I. A retrospective look at sovereign bond dynamics in the euro area

This section looks back at sovereign bond dynamics in the euro area over the past two decades, taking stock of both the price and flow dimensions. As regards cross-border flows, the 2008 crisis appears to have provoked, amongst its more immediate effects, investment fund outflows from EU bond markets. The years of the subsequent Great Recession witnessed a mutual retrenchment in the US and the EU from each other's international debt markets. At the same time, debt flow dynamics within the euro area largely reversed when compared with the pre-crisis period, with the countries more severely affected by the crisis experiencing outflows, as less vulnerable countries pulled back their cross-border debt investments. As regards bond prices, the crisis period was characterised by highly asymmetric dynamics across groups of euro area countries which – according to model-based results – appear to have been largely driven by differences in debt ratios, bouts of illiquidity and divergent market sensitivities, the latter being suggestive of flight-to-safety phenomena, among other factors. Panel model-based evidence is also suggestive of instances of price misalignment from fundamentals, in different moments and countries. Unconventional monetary policy is seen to have played an important role in stabilising sovereign debt markets since 2012. Overall, an institutional setup that can eliminate bouts of illiquidity, prevent market sensitivities from reacting in a divergent manner to yield drivers and remove redenomination risk could deliver significant stability benefits for the euro area. ([1])

I.1. Introduction

Sovereign bond markets are now completing two decades of existence under the single currency in several Member States. Throughout this period they have experienced distinct phases, from a period of quietude and synchronous dynamics before the global financial crisis, through years of turbulence and marked cross-country divergences, to a period of imperfect re-convergence in a context of resuming growth, an improved institutional framework and unconventional monetary policy.

Sovereign bond prices are generally expected to reflect the risk-free rate and a credit risk premium which is specific to the sovereign issuer. However, as discussed in the following subsections, a large body of economic literature has found that, besides these fundamental drivers, sovereign bond prices also reflect other factors, namely those related to bond market structure, liquidity and investor sentiment. Given the close linkages between euro area countries, such factors can have a significant euro area dimension.

A monetary union implies some particularities as to the role of sovereign funding costs. On one hand, the cost of funding complements fiscal rules and contributes to exert market pressure on Member States to enact responsible fiscal policies. On the other hand, excessive divergences and volatility in sovereign funding costs may hamper the transmission of monetary policy. In particular, sovereign funding costs affect bank funding costs and, in turn, lending rates to households and non-financial corporations. ([2]) This is related to three facts: (i) sovereign credit ratings usually represent the ceiling for other credit ratings in the same jurisdiction, (ii) the euro-area banking sector has a large exposure to sovereign bonds along with a significant degree of home bias and, (iii) in the euro area, bank credit represents the main source of financing of the private sector. The experience of the past two decades shows that a procyclical interest rate channel was at play both before and after the crisis, exacerbating differences in economic performance across Member States. ([3])

Graph I.1 depicts the evolution of sovereign funding costs of selected euro area countries since the introduction of the common currency. It is possible to distinguish three structurally different periods. First, by the time the common currency


([2]) In particular, firms that are more likely to benefit from government aid, those more concentrated in the domestic market, and those relying more heavily on bank financing are seen to have been affected more significantly by an increase in sovereign funding costs. See for example: Bedendo, M. and P. Colla (2015), 'Sovereign and corporate credit risk: Evidence from the Eurozone', *Journal of Corporate Finance*, Vol. 33, pp. 34-52.([3])

([3]) Ruscher, E. and B. Vašíček (2015), 'Revisiting the Real Interest Rate Mechanism', *Quarterly Report on the Euro Area,* Vol. 14, No 4, pp. 33-48.

had been introduced, exchange rate risk had been fully eliminated and sovereign bond yields had almost perfectly converged for the euro-area Member States. Such alignment lasted until 2008, when sovereign funding costs started to significantly diverge amidst the global financial crisis and the consecutive euro area debt crisis. Finally, the ECB's announcement of the Outright Monetary Transactions program in August 2012 represented a turning point in the euro area debt crisis and initiated a period of renewed, if imperfect, interest rate convergence, which was further supported by the economic recovery that started in 2013, by an on-going process of balance sheet repair in crisis-hit countries, by an improved institutional framework, as well as by the Eurosystem's Public Sector Purchase Programme, initiated in 2015.
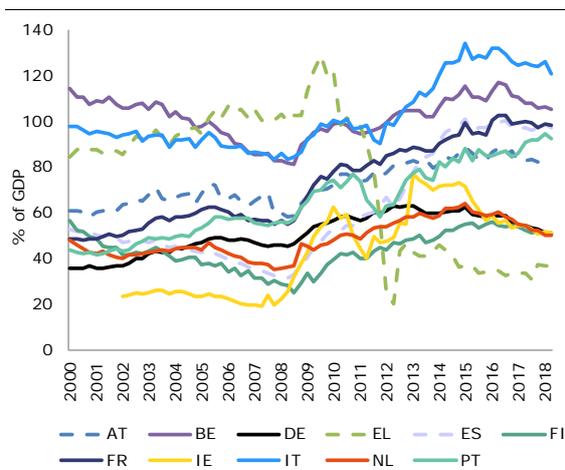
Graph I.1: **Evolution of 10-year sovereign bond yields in euro area countries**
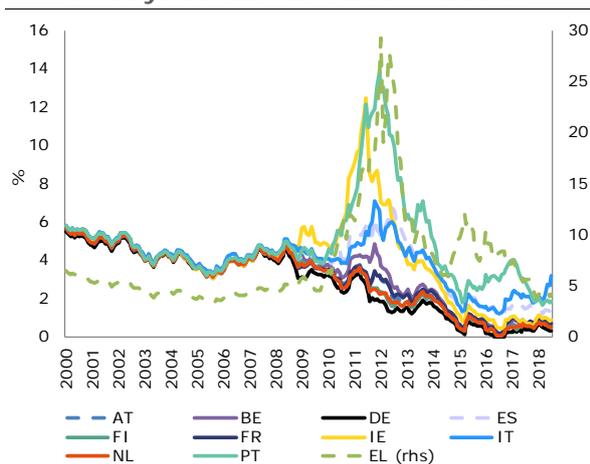
(1) Country sample comprises the 11 largest euro area economies.
Source: Eurostat

Graph I.2: **Evolution of sovereign bond volumes in euro area countries**
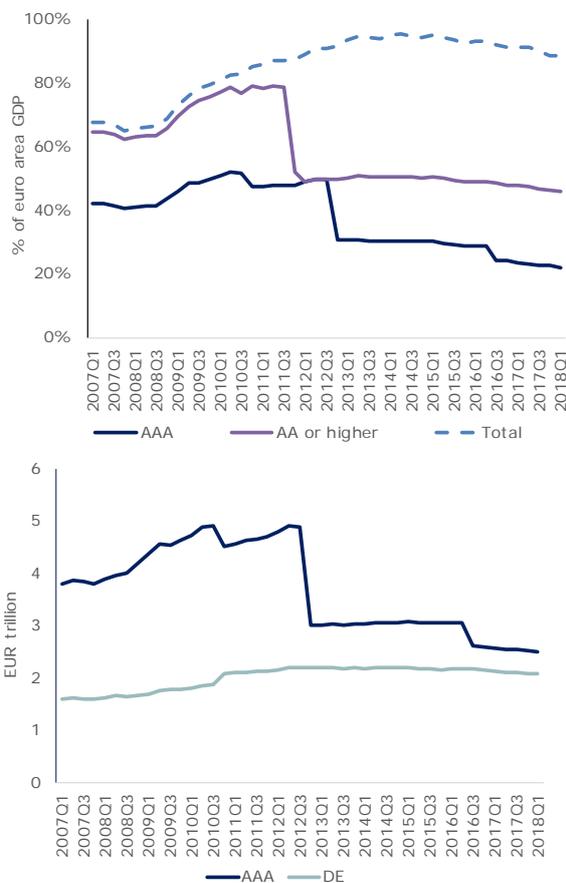

(1) Country sample comprises the 11 largest euro area economies.
Source: Eurostat

Graph I.2 reports the evolution of outstanding amount of sovereign bonds in selected euro area countries. Since the global financial crisis and until 2016, a general increase in outstanding bond amounts can be observed as government debt was on an increasing path until then. Greece represents an exception due to its debt restructuring and re-composition of liabilities towards loans under a financial assistance programme. While overall volumes increased, credit quality has decreased, with the amount of sovereign debt rated AAA and AA declining markedly (Graph I.3).

Graph I.3: **Outstanding sovereign debt in the euro area, per credit rating**

Source: Moody's, Eurostat, own calculations

sovereign bond dynamics. In equilibrium, capital flows must reflect the confluence of push (supply-side) factors and pull (demand-side) factors so that it will be hard to attribute the observed flows exclusively to one side or the other. (⁴) The literature on cross-border flows has mainly focused on emerging markets, where it is generally more meaningful to consider the determinants of inflows that are abnormally large, referred to as 'surges'. (⁵)

Cross-border debt data for the euro area shows that the crisis period witnessed a reversal from positive net debt inflows (⁶) to net debt outflows vis-à-vis the rest of the euro area in some of the debtor countries more severely affected by the crisis. These dynamics had their counterpart in creditor countries, where debt outflows are seen to have reversed into inflows from the rest of the euro area, or at least to move into balanced dynamics, with the onset of the crisis (see Graph I.4). (⁷)

This Section aims to provide a retrospective look at sovereign bond dynamics in the euro area countries since the introduction of the euro. It is structured as follows. Subsection I.2 first reviews the evolution of cross-border debt flows in the euro area. Subsection I.3 reviews the literature on the determinants of bond yields, as well as the euro area dimension of sovereign bond price dynamics. Moreover, it provides empirical evidence on these determinants based both on a standard panel regression as well as on a time-varying parameter model. The latter allows tracking both the impact of changes in each yield determinant, as well as changes in market sensitivities to these determinants, across Member States and across time. Subsection I.4 concludes and provides some tentative policy implications.

I.2. The evolution of euro area cross-border debt flows

Cross-border flows represent an alternative dimension to prices when analysing euro area

(⁴) The determinants of financial flows can be broadly classified into three categories of variables: 1. global or push factors (e.g., foreign growth, global interest rates, global liquidity, global risk, commodity prices and policy uncertainty), 2. domestic or pull (e.g., industrial production, domestic interest rates, inflation, equity returns, exchange rate dynamics and regime, trade openness, credit growth, stock market capitalisation and financial openness) and 3. contagion (i.e., mostly factors outside of country control such as geographical proximity, trade and financial linkages). See for example: Calderón, C., and M. Kubota (2013), 'Sudden stops: Are global and local investors alike?', *Journal of International Economics*, Vol. 89, No 1, pp. 122-142.
(⁵) Ghosh, A., M. Qureshi, J. Kim and J. Zalduendo (2014), 'Surges', *Journal of International* Economics, No 92, pp. 266–285.
(⁶) The financial flow data refers to overall bilateral debt flows between countries, irrespective of the institutional sector originating or receiving the flows. It includes portfolio investment and other investment (e.g., loans), but excludes official debt flows such as financial assistance and asset purchase programmes.
(⁷) Also, Bijlsma, M. and R. Vermeulen, R. (2016), 'Insurance companies' trading behaviour during the European sovereign debt crisis: Flight home or flight to quality?', *Journal of Financial Stability*, Vol. 27, pp. 137-154 analyse whether Dutch insurers exhibit a flight to home or a flight to quality behaviour during the recent financial crisis using a detailed micro dataset. They find that these insurance companies engaged in procyclical investment behaviour during the height of the European debt crisis, selling periphery assets and investing into core assets, but not specifically of the Netherlands.

Graph I.4: **Net debt inflows vis-à-vis RoEA in creditor and debtor countries**
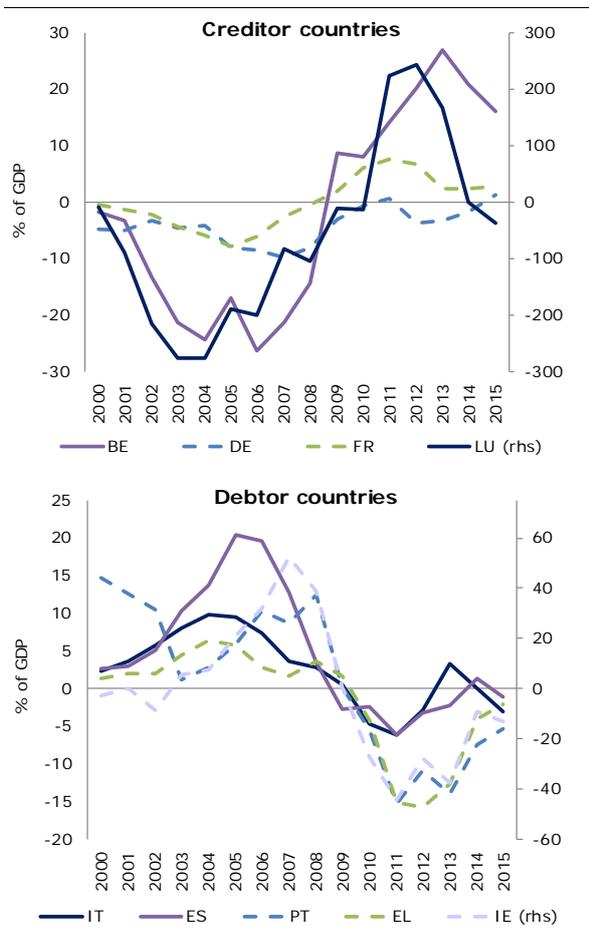
(1) The net debt inflows are the difference between debt inflows (+) and outflows (-) vis-à-vis RoEA (% of the GDP, 3 year centred moving average). France was included among the set of creditor countries notwithstanding its modestly negative NIIP due to the similarity in net debt flow dynamics when compared with other countries in this group.
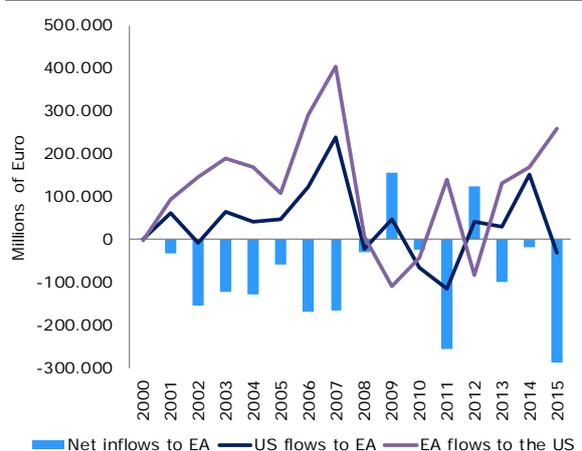*Source:* Based on an update of the database described in Hobza, A. and S. Zeugner (2014). 'Current accounts and financial flows in the euro area', Journal of International Money and Finance, Vol. 48, pp. 291-313; authors' calculations.

An analysis of bilateral flows reveals consistently positive net debt inflows from the euro area to the US in the pre-crisis period, possibly reflecting the dollar's pre-eminence as a reserve currency. A general retrenchment of cross-border movements in both economies can be observed with the onset of the 2008 financial crisis (Graph I.6). The emergence of the sovereign debt crises in the euro area appears to have coincided with a surge in outflows in 2011. Focusing specifically on the bond flows of global investment funds (⁸) there is some

evidence of flight-to-safety dynamics during the financial crisis years of 2007 to 2009 (Graph I.6). (⁹) In particular, outflows linked to bond instruments were noticeably less pronounced in "core" EU economies when compared with more "peripheral" economies. In fact, while the four largest euro area sovereign bond markets are depicted in Graph I.6 for illustration purposes, similar dynamics are seen to broadly apply to other "core" and "periphery" countries. At the same time, the US appears comparatively insulated from bond outflows driven by investment funds, suggesting that is was perceived as the main "safe haven", despite the fact that the financial crisis originated in its financial and housing markets. It is worth noting that in the post-financial crisis years, bond flow dynamics of investment funds are broadly convergent across US, "core" and "periphery" countries.

Graph I.5: **Debt flows between the US and the euro area**

Source: Based on an update of the database described in Hobza and Zeugner (2014), op. cit.; authors' calculations.

(⁸) There is no single dataset that covers all the types of cross-border flows on a bilateral basis at infra-annual frequency. Empirical studies mostly look at one specific type of financial flow. Some

studies cover international investment fund flows as these are among the most volatile capital flows (Eichengreen, B., P. Gupta and O. Masetti (2017), 'Are Capital Flows Fickle? Increasingly? And Does the Answer Still Depend on Type?', *World Bank Policy Research Working Paper*, No. 7972; Fratzscher, M. (2012), 'Capital flows, push versus pull factors and the global financial crisis', *Journal of International Economics*, Vol. 88 (2), pp. 341–356; Li, S., J. de Haan and B. Scholtens (2018), 'Surges of international fund flows', *Journal of International Money and Finance*, Vol. 82, pp. 97-119) or cross-border banking flows (Choi, S. and D. Furceri (2018), 'Uncertainty and Cross-Border Banking Flows', *IMF Working Papers*, No 18/4).

(⁹) The data is based on the EPFR Global Database, which tracks the flows and allocations of global investment funds.

Graph I.6: **Net investment flows into bonds by global investment funds, per country of issuance**
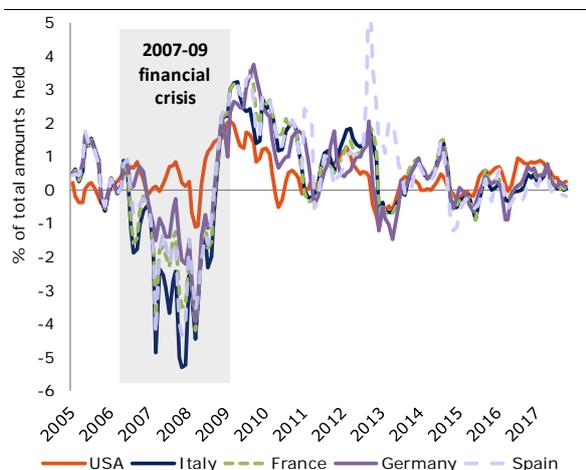
(1) The net flows represent the difference between inflows (+) and outflows (-); based on the flows and amounts held by bond funds; 3-month centred moving averages
Source: EPFR, authors' calculations

I.3. A lookback at the evolution of bond prices in euro area countries

The following subsections review the literature on the determinants of sovereign bond yields, consider some of the specificities implied by a currency union and present an empirical assessment of the drivers of yields in euro area countries based on constant-parameter and time-varying parameter models.

I.3.1. The determinants of bond yields

This subsection reviews the determinants of sovereign bond yields, as presented in the literature, and lays the ground for their joint empirical assessment in Subsection I.3.2. As mentioned in the introductory subsection, in the absence of exchange rate risk, sovereign bond yields in the euro area are expected to primarily reflect the **risk-free yield curve** plus a premium for **credit risk.** The risk-free yield curve is itself driven by short-term rates and longer term expectations for the risk-free rate at different maturities, which are linked to inflation expectations. Credit risk is usually related to fundamental macroeconomic variables such as current and expected debt-to-GDP ratios and potential growth. The pre-crisis evidence for the euro area countries confirmed the role of both of these factors but also of **liquidity risks** that are related to the size and depth of bond markets (as proxied, e.g., by bid-ask spreads and the volume of

transactions) and **international risk factors.** [10] While liquidity will be further discussed in Subsection I.3.3, the dynamics of global risk factors can be observed in Graph I.7 which plots two risk measures for the US (the corporate bond spread and the VIX index of implied stock market volatility) and one for the euro area (VTSOXX, the euro area counterpart of the VIX index). Two periods of heightened volatility are discernible across all the measures, one during the recession of the early 2000s, and the second around the 2008 Global Financial Crisis.

The role of country fundamentals in the **pricing of sovereign bonds during the crisis** remains a contentious issue. The tumultuous yield developments observed after 2008 and depicted in Graph I.1 have been both interpreted as an overreaction that largely ignored Member States' fundamentals and as a "wake up call" after a long pre-crisis period of oversight of fundamentals by investors. However, there is a broad agreement on a greater sensitivity of government bond yields to fundamentals in euro area "peripheral" countries during the debt crisis of 2010-2012, and on sovereign risk premium being reinforced by the riskiness of domestic banks, [11] by existing external imbalances [12] and by international risk and liquidity factors. [13] Furthermore, it has been found that part of the risk premia on some sovereigns was a reflection of **redenomination risk**, i.e., the risk that one or more countries would leave the European Monetary Union and reintroduce their own national currencies, which would likely depreciate subsequently. [14]

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[10] See, for example: Manganelli, S. and G. Wolswijk (2009), 'What drives spreads in the euro-area government bond market?', *Economic Policy*, Vol. 24 (58), pp. 191-240; Favero, C., M. Pagano and E.-L. von Thadden (2010), 'How does liquidity affect government bond yields?', *Journal of Financial and Quantitative Analysis*, Vol. 45(1), pp. 107-134.

[11] See for example: Afonso, A., M. Arghyrou and A. Kontonikas (2014), 'Pricing sovereign bond risk in the European Monetary Union area: an empirical investigation', *International Journal of Finance & Economics*, Vol. 19(1), pp. 49-56; Bruneau, C., A. Delatte and J. Fouquau (2014), 'Was the European sovereign crisis self-fulfilling? Empirical evidence about the drivers of market sentiment', *Journal of Macroeconomics*, Vol. 42, pp. 38-51; Delatte, A., L. Fouquau and R. Portes (2017), 'Regime-dependent sovereign risk pricing during the euro crisis', *Review of Finance*, Vol. 21(1), pp. 363-385.

[12] Salem, M. and B. Castelletti-Font (2016), 'Which combination of fiscal and external imbalances to determine the long-run dynamics of sovereign bond yields?', *Banque de France, Working Paper*, No. 606.

[13] Afonso, op. cit.

[14] See for example: De Santis, R. (2015), 'A measure of redenomination risk', *ECB Working Paper,* No 1785; Klose, J. and
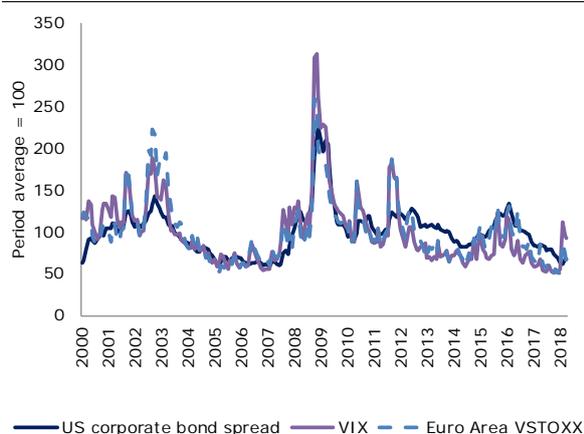
(1) The corporate bond spread refers to the difference between the bond yields of Baa-rated US companies and 10-year US treasuries.
Source: FRED, DataInsight, STOXX and authors' calculations

The widely discussed **loop between sovereigns and domestic banks** is also understood to have been reflected in a two-sided link between sovereign and bank funding costs at country level. [15] This loop, whereby banks and their sovereigns mutually enfeeble themselves in vulnerable countries in periods of distress, became evident in some Member States in the crisis period when bank losses led to government-sponsored recapitalisations, thereby increasing government debt and putting downward pressure on bond prices. Given banks' bias towards holding domestic sovereign bonds, this contributed to weakening their balance sheets, thereby re-starting the loop. The loop is understood to have also originated in some cases on the side of the sovereign, as when macroeconomic shocks led to increases in government debt and country risk, which transmitted to domestic banks. [16]

There is also evidence that sovereign bond dynamics have at times been affected by **discrete events and news**. The credit rating actions represent the most prominent type of event and studies show that government bond yields respond significantly to changes in ratings and outlook, especially in the case of negative announcements. Conversely, spread dynamics are seen to have a feedback effect on sovereign rating decisions. These may affect also corporate ratings and hence have a broader impact on the economy. In addition, effects appear to be persistent, as recently-downgraded countries face higher spreads than countries with similar ratings that were not recently downgraded. [17] It is also documented that sovereign bond yields were affected by other, usually negative, news, especially during the euro area crisis period. [18]

Finally, the sovereign bond market is closely linked to the **sovereign credit default swap (CDS) market** which allows sovereign bond holders to insure themselves against a credit event. The use of sovereign CDS has increased dramatically during the last 15 years. [19] CDS spreads are sometimes deemed to be more direct measures of credit risk than sovereign bond yields, since they are not distorted by market liquidity. [20] Sizable deviations between CDS premia and the yield spread of the underlying bonds have been observed during the crisis, which has triggered a discussion on the direction of price discovery between the derivatives

B. Weigert (2014), 'Sovereign yield spreads during the euro crisis: fundamental factors versus redenomination risk', *International Finance*, Vol. 17(1), 25-50. For a recent assessment of redenomination risk in a large euro area Member State, see Gros, D. (2018), 'Italian risk spreads: Fiscal versus redenomination risk', VoxEU.org, 29 August.

[15] See for example: Acharya, V., I. Drechsler and P. Schnabl (2014), 'A pyrrhic victory? Bank bailouts and sovereign credit risk', *The Journal of Finance*, Vol. 69(6), pp. 2689-2739; Alter, A. and Y. Schüler (2012), 'Credit spread interdependencies of European states and banks during the financial crisis', *Journal of Banking & Finance*, Vol. 36(12), pp. 3444-3468; De Bruyckere, V., M. Gerhardt, G. Schepens and R. Vander Vennet (2013), 'Bank/sovereign risk spillovers in the European debt crisis', *Journal of Banking & Finance*, Vol. 37(12), No. 4793-4809.

[16] A form of the sovereign-bank loop can also emerge in the absence of government recapitalisations or of banks' bias towards

holding domestic bonds, when a shock leads to reduced bank lending, thereby negatively impacting the economy, government revenues and bond prices. The government in its turn may see its debt increase, or embark on fiscal consolidation. As a result, economic activity as well as banks' balance sheets and lending capacity may be weakened.

[17] See, for example, Afonso, A., D. Furceri, and P. Gomes (2012), 'Sovereign credit ratings and financial markets linkages: Application to European data', *Journal of International Money and Finance*, Vol. 31(3), pp. 606-638; Arezki, M., B. Candelon and M. Sy (2011), 'Sovereign rating news and financial markets spillovers: Evidence from the European debt crisis', *IMF Working Papers*, No. 11/68; De Santis, R. (2012), 'The Euro area sovereign debt crisis: safe haven, credit rating agencies and the spread of the fever from Greece, Ireland and Portugal', *ECB Working Paper Series*, No. 1419.

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

[19] Sovereign CDS represent key instruments for transferring credit risk related to sovereign exposures. However, since the onset of the U.S. subprime crisis the sovereign CDS has become subject to controversies as their usage was blamed for exacerbating the credit crunch by allowing excessive leverage and risk-taking by financial institutions and even market manipulation.

[20] Longstaff, F. (2004), 'The flight to liquidity premium in US Treasury bond prices', *Journal of Business* No 77, pp. 511-526.

Graph I.8: **Decomposition of the evolution of average sovereign 10-year bond yields in the euro area based on a fixed effects panel model**
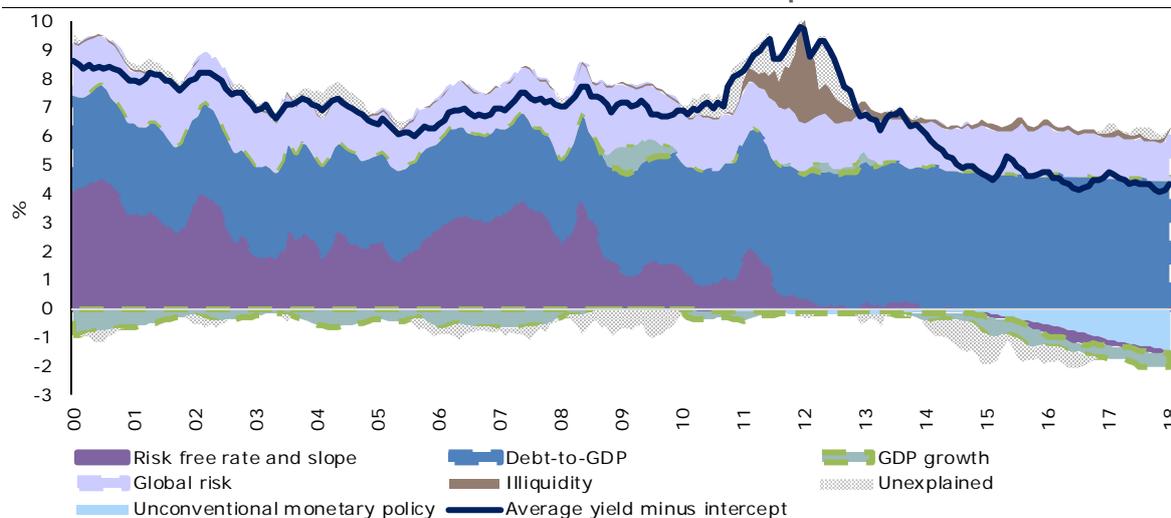
(1) Based on the simple average for AT, BE, DE, EL, ES, FI, FR, IE, IT, NL and PT. For readability, the constant (negative) contribution of the average intercept was subtracted from the average yield.
Source: Authors' estimations

market and the underlying cash market. [21] CDS markets often behaved as a further shock transmitter, a phenomenon which has been linked, in particular, to uncovered ("naked") CDS positions, where the protection buyer does not hold the reference sovereign bond. [22]

I.3.2. Evidence from a fixed effects panel model

In order to assess the effects of different determinants on sovereign bond yields a panel regression model with fixed effects was estimated, covering the 11 largest euro area economies. [23] Beyond the country-specific fixed effects, the explanatory variables in the regression include a measure of the risk-free rate and of the risk-free yield curve slope, the debt-to-GDP ratio, year-on-year GDP growth, the VIX index as a measure of global risk, the bid-ask spread as a measure of liquidity, and the amount of securities held by the Eurosystem for monetary policy purposes, to control for the effects of the asset

purchase programmes. The details of the model specification and estimation results are provided in Box I.1. A country-level assessment using a time-varying parameter version of the model is provided in Subsection I.3.4.

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[21] Fontana, A. and M. Scheicher (2016), 'An analysis of euro area sovereign CDS and their relation with government bonds', *Journal of Banking & Finance*, Vol. 62, pp. 126-140.

[22] EU Regulation No 236/2012 effectively banned "naked" CDS.

[23] This group of countries also offers the advantage of greater data availability given that it represents the first wave of Member States having adopted the euro. The sample thus includes Austria, Belgium, Finland, France, Germany, Greece, Italy, Ireland, the Netherlands, Portugal and Spain. Luxembourg is not included due to the small size of its sovereign bond market and attendant difficulties in terms of data availability.

Box I.1: **Sovereign bond yield drivers in a fixed effects panel model**

In order to investigate the effects of different determinants on the euro area sovereign bond yields a panel regression model was estimated for a period running from February 2000 to February 2018 and comprising the 11 largest euro area economies (i.e., Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain). The model takes the following form:

$$y_{i,t} = I_i + \beta_{rf}\, rf_t + \beta_{slope}\, slope_t + \beta_{debt}\, debt_{i,t} + \beta_{GDP}\, growth_{i,t} + \beta_{risk}\, risk_t + \beta_{liq}\, liq_{i,t-1} + \beta_{APP}\, APP_t + \varepsilon_{i,t}$$

where the dependent variable, $y_{i,t}$, represents the average 10-year sovereign bond yield ([1]) for country *i* during month *t*. The explanatory variables are as follows: *I* represents a country-specific intercept, or fixed effect; *rf* represents the short-term risk-free rate as measured by the 3-month EONIA overnight indexed swap (OIS); *slope* represents the slope of the risk-free yield curve, as measured by the spread between the 3-month and the 2-year EONIA OIS; ([2]) *debt* is the debt-to-GDP ratio; *growth* is the year-on-year GDP growth; *risk* represents a global risk factor as measured by the (logged) VIX index; *liq* represents market liquidity as measured by the bid-ask spread on 10-year sovereign bonds, with a higher figure therefore representing a higher degree of market illiquidity; *APP* represents the effects of the asset purchase programmes, as measured by the value of the securities held for monetary policy purposes by the Eurosystem, in billions of euros; ([3]) finally, ε is an error term.

Overall, the model seeks to assess the role of fundamental factors such as monetary policy (expressed, e.g., in the risk-free rate and in the APP), key macroeconomic variables bearing on credit risk such as the government debt ratio and economic activity, as well as global risk factors and liquidity conditions. While some of the included variables such as the slope of the risk-free rate and the risk factor have a clear forward-looking nature, the debt and growth variables are based on contemporaneous year-on-year growth rates, cubically interpolated from quarterly data. ([4]) Given investors' forward-looking perspective, it would be theoretically correct to use expect values for *debt*, *growth* and *APP*. However, from an empirical viewpoint such approach is not without issues. For instance, if expected values are inferred from contemporaneous forecasts, these are typically updated at low frequency, may cover a relatively short horizon and may refer only to whole year (or end-of-year) figures. Due to the difficulties involved in accurately deriving expectations at a relatively high macroeconomic frequency some practitioners use contemporaneous outturns, which generally produce sensible results.

Another issue worth of consideration is the possible endogeneity of some of the explanatory variables. Given the financial market nature of sovereign bond yields, they should respond contemporaneously to all the explanatory variables. The risk-free rate and slope are forward looking and largely driven by inflation and monetary policy implications. As such, contemporaneous sovereign yields should play a limited causal role. Debt dynamics only respond slowly to changing yields and therefore can be assumed as essentially exogenous. Likewise, the expenditure components of GDP growth should be mostly driven, inter alia, by sustained, long-term expectations for interest rates and financing conditions, rather than react immediately to contemporaneous government rates. As regards risk perceptions and attitudes, a global, US-based risk factor was preferred as compared to an EU-specific one in order to mitigate issues of endogeneity. Liquidity conditions should, in their turn, be endogenous to bond yields in the sense that not only can bouts of illiquidity cause spikes in yields but also very high sovereign risk can cause market liquidity to dry up. To mitigate this issue, *liq* is included with a lag in the regression. Finally, APP comprises rules-based asset purchase programmes that were not designed to respond to particular changes in interest rates.

([1]) A 10-year maturity is often used in the literature on bold yield drivers, and is also the maturity of the Maastricht convergence criterion for long-term interest rates. 10-year bond yields are understood to reflect not only short-term policy developments but also longer term economic prospects.

([2]) The 2-year tenor is the longest for which data is available covering our whole sample period.

([3]) The value of the securities held for monetary policy purposes takes the value zero prior to July 2009. With the introduction of the public sector purchase programme in March 2015, its magnitude has become increasingly dominated by the latter.

([4]) Using industrial production growth – a narrower measure of economic activity available at monthly frequency – instead of interpolated monthly GDP growth does not materially change the results presented in this subsection.

Box (continued)

In line with the literature and with the results of a Hausman test, the model was estimated as a fixed effects model. Given a relatively small dimension for the cross section (11 countries) along a relatively long dimension for the time series (217 months) the fixed effects estimator can ideally be implemented by introducing 11 country-specific dummy variables *I* in the regression (and no common intercept). The results of the estimation are reported in Table 1. All the regression coefficients show the expected sign and are significant at a 1% significance level. The goodness-of-fit of the model is relatively high, with an R^2 of 79%.

Table 1: estimation results for a sovereign bond yield panel data model with fixed effects

β_{rf}	β_{slope}	β_{debt}	β_{growth}	β_{risk}	β_{liq}	β_{APP}
0.78	1.56	0.047	-0.17	0.54	5.14	-0.00058
(0.05)	(0.15)	(0.006)	(0.04)	(0.15)	(1.03)	(0.0001)

Note: HAC standard errors in parentheses.

The regression coefficients can be interpreted as follows. As must needs be the case, yields respond positively to changes in the short-term risk-free rate and the medium-term risk-free spread, loading more on the latter given the 10-year maturity of the sovereign bonds under consideration. A ten percentage point increase in the government debt-to-GDP ratio increases sovereign yields by 47 basis points (bps) while a 1 pp increase in the annual growth rate lowers yields by 17 bps. A 10% increase in the VIX global risk factor increases yields by approximately 5 bps. An increase in the bid-ask spread of 1 bp increases yields by 5 bps. A EUR trillion of asset purchases under the asset purchase programmes of the Eurosystem can lower yields by 58 bps.

Graph I.8 provides a decomposition of the evolution of the average euro area yield over time, based on the regression model and results detailed in Box I.1. As expected, monetary policy loosening in the wake of the crisis, as captured by the risk-free rate and slope variables, put strong downward pressure on sovereign bond yields across the euro area over the past decade. Debt ratios are also seen to have played a major contribution to the yield level. In fact, as of early 2018, relatively large government debts were the largest factor putting upward pressure on sovereign interest rates. GDP growth has played a moderate role, helping to bring down average yields by 30 to 60 bps during most of our sample period. During the 2008-09 financial crisis, however, average negative growth is reckoned to have contributed to increase average yields by up to 100 bps. Changes in a global risk factor have induced yield variations of at most 100 bps over our sample period. Market illiquidity played a negligible role up until 2010. However, it is seen as the major driver of the spike in average yields observed during the 2011-12 sovereign debt crisis. Unconventional monetary policy and the associated asset purchase programmes of the Eurosystem have contributed, as expected, to lower interest rates across the euro area since 2012.

It may also be useful to consider the periods where the unexplained component of the average yield is largest. The first such period was during the 2008-09 financial crisis, when average yields remained lower than predicted by the panel regression model. This result is consistent with some risk under-pricing in the early stages of the recession, possibly linked to favourable expectations regarding the short-term nature of the economic troubles and the supportive role of fiscal and monetary policies. Such undershooting reversed in 2010-13, when actual average yields exceeded model-predicted yields. This was a period of asymmetric bond market dynamics in the euro area, which included panic-like yield spikes in some countries. Finally, the fact that actual yields were lower than predicted by the panel model in the 2014-16 is likely due to the frontloaded market anticipation of the effects of the Eurosystem's public sector purchase programme, which began gradually in March 2015, after having been announced in 2014.

I.3.3. The euro area dimension of bond price dynamics

As already hinted at in the previous subsection, the pricing of sovereign bonds can be affected by other factors beyond sovereign credit risk per se. In the euro area some of these factors carry an important cross-country dimension given the strong economic and institutional linkages between Member States.

Cross-border spillovers and contagion

While the period before the Global Financial Crisis was characterised by strong convergence across sovereign bond prices, the subsequent period witnessed the emergence of significant divergence among Member States. Graph I.9 shows the evolution of price-based indices of both bond market and broader financial integration. In both cases, a trend towards closer integration is clear until 2006. This trend inverted after 2007, leading to a full reversion in integration in the case of the bond market. After reaching its through during the euro area debt crisis in mid-2012, bond market integration has been increasing, which was likely supported by a broad-based economic recovery, an improvement in credit ratings and the unconventional monetary policy of the ECB.

Graph I.9 also suggests that convergence and divergence dynamics in bond markets have preceded similar dynamics in the broader financial market since 1995. In fact, Granger causality tests suggest that changes in bond market integration have caused changes in overall financial integration, while the reverse is not true. [24]

Despite fragmentation at euro area level, the interdependence between bond markets of some Member States has increased since the global financial crisis. This increase in co-movements between the sovereign bond markets of some Member States has often been titled as a spillover or even contagion effect. Several studies have tried to measure such linkages and distinguish spillovers – which are usually understood as increased co-movements between sovereign bond yields – from pure contagion, which represents an intensification in the transmission of shocks from a crisis-hit country to another country that cannot be objectively explained by financial linkages between them. [25] These studies broadly agree that there were significant co-movements, especially within the euro area periphery, but also that pure contagion was largely limited to short-lived episodes before the announcement of the ECB's Outright Monetary Transactions programme in 2012.

Graph I.9: **Indices of bond market and broader financial market integration**
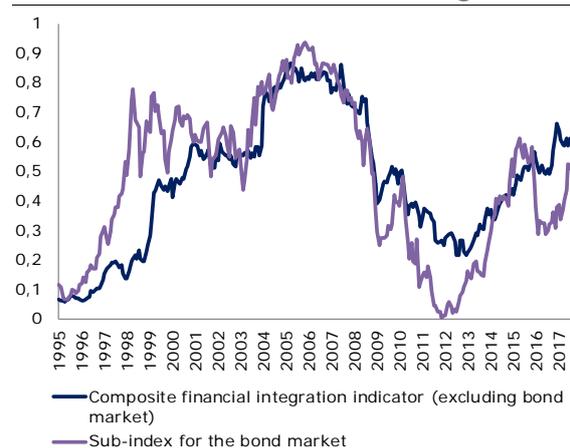
(1) The financial integration index is constructed from a selection of price-based indicators that cover the money, bond, equity and banking markets. It is defined to be bounded between 0 and 1. The indicators aggregated into the bond market sub-index are the cross-country standard deviations of two and ten-year sovereign bond yields (Greece excluded), and the cross-country standard deviation of the bond yields of uncovered corporate bonds issued by non-financial corporations.
Source: ECB and authors' calculations

Cross-border effects have also been documented for rating actions, when a rating decision affecting lower-rated countries also affects yields of higher-rated countries, as well as for negative news, especially within the group of periphery countries. The size of cross-border spillovers also seems to be related to cross-border bank holdings. [26] As past rating announcements have seemed to have only a limited effect on the euro exchange rate, there is evidence that they have led investors to rebalance their sovereign bond portfolios within the euro area. [27]

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[24] Granger causality tests were run for the following two variables: i) changes in the bond market integration indicator (BM indicator) and ii) changes in the broader financial integration indicator, excluding the bond market (FI indicator). The sample runs from January 1995 to December 2017. The null hypothesis that BM does not Granger cause FI is rejected at a 5% confidence level, irrespective of whether the test is run with 9 month ("3 quarter"), 6 month ("2 quarter") or 3 month ("1 quarter") lags. This result is stronger when the test is run with a 9-month lag (where the p-value equals 0.013). Furthermore, the hypothesis that FI does not Granger cause BM is not rejected for the same lag lengths, even at a 10% confidence level (with p-value for the test with a 9-month lag equal to 0.26).

[25] There is significant ambiguity in the literature in terms of definitions and empirical methods for testing contagion. See for

example: Rigobon, R. (2016), 'Contagion, spillover and interdependence', *ECB Working Paper*, No. 1975.

[26] Böninghausen, B. and M. Zabel (2015), 'Credit ratings and cross-border bond market spillovers', *Journal of International Money and Finance*, Vol. 53, pp. 115-136.

[27] Baum, C., D. Schäfer and A. Stephan (2016), 'Credit rating agency downgrades and the Eurozone sovereign debt crises', *Journal of Financial Stability*, Vol. *24*, pp. 117-131.

Flight to safety and flight to liquidity

Flight to safety (FTS) is usually identified as a negative price co-movement between different asset categories (typically, stocks vs. bond returns) in periods of financial stress (e.g. when the stock market is falling), although the concept can also be applied to securities with different perceived risk levels within the same asset class. In a FTS episode, investors shed assets perceived to be riskier in favour of safer ones. [28] FTS episodes are not necessarily triggered by observed changes in fundamentals. Rather, they are often triggered by changes in risk perceptions and attitudes, which motivates the time-varying parameter analysis in the following subsection. Moreover, portfolio reallocations in connection with FTS usually reflect both safety and liquidity concerns. Therefore, flights to safety are often accompanied by flights to liquidity. In fact, market illiquidity appears to have played an important role in driving yield spikes in "periphery" countries at the height of the crisis, as documented in Graph I.14 of the next subsection. In other countries, market liquidity, as measured by bid-ask spreads, has played a more modest role, although with noticeable cross-country and intertemporal variations (Graph I.10). In particular, it is interesting to note that there has not been a clear link between bid-ask spreads and bond market shares (Graph I.11), another possible indicator of liquidity. As such, the Italian sovereign bond market, the largest in the euro area, has often experienced some of the largest bid-ask spreads among non-periphery countries, while Finland, the smallest market in our sample, does not show particularly unfavourable dynamics.

FTS has been identified as a factor affecting the pricing of sovereign bonds during the euro area debt crisis, when yields of some "core" countries moved in the opposite direction from that of the yields of vulnerable countries. Such joint dynamics confirm the increased importance of investors' risk aversion in times of uncertainty, which leads them to favour bonds of countries that are generally regarded to have a low default risk, and implies

consequently a risk premium increase in other countries. [29] Some part of the yield divergence seems to be also driven by liquidity premia, as the liquidity of "core" bond markets increased, at the same time as it decreased for the "periphery". [30] FTS has been identified also as one of the drivers of worsening efficiency in the bond markets, and one of the reasons for the observed deviation between CDS and bond spreads. [31]

Graph I.10: **Bid-ask spreads on 10-year sovereign bonds in selected euro area Member States**
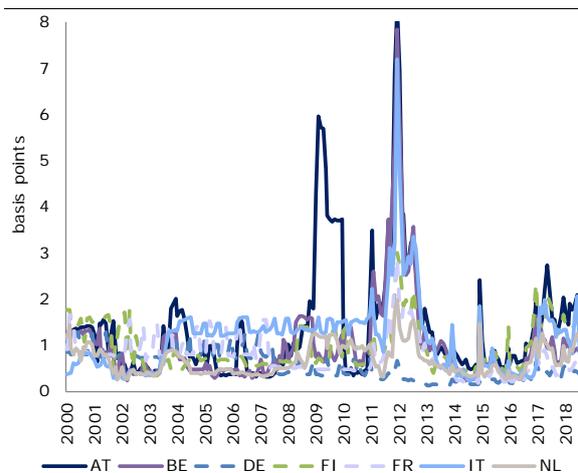

Source: Bloomberg

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[28] Baur, D. and B. Lucey (2009), 'Flights and contagion—An empirical analysis of stock–bond correlations', *Journal of Financial stability*, Vol. 5(4), pp. 339-352. Several papers provided stylised micro-founded models that aim to rationalise the flight to quality behaviour, e.g. Caballero, R. and A. Krishnamurthy (2008), 'Collective risk management in a flight to quality episode', *Journal of Finance*, Vol. 63(5), pp. 2195-223; Brunnermeier, M. and L. Pedersen (2009), 'Funding liquidity and market liquidity', *Review of Financial Studies*, 22, pp. 2201-2238.

[29] See for example: De Santis (2014), op. cit., Monfort, A. and J. Renne (2013), ' Decomposing euro-area sovereign spreads: credit and liquidity risks', *Review of Finance*, Vol. 18(6), pp. 2103-2151; Ehrmann and Fratzscher (2017), op. cit.

[30] Garcia, J. and R. Gimeno (2014), 'Flight to liquidity Flows in the Euro Area Sovereign Debt Crisis', *Banco de Espana Working Paper*, No. 1429. Fontana and Scheicher (2016), op. cit.

[31] Arce, O., S. Mayordomo and J. Peña (2013), 'Credit-risk valuation in the sovereign CDS and bonds markets: Evidence from the euro area crisis', *Journal of International Money and Finance*, Vol. 35, pp. 124-145.

Graph I.11: **Average sovereign bond market shares in the euro area (2000-2018)**
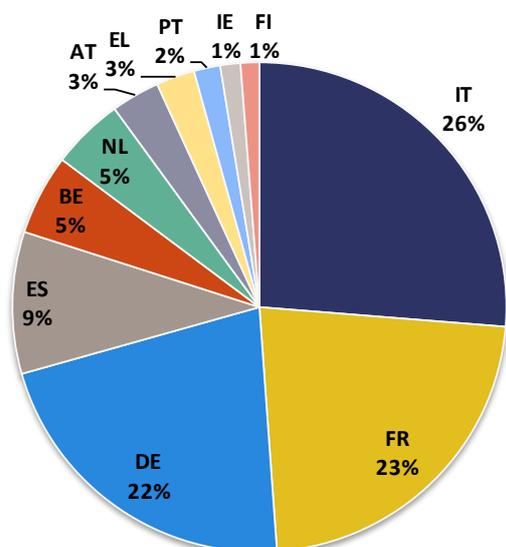
(1) Based on a sample of the 11 largest euro area economies.
Source: Eurostat, authors' calculations

Common monetary policy

Monetary policy in the euro area seeks to stabilise prices, typically by adjusting short-term policy interest rates. Current and expected short-term interest rates are, in turn, linked to long-term rates, with their term structure defining the slope of the yield curve and affecting the funding costs (and profitability) of banks and, consequently, of non-financial corporations and households. The Global Financial Crisis represented a major challenge both for monetary policy and financial stability, with central banks having to facilitate financial intermediation when private markets were reluctant to do so. In the following years, the need to for monetary accommodation drove short-term rates to the zero lower bound, and central banks began to use other, unconventional measures which had often direct impact on long-term interest rates.

The ECB has adopted since the globalfinancial crisis several unconventional monetary policy measures, with some of them having a direct effect on sovereign funding costs. These include the Securities Market Programme of 2010, the Outright Monetary Transactions programme announced in 2012, the subsequent forward guidance policies, as well as the Public Sector

Purchase Programme (PSPP) initiated in 2015. [32] The available empirical evidence suggests that these measures contributed to oppose disinflationary dynamics, to reduce sovereign funding costs and to ensure a more uniform transmission of monetary policy. [33] This can be attributed, inter alia, to the portfolio-rebalancing channel and to the (expected monetary policy) signalling channel. [34]

I.3.4. The time-varying role of sovereign yield drivers

This subsection investigates the role of country-specific dynamics in explaining observed bond yields using a time-varying parameter (TVP) panel data model. Such a model allows us to consider not only the evolution of fundamental yield drivers, but also how the importance of these drivers changes over time and across countries. In such a context, the contribution of a given driver – say, the debt ratio – can change not only because the variable itself has changed (e.g., the debt ratio has increased) but also because the TVP associated with it has evolved (e.g., markets have grown more sensitive to the level of debt). The explanatory variables included in the model are the same as in the constant parameter model of Subsection I.3.1 and Box I.1. For methodological details, as well as a breakdown of the contribution of the different drivers for the 11 largest euro area economies, see Box I.2. [35]

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[32] See for example: Constâncio, V. (2017), 'Role and effects of the ECB non-standard policy measures', speech at the ECB Workshop "Monetary Policy in Non-Standard Times", September 2017, Frankfurt am Main.

[33] See for example: Szczerbowicz, U. (2015), 'The ECB unconventional monetary policies: have they lowered market borrowing costs for banks and governments?', *International Journal of Central Banking*, Vol. 11(4), pp. 91-127; Falagiarda, M. and S. Reitz (2015), 'Announcements of ECB unconventional programs: Implications for the sovereign spreads of stressed euro area countries', *Journal of International Money and Finance*, Vol. 53, pp. 276-295; Jäger, J. and T. Grigoriadis (2017), 'The effectiveness of the ECB's unconventional monetary policy: Comparative evidence from crisis and non-crisis Euro-area countries', *Journal of International Money and Finance*, Vol. 78, pp. 21-43.

[34] Lemke, W. and T. Werner (2017), 'Dissecting long-term Bund yields in the run-up to the ECB's Public Sector Purchase Programme', *ECB Working Paper Series*, No. 2106 show using an affine term structure model that the yield declines (of the German bund at the time PSPP was announced and initiated) are almost fully attributable to a decline in the term premium as opposed to the expectations component, suggesting that the PSPP transmits to long-term yields mainly via a portfolio re-balancing channel rather than a signalling channel.

[35] The empirical framework used in this analysis is broad and seeks to track in a flexible manner the contributions of the main drivers of sovereign bond dynamics during the past two decades. However, the framework does not seek to provide definite

Among the explanatory variables, the **debt-to-GDP** TVP is a key contributor ([36]) to sovereign bond yield dynamics, both in terms of the magnitude of its impact and of its variability over time and across countries. As shown in Graph I.12, the cross-country variability of the debt TVP was relatively small in the pre-crisis period, with the TVP of high-debt countries such as Greece and Italy tracking the lower bound of the yield range of a set of "core" euro area Member States, denoted here and elsewhere as EA-6. This group of countries (which includes Austria, Belgium, Finland, France, Germany and the Netherlands), are represented together for readability sake and given that they have often experienced similar dynamics. With the onset of the crisis, market sensitiveness to the debt ratio began to rapidly increase in Greece, Portugal, Ireland and Spain, even as "core" euro area countries experienced stable or decreasing sensitiveness, as shown by the evolution of the EA-6 range. A combination of increased sensitiveness and increased debt levels drove large increases in yields in "periphery" countries. Between mid-2011 and mid-2012 the contribution of debt peaked, first for Ireland, then for Portugal, Spain and Greece, possibly reflecting uncertainty on the evolution of the economy and on the implementation of financial assistance programmes. Asymmetric market sensitiveness eased considerably and continuously until year-end 2014, when it began to increase again (though in a short-lived manner in the case of Ireland). While not having experienced a marked degree of market stress, the TVP dynamics for Italy tended to track in a muted way the dynamics of the aforementioned periphery Member States until 2015.

Graph I.12: **Debt-to-GDP TVP**
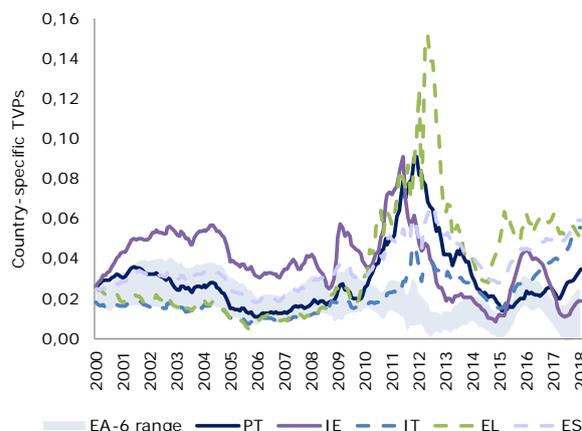
(1) EA-6 range is calculated based on the maximum and minimum values for AT, BE, DE, FI, FR and NL.
Source: Authors' estimations

Overall, the debt TVP appears to capture the panic-like effects observed during the crisis. This suggests that these effects interact with debt levels, so that the most indebted Member States were the most exposed to this type of market behaviour. It should also be noted at this point that, generally speaking, the increases in market sensitiveness to yield drivers observed in "periphery" countries can be ascribed both to factors linked to an incomplete Economic and Monetary Union (EMU) architecture, and to other factors that are less directly linked to the state of EMU completeness. Among the latter are changes in expected debt levels and growth prospects, or incomplete information regarding the true state of public finances. Among factors directly linked to EMU incompleteness are the risk of redenomination ([37]) and the risk of an aggravation of sovereign bank loops which is born of banks' home bias and the absence of proper bank resolution tools during the past crisis period.

At the same time as market responses to debt ratios were increasing in periphery countries, the debt TVPs of core euro area countries embarked on an opposite declining trend from 2009 to 2012. This suggests that markets discounted debt levels and credit risk in some countries during (and beyond) the sovereign debt crisis period, which is consistent with the notion of flight to safety. In fact, with prospects of robust growth resuming across the euro area and unconventional monetary

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answers to some contentious issues like the relevance of redenomination risks or the relative importance of flight-to-safety versus flight-to-liquidity phenomena, which have been the object of the specialised literature previously reviewed.

([36]) The contribution of a given determinant is calculated as the associated TVP multiplied by the associated variable. As such, the contribution of debt to sovereign yields in country i at time t is $\beta^{debt}_{i,t} debt_{i,t}$.

([37]) Redenomination risk can interact with debt levels and therefore be picked up by the debt ratio TVP.

policy in full swing, debt levels even appear to have been momentarily written off as risk factors in the second half of 2017 in the case of Germany.

TVP estimations ascribe a modest role to contemporaneous **GDP growth**. However, inasmuch as growth can improve or aggravate debt-to-GDP ratios, its effect on yields is also captured via the debt ratio. Graph I.13 plots the contribution of GDP growth to sovereign bond yields over time. As can be observed, the contributions of growth show similar magnitudes for most countries during most of the time. Pure growth effects are seen to have switched from a supportive role (i.e., a negative contribution) in the pre-crisis period to adding up to 30 basis points to yields in the 2008-09 recession. Growth effects have generally been favourable in the post-crisis period, safe for the "double dip" recession of 2012. Two notable cases are Greece and Ireland. Prolonged negative growth has put upward pressure on Greek sovereign bond yields up until 2014, while dynamic growth in Ireland has had the reverse effect during the post-crisis period.

Graph I.13: **Contribution of growth to yields**
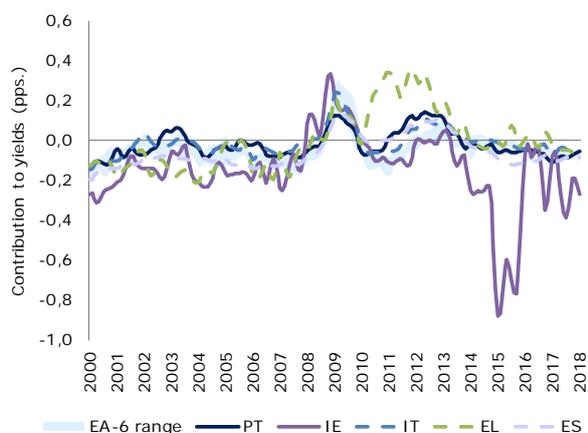
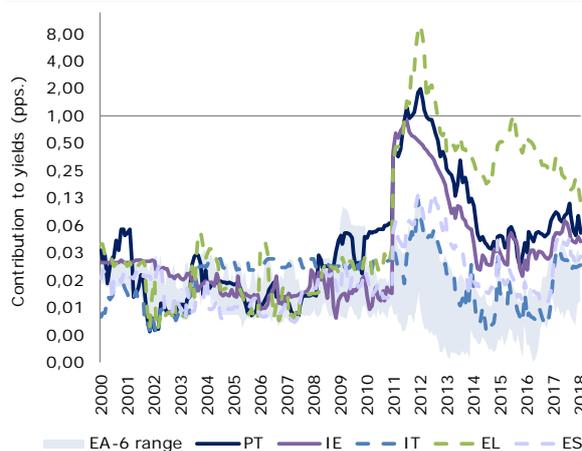(1) EA-6 range is calculated based on the maximum and minimum values for AT, BE, DE, FI, FR and NL.
Source: Authors' estimations

The **global risk factor** (not shown here) has played a relevant role, having added more than 50 bps to euro area sovereign bond yields at the height of the 2008-09 crisis. The importance ascribed to the global risk factor is, nevertheless, significantly smaller in the TVP model than in the fixed effects model estimated in the previous subsection. TVP estimations suggest similar global risk sensitivities across the euro area over time, so that differences in country-specific TVPs induce only negligible

differences in the contribution of global risk to yields.

Spikes in market **illiquidity** in the peak of the sovereign debt crisis had an increased, sizeable effect on the yields of Portugal and Ireland, and a major effect on the yields of Greece. While Italy and Spain do not show spikes in illiquidity, their bid-ask spreads have nevertheless tended to remain on the high side since 2011 when compared with "core" countries. Graph I.14 shows the effects of illiquidity over time. ([38]) The observed increases in the contribution of liquidity were essentially driven by spikes in bid-ask spreads, rather than by spikes in the associated TVPs.

Graph I.14: **Contribution of illiquidity to yields**

(1) Vertical axis in logarithmic scale; EA-6 range is calculated based on the maximum and minimum values for AT, BE, DE, FI, FR and NL.
Source: Authors' estimations

The **asset purchase programmes** (APP) of the Eurosystem have played an important role in stabilising government interest rates. Our measure of APP is the aggregate amount of securities held by the Eurosystem for monetary policy purposes. ([39]) This variable is zero prior to July 2009 and has grown since then in connection with the private sector asset purchase programmes of the Eurosystem. With the introduction of the public sector purchase programme (PSPP) in March 2015 the magnitude of this asset class has become increasingly dominated by the latter. In

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([38]) The vertical axis is plotted in a non-linear (logarithmic) scale for readability purposes.

([39]) I.e., the total amount on the balance sheet of the Eurosystem, summed over all participating countries. This variable is not, therefore, country-specific.

order to identify the time-varying role of the asset purchases a common constant coefficient is assumed until July 2012. This was the month when the president of the ECB, Mario Draghi, delivered a pivotal speech to the effect that "*the ECB is ready to do whatever it takes to preserve the euro*." This speech is widely regarded as having changed market perceptions, namely as concerns expectations of a greater role for the ECB's non-conventional monetary policy. As such, from July 2012 onwards our identification strategy allows country-specific reactions to the balance sheet size of the ECB to emerge and complement the constant, common coefficient. [40]

In Box I.3 a simple counterfactual exercise is conducted whereby the actual sovereign bond yields are compared with the yields predicted by three different models capturing an "average" behaviour of parameters: a common-intercept version of fixed effects model discussed in Box I.1 (FE-CI); a "EA-6" model which is based on the average TVP values for the set of EA-6 countries; and a constant parameter model based on the FGLS-estimated coefficients in Box I.2 (CP FGLS). The objective is to assess what the yield dynamics might have looked like under a symmetric reaction to fundamental yield drivers. In order to assume cross-country symmetry, an average intercept value is taken in the fixed effects model. All three models predict much smoother profiles for Member States that underwent market stress, [41] reinforcing the notion that a large part of the sovereign bond dynamics observed during the 2008-09 financial crisis and the ensuing Great Recession were not driven by observed changes in country-specific fundamental determinants, but rather by differentiated and time-varying market reactions.

The models also present instances of downward price misalignment in both pre-crisis and post-crisis periods, when predicted yields are noticeably above actual yields.

I.4. Conclusion

When the common currency was launched in 1999, exchange rate risks had been eliminated and sovereign funding costs had almost perfectly converged for the (at the time) euro area Member States. Sovereign interest rate differences across these countries remained negligible for almost a decade, also reflecting the strong credibility of the European Monetary Union project. The subsequent fragmentation of sovereign bond markets brought to the fore the double role played by sovereign funding costs in a monetary union. While they incentivise prudent fiscal policies at Member State level, excessive differences across Member States can hamper the transmission of monetary policy. Moreover, this differentiation is typically procyclical and can exacerbate divergences in economic performance across the euro area.

While sovereign bond yields represent a prominent indicator of sovereign credit risk, it has been shown that it reflects also other factors such as market liquidity and general investor sentiment. [42] The empirical assessment conducted in this Section confirms the role of these and other factors in driving bond yields in the euro area over time.

In particular model-based evidence suggests that heightened market sensitiveness to debt ratios, combined with an increase in debt levels, appear to have explained a large part of the asymmetric dynamics observed during the sovereign debt crisis and the Great Recession. Changes in market sensitiveness are seen to have evolved in a divergent manner during this period, increasing for some euro area economies, while decreasing for others, which is suggestive of flight-to-safety dynamics. At the same time, data on cross-border flows supports the notion of a flight-to-safety from "periphery" to "core" euro area economies, and also from the euro area to the US during the 2007-09 crisis period. In addition, bouts of illiquidity are seen to have driven yield peaks in periphery countries in the most acute phases of the crisis.

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[40] In the case of Greece, sovereign bonds were not eligible for the PSPP. Therefore, the bond yield effects estimated for Greece derive mainly from the existence and potential of APP as a set of policy measures, rather than from actual purchases of securities in the Greek jurisdiction.

[41] The exception is Greece in the first quarter of 2012. This is due to an extreme spike in bid-ask spreads which more than rationalise, and possibly over-explain, the observed yields.

[42] Garcia-de-Andoain, C. and M. Kremer (2018), 'Beyond spreads: measuring sovereign market stress in the euro area', *ECB Working Paper Series*, No. 2185 propose a composite indicator of sovereign bond market stress in the euro area. This indicator integrates measures of credit risk, volatility and liquidity at short-term and long-term government bond maturities into a broad measure of sovereign market stress.

While increased market sensitiveness to yield drivers can reflect fundamental country-specific issues, the divergent dynamics observed in the past also appear to be linked to an incomplete EMU architecture. An institutional setup that can contain abrupt and undue shifts in investors' perceptions in crisis periods, as well as eliminate bouts of illiquidity and remove redenomination risk can deliver significant stability benefits for the euro area.

Over the past years, significant progress has been achieved in strengthening the EU's institutional framework, namely as regards the implementation of a banking union, the capital markets union initiatives and the introduction of new monetary policy tools. A number of additional reforms are warranted as discussed in the Commission's Reflection Paper on EMU, [43] which can potentially help to overcome the observed fragmentation in sovereign bond markets and address some of the issues reviewed in this Section. Such issues include i) the emergence of flight-to-safety dynamics observed within the euro area and with respect to the rest of the world; ii) the risk of bond market fragmentation experienced in the euro area, which could materialise again and foment broader financial market disintegration in periods of stress; iii) the risk of illiquidity spikes in such periods, which could transmit through the credit channel to the real economy; and iv) the risk of currency redenominations. In any case, given the prominent and continued role of debt ratios in driving yield dynamics, polices that are fiscally prudent and growth friendly remain an important complement to past or prospective improvements in the institutional setup of the euro area.

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[43] See Buti, M., S. Deroose, J. Leandro, and G. Giudice (2017), 'Completing EMU', VoxEU.org, 13 July.

Box I.2: **A time-varying parameter analysis of sovereign bond yields in euro area countries**

Time-varying parameter (TVP) models are particularly useful when causal relationships are unstable, or evolve, over time. They can help deal with different forms of model misspecification by allowing regression coefficients to evolve stochastically under some law of motion. The literature on TVP panel data models is limited, and this is particularly true of applications to bond yields. The authors are aware of two studies that apply a TVP approach to explain sovereign bond yields in the euro area. The first, by Bernoth and Erdogan, [1] applies a semi-parametric approach to derive common (i.e., not country-specific) TVPs for a time period running from 1999 to 2010. The second, by Paniagua, Sapena and Tamarit, [2] is the closest in nature to the approach developed in this subsection. Like Paniagua et al, country-specific TVPs are estimated to analyse sovereign bond yields in euro area countries since the year 2000 using state-space techniques. Differently from Paniagua et al, the panel explicitly includes Germany and the sample was prolonged to cover the 2014-18 period. A different, enlarged set of explanatory variables is also included, as well as a more flexible parameter structure.

In particular, the panel regression model described in Box I.1 was adapted and expanded to a TVP context, and a model of the following form specified:

$$y_{i,t} = \bar{I} + \left(I_{i,t} - \bar{I} \right) + \overline{\beta^{rf}} rf_t + \left(\beta^{rf}_t - \overline{\beta^{rf}} \right) rf_t + \overline{\beta^{slope}} slope_t + \left(\beta^{slope}_{\ t} - \overline{\beta^{slope}} \right) slope_t + \overline{\beta^{debt}} debt_{i,t} + \left(\beta^{debt}_{\ i,t} - \overline{\beta^{debt}} \right) debt_{i,t} + \overline{\beta^{growth}} growth_{i,t} + \left(\beta^{growth}_{\ i,t} - \overline{\beta^{growth}} \right) growth_{i,t} + \overline{\beta^{risk}} risk_t + \left(\beta^{risk}_{\ i,t} - \overline{\beta^{risk}} \right) risk_t + \overline{\beta^{liq}} liq_{i,t-1} + \left(\beta^{liq}_{\ i,t} - \overline{\beta^{liq}} \right) liq_{i,t-1} + \overline{\beta^{APP}} APP_t + \left(\beta^{APP}_{\ i,t} - \overline{\beta^{APP}} \right) APP_t + \varepsilon_{i,t} \ (1)$$

An upper bar denotes a constant parameter that is common across countries. The meaning of the variables is the same as before: $y_{i,t}$, represents the 10-year sovereign bond yield for country *i* during month *t*; *I* represents an intercept; *rf* represents the short-term risk rate; *slope* represents the slope of the risk-free yield curve; *debt* is the debt-to-GDP ratio; *growth* is year-on-year GDP growth; *risk* represents a global risk factor; *liq* represents market liquidity; *APP* represents the effects of the Eurosystem's asset purchase programmes; and *ε* is an error term. [3]

For the *β* coefficient on variable *j* of country *i,* the specification allows for time-varying deviations from the constant parameter, $\left(\beta^{j}_{\ i,t} - \overline{\beta^{j}} \right)$, which evolve in an autoregressive manner:

$$\left(\beta^{j}_{\ i,t} - \overline{\beta^{j}} \right) = \rho^{j}_i \left(\beta^{j}_{\ i,t-t} - \overline{\beta^{j}} \right) + \mu^{j}_i cyas_{i,t} + u^{j}_{i,t} \qquad (2)$$

where *ϱ* is an autoregressive parameter, *μ* is a "coefficient driver" and *u* is an error term. Like Paniagua et al (2017 the evolution of the TVPs is allowed to respond to an indicator of cyclical asymmetry in the euro area, the *cyas* variable, through the coefficient driver *μ*. [4] The rationale behind its inclusion is that macroeconomic divergences may influence market expectations regarding the future of a currency union. It should be noted that the time-varying coefficients on *rf* and *slope* are assumed common to all Member States and that the coefficient drivers are therefore turned off for these two variables.

The model was estimated in three stages. Firstly, the constant parameters are estimated through feasible generalised least squares (FGLS). In a constant parameter (CP) panel data context this would be equivalent to

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

[2] Paniagua, J., J. Sapena, J. and C. Tamarit (2016), 'Sovereign debt spreads in EMU: The time-varying role of fundamentals and market distrust', *Journal of Financial Stability*, Vol. 33, pp. 187-206. The authors are grateful for the very useful exchanges with Juan Sapena on the estimation results presented in the aforementioned paper.

[3] For more details, please see Box I.1.

[4] The *cyas* variable measures, for each country, the difference between its year-on-year GDP growth and that of Germany, deemed as an "anchor country". The associated coefficients, μ^{j}_i, were found to be significant in most of the state equations. Nevertheless, removing *cyas* from our specification does not materially affect the results.

(Continued on the next page)

assuming a random effects model. In a FGLS estimation, observations with higher variance are given less weight. In our exercise this offers the advantage of a less erratic profile for the residuals,[5] less fit of the constant parameter model and therefore more revealing dynamics for the TVPs. The fact that the Hausman test recommends the fixed effects model need not be an obstacle as this is a test between two types of CP models rather than between different types of TVP models. In fact, as will be seen, our specification allows for permanent "country effects" irrespective of the initial FGLS estimation.

Secondly, given the CPs estimated via FGLS, the unexplained part of the $y_{i,t}$ in the set of equations (1) is taken as the "signal equations" to be explained by the set of "state equations". (2) In such a state-space setting, the time series for the TVP deviations from the CP, $\left(\beta^j_{\,i,t} - \overline{\beta^j}\right)$, can be estimated with a Kalman filter. Let R denote the covariance matrix of $\varepsilon_{i,t}$ and Q the covariance matrix of $u^j_{i,t}$. The Kalman filter estimation requires initial guesses on R, Q, the set of ρ^j_i and μ^j_i, as well as starting values for $\beta^j_{\,i,t} - \overline{\beta^j}$. An iterative procedure was followed whereby the Kalman filter is initially run by setting uninformed guesses on R and Q in the form of (scaled-down) identity matrices. Reversion of country-specific deviations to the constant parameters was assumed, and the initial ρ^j_i and μ^j_i were set to 0.9 and to zero, respectively. The exception are the TV intercepts where the ρ^I_i were set to one, thereby initially assuming a random walk, which allows country effects to be potentially permanent. Finally, the zero-period values of $\left(\beta^j_{\,i,t} - \overline{\beta^j}\right)$ were to zero.

Thirdly, an iterative procedure was run whereby the results of the Kalman filter estimation are used to formulate new initial guesses, until a good degree of convergence is achieved. All the constant parameters display the right sign and are significant at a X% significant level. The flexibility of the TVPs allows for a near-perfect fit of the model. Approximately half of the yield variance is explained by the CPs, with the rest being explained by the TVPs, with an overall R² of close to 100%. (6) Table 1 summarises our estimation results.

Table 1: estimation results for a sovereign bond yield TVP panel data model

	I	β_{rf}	β_{slope}	β_{debt}	β_{growth}	β_{risk}	β_{liq}	β_{APP}
Constant parameter	1.023	0.46	0.71	0.023	-0.03	0.13	1.7	-0.001
TVP deviations	[0.025, -0.017]	[0.005, -0.003]	[0.0007, -0.0005]	[0.128, -0.024]	[0.004, -0.007]	[0.003, -0.001]	[0.002, -0.001]	[0.001, -0.0104]

Note: the range across time and countries for the TVP deviations from the constant parameter is reported between squar brackets.

A look at Table 1 shows that the TVPs exhibiting the greatest (relative) variability are those associated with *debt* and *APP*. As in the fixed effects model estimated in the previous subsection, the debt ratio is a key determinant of bond yields and asymmetric market sensitiveness to this variable is a key driver of variability along the cross-section and the time-series dimensions. It can also be observed that none of the TVP deviations are sufficient to change the sign of the associated coefficient, with the exception of the debt coefficient for a particular country and quarter. This exception is discussed in the main text. The chart panels below provide decompositions for the evolution of 10-year sovereign bond yields for the 11 largest euro area economies.
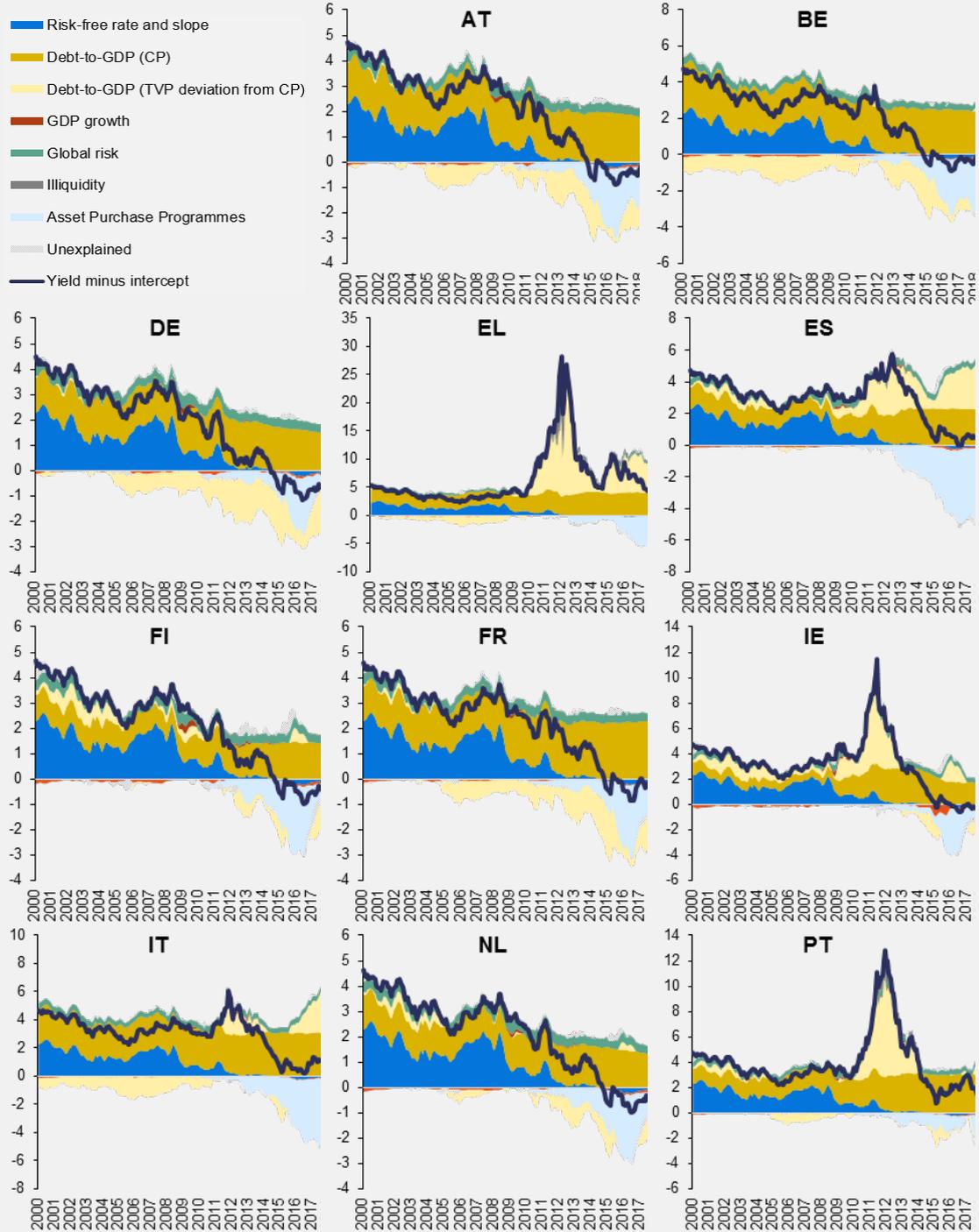
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[5] For instance, in countries that have experienced acute market stress, spikes in illiquidity more than fully rationalise spikes in yields in the peak period of the crisis under a fixed effects CP model, so that the resulting time series of the residuals follow an M shape, with the through observed precisely during the crisis peak. This is a counter-intuitive result which is avoided by FGLS estimation, which places a lower weight on this very erratic period and produces Λ-shaped residuals. Under FGLS estimation the effect of spikes in illiquidity are not over-explained by the constant liquidity parameter but rather by changes in country-specific TVPs.

[6] An R² of 100% is a characteristic of the TVP approach and does not constitute, in itself, evidence in favour of our model specification.
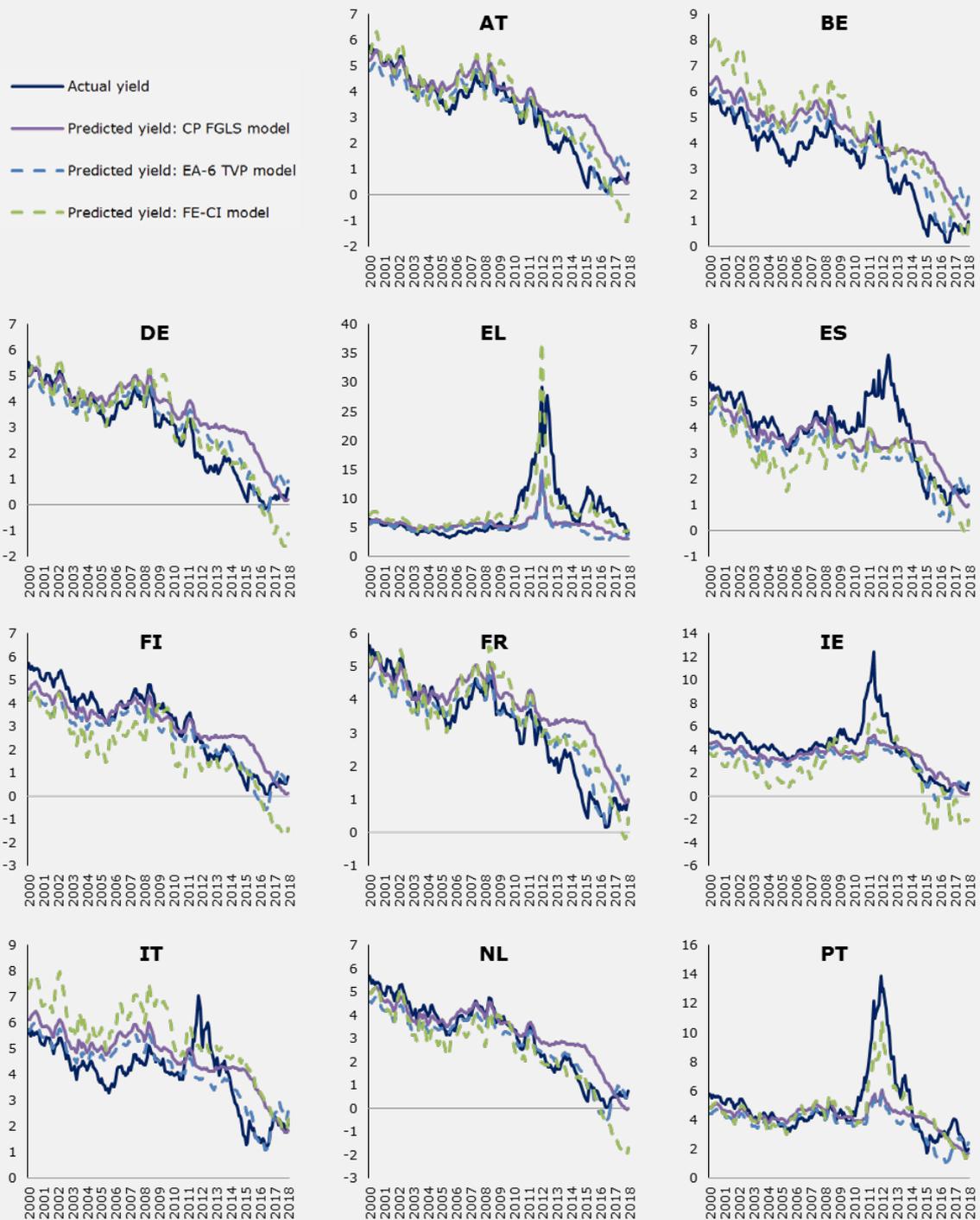
Box (continued)

Decomposition of the evolution of 10-year sovereign bond yields based on a panel TVP model

Legend:
- Risk-free rate and slope
- Debt-to-GDP (CP)
- Debt-to-GDP (TVP deviation from CP)
- GDP growth
- Global risk
- Illiquidity
- Asset Purchase Programmes
- Unexplained
- Yield minus intercept

Charts: AT, BE, DE, EL, ES, FI, FR, IE, IT, NL, PT

Box I.3: **Actual yields vs. predicted yields from CP FGLS, FE-CI and EA-6 models**

Note: the FE-CI model is based on the constant parameters shown in Box I.1 and on an average, common intercept; the EA-6 TVP model is based on the average TVPs for AT, BE, DE, FI, FR and NL; CP FGLS model is based on the constant parameters shown in Box I.2.