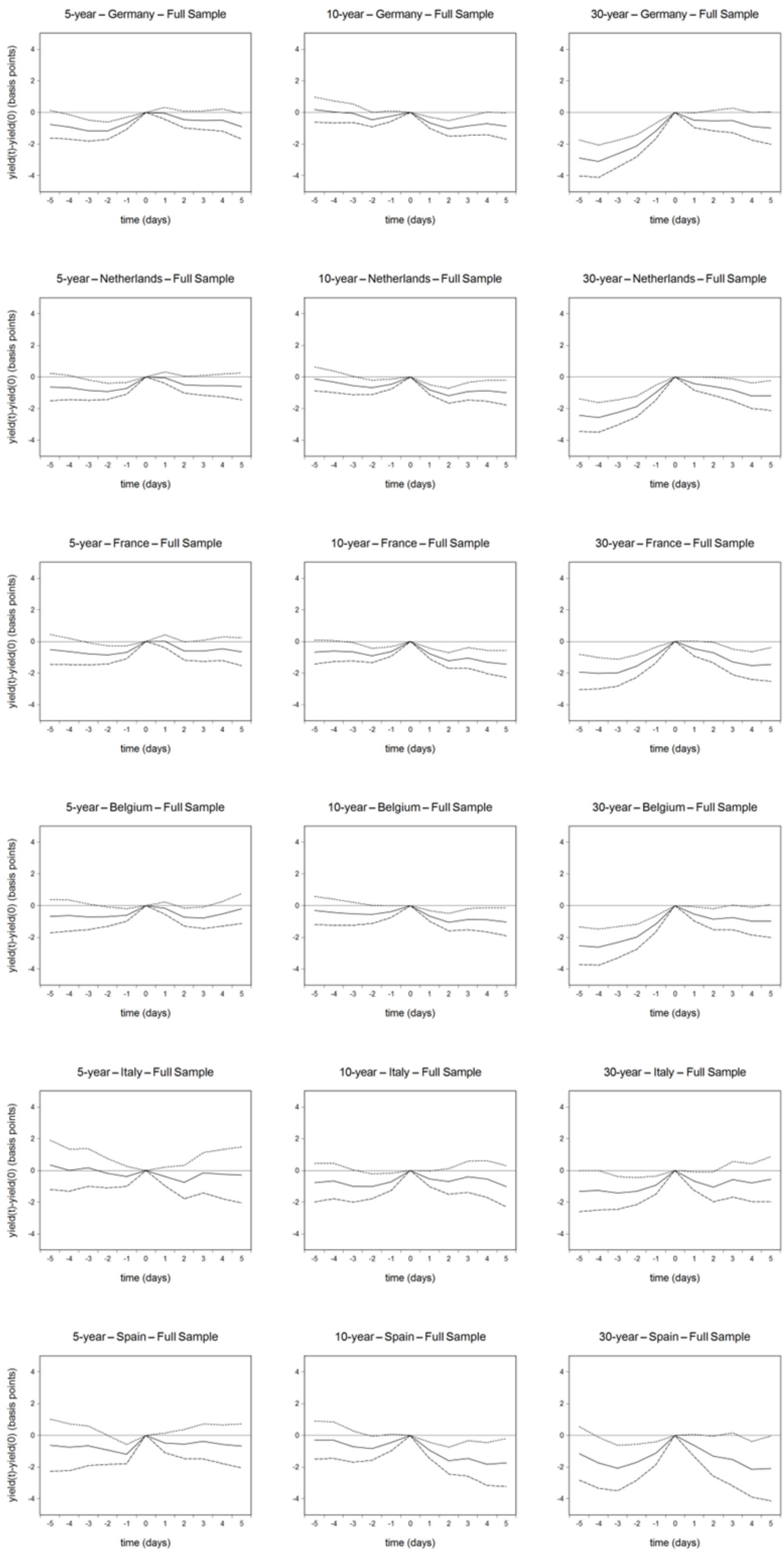


Figure 3: Average yield movement before and after a domestic auction



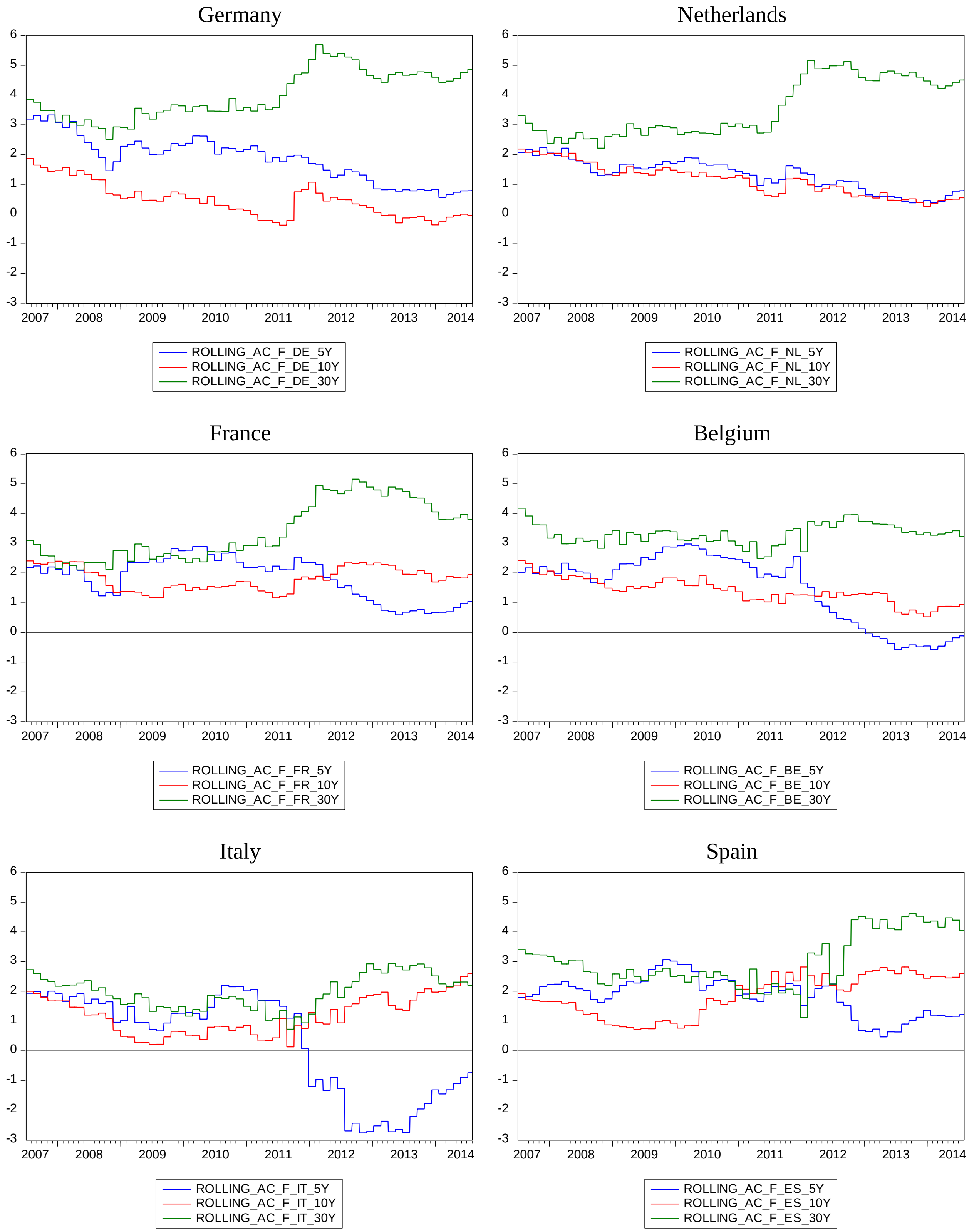
Notes: The figure reports the average of $y_t - y_0$, where y_t is the end-of-day yield of the bond on day *t*, and y_0 is the end-of-day yield on the same maturity bond on the auction day 0. All yields are expressed in basis points. The dotted lines are the 90% confidence intervals with Newey-West adjusted standard errors.

Figure 4: Average yield movements before and after a foreign auction



Notes: The figure reports the average of the domestic end-of-day yield difference $y_t - y_0$, where 0 refers to the day a foreign auction of the same maturity takes place, and the average is taken over all foreign auctions of the same maturity. Further, see notes to Figure 3.

Figure 5: Results from rolling regressions



Appendix A (NOT for publication): Additional tables

Table A.1: Overview of auction procedures

	Auction type			Primary Dealer requirement on primary market
	Single price	Multiple price	Tap	
Belgium		X		Place on average 2% of total competitive bids
France		X		Place on average 2% of total competitive bids
Germany		X		Buy 0.05% of total amount issued per calendar year
Italy	X			Buy 3% of total amount issued per calendar year
Netherlands			X	-
Spain	X	X		Bid each auction 3% of the amount allotted[1]

Notes: Source is AFME (2014). [1] At a price no lower than the marginal price minus 5 cents (for 10-year bonds), 10 cents (5Y-bonds) or 15 cents (10Y-bonds).

Table A.2: Number of auctions on the same date and within a 10-day window

5Y	DE	NL	FR	BE	IT	ES	10Y	DE	NL	FR	BE	IT	ES	30Y	DE	NL	FR	BE	IT	ES
DE		16	48	15	60	46	DE		12	47	32	61	49	DE		2	1	5	4	3
NL	0		13	4	17	15	NL	0		34	5	8	27	NL	0		3	3	5	1
FR	0	1		20	126	30	FR	0	0		22	119	54	FR	0	0		3	14	9
BE	0	0	0		23	20	BE	0	1	0		71	20	BE	0	0	0		1	3
IT	8	1	0	2		78	IT	1	0	0	10		49	IT	0	0	0	0		22
ES	1	0	22	0	3		ES	1	0	43	0	0		ES	0	0	1	0	0	

Note: Lower diagonal entries are auctions on the same date, upper diagonal entries are auctions within a 10-day window from each other.

Appendix B (NOT for publication): Derivations theoretical model

The equilibrium price satisfies

$$P = \mathrm{E}\left[\tilde{F}\right] - \rho\left[\begin{bmatrix} W_h\Sigma_h^{-1} & 0 \\ 0 & W_f\Sigma_f^{-1} \end{bmatrix} + W_g\Sigma^{-1}\right]^{-1} X.$$

Taking Σ out of the matrix inverse gives:

$$P = \mathrm{E}\left[\tilde{F}\right] - \rho\left[\begin{bmatrix} \Sigma_{hh} & \Sigma_{hf} \\ \Sigma_{fh} & \Sigma_{ff} \end{bmatrix}\begin{bmatrix} W_h\Sigma_{hh}^{-1} & 0 \\ 0 & W_f\Sigma_{ff}^{-1} \end{bmatrix} + W_g I\right]^{-1} \Sigma X,$$

which can be written as:

$$P = \mathrm{E}\left[\tilde{F}\right] - \rho A^{-1}\Sigma X,$$

where

$$\begin{bmatrix} \left(W_h + W_g\right) I & W_f\beta_{hf} \\ W_h\beta_{fh} & \left(W_f + W_g\right) I \end{bmatrix},$$

Where $\beta_{hf} = \Sigma_{hf}\Sigma_{ff}^{-1}$ and $\beta_{fh} = \Sigma_{fh}\Sigma_{hh}^{-1}$. Using the partioned matrix inverse formulas of Bierens (2014), we can write the elements of A^{-1} as

$$A^{11} = \left(A_{11} - A_{12}A_{22}^{-1}A_{21}\right)^{-1} = \left[\left(W_h + W_g\right)I - \frac{W_h W_f}{W_f + W_g}\beta_{hf}\beta_{fh}\right]^{-1}$$

$$A^{12} = -A^{11}A_{12}A_{22}^{-1} = -A^{11}\frac{W_f}{W_f + W_g}\beta_{hf}$$

Notice that we can also write:

$$\Sigma X = \begin{bmatrix} \Sigma_{hh} & \Sigma_{hf} \\ \Sigma_{fh} & \Sigma_{ff} \end{bmatrix}\begin{bmatrix} X_h \\ X_f \end{bmatrix} = \begin{bmatrix} \Sigma_{hh}X_h + \Sigma_{hf}X_f \\ \Sigma_{fh}X_h + \Sigma_{ff}X_f \end{bmatrix}$$

Adding it all together, Home bond prices are given by:

$$P_h = \mathrm{E}\left[\tilde{F}_h\right] - \rho A^{11}\left[\Sigma_{hh}X_h - \frac{W_f}{W_f + W_g}\beta_{hf}\Sigma_{fh}X_h + \Sigma_{hf}X_f - \frac{W_f}{W_f + W_g}\beta_{hf}\Sigma_{ff}X_f\right].$$

Substituting the definitions of β_{hf} and β_{fh} and collecting terms we find:

$$P_h = \mathrm{E}\left[\tilde{F}_h\right] - \rho A^{11}\left[\left(\Sigma_{hh} - \frac{W_f}{W_f + W_g}\Sigma_{hf}\Sigma_{ff}^{-1}\Sigma_{fh}\right)X_h + \frac{W_g}{W_f + W_g}\Sigma_{hf}X_f\right],$$

where $\Sigma_{hf}\Sigma_{ff}^{-1}\Sigma_{fh}$ is the variance of the portfolio of Foreign bonds that best replicates the Home bonds. Going back to the definition of A^{11}, define

$$R = \beta_{hf}\beta_{fh} = \Sigma_{hf}\Sigma_{ff}^{-1}\Sigma_{fh}\Sigma_{hh}^{-1}.$$

Using this in the preceding expression we obtain equation (1). With two Home bonds, an old and a new one, the second element of the two-element vector P_h simplifies to:

$$P_{h,o} = \mathrm{E}\left[\tilde{F}_{h,o}\right] - \frac{\rho}{W_h + W_g}\left[Cov\left(\tilde{F}_{h,o}, \tilde{F}_{h,n}\right)X_{h,n} + Var\left(\tilde{F}_{h,o}\right)X_{h,o}\right].$$

Finally, with two Home bonds, one Foreign bond and no Foreign local primary dealers, i.e. $\theta_f = 0$, the second element of the two-element vector P_h simplifies to:

$$P_{h,o} = \mathrm{E}\left[\tilde{F}_{h,o}\right] - \frac{\rho}{W_h + W_g}\left[Cov\left(\tilde{F}_{h,o}, \tilde{F}_{h,n}\right)X_{h,n} + Var\left(\tilde{F}_{h,o}\right)X_{h,o} + Cov\left(\tilde{F}_{h,o}, \tilde{F}_f\right)X_f\right].$$

Appendix C (NOT for publication): Tests for symmetry in auction cycles

Table C.1: Symmetry of cycle estimates in Table 5

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \varepsilon_t^{j,m}$

Hypothesis: $(\sum_{l=4}^{0} \alpha_l) = -(\sum_{l=-1}^{-5} \alpha_l)$

Full sample

		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	3.54**	3.51	3.05*	-2.15	0.57	-1.16
10-year	*AC*	0.15	-2.11	0.69	-0.76	1.43	1.72
30-year	*AC*	-1.72	6.98**	4.46**	-2.65	2.24	3.70

Notes: See Notes to Table 5.

Table C.2: Symmetry of cycle estimates in Table 6

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{l=4}^{-5} \gamma_l \sum_{i(\neq j)} AUC_{\ t+l}^{i,m} + \varepsilon_t^{j,m}$

Hypotheses: $(\sum_{l=4}^{0} \alpha_l) = -(\sum_{l=-1}^{-5} \alpha_l)$ and $(\sum_{l=4}^{0} \gamma_l) = -(\sum_{l=-1}^{-5} \gamma_l)$

Full sample

		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	*AC*	3.45*	2.94	3.55**	-2.31	0.74	-1.23
	AC_F	0.84	0.98	0.53	1.68**	0.12	0.46
10-year	*AC*	0.21	-2.27	1.70	-0.76	0.14	2.00
	AC_F	-0.03	-0.07	-0.28	0.40	1.35	-0.95
30-year	*AC*	-0.99	5.18	3.89**	-2.38	2.58	3.65
	AC_F	2.61***	2.14***	1.48	2.30**	0.58	-0.41

Notes: See Notes to Table 5.

Table C.3: Symmetry of cycle estimates in Table 7

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{l=4}^{-5} \sum_{i(\neq j)} \gamma_{i,l} AUC_{t+l}^{i,m} + \varepsilon_t^{j,m}$

Hypotheses: $(\sum_{l=4}^{0} \gamma_{i,l}) = -(\sum_{l=-1}^{-5} \gamma_{i,l})$.

5-year maturity

$i \downarrow \quad j \rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain
AC_DE	2.33	0.67	-0.19	2.13	-0.03	0.31
AC_NL	-1.12	3.21	1.86	3.20	-1.46	-0.90
AC_FR	1.29	2.02	3.14*	2.87	6.03**	8.34***
AC_BE	-2.13	-3.07	-3.64	-2.40	-5.51	-8.09*
AC_IT	2.22	2.63*	2.17	2.31	1.67	-2.34
AC_ES	0.56	-0.25	0.69	-0.87	-2.73	-0.05

10-year maturity

$i \downarrow \quad j \rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain
AC_DE	2.43*	1.78	1.52	0.96	1.65	2.25
AC_NL	-2.55	-3.06	-0.90	-1.54	2.67	1.40
AC_FR	-0.21	0.37	0.42	-0.15	-0.54	-2.48

AC_BE	-0.03	0.03	-0.67	-0.01	-1.58	-4.94
AC_IT	-0.46	-0.24	0.78	1.54	3.04	2.90
AC_ES	1.84	1.14	1.03	1.33	3.47*	1.84
30-year maturity						
$i \downarrow \quad j \rightarrow$	Germany	Netherlands	France	Belgium	Italy	Spain
AC_DE	-1.18	-0.48	-0.98	-0.69	-1.92	-4.38
AC_NL	6.24*	6.09*	4.90	3.76	-1.59	3.05
AC_FR	3.47*	3.75**	3.68*	2.06	3.75*	3.76
AC_BE	-0.71	-1.13	-1.99	-2.39	-3.38	-9.19
AC_IT	2.28	2.40	2.23	2.43	2.13	0.71
AC_ES	3.30*	3.41*	2.71	3.26	2.10	3.24

Notes: See Notes to Table 5.

Appendix D (NOT for publication): the role of the auction size

Now, we estimate

$$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l SIZE_{t+l}^{j,m} + \varepsilon_t^{j,m},$$

where *SIZE*, the size of the issue, replaces the auction dummy AUC in equation (6). Table D.1, which is structured analogously to Table 5, reports the new OLS estimates of the auction cycle. We can now interpret AC as the increase in the auction cycle, reported in basis points, in response to a one-billion euros increase in the size of the issue.

Table D.1: Estimates based on the auction size

$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l SIZE_{t+l}^{j,m} + \varepsilon_t^{j,m}$
$AC = (\sum_{l=4}^{0} \alpha_l) - (\sum_{l=-1}^{-5} \alpha_l)$

		Germany	Netherlands	France	Belgium	Italy	Spain
Full sample							
5-year	AC	0.68*	0.19	0.85**	6.43**	2.58***	-0.75
10-year	AC	0.62***	-0.06	0.22	2.58*	1.95***	2.57**
30-year	AC	0.61	2.42	2.90***	12.35*	3.99***	5.46**
Pre-crisis period							
		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	AC	-0.11	2.35	1.14**	3.37	0.75	-0.83
10-year	AC	0.74***	0.69	0.76*	-2.15	0.21	1.19
30-year	AC	0.25	2.30	2.11**	-1.96	3.24***	2.31
Post-crisis period							
		Germany	Netherlands	France	Belgium	Italy	Spain
5-year	AC	1.63***	-0.26	0.64	8.80**	3.85***	-0.72
10-year	AC	0.42	-1.07	-0.22	6.63***	3.21***	3.16*
30-year	AC	1.47	2.57	4.18*	23.19**	5.81***	7.12*

Notes: See Notes to Table 5.

Appendix E (NOT for publication): Excluding auctions associated with extreme cycles

Here we describe the details of the robustness analysis in Subsection 5.4 in which we exclude individual auctions that are associated with extremely large (in absolute terms) domestic secondary market movements around auction date.

Figure E.1 depicts the domestic cycle in secondary market yields associated with each individual auction, as well as the frequency distribution of these cycles. Specifically, we calculate each individual cycle as $(y_{i0} - y_{i,-5}) - (y_{i,5} - y_{i,0})$. Here, y_{it} is the end-of-day t secondary market yield on a bond of given maturity, where t=0 refers to the day of the individual auction by country i. The bond is either the bond that is issued or the preceding series of the bond of the same maturity. Hence, we subtract the secondary yield movement over the five days after the end of the auction day from the yield movement in the five days prior to that.

The distribution generally exhibits a positive mean, but its support differs across countries and maturities. In addition, we observe larger auction cycles in the period after the onset of the crisis in 2007. Inspection of Figure E.1 shows that in some instances the auction cycle is exceptionally large compared to the other cycles generated by the same country and maturity combination, which suggests the presence of unusual circumstances associated with those auctions, the effects of which might be difficult to capture with our theoretical model.

We identify the exceptional cases simply through visual inspection and observe that there are ten such cases. While this is not a very formal procedure, it is obvious from Figure E.1 that these cases are extreme when compared with the other domestic cycles. The extreme cycles are associated with the French 5 and 10-year auctions on December 1, 2011 (cycle sizes -110 and -87 basis points, respectively), the Belgium 5-year auctions on January 26, 2009, on June 7, 2010, and on June 24, 2013 (respective sizes 85, 80 and 85), the Belgium 10- and 30-year auctions on November 28, 2011 (respective sizes 200 and 168), the Italian 10-year auction on November 29, 2011 (size 178), the Spanish 5-year auction on May 6, 2010 (size 157) and, finally, the Spanish 10-year auction on June 7, 2012 (size -130).

In some instances we can identify the likely event that has led to the extraordinary cycle size, while in other cases we cannot. In the case of the 1 December 2011 French auctions, demand was large relative to supply and yields fell after the auctions. The 28 November 2011 Belgium auctions followed an S&P downgrade that had taken place shortly before that. The 29 November 2011 Italian auction suffered from tepid demand, and the 6 May 2010 Spanish auction followed shortly after the Greek crisis erupted and an S&P cut of Spanish debt.

If we think of our theoretical framework as being applicable in "normal" circumstances and not in situations of extreme events that are outside the model, then it would be reasonable to allow for the possibility that the spill-overs in the case of those extreme events differ from the spill-overs under normal circumstances. Hence, in Table E.1 we report the estimates of a generalized version of equation (7) in which we purge from our regular sample the auctions associated with the ten outliers identified above and allow for a separate auction cycle associated with each of these individual outliers. Hence, for each of our outliers we estimate:

$$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{l=4}^{-5} \gamma_l \sum_{i(\neq j)} AUC_{\ t+l}^{\ i,m} + \ \sum_{l=4}^{-5} \delta_l AUC\_O_{t+l}^{i,m} \ + \ \varepsilon_t^{j,m}$$

where $AUC\_O_{t+l}^{i,m}$ is the dummy associated with the specific outlier under consideration, which is one for country *i* and the date when the auction associated with the outlier occurs, and zero otherwise. The estimates in Table E.1. report the domestic auction cycle, the auction cycle associated with all foreign auctions with the ten outliers excluded and the auction cycle associated with the particular outlier under consideration.[14] In each instance we confine ourselves to the maturity of the outlier auction. Reassuringly, the estimates of the foreign auction cycles associated with the "regular" auctions tend to be close to the corresponding estimates in Table 6. We observe that the outlier auctions are always associated with strong and highly significant cross-border spill-overs of an order of magnitude that is usually the same as that of the domestic cycle that they cause (recall Figure E.1). Generally speaking,

[14] We were not able to include all exceptional auctions simultaneously as some of them took place at the same time or close in time, implying that it would not be possible to identify the effects of each auction separately.

the outliers, which were selected on the basis of the magnitude of the domestic cycle, indeed seem to be exceptional in terms of their spill-over effects, which are way larger than the spill-over effects associated with "normal" auctions. It should be noted, though, that these large spill-overs are not necessarily the result of the auctions themselves, but they may also be caused by large, euro-area wide events that simply coincide with the specific moments of the auctions.

Table E.1: Regressions controlling for the 10 identified outliers

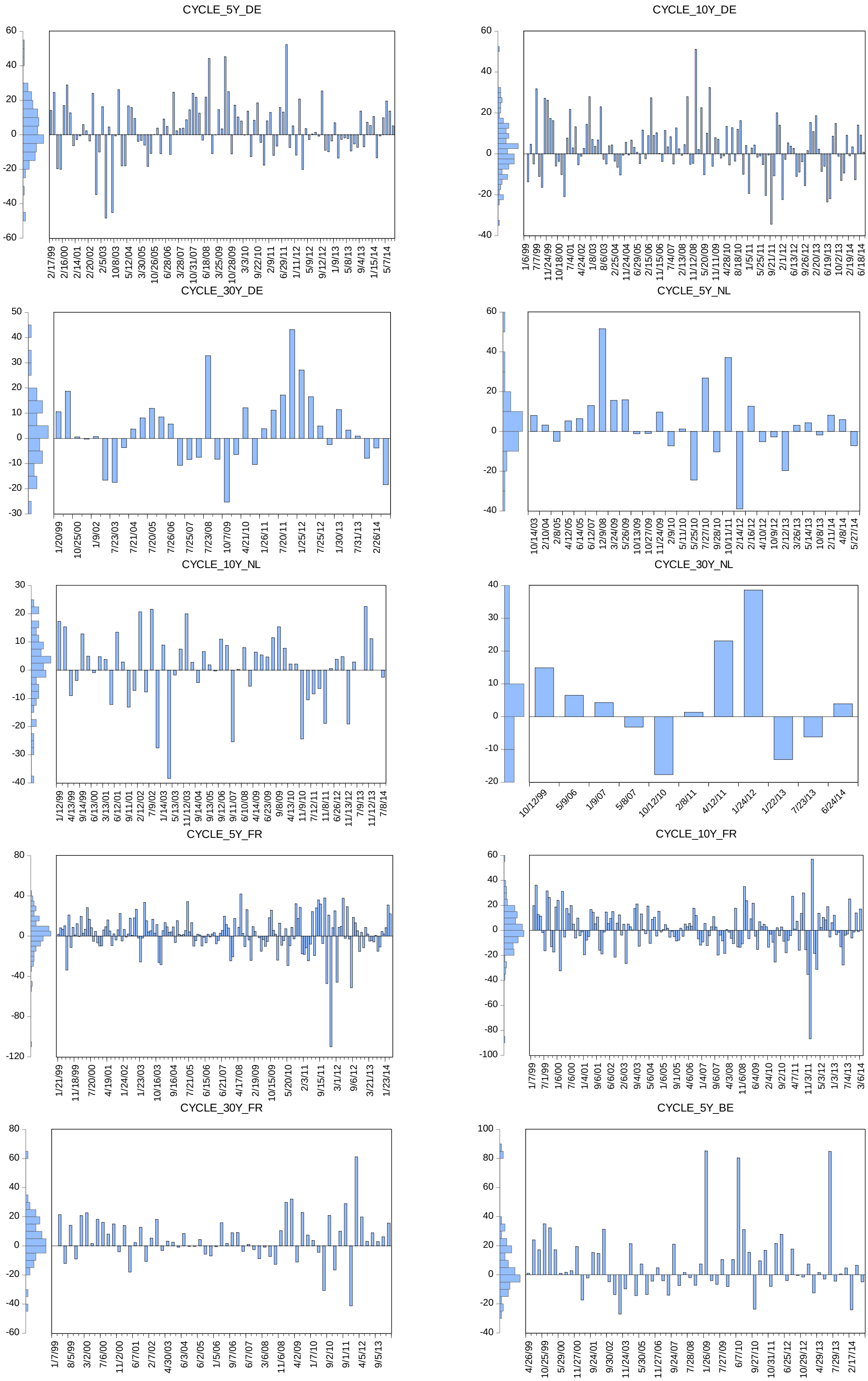
$\Delta y_t^{j,m} = c_0^{j,m} + \sum_{l=4}^{-5} \alpha_l AUC_{t+l}^{j,m} + \sum_{l=4}^{-5} \gamma_l \sum_{i(\neq j)} AUC_{t+l}^{i,m} + \sum_{l=4}^{-5} \delta_l AUC\_O_{t+l}^{i,m} + \varepsilon_t^{j,m}$

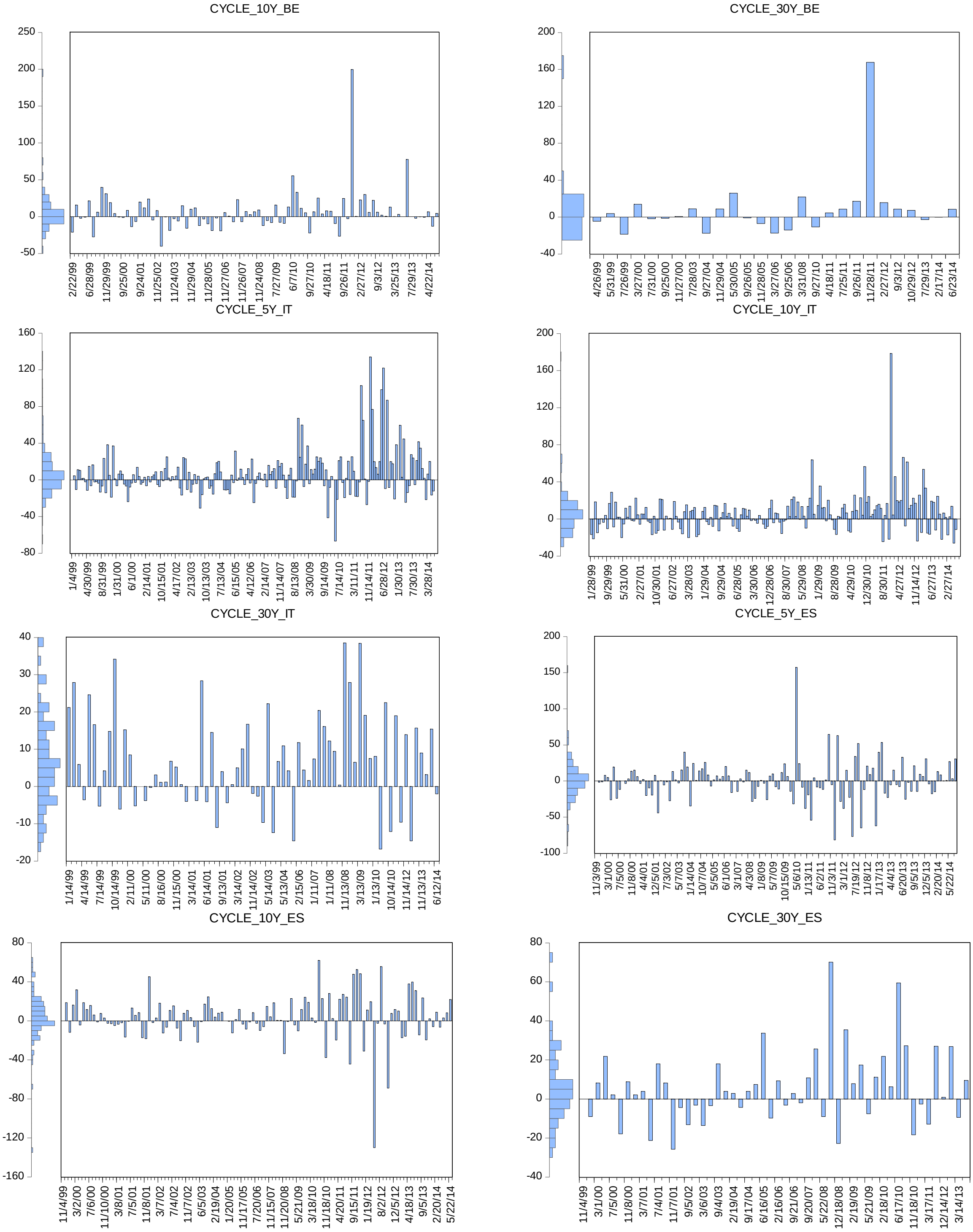
$AC = (\sum_{l=4}^{0} \alpha_l) - (\sum_{l=-1}^{-5} \alpha_l)$, $AC\_F = (\sum_{l=4}^{0} \gamma_l) - (\sum_{l=-1}^{-5} \gamma_l)$ and $AC\_OUTL = (\sum_{l=4}^{0} \delta_l) - (\sum_{l=-1}^{-5} \delta_l)$

	Germany	Netherlands	France	Belgium	Italy	Spain	Average
Outlier 1: France, 5-year, December 1, 2011							
AC	3.14**	3.15	2.97**	3.16	6.64***	-1.19	
AC_F	1.84***	1.32**	1.54**	1.23*	-0.27	1.46	
AC_OUTL	-2.28*	-33.48***	-109.05***	-148.76***	-48.66***	-103.54***	-74.30
Outlier 2: France, 10-year, December 1, 2011							
AC	2.84**	0.61	1.75	3.91**	5.82***	4.79**	
AC_F	0.81	1.35**	2.14***	1.51**	2.18***	2.01*	
AC_OUTL	14.95***	-11.74***	-86.43***	-89.89***	-26.28***	-95.44***	-49.14
Outlier 3: Belgium, 5-year, January 26, 2009							
AC	3.05**	3.15	2.92**	3.10	6.97***	-1.15	
AC_F	1.86***	1.29**	1.54**	1.14	-0.71	1.21	
AC_OUTL	31.92***	71.25***	45.40***	84.81***	78.55***	59.62***	61.93
Outlier 4: Belgium, 5-year, June 7, 2010							
AC	3.05**	3.20	2.88**	3.15	7.15***	-1.20	
AC_F	1.83***	1.32**	1.57**	1.27*	-0.67	1.31	
AC_OUTL	-15.52***	19.24***	11.75***	81.03***	68.08***	49.86***	35.74
Outlier 5: Belgium, 5-year, June 24, 2013							
AC	3.10**	3.15	2.88**	3.06	6.93***	-1.38	
AC_F	1.78***	1.32**	1.50**	1.16	-0.78	1.22	
AC_OUTL	45.08***	35.91***	73.18***	85.35***	100.31***	89.70***	71.59
Outlier 6: Belgium, 10-year, November 28, 2011							
AC	2.72**	0.60	1.80	3.83**	5.76***	4.88**	
AC_F	0.87	1.37***	2.17***	1.60***	2.22***	1.99*	
AC_OUTL	47.44***	28.33***	61.37***	199.31***	184.61***	147.86***	111.49
Outlier 7: Belgium, 30-year, November 28, 2011							
AC	2.94	5.07	6.80***	1.54	6.99***	5.81***	
AC_F	4.21***	3.85***	3.51***	4.10***	2.27**	3.46**	
AC_OUTL	49.62***	47.72***	37.86***	169.88***	60.79***	86.25***	75.35
Outlier 8: Italy, 10-year, November 29, 2011							
AC	2.71**	0.60	1.77	3.84**	5.76***	4.83**	
AC_F	0.87	1.37***	2.17***	1.60***	2.24***	2.00*	
AC_OUTL	55.46***	29.89***	27.68***	127.62***	177.97***	99.07***	86.28
Outlier 9: Spain, 5-year, May 6, 2010							
AC	3.07**	3.29	2.93**	3.15	7.34***	-1.14	
AC_F	1.82***	1.28**	1.54**	1.17	-0.68	1.48	
AC_OUTL	-43.03***	-37.26***	-41.90***	-5.28***	101.48***	159.55***	22.26
Outlier 10: Spain, 10-year, June 7, 2012							
AC	2.67**	0.62	1.64	3.97**	5.82***	4.78**	
AC_F	0.80	1.31**	2.16***	1.59***	2.16***	2.30**	
AC_OUTL	5.91***	4.29***	8.86***	-12.79***	-62.51***	-132.33***	-31.43

Notes: The column "average" shows for each outlier the average size of the auction cycle over the country sample. Further, see Notes to Table 5.

Figure E.1: Domestic auction cycle associated with each individual auction





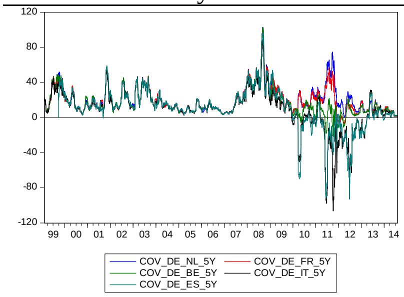
Notes: The figure reports the individual auction cycles $(y_{i,0} - y_{i,-5}) - (y_{i,5} - y_{i,0})$ and the frequency distribution of the individual auction cycles, in basis points. Here, y_{it} is the end-of-day t secondary market yield on a bond of given maturity, where t=0 refers to the auction day. The bond is either the bond that is issued or the preceding series of the bond of the same maturity.

Appendix F (NOT for publication): Rolling co-variances

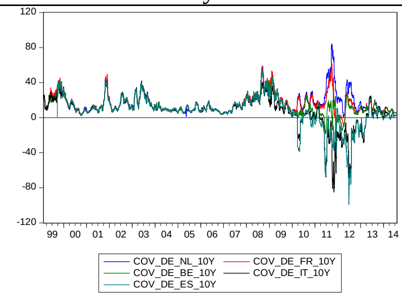
Figure F.1: Rolling covariance based on a 30-day window, shifted in steps of 1 day

Germany

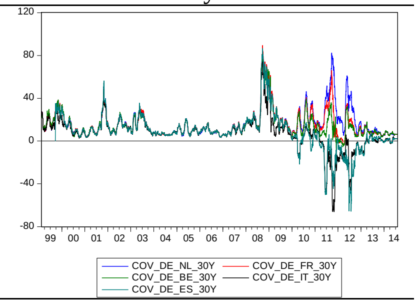
5-year



10-year

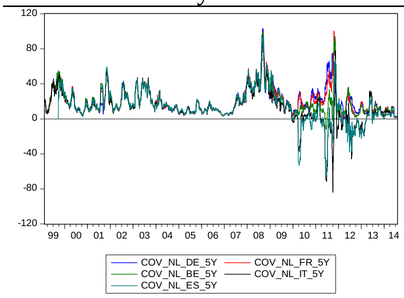


30-year

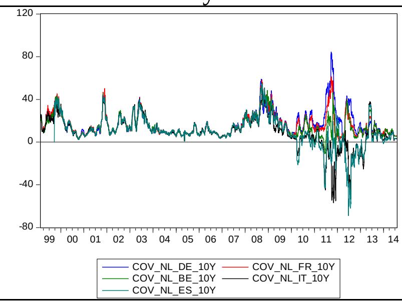


The Netherlands

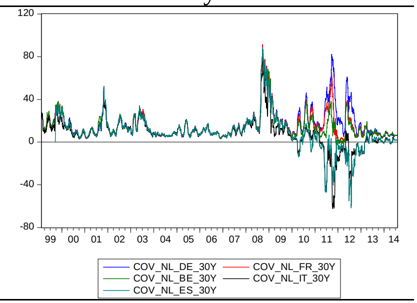
5-year



10-year

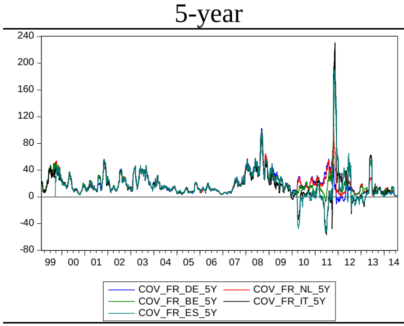


30-year

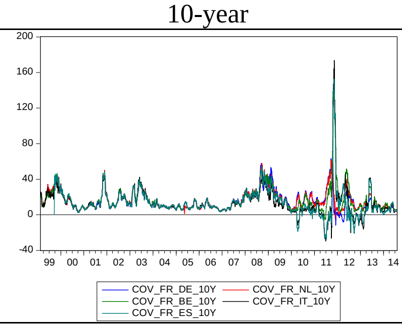


France

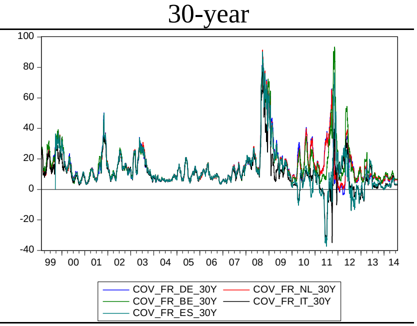
5-year



10-year

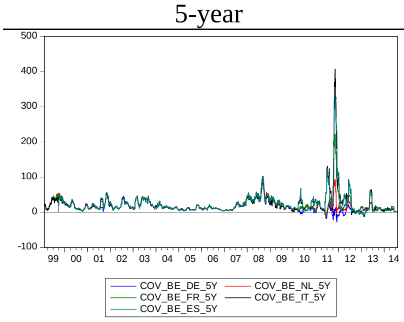


30-year

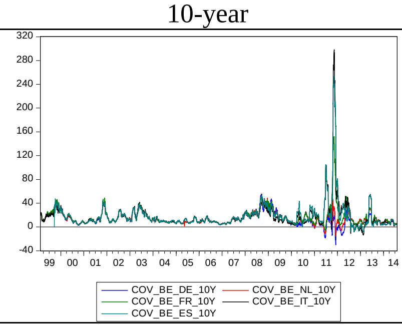


Belgium

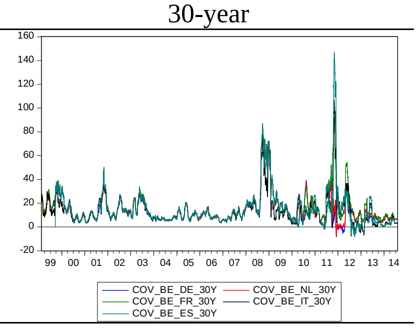
5-year



10-year

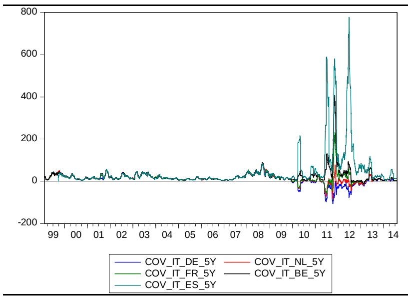


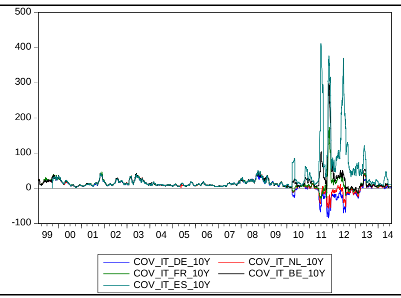
30-year

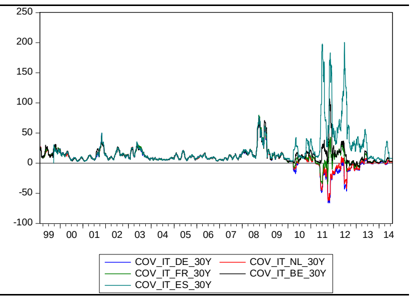


Italy

5-year | 10-year | 30-year







Spain

5-year	10-year	30-year