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A state space approach to measuring the impact of sovereign and credit risk on interest rate convergence in the euro area[☆]

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ABSTRACT

This paper employs a time-varying parameter state space model to explore the impact of the crisis on bank retail rates in the euro area. We show that σ-convergence in interest rates has been adversely affected by the crisis and quantify the role of sovereign and credit risk as two alternative explanations for the increase in financial fragmentation. A key finding is that the heterogeneity in sovereign risk across member states accounts for a sizable part of the increase in the cross-sectional dispersion of various lending and deposit rates. In contrast, the impact of the increased heterogeneity in credit risk on bank retail rates is negligible. Our results suggest that efforts to reduce sovereign tensions – as exemplified by the ECB's OMT program - may help to reduce financial fragmentation.

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1. Introduction

Since the start of the credit crisis, in many countries monetary policy has been relaxed by reducing policy rates to a level close to the lower zero bound. In addition, central banks have resorted to non-traditional policy actions aimed at stimulating the economy. In spite of these efforts, doubts have remained about the effectiveness of monetary policy to reduce the borrowing costs of households and firms (Blot and Labondance, 2011; Aristei and Gallo, 2014). These concerns are greatest in the euro area, which in addition to the recession and the fragility of a comparatively large banking sector also has to cope with the fragility of the monetary union itself (de Grauwe and Ji, 2013). These fragilities have culminated in a process of financial fragmentation, resulting in an increased heterogeneity in bank lending conditions across the euro area (Illes and Lombardi, 2013).

Prior to the crisis, various structural factors impeded a complete convergence of bank retail rates and a uniform pass-through of market to retail rates in the euro area. These include differences in the level of competition in the banking sector, the availability of market-based funding, product heterogeneity and institutional factors related to fiscal and regulatory frameworks (Cottarelli and Kourelis, 1994; Güntner, 2011). For these reasons, European financial integration in retail banking has always lagged behind the integration of financial markets and wholesale banking. Most studies conclude that significant barriers to integration in retail banking have remained following monetary unification (Casu and Girardone, 2010). This poses a problem for the effective conduct of monetary policy by the ECB, as differences in interest rate pass-through render both the speed and strength of monetary policy transmission heterogeneous across member states.

The existing heterogeneity in monetary transmission has been exacerbated by the adverse turn in the economy since 2008, which led to increased economic uncertainty, a breakdown in money market liquidity, and doubts about the soundness of euro area financial institutions and their sovereigns. More specifically, two additional factors affecting the heterogeneity in bank retail rates have since come to the fore. First, as cyclical developments started to diverge across the union, banks located in countries experiencing harsher economic conditions may have required a higher compensation for increased credit risk. A priori, one would expect this factor to primarily affect lending rates, not deposit rates. However, an effect of credit risk on deposit rates could arise if a deteriorating loan portfolio would hurt depositor confidence. Second, the twin factors of sovereign and banking risk, jointly dubbed the sovereign-bank doom loop, may also have affected retail rates. Changes in the yields on government bonds influence retail rates through arbitrage relations or due to their status as a benchmark asset. The weakness of some sovereigns has also raised doubts regarding the sovereign's ability to support domestic banks and about the soundness of banks with a high sovereign exposure. Both concerns have contributed to safe-haven flows to fiscally strong core countries. As a result, in distressed countries government bond spreads widened, liquidity dried up and the cost of bank funding, if available at all, increased. Sovereign and banking risk thus have put the process of financial integration in reverse, leading to financial fragmentation as borrowers retreated behind national borders (Pisani-Ferry, 2013). This unmaking of financial integration has influenced the ability of financial institutions to attract and retain deposit funding and may thus have manifested itself in diverging deposit rates.

At the height of the crisis the integrity of the euro area itself was put in doubt, as indicated by the peak score of 73 for the survey-based Euro Breakup Index in July 2012. In the ultimate scenario of a euro break-up, exchange rate risk would be reintroduced in the pricing of bank loans and deposits. This redenomination risk has been an important consideration for the ECB to introduce the instrument of Outright Monetary Transactions (OMT), aimed at restoring the singleness of monetary policy by conditionally purchasing short-dated governments bonds of euro area members. ECB president Draghi (2012) provides the following justification of the OMT program:

> "The euro area has experienced a very severe fragmentation in its financial markets. In recent months, we have seen highly divergent borrowing costs for the real economy in different parts of the euro area. In our analysis, these differences were larger than justified by individual credit risk. They reflected, to a considerable extent, unfounded fears about the future of the euro area."

The ECB's arguments have met with criticism. First, the ECB's wish to restore the normal transmission of monetary policy seems difficult to reconcile with the conditional nature of the OMT program. It is unlikely that the monetary transmission process is no longer in need of restoration when governments fail to comply with policy conditionality. More fundamental is a second criticism, which holds that substantial spreads in lending rates have been a repeating phenomenon in the history of the euro and that the underlying purpose of the OMT program is not to restore monetary transmission but to support fiscal policy (Der Spiegel, 2012). This debate underscores that from a policy perspective, the distinction between credit risk and risk relating to the fragility of the monetary union is highly relevant. If higher lending rates would result from increased credit risk of firms, a standard source of risk in banking, the case for central bank intervention to reduce financial fragmentation would be weak. If diverging bank retail rates result from the fragility of the monetary union and its susceptibility to sovereign debt crises, the case for policy intervention is stronger (Cœuré, 2013).

The aim of this paper is to empirically investigate to what extent the convergence in euro area bank retail rates has been affected by the recent increases in sovereign and credit risk. Our objective is to quantify the relative importance of these risk factors as alternative drivers of the increase in financial fragmentation. To this end we employ a state space model that allows for a time-varying impact of sovereign and credit risk on bank retail rates. We extend the basic partial adjustment model of interest rate pass-through (Vajanne, 2009) in two ways. First, retail rates depend not only on market rates but also on measures of sovereign and credit risk. Second, all coefficients are modeled as time-varying states. This allows the model to identify when and where the stresses in financial markets and the economic divergences across the union have spilled over into retail rates. By estimating the states we quantify the time-varying effect of the risk factors on retail rates and their convergence. We calculate two measures of σ-convergence. The first is the cross-sectional standard deviation of the raw interest rate data. The second is the cross-sectional standard deviation of these rates adjusted for sovereign and credit risk factors. A comparison of the two measures allows us to determine the impact of sovereign and credit risk on retail rate convergence.

The main contributions of this paper are as follows. First, to our knowledge this is the first study which aims to quantify the respective roles of sovereign and credit risk in thwarting bank retail rate convergence. Second, in contrast to most studies on interest rate pass-through and convergence we use both lending and deposit rates. The literature's focus on lending rates is understandable, as lending conditions for businesses and households are an important driver of economic growth. However, as we will show below, the crisis has disrupted the transmission of policy rates to deposit rates even more than that to lending rates. In our view, the impact of the crisis on deposit rates is a relatively under-researched field to which this paper hopes to contribute. Finally, the sample period ends in November 2013 from and thus includes the period during which the ECB's OMT program has become available.

The main findings can be summarized as follows. Heterogeneity in sovereign risk accounts for a sizable part of the increase in the cross-sectional dispersion of various bank lending and deposit rates. In contrast, the impact of the increased heterogeneity in credit risk on bank retail rates is negligible. The rest of the paper is structured as follows. Section 2 provides a brief overview of the relevant literature. Section 3 describes our dataset and methodology. Section 4 reports the results. Section 5 concludes.

2. Literature review

One of the anticipated effects of EMU on the financial sector was a rapid growth in cross-border retail banking and a wave of cross-border consolidation among banks at both wholesale and retail levels (e.g. European Commission, 2008). Neither has occurred. National segmentation in the European retail banking industry remains significant regardless of EMU. The empirical literature on integration in the European retail banking sector focuses either on estimating interest rate pass-through or on measuring convergence. If convergence in retail rates would be complete, the pass-through of market or policy rates to retail rates would be identical across the euro area. Measuring convergence or differences in pass-through are thus related ways to investigate the integration in retail banking markets.

Early studies in the field of bank interest rate pass-through relate different degrees of lending rate stickiness to structural features of the financial system, such as barriers to competition, the degree of development of financial markets, and the ownership structure of the banking system (Cottarelli and

Kourelis, 1994; Cottarelli et al., 1995; Borio and Fritz, 1995). For the euro area, Mojon (2000) documents significant country asymmetries in the response of bank rates to monetary policy, tracing these back to structural factors such as differences in volatility of national money market rates, competition from other sources of finance, and degree of banking competition.

A long string of literature has since looked into the heterogeneity of retail bank interest rate pass-through in EMU (e.g. Sander and Kleimeier, 2004; de Bondt, 2005; Hofmann, 2006; Kok Sørensen and Werner, 2006; Sander and Kleimeier, 2006; de Graeve et al., 2007; Gropp et al., 2007; Vajanne, 2007). The general findings in this line of research can be summarized as follows. First, bank interest rates are sticky. At least in the short and medium term, monetary policy rate pass-through is thus incomplete. Second, there is no consensus regarding complete pass-through in the long run. Third, there are significant differences in pass-through between product categories. Pass-through is most complete for short-term lending to enterprises. Deposit rates are stickiest. Fourth, there are significant differences in the pass-through mechanism between euro area countries. Finally, there is some evidence that the pass-through mechanism has become more homogeneous since the introduction of the euro and a common monetary policy, but convergence has mainly occurred in lending rates, not deposit rates (Sander and Kleimeier, 2004, 2006). Finally, differences in pass-through between product categories and between countries are related to differences in the degree of competition in markets (e.g. Kok Sørensen and Werner, 2006; de Graeve et al., 2007; Leuvensteijn et al., 2008).

The crisis and the ensuing unmaking of financial integration have led to further research in this field. Standard practice in recent studies is the use of the harmonized interest rate dataset made available by the ECB. Blot and Labondance (2011) find that since August 2007, interest rate pass-through proves less complete than in the pre-crisis period and that the heterogeneity of pass-through across euro area countries has increased. Karagiannis et al. (2010) illustrate that the efficiency of monetary policy transmission has been disrupted in the euro area, as mirrored by a widening of spreads between policy rates and money market as well as retail interest rates. Using nonlinear co-integration techniques, Belke et al. (2013) find considerable differences in the size of pass-through across countries and lending rates, which is in line with earlier findings. Hristov, Hülsewig and Wollmersmaüser (2013) employ a panel VAR and find that the pass-through from market to retail rates has become less complete since the crisis. Finally, Rughoo and Sarantis (2012, 2014) investigate convergence in the European banking sector using a panel convergence model. Their results indicate the presence of convergence up to the start of the crisis. After 2008, the null hypothesis of convergence is rejected.

Summing up, the available evidence testifies to a continued heterogeneity of interest rate pass-through in the euro area and to a sudden halt to the process of convergence due to the crisis. Recent studies document this development, but provide little insight in the underlying causes. In the remainder of this paper we will attempt to relate the recent developments in euro area bank retail rates to measures for sovereign and credit risk.

3. Data and methodology

3.1. Data

For the bank retail rates we use the ECB's MFI Interest Rate (MIR) statistics, which since January 2003 have been compiled on a harmonized basis across all euro area countries.[1] We use lending and deposit rates both for new business and for outstanding amounts. A priori one would expect sovereign and credit risk to have a direct impact first and foremost on new business. But in particular for deposit rates, we think that tensions relating to the sovereign-bank nexus may also have an impact on the willingness of the existing client base to hold deposits. Both categories are further broken down by client category (households or non-financial corporations) and maturity. For a number of interest rates, data availability was insufficient to include them in this study. Our sample period ranges from January

[1] Available at http://www.ecb.int/stats/services/escb/html/index.en.html.

2003 to November 2013. The dataset covers 131 monthly observations. We include the following countries: Austria, Belgium, Germany, Spain, Finland, France, Greece, Ireland, Italy, the Netherlands and Portugal. All these countries have been a member of the euro area since January 2003. For Belgium the interest rate data start in October 2006. We exclude Luxemburg because this is a small and a-typical country and because are chosen measure of sovereign risk is not available for this country.

Table 1 lists the MIR interest rates that have been included in the study, including a description and the abbreviations used in the remainder of this paper. Also reported for each country-interest rate combination is the *p*-value for an ADF-unit root test with automatic lag selection. The *p*-values show that for all combinations the null hypothesis of a unit root cannot be rejected. We may thus conclude that the interest rate series are non-stationary.

For the market rate we have selected the 3-month Euribor rate, as provided by the ECB. In order to measure sovereign risk, we use Credit Default Swap (CDS) rates from Datastream. For most countries, the CDS rates start in January 2004. In a few cases where the CDS series started later, we have back-dated a country's CDS rates to January 2004 by adjusting German CDS rates with the yield spread on government bonds, collected from the IMF's International Financial Statistics. Due to the strong multi-collinearity between sovereign and banking CDS rates (Angeloni and Wolff, 2012; De Bruyckere et al., 2013), we have refrained from including a separate measure for banking risk in the model. Our measure

Table 1
P-values ADF unit root tests on interest rates.

ECB-line	Abbreviation	Description	DE	NL	FI	AT	BE	FR	IT	IE	ES	PT	GR
Deposit rates – outstanding amounts													
1111	HH-ON	Households – overnight	0.50	0.78	0.37	0.31	0.63	0.77	0.35	0.50	0.61	0.22	0.66
1112	HH < 1 y	Households – maturity up to 1 year	0.46	0.27	0.39	0.43	0.72	0.21	0.29	NA	0.62	0.08	0.30
1121	NFC-ON	Non-financial corporations – overnight	0.62	0.62	0.29	0.35	0.67	0.41	0.21	0.34	0.40	0.30	0.73
1122	NFC<1 y	Non-financial corporations – maturity up to 1 year	0.55	0.31	0.36	0.64	0.59	0.36	NA	NA	0.25	0.59	0.37
Deposit rates – outstanding amounts													
211	HH < 2 y	Households – maturity up to 2 years	0.64	0.76	0.10	0.37	0.93	0.51	0.14	0.26	0.07	0.01	0.12
213	NFC<2 y	Non-financial corporations – maturity up to 2 years	0.51	0.53	0.27	0.61	0.64	0.44	0.11	0.17	0.10	0.06	0.02
Lending rates – new business													
1215	HH-HP	Households – housing purchase <1 year rate fixation	0.38	0.34	0.32	0.54	0.45	0.34	0.24	0.23	0.22	0.25	0.48
1228	NFC<1 m	Non-financial corporations – up to EUR 1 million	0.36	0.53	0.57	0.44	0.59	0.45	0.33	0.20	0.11	0.06	0.17
1229	NFC>1 m	Non-financial corporations – over EUR 1 million	0.89	0.74	0.71	0.54	0.67	0.42	0.65	0.68	0.63	0.47	0.67
Lending rates – outstanding amounts													
2211	HH-HP	Households – housing purchase over 5 years	0.97	0.14	0.40	0.56	0.92	0.10	0.43	0.41	0.12	0.22	0.95
2212	HH-CC	Households – consumer credit over 5 years	0.98	0.78	0.52	0.39	1.00	0.34	0.19	0.54	0.14	0.32	0.93
2221	NFC<1 y	Non-financial corporations – up to 1 year	0.70	0.70	0.50	0.39	0.43	0.89	0.25	0.29	0.15	0.05	0.19
2222	NFC-1-5 y	Non-financial corporations – over 1 and up to 5 years	0.37	0.29	0.26	0.38	0.74	0.69	0.25	0.36	0.23	0.14	0.21
2223	NFC>5 y	Non-financial corporations – over 5 years	0.89	0.47	0.61	0.36	1.00	0.70	0.43	0.42	0.07	0.25	0.18

Note: the numbers in the table are *p*-values of augmented Dickey-Fuller unit root tests with automatic lag selection. NA implies that the data are not available.

thus includes the effects arising from the sovereign-bank nexus. As explained above, diverging cyclical developments may give rise to a divergence in lending rates, due to variation in the compensation for credit risk. Following Geyer et al. (2004) we choose industrial production and the Economic Sentiment Indicator (ESI) as our variables for credit risk. Industrial production measures the state of the business cycle, whereas the Eurostat's ESI measures the current business climate and its future outlook.

3.2. Convergence

Two measures of interest rate convergence, β- and σ-convergence, are commonly used to assess the speed and degree of financial integration. The concept of β-convergence is borrowed from the growth literature and has been applied to the convergence of euro area interest rates by Adam et al. (2002), Baele et al. (2004) and Vajanne (2007) to estimate the speed of convergence. A drawback of using β-convergence is that it does not provide any information on the actual degree of financial market

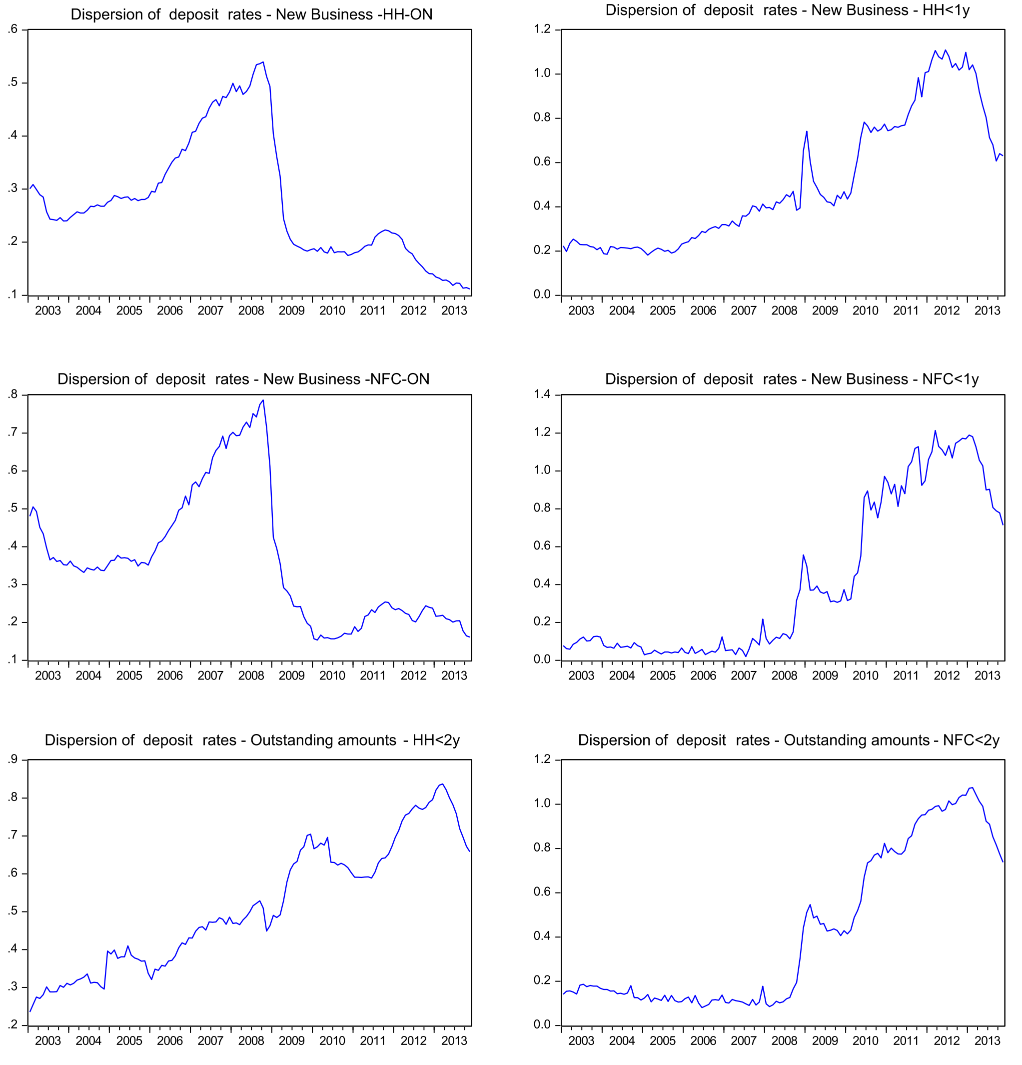

Fig. 1. Cross-sectional dispersion – deposit rates.

Table 2
Estimates of σ-convergence.

	(a)	(b)		(c)		(d)	
	Ratio:	2003:01–2008:08		2003:01–2013:11		2003:01–2013:11	
	2013.11/2006.10	β	Adj. Rsq.	β	Adj. Rsq.	β	Adj. Rsq.
						risk-adjusted	
Deposit rates – new business							
HH-ON	30%	0.0040*	0.81	−0.0014*	0.20	−0.0016*	0.23
HH < 1 y	203%	0.0035*	0.74	0.0069*	0.81	0.0027*	0.59
NFC-ON	32%	0.0055*	0.64	−0.0022*	0.21	−0.0030*	0.30
NFC<1 y	1685%	0.0002	−0.01	0.0097*	0.77	0.0042*	0.79
Deposit rates – outstanding amounts							
HH < 2 y	158%	0.0035*	0.89	0.0042*	0.92	0.0032*	0.83
NFC<2 y	632%	−0.0010*	0.52	0.0082*	0.77	0.0058*	0.78
Lending rates – new business							
HH-HP	142%	−0.0026*	0.74	0.0007*	0.12	−0.0001	−0.01
NFC<1 m	229%	−0.0028*	0.64	0.0077*	0.66	0.0050*	0.69
NFC>1 m	366%	−0.0012*	0.27	0.0084*	0.73	0.0030*	0.49
Lending rates – outstanding amounts							
HH-HP	253%	−0.0062*	0.59	0.0019*	0.16	0.0027*	0.23
HH-CC	112%	−0.0031*	0.13	0.0018*	0.18	0.0014*	0.10
NFC<1 y	232%	−0.0015*	0.62	0.0080*	0.72	0.0063*	0.73
NFC-1-5 y	172%	0.0010*	0.34	0.0028*	0.38	0.0020*	0.36
NFC>5 y	155%	−0.0030*	0.73	0.0011*	0.21	0.0015*	0.34

Note: * = significant at a 5% level.

integration. In contrast, the concept of σ-convergence, measured by the cross-sectional dispersion can be used as an indicator of how far away a retail banking market segment is from being fully integrated. It thus tells us the level of convergence at each point in time. For the purpose of our paper, which is to estimate the impact of risk factors on the level of integration, σ-convergence is the appropriate measure.

In the financial integration literature σ-convergence occurs when the cross-sectional standard deviation of interest rates is trending downwards. Following Vajanne (2007), we run a regression of the cross-sectional standard deviation on a linear time trend:

$$\sigma_{d,t} = \alpha + \beta \text{ time} + \varepsilon_t \tag{3.1}$$

The model in (3.1) is estimated using OLS. In case of σ-convergence, β_2 has a negative sign and is significantly different from zero.

3.3. *State space model*

We take a methodological approach that differs from most empirical studies on pass-through or convergence. Instead of the widely-used co-integration approach, we use a time-varying parameter state space model. This is because our interest is in the immediate impact of sovereign and credit risk on retail rates and because in our view efforts to establish long-run co-integrating relationships in such a brief and volatile crisis period are rather heroic. If "time-dependent negative market sentiments" are an important driver of the euro area's financial fragmentation, as argued by de Grauwe and Ji (2013), a time-varying parameter model would be an appropriate tool to capture their effects.

Our time-varying parameter model is derived from a simple pass-through model. If σ-convergence in retail rates would be complete (i.e. $\sigma_{d,t} = 0$), the pass-through of market to retail rates would be identical across the euro area. Measuring differences in pass-through is thus a related way to investigate the integration in retail banking markets. We start from a simple linear relationship between a bank's deposit rate and the market rate, which can be derived from theoretical models on optimal deposit rate setting (Hutchison and Pennacchi, 1996):

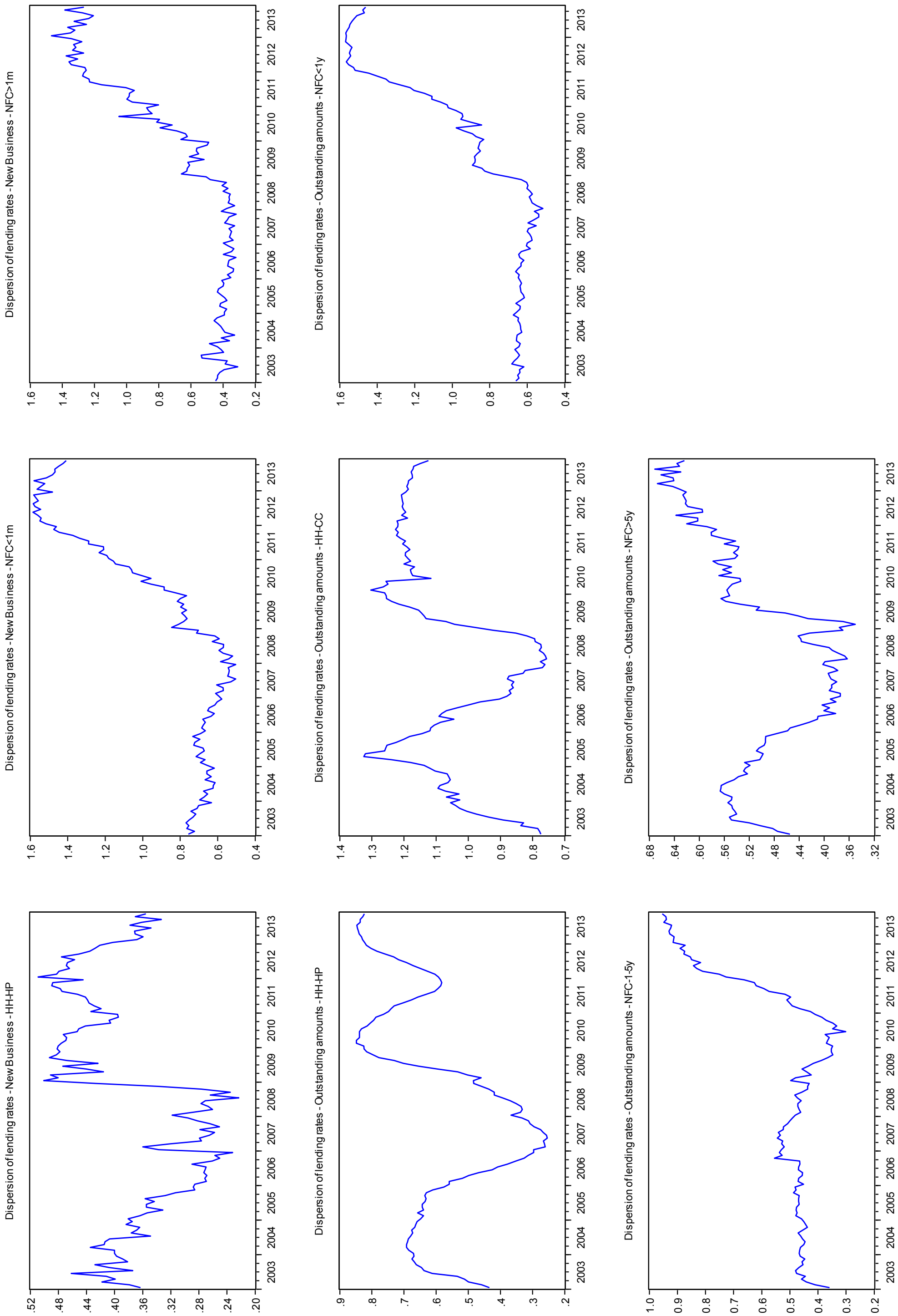

Fig. 2. Cross-sectional dispersion — lending rates.

$$r^*_{d,t} = a + b\, r_t + e_t, \tag{3.2}$$

where $r^*_{d,t}$ is the optimal retail deposit interest rate and r_t is the market rate at time t. Following Vajanne (2009), we use a partial adjustment mechanism of the form:

$$r_{d,t} - r_{d,t-1} = c\left(r^*_{d,t} - r^*_{d,t-1}\right) \quad 3.3)$$

where $r_{d,t}$ is the actual retail deposit interest rate at time t. Combining (3.2) and (3.3) results in the following partial adjustment model:

$$r_{d,t} = \alpha + \beta_1 r_t + \gamma\, r_{d,t-1} + \varepsilon_t. \quad \varepsilon_t \sim \text{idd } N\left(0, \sigma^2_\varepsilon\right) \tag{3.4}$$

In (3.4), the coefficient β_1 measures the short-term pass-through of market rates to deposit rates. The size of β_1 depends on the elasticity of the demand for deposits: the higher β_1, the more responsive

Table 3
Standard deviations of time-varying coefficients – deposit rates.

	New business				Outstanding amounts	
	HH-ON	HH < 1 y	NFC-ON	NFC<1 y	HH < 2 y	NFC<2 y
σ_{v1}, standard deviation of state β_1 (pass-through)						
DE	0.00	0.00	1.97	2.02	0.00	0.89
NL	0.30	0.70	1.24	0.95	0.00	0.00
FI	1.20	0.00	2.62	2.52	0.00	0.70
AT	0.00	0.84	2.36	0.98	0.00	0.13
BE	1.94	0.00	2.67	3.17	0.00	0.65
FR	0.38	0.00	1.45	1.76	0.68	0.00
IT	0.63	3.07	0.48		0.00	0.00
IE	1.13		1.39		0.00	0.00
ES	1.71	0.00	0.86	0.00	0.00	0.00
PT	0.80	1.44	3.21	1.41	0.00	0.00
GR	0.20	0.00	0.58	0.00	0.00	0.00
Average	0.75	0.61	1.71	1.42	0.06	0.22
σ_{v2}, standard deviation of state β_2 (sovereign risk)						
DE	0.26	3.16	0.00	1.16	0.68	0.64
NL	0.17	5.00	1.05	2.72	1.55	2.09
FI	0.32	2.00	0.24	2.37	0.67	0.31
AT	0.36	1.05	0.53	0.62	1.11	0.88
BE	2.04	0.00	0.42	0.84	0.33	0.01
FR	0.00	1.81	0.15	2.83	0.24	0.70
IT	0.18	2.13	0.64		1.06	1.14
IE	0.00		0.57		0.00	0.60
ES	1.79	2.99	0.00	2.09	0.46	0.60
PT	0.12	2.93	0.16	5.48	1.05	2.11
GR	0.14	1.77	0.15	3.54	0.92	1.20
Average	0.49	2.28	0.35	2.41	0.73	0.93
σ_{v3}, standard deviation of state β_3 (credit risk)						
DE	0.01	0.69	0.00	0.00	0.12	0.00
NL	0.00	0.00	0.41	0.00	0.63	0.00
FI	0.00	0.61	0.00	0.00	0.00	0.00
AT	0.00	0.36	0.00	0.00	0.00	0.00
BE	2.07	3.42	0.00	0.14	0.86	1.06
FR	0.15	0.92	0.00	0.00	0.13	0.00
IT	0.00	0.02	0.00		0.00	0.12
IE	0.43		0.00		0.64	0.45
ES	1.99	0.00	0.00	1.17	0.00	0.00
PT	0.00	0.00	0.00	0.00	0.00	0.00
GR	0.00	0.00	0.00	0.00	0.00	0.00
Average	0.42	0.60	0.04	0.15	0.22	0.15

Note: for presentation purposes the standard deviations have been pre-multiplied by 100.

Table 4
Standard deviations of time-varying coefficients – lending rates.

	New business			Outstanding amounts				
	HH-HP	NFC<1 m	NFC>1 m	HH-HP	HH-CC	NFC<1 y	NFC-1-5 y	NFC>5 y
σ_{v1}, standard deviation of state β_1 (pass-through)								
DE	0.45	0.53	0.00	0.00	0.09	0.43	0.47	0.00
NL	2.13	0.00	0.00	0.28	0.00	0.56	0.70	0.51
FI	2.09	0.00	0.00	1.89	2.00	0.70	0.42	0.39
AT	0.00	1.74	1.04	0.00	0.33	1.15	0.17	0.68
BE	1.16	0.00	2.43	0.17	0.00	1.67	0.37	3.92
FR	0.00	0.00	3.38	0.00	0.00	0.00	0.00	0.00
IT	0.24	0.00	0.98	0.00	0.43	0.01	0.15	0.00
IE	2.10	0.00	0.00	2.26	0.00	1.18	0.76	0.00
ES	1.13	0.00	1.60	0.24	0.10	0.00	0.00	0.33
PT	1.95	0.00	0.00	4.04	0.70	0.00	0.00	0.40
GR	3.40	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Average	1.33	0.21	0.86	0.81	0.33	0.52	0.28	0.57
σ_{v2}, standard deviation of state β_2 (sovereign risk)								
DE	0.06	0.00	0.00	0.00	0.22	0.18	0.00	0.09
NL	0.77	2.53	0.00	0.00	0.00	0.37	0.65	0.00
FI	0.78	1.07	3.68	0.97	0.00	0.80	0.03	0.00
AT	0.00	0.00	1.88	0.00	0.00	0.12	0.01	0.15
BE	1.29	0.53	0.36	0.03	0.56	0.31	0.53	3.87
FR	0.07	0.00	0.00	0.37	0.00	0.00	0.00	0.81
IT	1.01	1.57	2.38	0.00	0.12	0.99	0.61	0.00
IE	1.99	4.98	3.81	1.10	0.00	0.84	0.00	0.00
ES	0.69	1.95	4.06	0.27	0.06	0.44	0.34	0.13
PT	1.71	0.93	1.88	4.06	0.00	0.62	0.58	0.31
GR	2.49	1.26	2.69	0.21	1.29	0.23	0.64	0.37
Average	0.99	1.35	1.89	0.64	0.21	0.45	0.31	0.52
σ_{v3}, standard deviation of state β_3 (credit risk)								
DE	0.00	0.55	1.10	0.03	0.00	0.48	0.41	0.29
NL	0.00	0.62	0.44	0.08	0.50	0.53	0.42	0.21
FI	0.48	1.08	0.00	0.00	0.00	0.32	0.17	0.00
AT	0.51	0.55	0.00	0.00	0.00	0.00	0.62	0.00
BE	0.00	0.97	0.98	0.00	0.24	0.00	0.00	3.81
FR	0.00	0.75	1.14	1.51	2.26	0.20	0.44	0.70
IT	0.00	0.00	0.00	0.30	0.00	0.47	0.00	0.26
IE	0.00	1.11	1.69	0.00	0.81	0.32	0.03	0.69
ES	0.25	0.67	0.33	0.00	0.10	0.35	0.33	0.00
PT	0.00	0.00	0.00	4.13	0.24	0.00	0.00	0.00
GR	2.54	2.56	3.66	0.37	1.81	0.46	0.00	0.30
Average	0.34	0.81	0.85	0.58	0.54	0.28	0.22	0.57

Note: for presentation purposes the standard deviations have been pre-multiplied by 100.

deposit rates are to market rates. In contrast to Vajanne (2009), our prime interest is in time-variation and in the effect of sovereign and credit risk on retail rates. We therefore adapt (3.3) to incorporate risk factors and time-varying coefficients, which are modeled as random walks:

$$r_{d,t} = \alpha + \beta_{1t} r_t + \beta_{2t} \mathrm{cds}_t + \beta_{3t} \mathrm{cr}_t + \gamma_{d,i,t-1} + \varepsilon_t \quad \varepsilon_t \sim \mathrm{idd}\ N\left(0, \sigma_\varepsilon^2\right) \tag{3.5}$$

$$\beta_{1,t} = \beta_{1t-1} + \nu_{1t} \quad \nu_{1t} \sim \mathrm{idd}\ N\left(0, \sigma_{\nu 1}^2\right) \tag{3.6}$$

$$\beta_{2,t} = \beta_{2t-1} + \nu_{2t} \quad \nu_{2t} \sim \mathrm{idd}\ N\left(0, \sigma_{\nu 2}^2\right) \tag{3.7}$$

Table 5
Summary of time-varying coefficients.

	Deposit rates						Lending rates							
	New business				Outstanding amounts		New business			Outstanding amounts				
	HH-ON	HH < 1 y	NFC-ON	NFC<1 y	HH < 2 y	NFC<2 y	HH-HP	NFC<1 m	NFC>1 m	HH-HP	HH-CC	NFC<1 y	NFC-1–5 y	NFC>5 y
State 1 (pass-through): pre-post change in mean β_1														
GIIPS	−0.02	0.06	−0.02	0.01	0.00	0.00	0.04	0.00	0.02	−0.01	0.00	−0.02	0.00	0.00
non-GIIPS	0.00	0.00	−0.12	−0.06	−0.01	0.00	0.02	−0.01	0.00	0.00	−0.01	−0.03	0.01	−0.01
State 1 (pass-through): pre-post change in % significant β_1's														
GIIPS	−0.10	0.10	−0.03	0.01	0.06	0.05	0.03	0.03	0.04	0.01	0.05	0.05	0.05	0.05
non-GIIPS	−0.06	0.03	0.03	0.13	0.09	0.15	0.14	0.02	0.08	0.13	0.14	0.15	0.15	0.05
State 2 (sovereign risk): pre-post change in mean β_2														
GIIPS	0.00	0.14	0.01	0.11	0.03	0.09	0.03	0.10	0.08	0.00	−0.01	0.03	0.02	0.01
non-GIIPS	0.00	0.03	−0.01	−0.04	0.00	0.00	0.00	0.01	0.00	0.00	−0.01	−0.01	−0.01	−0.02
State 2 (sovereign risk): pre-post change in % significant β_2's														
GIIPS	0.14	0.75	0.10	0.45	0.63	0.65	0.23	0.58	0.29	0.00	0.01	0.52	0.28	0.24
non-GIIPS	0.11	0.16	0.02	0.03	0.22	0.20	0.02	0.13	0.06	0.00	0.01	0.00	0.00	−0.16
State 3 (credit risk): pre-post change in mean β_3														
GIIPS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
non-GIIPS	0.00	0.00	0.00	−0.01	0.00	0.10	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01
State 3 (credit risk): pre-post change in % significant β_3's														
GIIPS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
non-GIIPS	0.00	0.00	0.00	−0.01	0.00	0.10	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01

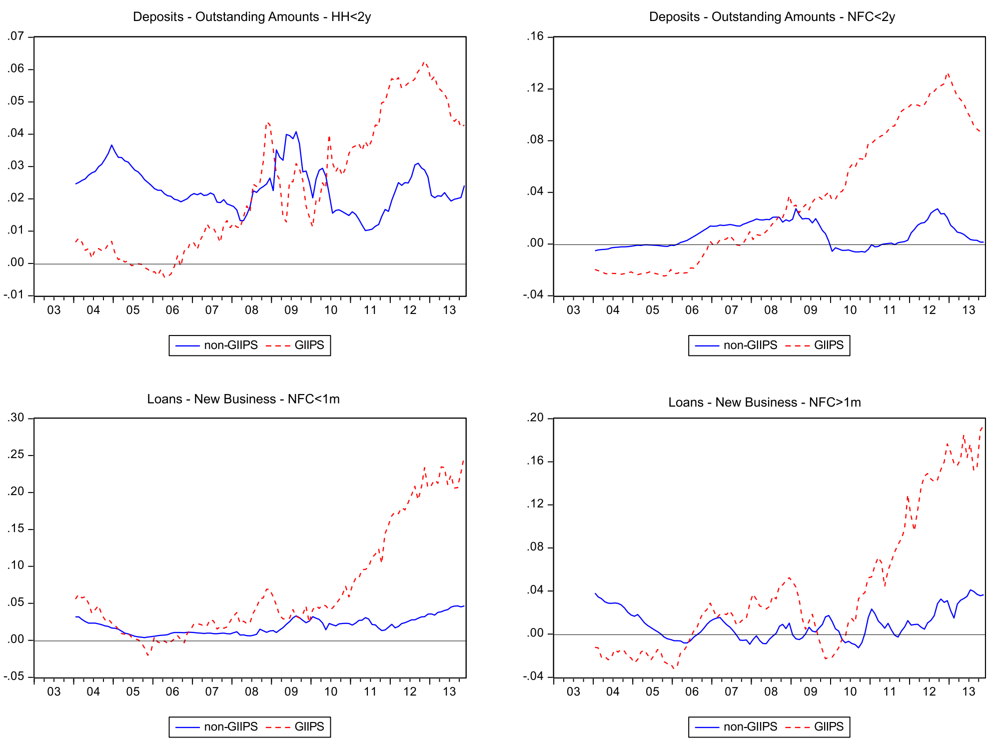

Fig. 3. β_{2t} (sovereign risk) – with industrial production.

$$\beta_{3,t} = \beta_{3t-1} + \nu_{3t} \quad \nu_{3t} \sim \text{idd } N\left(0, \sigma^2_{\nu 3}\right) \tag{3.8}$$

In (3.5), cds_t is the log of a country's CDS rate and cr_t is the log of the credit risk measure (either industrial production of the ESI). We take the log of the risk factors to dampen the effect of extreme values. The coefficients β_{2t} and β_{3t} serve to capture time-dependent effects of sovereign and credit risk on retail rates. In addition, we allow for a time-varying pass-through coefficient, which may capture changes in other determinants of pass-through. Our prime interest is, however, in β_{2t} and β_{3t}. Estimation is done separately for each combination of country and interest rate.

The model in (3.5)–(3.8) can be represented in state space form. The state space methodology, combined with Kalman filter estimation, offers a convenient tool to work with unobservable variables like β_{1t}, β_{2t} and β_{3t}. State space modeling has become widespread in macroeconomics and finance and is introduced in Harvey (1989) and Shumway and Stoffer (2000), among others. State space models distinguish between a measurement equation and a transition equation. The measurement equation describes the observed variable(s) in terms of unobserved state variables, observed explanatory variables and disturbances. The transition equation describes the evolution of the unobserved state variables over time. In our model, equation (3.5) represents the measurement equation and equations (3.6)–(3.8) represent the transition equations. The innovations in the measurement and transition equations (ε_t,ν_{1t},ν_{2t},ν_{3t}) are both independent and identically distributed random variables with respectively variances σ^2_ε, $\sigma^2_{\nu 1}$,$\sigma^2_{\nu 2}$ and $\sigma^2_{\nu 3}$. Estimation of the parameters in (3.5)–(3.8) is done by maximizing the Likelihood-function using the Berndt et al. (1974) algorithm. The Kalman filter is used to produce smoothed estimates of the state variable β_{1t}, β_{2t} and β_{3t}. In a survey of potential estimation strategies for time varying parameter models, Neumann (2003) concludes that the state space model with a random walk specification for the time varying parameter generally performs very well.

4. Results

4.1. Convergence

Figs. 1 and 2 plot the cross-sectional standard deviations of respectively the deposit and lending rates which are used throughout this study. Based on a visual inspection, a number of preliminary observations can be made. First, for the overnight deposit rates on new business, the strong downward movement in the ECB policy rate in the wake of the 2008 Lehman crisis seems to coincide with a convergence in interest rates. This can be explained by the fact that in some countries little or no interest is paid on deposits which can be withdrawn upon demand, to compensate for the cost of the payments system. When in other countries the remuneration declines under the influence of lower policy rates, a natural tendency towards convergence may result. Second, for rates on non-overnight deposits the reverse holds. Their dispersion has increased strongly since the Lehman collapse, both for new business and outstanding amounts. This may imply that the deposit rate stickiness reported in the literature has changed due to the crisis. With regard to the lending rates, Fig. 2 shows that the dispersion in lending rates increased strongly since the crisis for non-financial corporations, but much less so for households. A final observation from Figs. 1 and 2 is that since 2012 the cross-sectional dispersion has dropped noticeably for deposit rates, but not for lending rates. This suggests that the ECB's OMT program may have succeeded in easing banks' problems on the funding side, but may not yet have affected lending conditions.

For the purpose of comparing lending and deposit rates, column (a) in Table 2 shows the ratio of the cross-sectional dispersion at our last data point (November 2013) to the dispersion in October 2006. The latter date was chosen as this is the first pre-crisis date for which the full cross-section, including Belgium, is available. The numbers show that the percentage increase in dispersion from October 2006 to November 2013 was largest for non-overnight deposits for non-financial corporations (a seventeen-

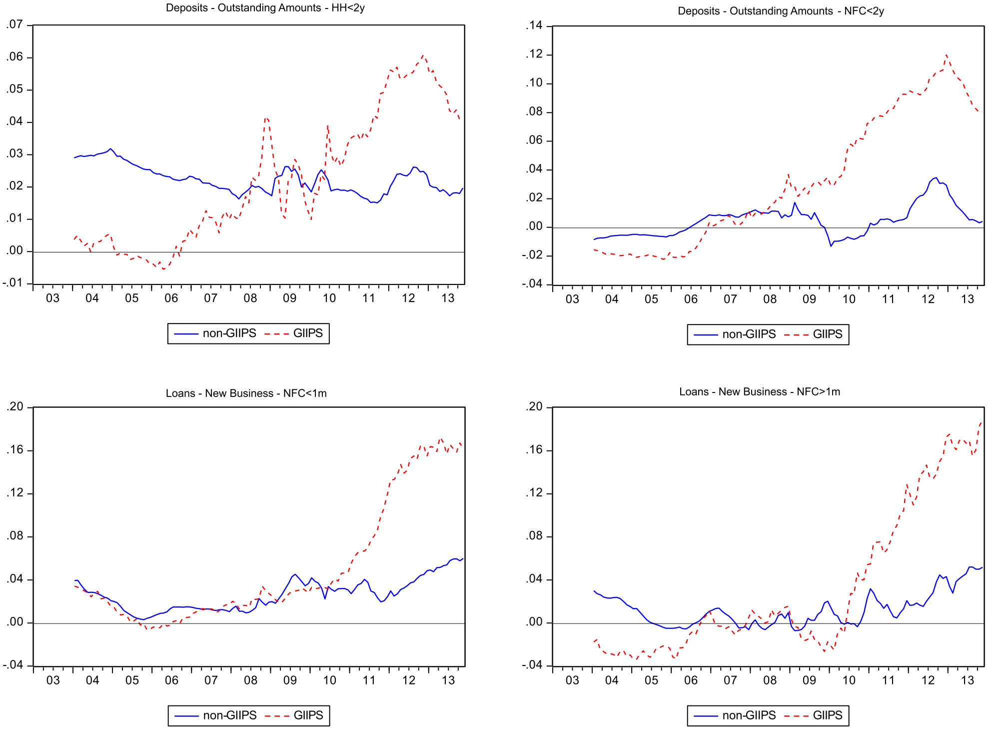

Fig. 4. β_{2t} (sovereign risk) – with economic sentiment indicator.

Table 6
Reduction in cross-sectional dispersion.

	Deposit rates						Lending rates							
	New business				Outstanding amounts		New business			Outstanding amounts				
	HH-ON	HH < 1 y	NFC-ON	NFC<1 y	HH < 2 y	NFC<2 y	HH-HP	NFC<1 m	NFC>1 m	HH-HP	HH-CC	NFC<1 y	NFC-1–5 y	NFC>5 y
A: Credit risk measured by industrial production mean % reduction in dispersion (mean 2008.09–2013.11) from:														
Common credit risk	1.0	−0.8	−1.1	−0.8	−0.4	0.3	0.5	0.5	0.1	0.1	−0.4	−0.3	0.3	0.1
Common sovereign risk	0.4	−16.4	−6.1	−17.9	−4.7	−12.1	−7.7	−9.3	−12.4	1.1	−0.7	−4.5	−0.3	−0.7
No sovereign risk	3.5	−37.5	−7.7	−44.6	−5.6	−25.9	−14.4	−19.7	−23.1	2.5	−1.5	−12.9	2.2	1.0
B: Credit risk measured by Economic Sentiment Indicator % reduction in dispersion (mean 2008.09–2013.11) from:														
Common credit risk	3.0	−0.9	−3.4	0.0	1.8	2.9	3.9	1.4	−5.3	−1.3	1.8	3.0	3.3	2.6
Common sovereign risk	−1.3	−16.7	−3.0	−18.5	−6.1	−12.6	−7.5	−8.7	−15.3	1.4	0.0	−7.2	−1.5	−0.5
No sovereign risk	−7.0	−36.4	−6.4	−41.2	−9.7	−27.2	−20.0	−17.6	−26.5	3.6	−0.1	−17.3	−2.1	2.9

fold increase for new business and a six-fold increase for outstanding amounts). In contrast, the percentage increase in lending rate dispersion was more modest. This shows that by focusing on lending rates, as most empirical studies do, one may miss out on the destabilizing effect of the crisis on the funding side of banks' balance sheets.

Table 2 also reports estimates for (3.1) on σ-convergence, which confirm the graphical evidence. Columns (b) and (c) contain β coefficients for both the pre-crisis period and for the complete sample For the overnight deposit rates, the β coefficient turns from significantly positive pre-crisis to significantly negative, reflecting the convergence following the post-Lehman reduction in policy rates. An opposite movement is evident for the non-overnight deposit rates and the lending rates, for which the β coefficients have become positive and/or larger after the inclusion of post-Lehman data. On the basis of these estimates we may conclude that over the complete sample period σ-convergence has worsened, with the exception of overnight rates, where continuing convergence has been driven largely by the strong decrease of the ECB's policy rate since 2008. Finally, column (d) in Table 2 reports estimates for risk-adjusted interest rates, to which we will return after the discussion of the estimates of the state space model.

4.2. State space estimates

Tables 3 and 4 report the standard deviations of the shocks to the time-varying coefficients in the state space model for respectively deposit and lending rates. The estimations include industrial production as credit risk measure. The results show a wide cross-country and cross-interest rate variation in $\sigma_{\nu1}$, $\sigma_{\nu2}$ and $\sigma_{\nu3}$. Nonetheless, a few observations can be made. For both deposit and lending rates, time variation is highest for β_{2t}, which measures the effect of sovereign risk. Parameter $\sigma_{\nu2}$ is especially high for the new business non-overnight deposit rates and for the new business lending rates over € 1 million. In contrast, β_{2t} shows low time variation for overnight deposit rates and for lending rates for outstanding amounts. The time-variation in β_{3t}, the coefficient for credit risk, is much lower for deposit rates than for lending rates. This fits with the fact that credit risk primarily affects lending rates and that deposit rates are at best indirectly affected via a reduction in depositor confidence. For β_{3t}, the new business lending rates for loans to non-financial corporations over € 1 million show the strongest time variation. Parameter $\sigma_{\nu1}$, measuring the time-variation in the pass-through coefficient of market to retail rates, is on average smaller than $\sigma_{\nu2}$, but higher than $\sigma_{\nu3}$.

Table 5 summarizes the information on β_{1t}, β_{2t} and β_{3t}, using the estimates with industrial production as credit risk measure. The presentation of the results focuses on the changes in the magnitude and the significance of the three β's, when we compare the post-Lehman period with the pre-crisis sample. The information is condensed by presenting for each interest rate the pre-post change in the mean β. This change is defined as the mean β over the period 2008.9–2013.11 minus the mean β over the period 2004.1–2008.08. Out of space considerations, the information is further condensed by constructing two country groups: the GIIPS countries (Greece, Ireland, Italy, Portugal and Spain) and the non-GIIPS euro area countries. This grouping is based both on the well-known differences in sovereign and credit risk between these groups and on an inspection of the individual country β estimates (which are available upon request). As an example, comparing the two subsamples the mean β_{2t} for new business lending rates for non-financial corporations (loans over € 1 million) increased by 0.08 for the GIIPS group. For the non-GIIPS group, the corresponding change was nil.

In order to summarize changes in the significance of the time-varying β's, Table 5 also reports the pre-post change in the percentage of data points for which a β is significant at a 5% level. For the same example as above, the percentage data points in the subsample for which β_{2t} was significant increased by 29 percentage points for the GIIPS group compared to 6 percentage points for the non-GIIPS group.

The biggest pre-post changes in the magnitude and the significance of the β's are concentrated in the center of Table 5 and relate to the impact of sovereign risk on GIIPS retail rates. The contrast with credit risk, where the pre-post changes are negligible, is striking. Changes in β_{2t} are especially large for new business non-overnight deposit rates and new business lending rates for non-financial corporations, while the pre-post increase in the significance of β_{2t} is more widespread among retail rates. In order to visualize the differential impact of sovereign risk on GIIPS and non-GIIPS retail rates, Fig. 3 presents the smoothed estimates of β_{2t} for four selected retail rates. The top graphs show a strong divergence of β_{2t} between the GIIPS and the non-GIIPS group for deposit rates on outstanding amounts. Though the change in mean β_{2t} is larger for new business non-overnight deposit rates, these graphs serve to illustrate that the sovereign risk factor has had on impact on deposit pricing for the whole client base of depositors. The lower graphs show the impact of sovereign tensions on new business lending rates to non-financial corporations. Again the divergence between the two groups is noteworthy.

As a robustness check, all estimations have been redone using the ESI as an alternative credit risk measure. The results are comparable, but go largely unreported. Fig. 4 shows that replacing industrial production by the ESI yields a similar divergence in the β_{2t} coefficients.

Our final step is to investigate the impact of the risk factors on σ-convergence. To this end, we have made a number of adjustments to equation (3.5). To measure retail rates in the absence of divergences in credit risk we have adjusted the retail rates by subtracting the term $\beta_{3t}\, cr_t$ from (3.5) and adding the term $\beta_{3t}\, cr_{tDE}$, where cr_{tDE} is the German credit risk measure. This adjustment has the effect of imposing the German pattern of industrial production on each euro area country and thus eliminating cyclical divergences. For each interest rate category, we next calculate the cross-sectional dispersion for the adjusted rates and compare these to the dispersion based on the actual retail rates. The average percentage deviation between these two convergences measures are reported in the row headed "common credit risk". This row affirms that over the post-Lehman period the quantitative impact of credit risk has been negligible. Absent cyclical divergences, σ-convergence would have been very similar to the original estimate of σ-convergence. A further adjustment is done by equalizing sovereign risk to German levels. In the same vein as before, the adjustment term is in this case $-\beta_{2t}\, cds_t + \beta_{2t}\, cds_{tDE}$, where cds_{tDE} is the German sovereign risk measure. Again the dispersion of the adjusted retail rates is calculated and compared to the non-adjusted dispersion. The percentage deviation is reported in Table 6 under the row heading "common sovereign risk". The values show a sizable reduction in dispersion, up to 18%, for a number of retail rates. However, these adjusted retail rates still include the effect of the divergences in the β_{2t} estimates, see Figs. 3 and 4. To eliminate this final source of differences across euro area countries due to sovereign risk, as a last adjustment we substract the $\beta_{2t}\, cds_t$ term altogether from the retail rates (thus without replacing it with $\beta_{2t}\, cds_{tDE}$). This yields our final set of adjusted rates for which we calculate the dispersion. The percentage deviation from the original dispersion is reported under the row heading "no sovereign risk". Table 6 shows that filtering out the sovereign risk factor in this way leads to a substantial reduction in the cross-sectional dispersion of euro area retail rates, up to a maximum of 45%. A comparison of Table 6 to column (a) in Table 2 shows that in general the percentage reduction in dispersion is highest for those interest rates that showed the strongest increase in dispersion post-crisis. As a robustness check, panel B in Table 6 reports the results when we replace industrial production by the ESI. It can be seen that this change in credit risk measure has no substantial effect on the results.

We finally return to the σ-convergence regressions in Table 2. Using the final set of adjusted retail rates ("no sovereign risk"), column (d) shows that the coefficients in the convergence regressions are still significantly positive for most retail rates, but their size is much smaller than in column (c). In other words, absent sovereign tensions, σ-convergence would still have witnessed a post-Lehman reversal, but to a much lesser degree. This implies that while this paper identifies sovereign tensions as a major factor in financial fragmentation, it cannot provide a complete explanation of the increase in retail rate dispersion. Other confounding factors, possibly related to changes in the regulatory environment, may also have played a role. In our model, these factors are not identified and discussed separately and could lead to time-variation in the pass-through coefficient.

5. Conclusions

In this paper we have explored the impact of sovereign and credit risk on the reversal in bank retail interest rate convergence during the recent crisis period. To this end, we have employed a state space model that incorporates a time-varying impact of these risk factors on euro area deposit and lending rates. In contrast to most previous studies in the field, we have included deposit rates in our investigation. Our main finding is that the heterogeneity in sovereign risk across euro area countries accounts for a large part of the post-crisis reversal in σ-convergence of various lending and deposit rates during the crisis. In contrast, we find that the impact of the increased heterogeneity in credit risk on bank retail rates is negligible. We also find that the impact of sovereign risk on non-overnight deposit rates is stronger than that on lending rates. The inclusion of deposit rates in our analysis thus has revealed the extent of the disruption that sovereign tensions can create to banks' funding.

We think that these findings have policy relevance. Credit risk can be viewed as the "bread and butter" of the banking industry. Any regional variation in the level of credit risk across a currency union would not automatically trigger central bank intervention. The sovereign tensions within EMU and the related sovereign-banking "doom loop" are, however, of a different nature. They have exposed structural weaknesses in the euro area's institutional setup and, as a by-product, thwarted interest rate convergence in the euro area. If sovereign risk is indeed a major factor contributing to the increase in financial fragmentation, as our findings suggest, policy efforts to reduce the effect of sovereign tensions on bank retail rates are called for.

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