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THE INTEREST RATE SENSITIVITY OF LUXEMBOURG BOND FUNDS: RESULTS FROM A TIME-VARYING MODEL

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THE INTEREST RATE SENSITIVITY OF LUXEMBOURG BOND FUNDS: RESULTS FROM A TIME-VARYING MODEL[*]

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Abstract

The primary aim of this work is to study the sensitivity of Luxembourg bond funds to interest rate movements. For this purpose, the dataset compiled at the Banque centrale du Luxembourg (BCL) since December 2008 is used to analyse the balance sheet composition of Luxembourg bond funds and to measure the interest rate exposure of their bond portfolio. An econometric model with time-varying parameters is then estimated on monthly data over the sample 2008:1-2014:6 to analyse the evolution of the interest rate sensitivity of the Net Asset Value (NAV) of Luxembourg bond funds. The main findings of the study are the following. At the end of the period under review, Luxembourg bond funds have lengthened the residual maturity and the duration of their portfolio, which have returned to a similar level as the one observed in December 2008. This evolution, which points toward a search-for-yield behaviour in a low interest rate environment, suggests that Luxembourg bond funds have recently become more sensitive to fixed-income market developments. According to the level of the parameter estimate obtained with the Kalman filter at the end of the sample, a 100 basis points rise in long term interest rates on the sovereign bond markets associated with an additional 100 basis points rise in the risk premium on the high-yield bond markets would materialise approximately into a 10% decrease in the NAV of Luxembourg bond funds.

Keywords: Bond funds, risk analysis, security-by-security reporting, Kalman filter.

JEL classification: C32, C81, F30, G11, G23.

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Résumé non-technique

Après avoir enregistré une baisse en 2007-2008, la Valeur Nette d'Inventaire (VNI) des OPC obligataires domiciliés au Luxembourg a significativement augmenté pour atteindre près de 1000 milliards d'euros en juin 2014. Cette évolution s'explique par le niveau élevé des émissions nettes de parts, qui a bénéficié du contexte d'aversion au risque, et par d'importants effets de revalorisation, induits par le niveau historiquement bas des taux d'intérêt à long terme.

Cet environnement de taux d'intérêt faibles, alimenté par les mesures conventionnelles et non conventionnelles des principales banques centrales, s'est accompagné d'une recherche de rendement de la part des investisseurs qui s'est propagée à l'ensemble des marchés obligataires. Cependant, dans le contexte actuel, la hausse des taux d'intérêt à long terme et son corollaire, le changement d'attitude des investisseurs vis-à-vis des marchés de titres à revenu fixe, représente un facteur de risque potentiel pour l'industrie des OPC obligataires luxembourgeois.

Ce cahier d'études s'attache à analyser la sensibilité de la VNI des OPC obligataires luxembourgeois aux mouvements des taux d'intérêt à long terme, en insistant notamment sur les évolutions qui se sont produites depuis le début de la crise financière. Dans cette perspective, les données compilées par la Banque centrale du Luxembourg (BCL) depuis le mois de décembre 2008 sont utilisées pour analyser la composition du bilan des OPC obligataires luxembourgeois et pour mesurer la duration de leur portefeuille de titres. Un modèle économétrique avec des paramètres variables dans le temps est ensuite estimé sur la période 2008:1 à 2014:6 pour analyser l'évolution de la sensibilité de la VNI des OPC obligataires luxembourgeois aux mouvements des taux d'intérêt à long terme.

Les principaux résultats obtenus dans cette étude sont les suivants. À la fin de la période sous revue, les OPC obligataires luxembourgeois ont allongé la maturité résiduelle et la duration de leur portefeuille de titres, qui se sont ainsi rétablies à un niveau proche de celui qui prévalait au mois de décembre 2008. Cette évolution, qui suggère un comportement de recherche de rendement dans un contexte de taux d'intérêt faibles, implique que la sensibilité des OPC obligataires luxembourgeois aux développements de marché a récemment augmenté. Selon les estimations obtenues en fin de période à partir du filtre de Kalman, et dans une perspective similaire au scénario adopté par le FMI dans son rapport d'octobre 2014 sur la stabilité financière dans le monde, une hausse de 100 points de base des taux d'intérêt à long terme sur les obligations d'Etat assortie d'une revalorisation de 100 points de base des primes de risque sur les obligations à haut rendement pourraient se matérialiser par une baisse de près de 10% de la VNI des OPC obligataires luxembourgeois.

Non-technical summary

After the decline registered in 2007-2008, the Net Asset Value (NAV) of Luxembourg bond funds has significantly increased to reach a new record high of about EUR 1000 billion in June 2014. This evolution has been supported by the net issuance of shares, which has benefited from the low risk aversion environment, and by important revaluation effects, arising from the historically low level of interest rates.

This low interest rate environment, driven by the conventional and unconventional measures of the major central banks, has induced a search-for-yield behaviour which has been spread across most of the bond markets around the world. However, in the current context, the rise in long term interest rates and its corollary, the change in the investors' behaviour for fixed-income products may potentially constitute a risk factor for the Luxembourg bond funds industry.

The aim of this paper is to investigate the sensitivity of the NAV of Luxembourg bond funds to interest rate movements, focusing in particular on the developments observed during the crisis period. For this purpose, the data compiled at the Banque centrale du Luxembourg (BCL) since December 2008 are used to analyse the composition of the balance sheet of Luxembourg bond funds and to measure the duration of their bond portfolio. An econometric model with time-varying parameters is then estimated over the period 2008:1-2014:6 to analyse the evolution of the interest rate sensitivity of the NAV of Luxembourg bond funds.

The main results of this study are the following. At the end of the period under review, Luxembourg bond funds have lengthened the residual maturity and the duration of their portfolio, which have returned to a similar level as the one observed in December 2008. This evolution, which points toward a search-for-yield behaviour in a low interest rate environment, implies that the sensitivity of Luxembourg bond funds to market developments has recently increased. According to the estimate obtained at the end of the sample with the Kalman filter, and following the scenario sketched out by the IMF in its October 2014 Global Financial Stability Report, a 100 basis points rise in long term interest rates on the sovereign bond markets associated with an additional 100 basis points rise in the risk premium on the high-yield bond markets would materialise approximately into a 10% decrease in the NAV of Luxembourg bond funds.

1. Introduction

After the decline registered in 2007-2008, the Net Asset Value[1] (NAV) of Luxembourg bond funds has significantly increased to reach a new record high of about EUR 1000 billion in June 2014. This evolution has been supported by the net issuance of shares, which has benefited from the low risk aversion environment, and by important revaluation effects, as the monetary policy stimulus provided by the major central banks has driven long term interest rates to historically low levels, both at the short and long end of the yield curve.

This low interest rate environment has encouraged additional risk-taking through a search-for-yield behaviour which has been spread across most of the fixed-income markets all around the world (BIS, 2014). However, as mentioned by the IMF (2014), at the current juncture, the process of normalisation of monetary policy in the US could trigger a significant disruption in global markets, thereby generating a sharp reversal of risk appetite and a concomitant broad-based market repricing and interest rate adjustment, as illustrated by the market tantrum that followed the announcement of the Fed tapering in May 2013. As a matter of fact, the European Systemic Risk Board (ESRB, 2014) considers the *"increase in global bond yields amplified by an abrupt reversal in risk assessment, especially towards emerging market economies"* as the most important systemic risk concern for the forthcoming period[2].

Thus, the current financial environment may have important implications for Luxembourg, given that the activity of the fixed-income funds industry is highly sensitive to developments in bond yields and, also, to monetary policy decisions. As outlined in the last IMF report, *"[m]onetary policy tightening has been a key trigger for losses in fixed-income markets in the past, resulting in highly persistent outflows as policy normalizes. [...]. With interest rates low and credit spreads having narrowed as the search-for-yield intensified, [...] the probability of losses to fixed-income portfolios has increased substantially in the event of normalization of monetary policy and a rise in rates"* (IMF, 2014, p.40). To date, however, the recent Fed declarations and the implementation of further unconventional measures by the ECB have somehow postponed the expectations of a changing interest rate environment, thus maintaining this search-for-yield behaviour and delaying future adjustments for financial markets and fixed-income mutual funds.

Against this background, the aim of this work is to investigate the interest rate sensitivity of the NAV of Luxembourg bond funds and its evolution over time, focusing in particular on the developments observed during the crisis period. For this purpose, the detailed information provided by the database compiled at the Banque centrale du Luxembourg (BCL) since December 2008 is exploited to analyse the balance sheet composition of fixed-income funds and to deliver a preliminary measure of the duration of their bond portfolio. An econometric model aimed at replicating the NAV dynamics of Luxembourg bond funds is then estimated with the Kalman filter over the period 2008:1-2014:6 in

[1] The Net Asset Value (NAV) is defined as the value of a fund's assets less the value of its liabilities.
[2] A similar concern is emphasized in the ECB Financial Stability Review (ECB, 2014b).

order to provide an empirical framework for analysing the time-varying sensitivity of the NAV to movements in market interest rates.

The main findings of the study are the following: (i) In comparison with Luxembourg equity funds, the bulk of the NAV evolution of Luxembourg bond funds is driven by the net issuance of shares, which account for about 55% of its monthly fluctuations in absolute terms for the period under review. In addition, in conformity with the stylized facts pointed out in the existing literature, the net issuance of shares into Luxembourg bond funds display a high persistence, which means that they should be highly predictable, at least in normal times. (ii) A breakdown of the bond portfolio indicates the existence of a regional bias, with a large proportion of securities held by Luxembourg bond funds being denominated in euro and issued by euro area residents. However, during the crisis period, Luxembourg bond funds have increased their exposure to the US and emerging markets, and have consequently become more sensitive to exchange rate fluctuations, in particular vis-à-vis the US Dollar. (iii) At the end of the period under review, Luxembourg bond funds have lengthened the residual maturity and the duration of their portfolio, which have returned to a similar level as the one observed in December 2008. This evolution, which points toward a search for yield behaviour in a low interest rate environment, implies that the interest rate sensitivity of Luxembourg bond funds has recently increased. (iv) According to the estimate obtained at the end of the sample with the Kalman filter, and following the scenario sketched out by the IMF in its October 2014 Global Financial Stability Report, a 100 basis points rise in long term interest rates on the sovereign bond markets associated with an additional 100 basis points rise in the risk premium on the high-yield bond markets would materialise approximately into a 10% decrease in the NAV of Luxembourg bond funds.

This paper, which is the first macroeconomic study to estimate and analyse the evolution of the interest rate sensitivity of the NAV of Luxembourg bond funds, is related to the empirical literature investigating the determinants of the performance and cash flows of bond funds using benchmark indices and multifactor models[3].

In a seminal paper, Blake et al. (1993) study the performance of bond funds using a Capital Asset Pricing Model (CAPM) with a specific single benchmark index selected on the basis of the investment policy of the fund, as well as a multiple bond index model that captures the sensitivity of the funds to different risk-based and maturity-based indices. In the same vein, Detzler (1999) investigates the risk and return characteristics of global bond mutual funds in an international context, using a wide range of country-level benchmarks and investigating at the same time the impact of exchange rate movements on the performance of actively managed portfolios. Elton et al. (1995) apply the relative pricing (APT) model to evaluate bond funds performance, adding unexpected changes in macroeconomic variables to the baseline specification described above. Huij and Derwall (2008) provide evidence of persistence in the relative performance of bond funds, using alternative multifactor models such as the ones proposed in Blake et al. (1993) and Elton et al. (1995).

[3] For a similar study on Luxembourg equity funds, see Kultur and Morhs (2014).

Another strand of the literature analyses the pattern and determinants of net inflows into bond funds. Wharter (1995) and Remolona et al. (1997) emphasize the persistence of transactions into bond funds and their correlation with market returns. Zhao (2005) studies the determinants of flows into retail bond funds using microeconomic characteristics at the fund level and provides some evidence of return chasing performance among investors. Ferson and Kim (2012) and Chen and Qin (2014) respectively use a factor analysis and a multifactor model to investigate the sensitivity of flows to the financial and macroeconomic environment, pointing to the importance of flight-to-safety behaviours for bond funds. Ferreira et al. (2012) discuss the convexity of the flow-performance relationship on a cross-country basis and its implication for the risk-taking behaviour of mutual fund managers.

The structure of the paper is the following. The second section draws some stylized facts concerning the determinants of the NAV evolution in the medium run and the balance sheet composition of the Luxembourg bond funds industry in order to provide some background for the conceptual framework of the empirical analysis. The residual maturity and the duration of the bond portfolio are also addressed in this section, using the Security-by-Security reporting to the BCL. The third section introduces the econometric model, which relates the NAV dynamics to the long term interest rate developments in the sovereign and high-yield bond markets and the EUR/USD exchange rate movements. The empirical results obtained with the Kalman filter are then discussed, emphasizing the time-varying interest rate sensitivity of Luxembourg bond funds. Finally, the last section concludes and identifies questions for further analysis on this topic.

2. Luxembourg bond funds: Data and stylized facts

After the decline registered in 2007-2008, the NAV of Luxembourg bond funds has significantly increased to reach a new record high of about EUR 1000 billion in June 2014. This evolution has been supported by the net issuance of shares, which has benefited from the low risk aversion environment, and by important revaluation effects as the monetary policy stimulus provided by the major central banks has driven benchmark government bond yields to historically low levels, exerting at the same time important spillover effects on other fixed-income markets.

In order to set up the background for the empirical analysis, this section provides some stylized facts regarding the developments in the activity of Luxembourg bond funds, with a special focus on the crisis period. The macroeconomic and financial environment is first presented to introduce the main determinants of the NAV evolution in the medium run and to discuss the importance of monetary policy decisions on long term interest rate developments. The composition of the balance sheet of Luxembourg bond funds is then analysed using the BCL database, which provides detailed information with respect to the geographical, currency and interest rate exposures of the bond portfolio[4].

[4] The data used in this study are mainly based on the statistical balance sheets and the security-by-security reporting of investment funds. See http://www.bcl.lu/en/reporting/Investment_funds/index.html for the details of the regulatory reporting of the BCL.

2.1 The medium term evolution of the NAV

From an accounting point of view, the change in the NAV between period t-1 and t can be written as:

(1) $$NAV_t - NAV_{t-1} = TRA_t + VAL_t,$$

where TRA_t corresponds to the net issuance of shares (i.e. transactions), and VAL_t to the revaluation of existing shares.

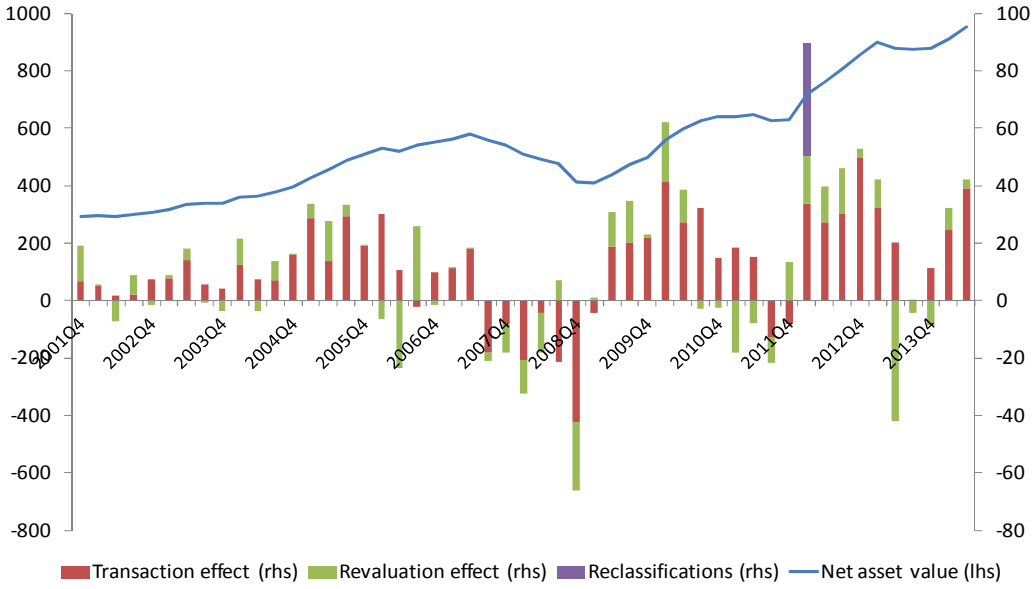
Accordingly, Figure 1 depicts the evolution of the NAV of Luxembourg bond funds and its decomposition into a transaction and a revaluation effect since the end of December 2001[5]. The NAV evolution of bond funds is mainly influenced by transactions, which account for about 55% of its monthly fluctuations in absolute terms for the period under review[6]. This stylized fact is not surprising as the revaluation effect of fixed-income products is related to the evolution of interest rates which are less volatile than stock market prices, in particular at the longer end of the term structure[7].

[5] The database for the NAV has been compiled from the O1.1 reports of the CSSF which are available at a monthly frequency. For the purpose of this study, exchange-traded funds (ETFs) and funds of funds have been retrieved from the sample. This restricted subset of bond funds has been retained as a reference base to extract the subsequent data presented in this paper. Most of the funds have an umbrella-type, open-ended structure and are UCITS compliant. Summary information and statistics on Luxembourg bond funds are displayed in the Appendix.

[6] In comparison, the proportion for Luxembourg equity funds between the transaction and the revaluation effect is respectively 23% and 77% over the same period.

[7] As a matter of fact, the net issuance of shares was quite similar on average across equity and bond funds prior to the crisis. During the crisis period, bond funds have overall benefited from the reduced risk appetite of investors. While some signs of "great rotation" out of bond funds and into equity funds were perceptible in the course of 2013, they disappeared during the first half of 2014, with the registered transactions being elevated for each category of funds.

Figure 1: Statistical decomposition of the NAV evolution[8] (billion euros)

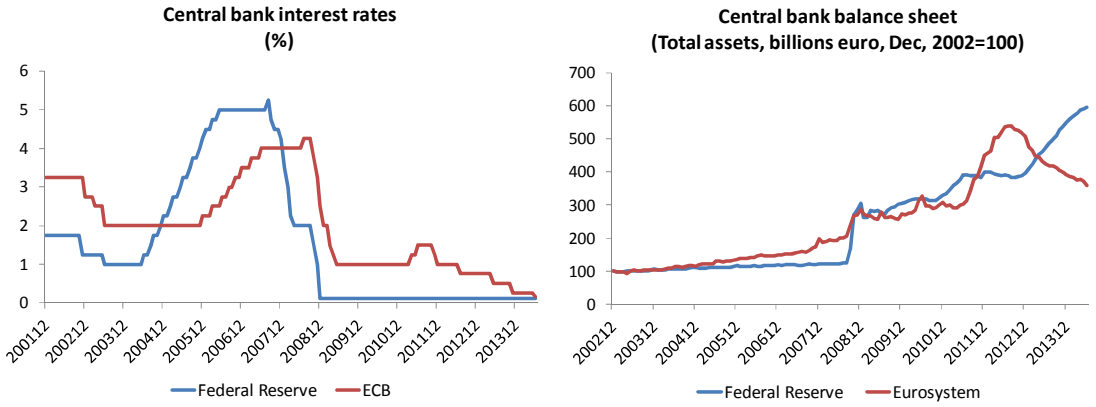


Source: CSSF

Overall, transactions into bond funds are positively correlated with the performance of fixed income markets which, in turn, is inversely related to movements in short- and long-term interest rates. Consequently, the monetary policy environment plays a major role in the NAV dynamics of Luxembourg bond funds (ICI, 2014). This is particularly true for the crisis period as the sensitivity of asset prices and investors' behaviour to unconventional measures has been particularly acute (ECB, 2014a). Accordingly, Figures 2 and 3 summarize the monetary and financial environment that has driven the NAV evolution of Luxembourg bond funds. Figure 2 displays the monetary policy developments concerning the interest rates and aggregate balance sheets of two major central banks. Figure 3 illustrates the financial market environment through the long term interest rate developments in the 10-year sovereign bond and the high-yield corporate bond markets.

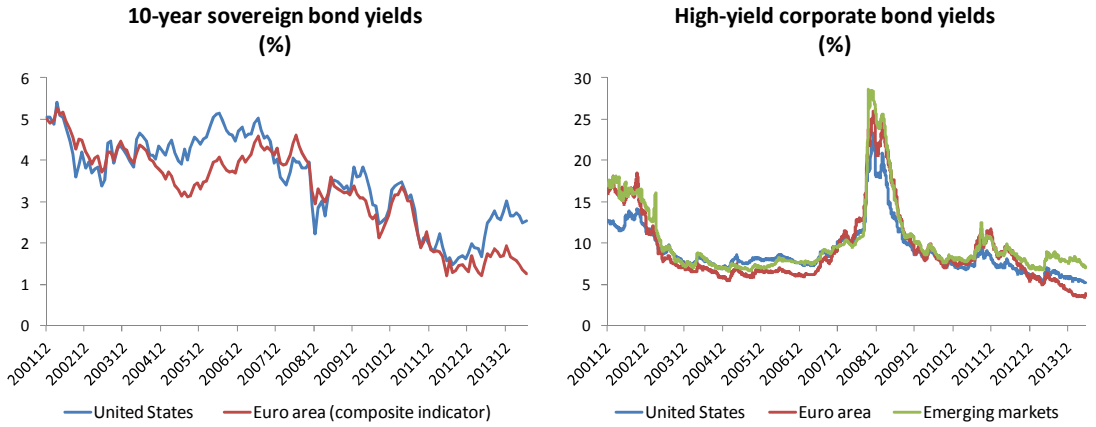
[8] In January 2012, the reclassification of some money market funds into bond funds translated into an increase in the NAV of about EUR 40 billion.

Figure 2: Monetary policy environment



Source: Federal Reserve, ECB

Figure 3: Fixed-income market environment



Source: FRED database[9]*, Bloomberg*

At the beginning of the period under review, falling interest rates in fixed income markets supported investor demand for Luxembourg bond funds. However, as the economy began to pick up, monetary policy interest rates started to rise, thus weighing on the performance of bond funds. At the same time, the revival of stock prices supported investor demand for equity funds. While this environment should have reduced the

[9] The high-yield corporate bond yields come from the FRED database provided by the Federal Reserve Bank of St. Louis. The series for the US, the euro area and the emerging markets respectively correspond to the BofA Merrill Lynch US High Yield Master II Effective Yield, the BofA Merrill Lynch Euro High Yield Index Effective Yield, and the BofA Merrill Lynch High Yield Emerging Markets Corporate Plus Sub-Index Effective Yield.

demand for fixed income products, investors increased significantly their holdings of shares in Luxembourg bond funds over this period. Beyond the cyclical economic factors driving the net issuance of shares, structural factors may explain this evolution: (a) the ageing of the population, with the retired people from the baby boom generation increasingly allocating their investments to fixed-income securities (ICI, 2014), (b) the rise in risk aversion of investors, in particular households, following the stock market turbulence associated to the dotcom bubble (ICI, 2014) and, in the case of Luxembourg, (c) the growing establishment of new bond funds and the improvement in the distribution channels.

Net inflows into bond funds started to slow down in 2006 but remained positive until the disruptions in financial markets that began in August 2007 and intensified throughout 2008, peaking in September with the failure of Lehman Brothers. During this period of uncertainty, bond funds registered substantial net outflows, with investors withdrawing EUR 89 billion from their bond fund holdings in 2008. At the same time, the global reassessment of risks in the financial system translated into a sharp widening of corporate bond spreads on most rating categories, generating significant negative valuation effects on bond portfolios. The crisis prompted the Federal Reserve and the ECB to lower their interest rate over the course of 2008/2009 to a level close to zero and to engage into several programs aimed at shoring up market confidence and adding liquidity in the financial system. In particular, the ECB implemented a fixed-rate full allotment procedure in October 2008, while the US Federal Reserve announced plans in the field of Quantitative Easing (QE) and adopted a forward guidance strategy on policy rates in March 2009. These unconventional measures translated into an increase in the size of the central banks' balance sheets and contributed to the lowering of sovereign long-term interest rates, exerting at the same time important spillover effects on other fixed-income markets.

From the second quarter of 2009, the easing of tensions in the financial system and the improvement in the macroeconomic outlook revived net inflows into bond funds along substantial positive valuation effects. In addition, low short-term interest rates and the relatively steep yield curve likely encouraged some investors to switch from money market funds into bond funds. The overall decline in risk appetite following the crisis also boosted flows into bond funds at the detriment of equity funds. However, this movement came to a halt in Spring 2010 as tensions in the financial markets resumed with the euro area sovereign debt crisis. Risk aversion and flight-to-safety behaviours translated into a decrease in AAA long-term euro area and US government bond yields and an increase in non-investment grade sovereign bonds and corporate bonds yields, thereby generating an overall negative valuation effect. The pace of inflows into bond funds, which was quite strong through the first nine months of 2010, slowed down to become negative in the second part of 2011, that is during the peak of the sovereign debt crisis.

The ECB's three-year LTROs in December 2011 and February 2012 alleviated strains in the financial sector and provided broader support to market confidence and, therefore, to the demand for bond funds. The commitment of Mario Draghi to support the euro

whatever it takes marked a turnaround for financial markets and investors sentiment. In September 2012, the Fed announced further quantitative easing programs while the ECB decided on a major initiative in the form of Outright Monetary Transactions (OMT). The ensuing fall in long term interest rates, in particular for peripheral countries and non-investment grade corporate bonds, translated into positive valuation effects along substantial net inflows, investors adding a record EUR 141 billion to their bond fund holdings during the course of the year. In a context of historically low long term interest rates on major sovereign bond markets and investors' low risk aversion, prices of most corporate bonds, particularly those rated BBB and below, continued to rise throughout 2012, as a result of an increasing search-for-yield behaviour that illustrated to some extent the risk-taking channel of monetary policy (BIS, 2014). In this context, investor demand for corporate bond funds, global bond funds, emerging markets bond funds and high-yield bond funds has been particularly sustained, thereby contributing to the elevated net inflows during this period (Boston Consulting Group, 2013).

In 2013, concerns about the course of monetary policy played a central role as demonstrated by the May-June bond market turbulence triggered by the announcement by the Federal Reserve of a possible scaling back in the pace of asset purchases and end of its QE program, which translated into a sell-off and a sharp fall in bond prices all around the world, in particular in the emerging markets. These developments generated substantial negative valuation effects and a slowing down in the demand for Luxembourg bond funds in the second half of the year, after the net outflows registered in June. In December, the Fed announced it would steadily reduce asset purchases beginning in January 2014 and likely end then in October 2014. However, the Fed communication strategy contributed to calm down the market reaction and investors quickly shrugged off the tapering scare. As benchmark yields remained low by historical standards, the search-for-yield resumed, translating into a further compression of credit spreads in government and corporate bond markets, while some rebalancing of portfolios from emerging to advanced economies took place at the same time (ECB, 2014a). Although some investors worried about a possible downturn in fixed income markets, Luxembourg bond funds registered substantial net inflows in the first half of 2014, which were likely supported by the announcement of additional unconventional measures by the ECB. This stood in contrast with the first half of 2013 when big outflows of cash largely found their way into equity funds, rather than bond funds, in what was termed as the "great rotation".

2.2 The balance sheet composition

The harmonised reporting introduced by the Eurosystem in 2009 provides detailed information regarding the composition of the balance sheet of investment funds, in particular with respect to the geographical, currency and maturity breakdown of the asset portfolio. Thus, the available statistics compiled by the BCL allow a better understanding of the activity of Luxembourg bond funds and its developments during the crisis period.

The evolution of the aggregate balance sheet of Luxembourg bond funds since the end of 2008 is displayed in Table 1. As expected, bond funds mostly invest in securities other than shares, which constitute the bulk of their asset portfolio. At the end of June 2014,

this category amounted to EUR 882.2 billion out of a total asset of EUR 1144.9 billion. Shares and other equities including mutual fund shares stood at EUR 22.8 billion. The remaining assets were made up of deposits and loan claims, financial derivatives and other assets. On the liability side, shares issued accounted for 83.2% of total liabilities, with the residual items including loans and deposits received, financial derivatives and other liabilities.

Table 1: Aggregate balance sheet of Luxembourg bond funds (outstanding amounts at the end of the period, billion euros)

	2008Q4	2009Q4	2010Q4	2011Q4	2012Q4	2013Q4	2014Q2
Assets							
Deposits and loan claims	40.4	32.4	36.5	37.4	51.9	63.8	69.1
Securities other than shares	362.4	452.6	588.8	582.5	790.5	811.5	882.2
Issued by euro area residents	198.8	231.0	242.0	223.7	296.4	323.1	356.8
Issued by non-euro area residents	163.6	221.6	346.8	358.8	494.1	488.4	525.4
Shares and other equity	12.3	13.3	17.2	15.6	19.1	20.8	22.8
Other assets	25.0	19.2	25.0	19.4	26.7	26.1	44.2
Financial derivatives	50.1	43.6	65.8	104.3	103.2	117.5	126.6
Liabilities							
Loans and deposits received	7.2	3.6	4.2	3.8	6.7	15.6	17.7
Investment funds shares/units issued	411.3	496.7	639.3	630.2	858.2	877.4	952.0
Other liabilities	25.6	29,0	30.2	23.8	28.8	36,0	54.2
Financial derivatives	46.1	31.8	59.6	101.4	97.7	110.7	120.9
Total Assets/liabilities	490.2	561.2	733.4	759.2	991.4	1039.7	1144.9

Source: BCL

2.2.1 The geographical exposures

From the point of view of the geographical exposures, the breakdown of the bond portfolio indicates the existence of a regional bias, with a large proportion of the securities other than shares held by Luxembourg bond funds being issued by euro area residents. This is a standard result according to the existing literature, as the monetary union created the conditions for investors to diversify their portfolio internationally without incurring an exchange rate risk (Schoenmaker and Bosch, 2008). However, during the period under review, the regional bias significantly decreased as a consequence of a portfolio rebalancing between euro area and non-euro area assets, in particular since the eruption of the sovereign debt crisis in 2010. The proportion of securities other than shares issued by non-euro area residents increased from 45% to 60% between December 2008 and June 2014, mostly reflecting an increased exposure vis-à-

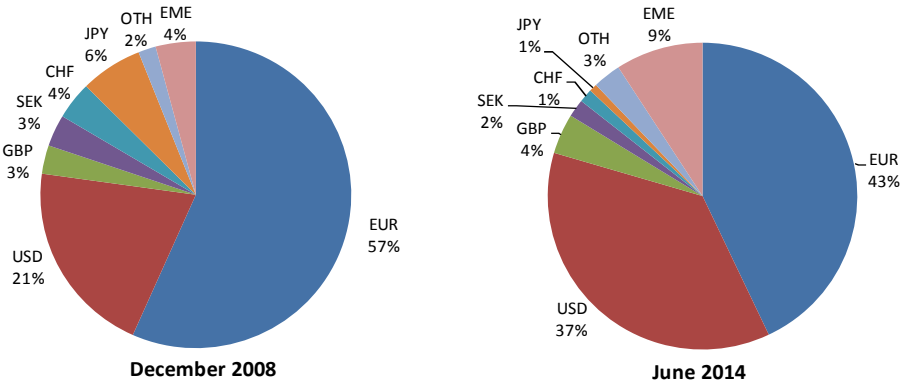
vis the US and emerging markets[10]. Given that the latter markets exhibited an elevated volatility after the announcement of the Fed tapering, this major change in the portfolio composition of bond funds may imply a higher sensitivity of the NAV to future interest rate movements associated with a monetary policy normalisation in the US.

2.2.2 The currency exposures

The currency breakdown of the balance sheet is displayed in Figures 4 and 5. The proportion of securities denominated in euro, which is relatively elevated in conformity with the regional bias, has decreased during the crisis period, from 57% in December 2008 to 43% in June 2014. This movement took place against an increase in the proportion of securities denominated in USD and, to a lesser extent, in emerging market currencies, which have respectively increased from 21% to 37%, and from 4% to 9% over the period under review. As for the liability side of the balance sheet, euro-denominated shares constitute the bulk of the issuance, but their proportion also decreased during the crisis period, from 73% to 58%, while shares issued in USD significantly increased, from 15% to 26%. Overall, depending on the currency hedging strategy of Luxembourg bond funds, exchange rate fluctuations may contribute to the NAV evolution on both sides of the balance sheet. More precisely, a depreciation (appreciation) of the euro vis-à-vis other currencies, and particularly the USD, should translate into an increase (decrease) in the NAV expressed in euro[11]. In addition, given the evolution in the currency composition of the balance sheet during the crisis period, the sensitivity of the NAV to movements in the exchange rate may actually have increased[12].

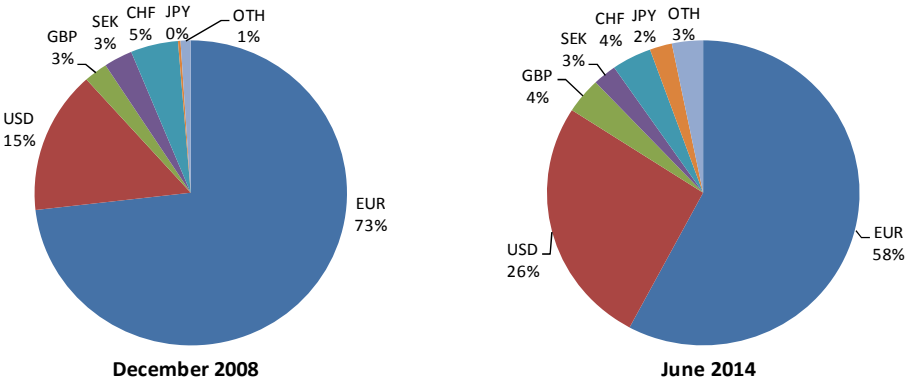
[10] A more detailed geographical composition of the bond portfolio is provided in the Appendix.
[11] See Kultur and Morhs (2014) for further details.
[12] The existing literature suggests that foreign exchange risk in international bond portfolio should be partly hedged as asset managers seek to diversify their portfolio internationally without incurring an exchange rate risk, currency movements being usually highly correlated with changes in interest rates (e.g. Solnik, 1991, Glen and Jorion, 1993). The lower propension of asset managers to add exchange rate exposure to the interest rate and credit risk of the bond portfolio probably explains the size of the ratio of financial derivatives expressed as a percentage of total assets, which is relatively higher in comparison with the one observed for Luxembourg equity funds. See Kultur and Morhs (2014) for a detailed presentation of the balance sheet of Luxembourg equity funds.

Figure 4: Currency breakdown of the asset portfolio



Source: BCL

Figure 5: Currency breakdown of the shares issued



Source: BCL

2.2.3 The interest rate exposures

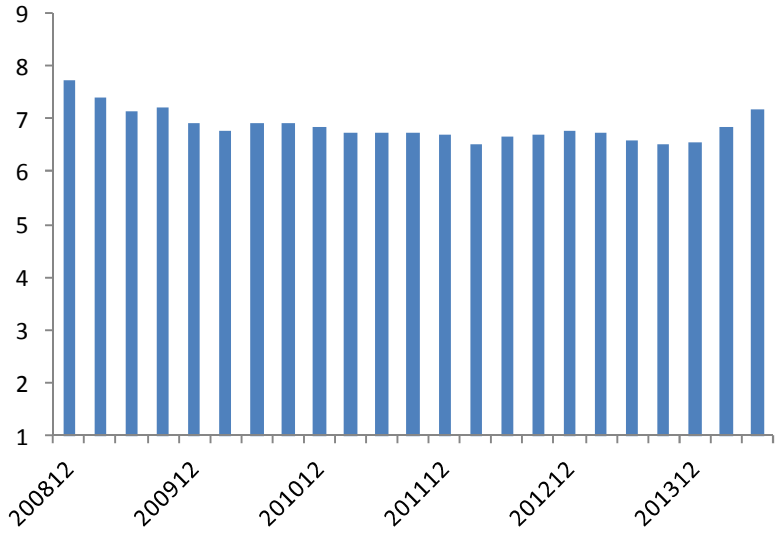
The Security-by-Security reporting of the BCL matched against the ECB Centralised Security DataBase (CSDB) provides detailed attributes for the individual securities comprised in the bond portfolio, e.g. the issuance date, the maturity date, the yield, the coupon rate. Accordingly, the current reporting allows drawing some preliminary analysis regarding the interest rate risk borne by Luxembourg bond funds.

The average residual maturity provides a first indication with respect to the interest rate sensitivity of the bond portfolio[13]. Indeed, the higher the residual maturity, the higher the impact of an interest rate change on the value of the bond portfolio. The evolution

[13] The residual maturity corresponds to the remaining time until the expiration or the repayment of the debt security.

displayed in Figure 6[14] indicates that the residual maturity of the bond portfolio has been adjusted upward at the end of the period, increasing from 6.6 years in December 2013 to 7.2 years in June 2014[15], a level similar as the one observed in December 2008. Over that period, the persistence of a low interest rate environment in the US and the euro area may have induced investors and asset managers to lengthen the average maturity of their portfolio, thereby reflecting a search-for-yield behaviour (BIS, 2014, IMF, 2014).

Figure 6: Residual maturity of the bond portfolio (end of period, number of years)



Source: BCL

The modified duration and convexity of the bond portfolio are calculated to provide a better approximation of the interest rate sensitivity[16]. The modified duration indicates the change in the value of a bond portfolio following a 100 basis points variation in the market interest rate, while the convexity takes into account the curvature of the price-yield relationship. Both the modified duration and the convexity are decreasing in the coupon rate and the average yield, and increasing in the residual maturity. The higher the modified duration and the convexity of the portfolio, the higher its sensitivity to interest rates movements. These indicators along with the figures displayed in Table 2 have been

[14] The average residual maturity has been calculated for the whole bond portfolio. Perpetual bonds, which have no maturity date by definition, have been retrieved from the sample. It is worth noting that these figures only provide a partial indication of the evolution of the interest rate sensitivity of bond funds as they also include floating-rate and indexed securities which represent about 10% of the portfolio. The distribution of the bond portfolio broken down by type of coupon is displayed in the Appendix.

[15] More specifically, the distribution of the residual maturity broken down by key relevant terms, which is displayed in the Appendix, indicates a lower exposure to short maturities. Overall, during the period under review, Luxembourg bond funds seem to have decreased their exposure to both the shorter and the longer end of the yield curve, moving toward more intermediate maturities.

[16] The formulas used to calculate the modified duration and the convexity of the bond portfolio are presented in the Appendix.

calculated for a sample including the securities with an ISIN code and a zero-coupon or a fixed-rate coupon payment, which cover about 70% of the value of the aggregate bond portfolio.

Table 2 : Average interest rate exposure of the bond portfolio (end of period values)

	201312	201406
Residual maturity (years)	6.42	7.02
Coupon rate (%)	4.85	4.82
Nominal yield (%)	3.74	3.40
Modified duration	4.84	5.29
Convexity	51.4	59.3
Portfolio value (billions euro)	577.3	620.4
Portfolio losses (billions euro)		
100 bps increase	*26.5*	*31.0*
200 bps increase	*49.9*	*58.3*

Source: BCL, Authors' calculations

Since the end of 2013, the increase in the modified duration and the convexity of the bond portfolio has been mainly driven by the lengthening of the residual maturity and the lowering of the nominal yield. As a consequence of this evolution, the potential losses to the bond portfolio arising from an unexpected normalisation of monetary policy and a sudden surge in market interest rates have increased, as illustrated in Table 2. The results of the simulation presented above are based on the scenario sketched out by the IMF, which emphasizes *"a rapid market adjustment that causes term premiums in bond markets to revert to historical norms (increasing by 100 bps) and credit risk premiums to normalize (a repricing of credit risk by 100 bps)"* (IMF, 2014, p.40). Following a 100 basis points and a 200 basis points increase in market interest rates, the market value of the portfolio of Luxembourg bond funds would have been respectively reduced by 5.0% (EUR 31.0 billion) and 9.4% (EUR 58.3 billion) in June 2014, against 4.6% (EUR 26.5 billion) and 8.7% (EUR 49.9 billion) in December 2013[17].

The previous result represents a crude proxy of the interest rate sensitivity of the bond portfolio, not only because it covers 70% of the outstanding amount of securities, but also because it does not distinguish between the different types of bonds comprised in the portfolio (e.g. callable and non-callable bonds, convertible bonds). In addition, the exposure to market interest rate movements may be overestimated as the coverage of the interest rate risk by the use of derivatives is not taken into account in the analysis. Finally and more importantly from a macroeconomic point of view, this measure does not encompass the indirect effect on the NAV arising from transactions, which are largely determined by the past performance of bond funds. As such, an econometric model may deliver a better measure of the interest rate sensitivity of the Luxembourg bond funds

[17] See formula A.2 in Appendix 5 for the calculation of the interest rate sensitivity of the bond portfolio.

industry. As a result and given the evolution in the financial environment and the changing composition of the balance sheet observed during the period under review, the estimate of a time-varying parameter model is a natural choice .

3. Econometric analysis

The aim of the econometric model is to replicate the NAV dynamics and to provide an analytical framework that delivers an estimate of the interest rate sensitivity of Luxembourg bond funds. The regression analysis, which uses monthly data over the sample 2008:1-2014:6, is first carried out with the Ordinary Least Square (OLS) method to check for statistical adequacy. The time-varying version of the model is then estimated with the Kalman filter to improve the goodness of fit and to analyse the evolution of the beta coefficients over time. The empirical results are finally discussed.

3.1 The structure of the model

The empirical model used to analyse the impact of interest rate movements on the NAV of Luxembourg bond funds directly relates to the performance model used by Blake et al. (1993). However, as we adopt a macroeconomic approach, rather than using the monthly return of a specific investment fund, the aggregate NAV, which includes both the valuation and the transaction effects, is used as the dependent variable in the estimate.

The baseline model used for the regression analysis is the following:

$$(2) \qquad \Delta nav_t = \alpha + \sum_{i=1}^{3} \beta_i \Delta nav_{t-i} + \beta_4 \Delta sov_t + \beta_5 \Delta hy_t + \beta_6 \Delta usd_t + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma^{\varepsilon})$$

where the aggregate NAV of Luxembourg bond funds (*nav*) is regressed against a vector of explanatory variables including the lagged values of the dependent variable, the long term interest rates in the sovereign bond markets (*sov*), the risk premium in the high-yield bond markets (*hy*), and the nominal EUR/USD exchange rate (*usd*). The β coefficients measure the sensitivity of the NAV to the different risk factors and ε_t is an i.i.d. disturbance error term which reflects the evolution of the NAV dynamics that is not explained by the model[18]. All the variables included in the model are expressed in first log-difference, except the market interest rates which are expressed in first difference[19].

[18] According to the existing literature aimed at investigating the determinants of the performance and cash flows in bond funds, additional explanatory variables have been included in the model such as the world inflation rate, the world industrial production growth, the stock market index, the term structure of interest rates or the VIX. However, these variables were not statistically significant and have been dropped from the analysis to get a parsimonious model. The results obtained from a standard regression analysis are presented in the Appendix.

[19] All the data are end-of-month values and come from Bloomberg, except the NAV which is produced internally using the O1.1 reports of the CSSF, and the high-yield bond interest rates, which come from the FRED database. Summary statistics of the variables are presented in the Appendix.

More specifically, the dynamics of the growth rate of the NAV of Luxembourg bond funds (Δnav_t) is explained by the following variables:

(i) $\sum_{i=1}^{3} \Delta nav_{t-i}$ takes into account the autocorrelation structure of the dependent variable, which is directly related to the persistence of the net issuance of shares emphasized in the literature[20] (Wharton, 1995, Remolona et al., 1997).

(ii) The traditional Capital Asset Pricing Model (CAPM) analyses the performance of a fund to a single bond index, with β representing the sensitivity of the fund to the selected market index. Given the international portfolio diversification of Luxembourg bond funds, the *JP Morgan Global Aggregate Bond Index* (JPM GABI) has been considered as a natural benchmark for this analysis. However, this approach proved to be inefficient, in particular in the context of the financial crisis as risk aversion translated into a divergent evolution between benchmark sovereign bonds and high-yield bonds interest rates. In order to capture the impact of this divergent evolution in the performance of fixed-income markets on the NAV dynamics of Luxembourg bond funds, the econometric model comprises sov_t, the average of the long term interest rates in the 10-year sovereign bond markets in the US and the euro area, and hy_t, the risk premium of the high-yield bond markets over sovereign benchmark bonds in the US and the euro area.

(iii) Finally, Δusd_t is the EUR/USD exchange rate return. This variable is a good proxy for the exchange rate risk supported by Luxembourg bond funds, as evidenced by the currency composition on both the asset side and the liability side of the balance sheet[21].

3.2 The state-space representation

The model sketched above is then transformed into a state-space representation in order to be estimated with time-varying parameters. This specification allows analysing the changes in the sensitivity of Luxembourg bond funds to the different risk factors during the period under review. The state-space model has the following form:

$$(3) \qquad y_t = \beta_t x_t + v_t \qquad\qquad v_t \sim N(0, r_t)$$

$$(4) \qquad \beta_t = \beta_{t-1} + \omega_t \qquad\qquad \omega_t \sim \mathrm{MV}N(0, Q_t)$$

[20] The analysis of the persistence of the net issuance of shares in Luxembourg bond funds is presented in the Appendix.

[21] A positive EUR/USD exchange rate return corresponds to an appreciation of the euro relative to the US dollar.

In the measurement equation (3), y_t is the growth rate of the NAV and x_t contains the set of explanatory variables described above. Each loading coefficient in the vector β_t changes over time and follows a random walk process (Lo Duca, 2012), as displayed in the state equation (4).

The random walk specification of the *beta* coefficients implies that the sensitivity of the growth rate of the NAV to the different risk factors changes over time as a result of shocks. These shocks have a permanent effect and may result from changes in the financial markets, the monetary policy environment, the balance sheet composition of bond funds or the behaviour of investors[22].

3.3 The empirical results

In comparison with the standard OLS model, which accounts for about 80% of the NAV fluctuations of Luxembourg bond funds during the period under review, the use of the Kalman filter improves the goodness of fit of the regression with the adjusted R-square increasing to more than 90%[23]. The evolution of the estimated coefficients over time is displayed in Figure 7. The following results are worth mentioning:

(i) All the coefficients have the expected sign and are statistically significant. According to the results obtained from the regression with the Kalman filter, the overall degree of persistence in the NAV dynamics, which is defined as the sum of the autoregressive coefficients in equation (2), has decreased during the period under review (Figure 7a), with important implications for the sensitivity of Luxembourg bond funds to market developments. Indeed, the degree of persistence determines the dynamic behaviour of the NAV in response to an exogenous shock. Consequently, the lower the persistence effect, the lower the cumulative impact of the explanatory variables on the NAV occurring indirectly through the lagged values of the dependent variable[24].

(ii) According to the results presented in Figures 7b and 7c, a 100 basis points rise in the 10-year interest rate on the sovereign bond markets and a 100 basis points rise in the risk premium on the high-yield bond markets respectively translated on average into an instantaneous 3.5% and 2.0% decrease in the NAV of Luxembourg bond funds. Taking into account the indirect effect transiting through the lagged values of the dependent variable, the long-run interest rate sensitivity of the NAV to these exogenous shocks respectively reached on average 6.5% and 3.7% for the period under review.

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[22] The extent to which the betas can vary across time depends on Q_t, the diagonal variance-covariance matrix of the shocks affecting the state equation. The initial guess values for Q_t and r_t are based upon the results of the OLS regression. The Kalman filter is used to calculate the maximum likelihood estimation of parameters Q_t, r_t and β_t.

[23] A dummy has been introduced in the model for the month 2012:1 to control for the statistical reclassification of money market funds into bond funds.

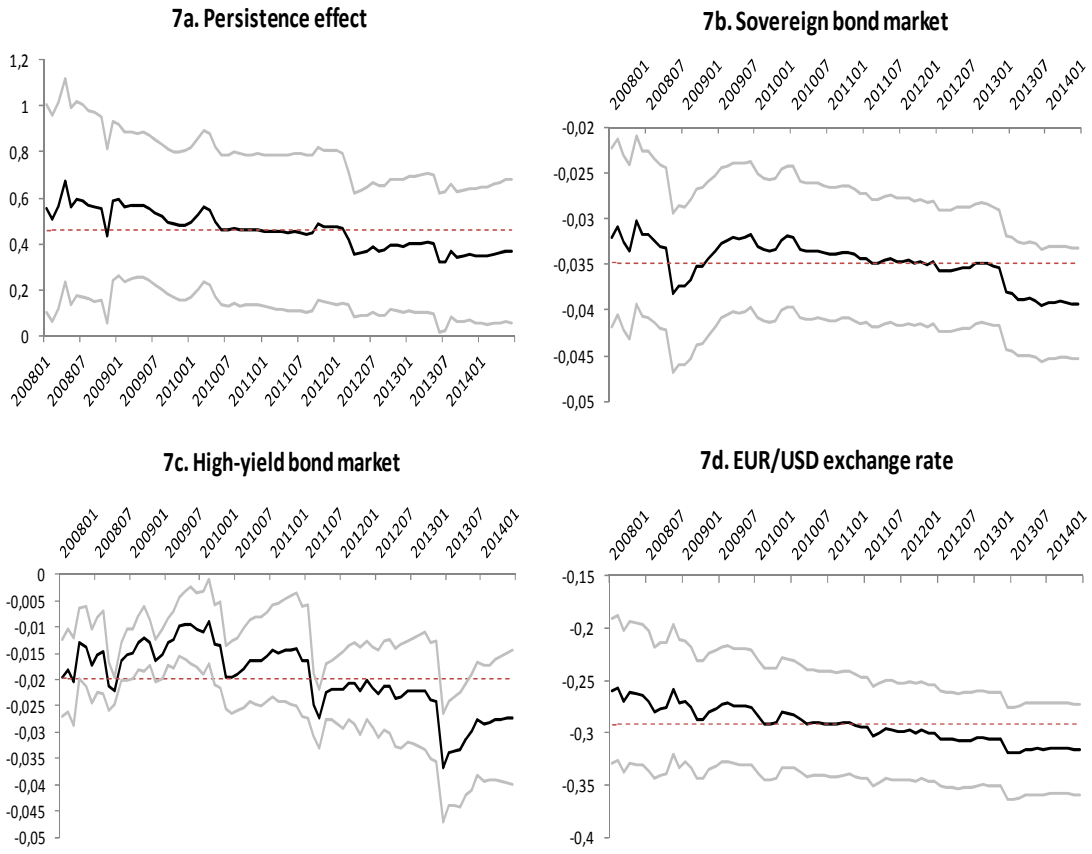
[24] In the regression model displayed in equation (2), the long-run cumulative effect of the explanatory variables on the dependent variable is given by $\frac{\beta_i}{1-\beta_1-\beta_2-\beta_3}$ for i = 4,5 and 6.

(iii) The sensitivity of the activity to exchange rate movements is also significant, thereby reflecting the high level of currency diversification on both the asset side and the liability side of the balance sheet. According to the results obtained from the regression with the Kalman filter, a 1% increase in the EUR/USD exchange rate has been associated on average with an instantaneous -0.29% change in the NAV (Figure 7d), with a corresponding long run cumulative effect of -0.54% for the period under review. Overall, the currency risk seems to be less important for Luxembourg bond funds than for Luxembourg equity funds, as the coefficient estimated for the latter was significantly higher over a similar sample (Kultur and Morhs, 2014). Actually, this result is not very surprising as Luxembourg bond funds display a higher regional bias and probably hedge a higher part of their foreign exchange exposures through the use of derivatives.

(iv) Finally, the change in the portfolio composition of the balance sheet and the financial environment seem to have delivered a higher short-run sensitivity of the NAV to both the interest rate and the exchange rate developments during the period under review, with the associated coefficients rising significantly, in particular with respect to the high-yield bond market. This result is relatively intuitive against the background of a low interest rate environment, a search-for-yield behaviour and an increase in the USD exposure of the bond portfolio. However, the long-run sensitivity of Luxembourg bond funds to market developments has remained relatively stable over time as the decrease in the overall degree of persistence has mitigated the cumulative impact of exogenous shocks on the NAV dynamics. According to the time-varying estimate obtained for the end of the sample, a 100 basis points increase in long term interest rates on the sovereign bond market associated with an additional 100 basis points rise in the risk premium on the high-yield bond markets would ultimately decrease the NAV by approximately 10.6%.

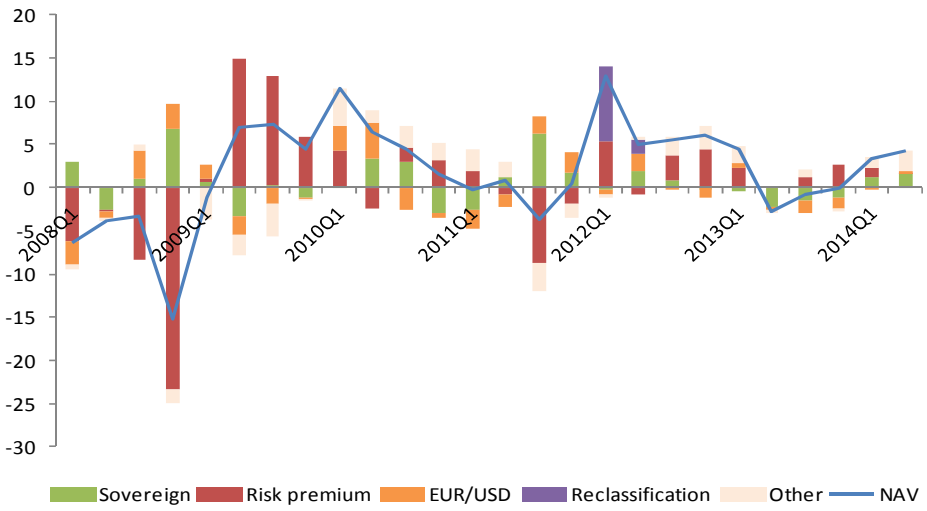
Figure 7: Time-varying beta coefficients with 90% confidence intervals

(Dashed line: average value over the sample)



To complete the analysis, the contribution of each factor to the quarterly evolution of the NAV of Luxembourg bond funds since the beginning of 2008 is displayed in Figure 8. The contribution of each factor is computed by multiplying the value of the factor by the estimated β coefficient for each month and then cumulating over the reference quarter. In order to take into account the degree of persistence of the NAV, the indirect effects of the explanatory variables transiting through the lagged values of the dependent variable are incorporated into the different risk factors.

Figure 8: Factor contribution to the NAV evolution of Luxembourg bond funds (%)



Overall, during the period under review, interest rate fluctuations have played a dominant role in the NAV evolution, with an absolute contribution reaching respectively 45% and 20% for the variables associated with the risk premium in the high-yield bond markets and the interest rate in the sovereign bond markets. Fluctuations in the exchange rate of the euro against the dollar also exerted a non-negligible impact on the NAV of Luxembourg bond funds, with an absolute contribution of 15%. More specifically, the evolution of the EUR/USD exchange rate and the 10-year sovereign bond interest rates seem to have globally mitigated the adverse effects of the high-yield bond market developments on the NAV evolution, thereby mirroring the positive correlation between the sovereign bond market and the exchange rate of the euro against the dollar observed during the period under review. This offsetting effect indicates that the EUR/USD exchange rate played a natural hedging role against market developments for the Luxembourg bond funds industry as a whole[25]. The divergent movements in the sovereign and high-yield bond markets have also mitigated the NAV fluctuations, in particular during heightened tensions in the financial system, such as the ones observed in 2008Q4 and 2011Q3. However, this financial context may change in the future with the expected normalisation of the US monetary policy acting as a common factor for the evolution of long term market interest rates.

4. Conclusion

This empirical study provided a useful input for understanding the determinants of the NAV evolution of Luxembourg bond funds and measuring its sensitivity to interest rate developments. The results of the analysis suggest that Luxembourg bond funds have recently increased the residual maturity and the duration of their portfolio, which have

[25] Kultur and Morhs (2014) provide evidence of a similar effect for the Luxembourg equity funds industry.

returned to a similar level as the one observed in December 2008. This evolution, which points toward a search-for-yield behaviour in a low interest rate environment, implies that Luxembourg bond funds have recently become more sensitive to fixed-income markets developments. According to the estimate obtained at the end of the sample with the Kalman filter, and following the scenario sketched out by the IMF in its October 2014 Global Financial Stability Report, a 100 basis points rise in long-term interest rates on the sovereign bond markets associated with an additional 100 basis points rise in the risk premium on the high-yield bond markets would approximately materialise into a 10% decrease in the NAV of Luxembourg bond funds.

As outlined by the IMF (2014) and the ECB (2014b), the occurrence of such a scenario based on a generalized increase in bond yields is largely plausible. Indeed, while the divergent movements in sovereign and high-yield bond markets have mitigated the NAV evolution during the period under review, the financial context may change in the future with the reversal of the search-for-yield behaviour acting as a common factor for the evolution of long-term market interest rates. From this point of view, the hypothetical scenario sketched out by the IMF, which relies upon *"a rapid market adjustment that causes term premiums in bond markets to revert to historical norms (increasing by 100 bps) and credit risk premiums to normalize (a repricing of credit risk by 100 bps)"* (IMF, 2014, p.40), would have important consequences for the activity of Luxembourg bond funds.

Overall, this study focused on the interest rate sensitivity of the Luxembourg bond fund industry. In a different perspective, Feroli et al. (2014) and IMF (2014) discuss the importance of fixed-income funds for the transmission of monetary policy decisions to long-term interest rates. In the context of the market tantrum that followed the announcement of the Fed tapering in May 2013, these authors point toward the financial propagation mechanisms that could arise from the existence of feedback effects between pressures on prices, negative fund performance, and outflows from fixed-income funds. Against this background, a possible extension of this work would be to analyse the impact of the behaviour of asset managers and investors on long-term interest rate developments, emphasizing the role of Luxembourg bond funds in the monetary policy transmission mechanisms and their implications on the stability of the financial system in the context of shares redemptions.

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Appendix 1: Descriptive data on Luxembourg bond funds (June 2014)

Number of subfunds	*Aggregate NAV (billions euro)*	*Mean*	*Standard deviation*	*Market share of the 5% largest subfunds (%)*
3050	952.0	0.3	1.0	50.4

Breakdown of the NAV by structure (billions euro)		*Breakdown of the NAV by legal framework (billions euro)*		
Open-end funds	Closed-end funds	Part 1	Part 2	SIF
950.9	1.1	861.4	24.8	65.8

Source: BCL, CSSF

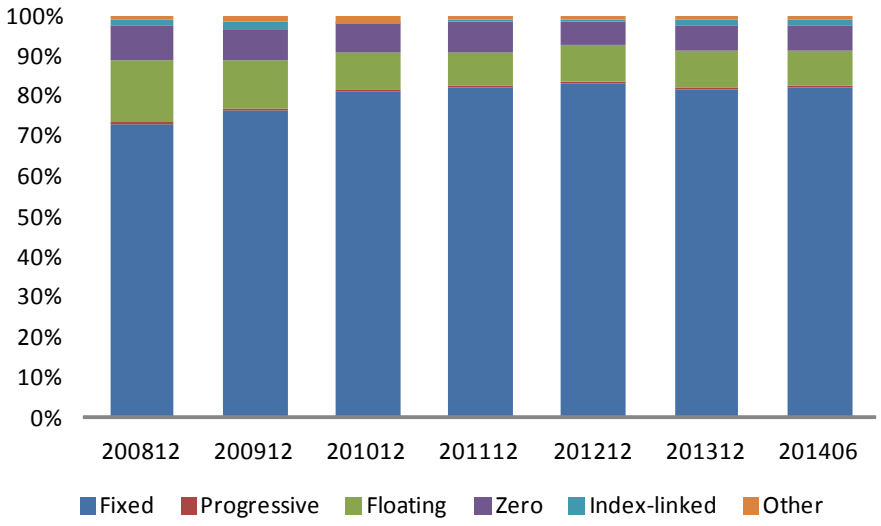
Appendix 2: Geographical breakdown of the bond portfolio[26] (outstanding amounts, billion euros)

	2008Q4	2009Q4	2010Q4	2011Q4	2012Q4	2013Q4	2014Q2
Securities other than shares	362.4	452.6	588.8	582.5	790.5	811.5	882.2
Issued by euro area residents	198.8	231,0	242,0	223.7	296.4	323.1	356.8
o/w core countries	*137.2*	*158.5*	*173.1*	*164.1*	*205.6*	*210.4*	*228.6*
o/w peripheral countries	*61.6*	*72.5*	*68.9*	*59.6*	*91,0*	*112.7*	*128.2*
Issued by non-euro area residents	163.6	221.6	346.8	358.8	494.1	488.4	525.4
o/w other advanced economies	*119.8*	*156.6*	*217.4*	*214.4*	*298.0*	*301.2*	*326.6*
o/w United States	*61.2*	*81.4*	*120.7*	*123.9*	*178.3*	*182.1*	*204.6*
o/w United Kingdom	*24.1*	*30.3*	*39.8*	*37.3*	*46.6*	*48.5*	*56.9*
o/w Sweden	*13.9*	*18.9*	*22.5*	*21.5*	*35.2*	*33.2*	*23.2*
o/w Canada	*3.0*	*4.3*	*6.0*	*6.0*	*9.1*	*10.5*	*11.7*
o/w Japan	*6.2*	*5.7*	*7.3*	*7.6*	*7.1*	*6.4*	*7.7*
o/w Others	*11.4*	*16.0*	*21.1*	*18.1*	*21.7*	*20.5*	*22.5*
o/w emerging market countries	*26.7*	*41.7*	*89.6*	*100.7*	*134.1*	*123.0*	*126.6*
o/w Asia	*8.3*	*13.9*	*32.8*	*41.9*	*49.9*	*47.2*	*45.6*
o/w Central/Latin America	*8.3*	*13.0*	*26.7*	*27.6*	*40.1*	*37.5*	*43.7*
o/w Europe	*8.2*	*12.1*	*21.0*	*23.8*	*35.3*	*30.9*	*31.7*
o/w Others	*1.9*	*2.7*	*9.1*	*7.4*	*8.8*	*7.4*	*5.6*
o/w other countries	*17.1*	*23.3*	*39.8*	*43.7*	*62.0*	*64.2*	*72.2*

Source: BCL

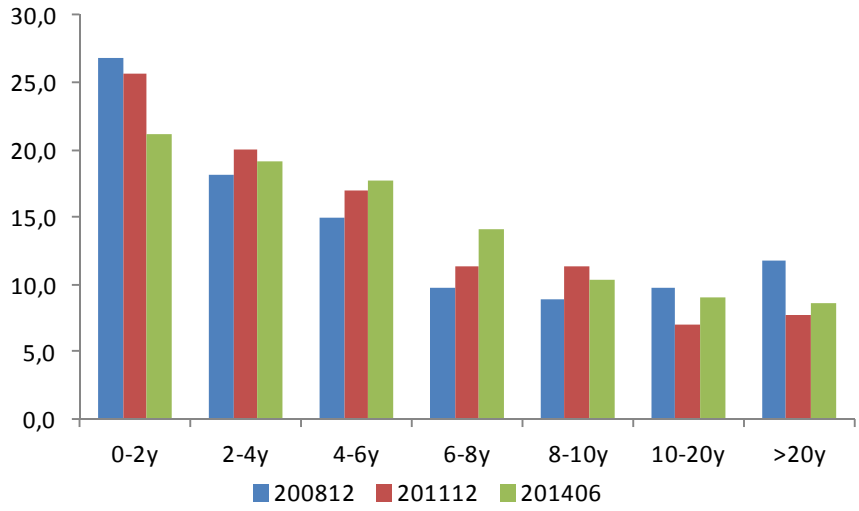
[26] *Euro area core countries*: Austria, Belgium, Germany, Estonia, Finland, France, Latvia, Luxembourg, Malta, Netherlands and Slovakia. *Euro area peripheral countries*: Cyprus, Greece, Ireland, Italy, Portugal, Slovenia and Spain. *Other advanced economies*: Australia, Denmark, New Zealand, Norway and Switzerland. *Asia emerging markets*: China, Hong-Kong, India, Indonesia, Malaysia, Phillipines, Singapore, South Korea, Thailand, Taïwan. *Central/Latin America emerging markets*: Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela. *Europe emerging markets*: Czech Republic, Hungary, Poland, Russia and Turkey.

Appendix 3: Breakdown of the bond portfolio by coupon type



Source: BCL

Appendix 4: Maturity breakdown of the bond portfolio (%)



Source: BCL

Appendix 5: Modified duration and convexity

The formula used to calculate the modified duration and the convexity of the bond portfolio are the following:

(A.1) $$Dm = \frac{\sum_{k=1}^{K} t_k \frac{c(k)}{(1+y)^{t_k}}}{P(1+y/n)} \quad \text{and} \quad C = \left(\frac{\sum_{k=1}^{K} t_k (t_k+1) \frac{c(k)}{(1+y)^{t_k}}}{P(1+y/n)^2} \right)$$

with :

$$t_k = nk_0 + k - 1$$

$$c(k) = \frac{c}{n} A \text{ for } t = 1,...,K-1$$

$$c(K) = \left(1 + \frac{c}{n}\right) A$$

$$P = \sum_{k=1}^{K} \frac{c(k)}{(1+y)^{t_k}}$$

where Dm is the modified duration, C the convexity, P the price of the bond at a given date, $c(k)$ the monetary flows, A the issuance price, c the coupon rate, n the frequency of the coupon, K the number of remaining coupons, k_0 the remaining time until the next coupon and y the yield to maturity.

The following formula is used to calculate the interest rate sensitivity of the bond portfolio:

(A.2) $$\frac{\Delta P}{P} = \left[- Dm \Delta y \right] + \left[\frac{1}{2} C (\Delta y)^2 \right]$$

Appendix 6: Presentation of the variables used in the econometric model

Summary statistics (2008:1-2014:6)

	Mean	Standard error	Minimum	Maximum
ΔNAV	0.0072	0.0255	-0.0982	0.0944
ΔSOV	-0.0292	0.2419	-0.8375	0.4865
ΔHY	-0.0031	1.2012	-2.5559	5.7727
ΔUSD	-0.0010	0.0348	-0.1144	0.0894

All the variables are expressed in first-log difference except market interest rates which are expressed in first difference

Correlation matrix (2008:1-2014:6)

	ΔNAV	ΔSOV	ΔHY	ΔUSD
ΔNAV	1.000			
ΔSOV	-0.017	1.000		
ΔHY	-0.602	-0.465	1.000	
ΔUSD	-0.013	-0.109	-0.457	1.000

All the variables are expressed in first-log difference except market interest rates which are expressed in first difference

Appendix 7: Persistance analysis of the net issuance of shares

Following Warther (1995), the Table below displays the correlation and the time series regressions of the net issuance of shares into bond funds for the period 2008:1 to 2014:6. The net issuance of shares is normalized by dividing by the outstanding amount of the NAV at the end of the previous month. Thus, the variable used in the analysis corresponds to the transaction effect in the NAV evolution. According to the results, the net issuance of shares into Luxembourg bond funds display an elevated persistence, which means that they should be highly predictable, at least in normal times.

	Mean	Median	Std. Dev.	**Autocorrelations**			
Obs.	(%)	(%)	(%)	Lag 1	Lag 3	Lag 6	Lag 12
78	0.6	1.1	1.52	0.60	0.38	0.21	0.13

Regression analysis

Constant	Lag 1	Lag2	Lag3	Adj. R2
0.002	0.522***	0.027	0.159**	0.37
(0.001)	(0.029)	(0.092)	(0.076)	

*** and ** respectively indicate statistical significance at the 1% and 5% confidence levels.

Appendix 8: Empirical results obtained from a standard OLS regression

The main results of the standard regression analysis are provided in the following Table. Robust (HAC) standard errors are reported in parenthesis below the coefficients. A dummy has been introduced for the month 2012:1 to control for the statistical reclassification of money market funds into bond funds. The model is estimated with monthly data over the sample 2008:1-2014:6 in order to analyse the sensitivity of the NAV of Luxembourg bond funds to the different risk factors. All the variables are expressed in first log-difference, except the interest rates which are expressed in first difference.

Main results of the standard regression analysis

	Dependent variable:
	NAV
CONSTANT	0.002
	(0.001)
LAG 1	0.170***
	(0.055)
LAG 2	0.056*
	(0.032)
LAG 3	0.230**
	(0.095)
SOVEREIGN	-0.042***
	(0.006)
RISK PREMIUM	-0.019***
	(0.001)
EUR/USD	-0.307***
	(0.006)
Nb of Obs.	78
Adj. R squared	0.81

***, ** and * respectively indicate statistical significance at the 1%, 5% and 10% confidence levels.

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