2. THE LOW INTEREST RATE ENVIRONMENT: IMPACT ON LUXEMBOURG BANK PROFITABILITY

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ABSTRACT

This study analyses the relationship between interest rates and bank profitability in Luxembourg. We use a panel data model to investigate the links between bank profitability measures and a set of bank-specific variables and macro-financial factors, which include the short-term interest rate and the slope of the yield curve. System-GMM estimates show that, despite the negative impact of repricing frictions primarily affecting net interest margins in the short run, in the long run Luxembourg banks profit from a higher level of short-term rates and a steeper yield curve. Moreover, rolling window estimates confirm the non-linear nature of this relationship and indicate that over time, as the short term rate reaches the zero lower bound and the yield curve flattens, the relationship between Luxembourg bank profitability and the level of the rates becomes stronger. As a consequence, low interest rates have an unequivocal negative effect on bank profits, which might constitute a source of vulnerability for Luxembourg banking system in the long run. However, for the time being, we do not observe any significant business model shift toward non-interest income based activities that could amplify systemic risk.

INTRODUCTION

The low interest rate environment is a global phenomenon which is particularly pronounced in advanced economies. The decline of long term rates is often associated with the aftermath of the Global Financial Crisis (GFC) and the slowdown of the world economy, entangled in the down phase of the "financial cycle" and induced by the necessary balance sheet repair and deleveraging of financial intermediaries (Borio (2012)). Monetary policy stimulus has provided support to the post-crisis recovery by easing funding conditions and ultimately it should push long term rates back to their previous trajectory. However, some studies argue that the decline in long term rates began almost three decades ago, suggesting that structural forces drove interest rates down (see Figure 1, Bean et al. (2015), ESRB (2016)). Indeed, a global imbalance between excess saving and reduced investment opportunities, aging populations, increased risk aversion and lower total productivity growth are likely drivers of the slowdown in growth potential of industrialized economies. This reduction in growth leads to a mechanical fall in the equilibrium real interest rate (Bernanke 2005, Gorton 2012 and Summers 2014). If the economy were to settle into "secular stagnation", interest rates across the whole maturity spectrum could remain low for long.

While the materiality of a low for long scenario is still under debate, stress tests at the European level in 2016 adopted low rates for their macroeconomic narratives considering the financial stability challenges they generate. Among the many potential risks induced by a persistent low interest rate environment, pressure on the profitability of credit institutions appears to be one of the most relevant for Luxembourg. The persistently low profitability of credit institutions could eventually have an adverse effect on bank solvency because it limits the ability of credit institutions to meet their regulatory obligations. This could, in turn, encourage banks to take more risks through holding assets with longer maturities, easing lending conditions, increase lending volume. This environment could also force banks to modify

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their business models such that they rely more on non-interest income based activities (revenues from securities and commissions) which, as suggested by Brunnermeier et al. (2012), tend to increase systemic risks.

Such risks can arise from constantly evolving business conditions where traditional banks have to adapt to a new set of regulatory requirements, technological innovations (FinTech) and increased competition from online banking and shadow banking (investment funds). In the long run, the low interest rate environment may have important implications for the resilience of the banking sector and the stability of the financial system.
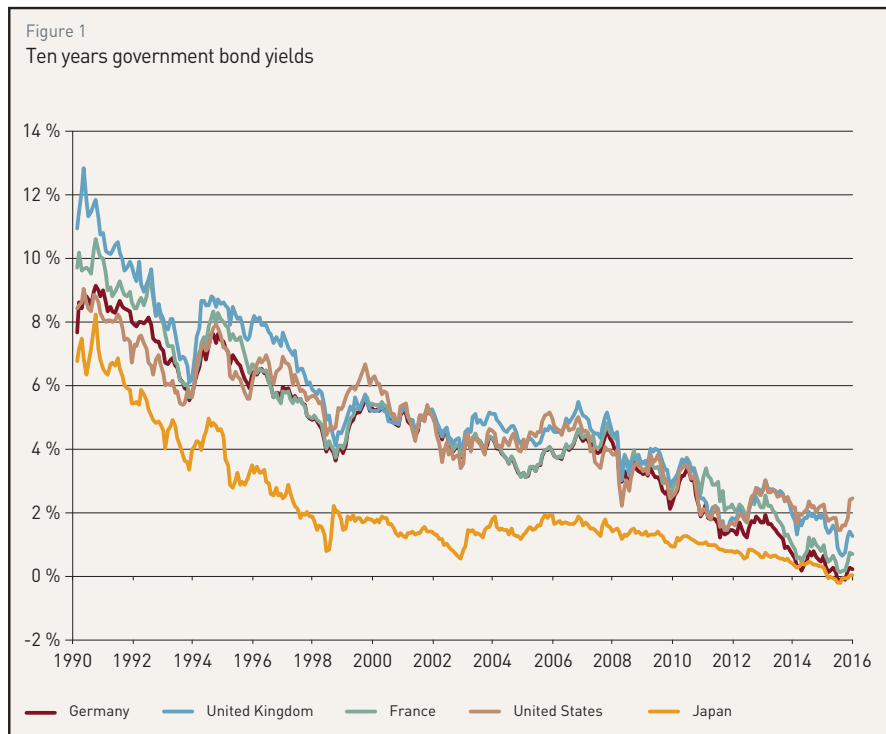
From an economic point of view banks, as intermediaries, are considered profit maximizing monopolies, which earn (transforma-

Figure 1
Ten years government bond yields

Germany   United Kingdom   France   United States   Japan

Source: Bloomberg

tion) margins by optimally setting the spread between the loan rates and deposit rates to accommodate funding and liquidity needs.[79] For these reasons, the net interest margin (NIM) channel is the usual way of interpreting the deterioration of banks' profitability in a low interest environment because the decline in the level of interest rates and the flattening of the yield curve reduce the spread between the short rate, at which banks finance part of their liabilities, and the long term rate, at which assets are paid. Moreover, since NIM arises from traditional intermediation activity, it often constitutes banks' main source of revenue and historically represents around half of Luxembourg's aggregate banking income.

NIM can be decomposed into three elements, partly owing to the oligopolistic structure of the banking sector, asymmetric information and price rigidities. The first element on the liability side is a commercial margin which is the difference between the deposit rate and the money market rate. Banks can typically mark down the deposit rate from the money market rate because of the low elasticity of demand for deposits. However, these monopoly rents on the liability side decrease as rates converge towards zero because banks are reluctant to pass negative deposit rates to their clients. The transformation margin is the spread between the deposit rate and the lending rate that would be offered in a perfectly competitive environment. This component is directly related to the shape of the yield curve and decreases as the curve flattens. Finally, a commercial margin on the asset side is determined by the difference between the lending rate that would be offered in a perfectly competitive environment and the effective rate paid by the customer. However, this element depends more on rate anticipations

79   See the Monty-Klein model presented by Freixas and Rochet (2008) and the dealer model of Ho and Saunders (1981).

of the bank, its market power and the characteristics of the contract offered to the client (like fixed or variable rate for example).

The econometric study of the determinants of bank profitability and NIM has traditionally been a micro-oriented field focusing on bank-specific characteristics, such as balance sheet structure, the oligopolistic environment or the fiscal and regulatory regime. Nevertheless, a number of papers have analyzed the relationship between economic conditions and bank profitability (Molyneux and Thornton (1992), Demirgüç-Kunt and Huizinga (1999), Saunders and Schumacher (2000) English (2002) among others). These studies confirm the positive relationship between long term interest rates and banks' profits, which is considered to be attributed to their maturity transformation activities. However, the relationship between the short-term rate and profitability appears to be more difficult to capture as seen in certain cases through insignificant parameters or inconsistent coefficient signs from one study to another. Regarding the specific case of Luxembourg, Rouabah (2006) studied the macroeconomic determinants of bank profitability. The results revealed that bank profitability displays co-movements with macroeconomic conditions, but that changes in the short term rates have only a marginal negative impact on banks' profits as measured by return on assets (ROA). The study found no impact on NIM.

More recent papers study bank profitability in a low interest rate environment. The empirical results are important as they suggest that, over time, unusually low interest rates erode bank profitability. Alessandri and Nelson (2015) find a positive relationship between UK banks' profitability and the level of the short term rate and slope of the yield curve. They also found that short run variations of rates compress bank profitability indicating the presence of repricing frictions. Borio et al. (2015) studied the link between the level of interest rates and global banking groups' profitability. Borio showed that these dependencies are positive but are also non linear; i.e. they are reinforcing as the rates and the term premium converge toward zero. Studying 47 countries between 2005 and 2013, Claessens et al. (2016) confirmed this finding. The authors found that between 2007 and 2013, NIM in the US, Euro area, Canada, Japan, and the UK fell by almost 26 basis points due to the decline in interest rates. Regarding the US specifically, the authors found that a low interest rate environment may be associated with decreased profitability. Busch and Memmel (2015) assessed the impact of low interest rates on bank profitability in Germany, and found that German banks have been negatively impacted and that their interest margins for retail deposits have recently declined.

Combined, these studies suggest the need for further analysis of the relationship between interest

Figure 2
Average return on equity and return on assets of the banking sector
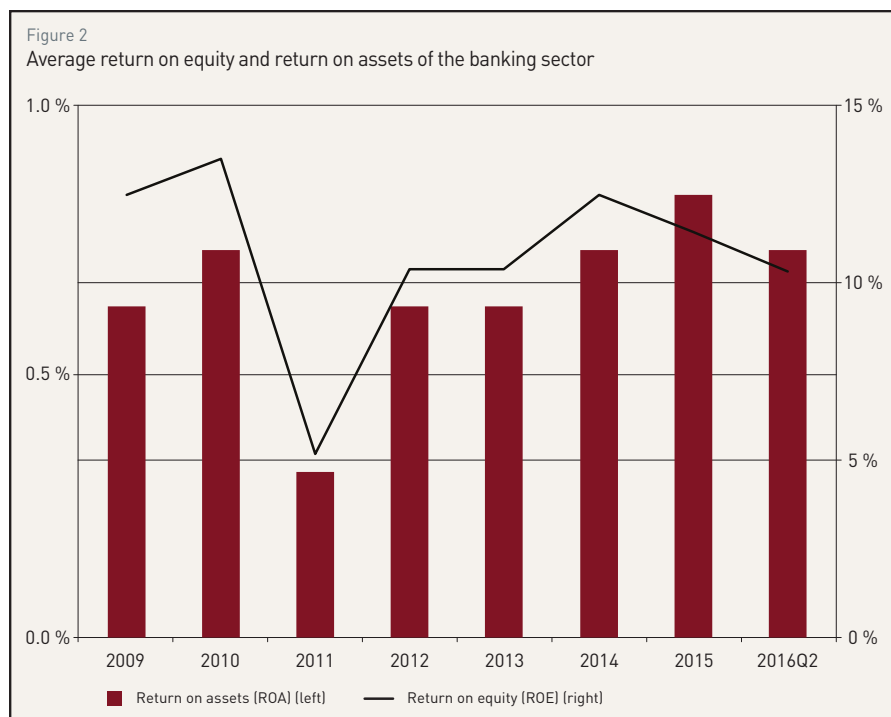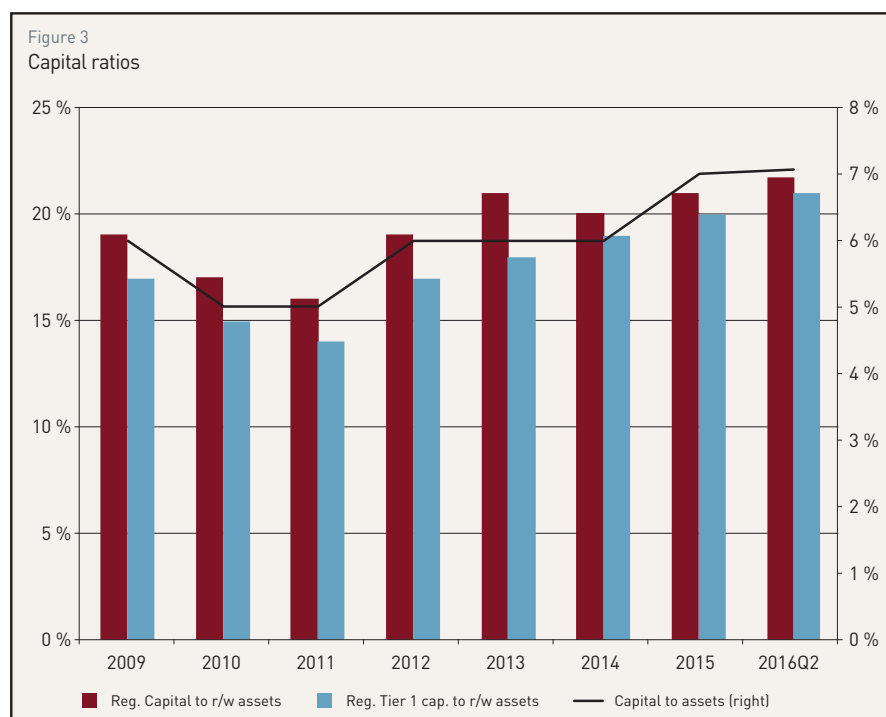
Source: BCL, sample 2009-2016Q2

rates and bank profitability in Luxembourg. Following Alessandri and Nelson (2015) and Borio et al. (2015) we use panel data models to investigate the links between bank profitability measures and a set of bank-specific variables and macroeconomic factors, which include the short term interest rate and the slope of the yield curve. System-GMM estimates show that, despite the negative impact of repricing frictions in the short run, in the long run Luxembourg banks indeed profit from a higher level of short term rates and a steeper yield curve. Rolling window estimates confirm the non-linear nature of this relationship indicating that over time, as the short term rate reaches the zero lower bound and the yield curve flattens, Luxembourg banks suffered more from the low interest rate environment. Estimates of non-interest income display no significant relationship with the rates, indicating that the low interest rate environment does not act as a push factor for banks to shift toward less stable business models from a systemic risk perspective.

The remainder of the paper is organized as follows. In section 1 we describe the specificities of the Luxembourg banking sector with a focus on the various business models in order to discern the likely consequences of the low interest rate environment on bank profitability. Section 2 presents the empirical approach used in the study, while section 3 presents the results. Finally, the conclusion summarizes the work and addresses potential policy considerations.

1 LUXEMBOURG BANKING SECTOR SPECIFICITIES AND THE LOW INTEREST ENVIRONMENT

Since the Global Financial Crisis, total assets of the Luxembourg banking sector have declined reaching 763 billion euro at the end of 2016 (around 15 times Luxembourg GDP). However, despite a drop in 2011, aggregate profitability has recovered since the crisis (Figure 2) and, although it is still below its pre-crisis levels, remains higher than the European median[80] on average. Indeed, Luxembourg banks do not suffer from the typical legacies of the crisis such as high levels of non-performing loans or costs related to past misconduct. [81]

Current profitability levels allow banks to continue to meet their regulatory obligations and to build and support strong capital positions. As shown in Figure 3, the average Tier 1 ratio of the aggregate Luxembourg banking sector is almost two times the

Figure 3
Capital ratios

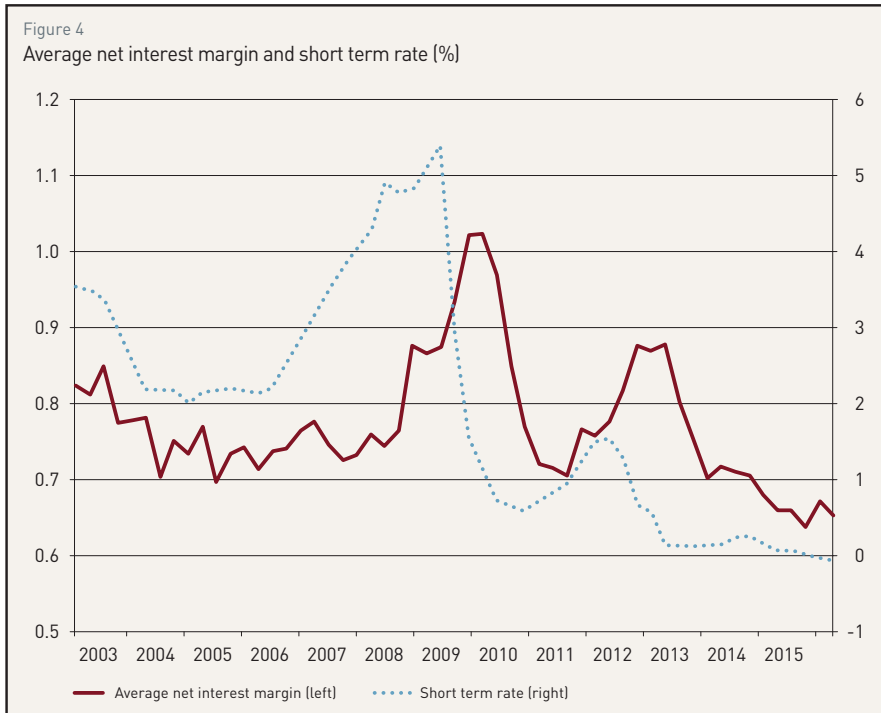Legend: Reg. Capital to r/w assets — Reg. Tier 1 cap. to r/w assets — Capital to assets (right)

Source: BCL, sample 2009-2016Q2

80 See ESRB risk dashboard, indicators 6.1a and 6.1b, page 29.

81 Bank of England, Financial Stability Report, November 2016.

Figure 4
Average net interest margin and short term rate (%)

— Average net interest margin (left)   ······ Short term rate (right)

Source: BCL

Figure 5
Contribution of various sources of income to total income growth

■ Commissions   ■ FX income   ■ Dividends
■ Other income   ■ Interest margin
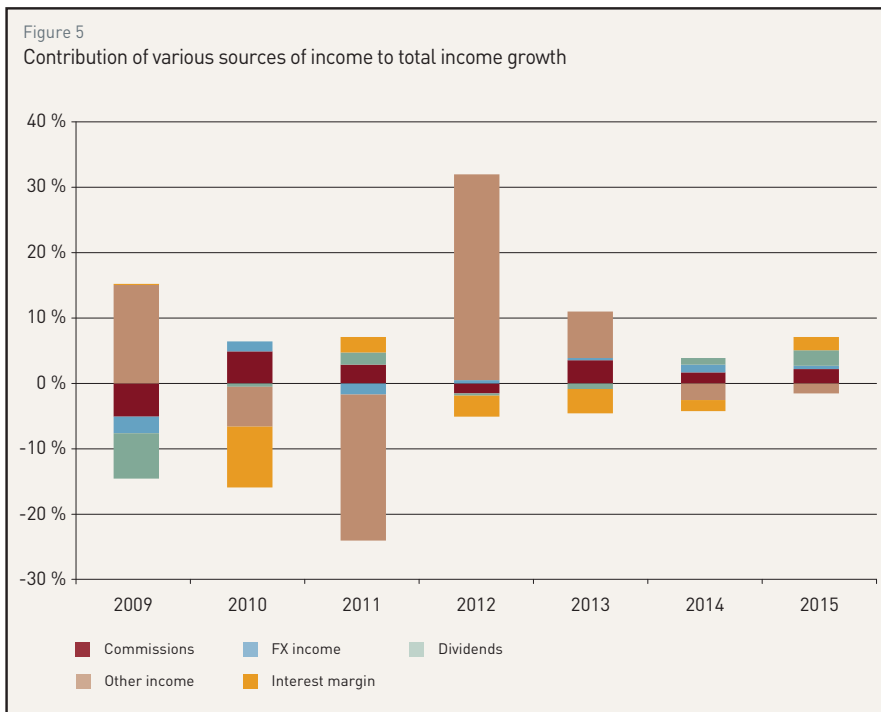
Source: BCL

required minimum level of 10.5% in 2016Q2.[82] Luxembourg banks currently have sufficient robustness to absorb adverse shocks.

The low interest rate environment is the primary challenge for Luxembourg banks' profitability and future resilience, especially in the event that rates remain low for a prolonged period of time. Figure 4 shows the significant downward trend of aggregate NIM which looks, *a priori*, highly correlated (with a lag) to the level of the short term rate. This tends to be confirmed at the broader European level where 81% of banks participating in the ECB Bank Lending Survey (BLS) in the first quarter of 2016 reported a decline in their net interest income for the past six months.[83] Since NIM has long been structurally low compared to international standards, Luxembourg banks do not rely on NIM as much as their European counterparts. However, NIM still represents 40% of the total income of Luxembourg banks. Hence, it is not clear if banks can fully substitute interest income with other sources of revenue. As shown in Figure 5, even if commissions seem to have supported bank profitability in the recent period, the contribution of the different sources of revenue are very volatile, and so far banks appear

82 See CSSF Regulation 14-01.
83 The April 2016 survey questionnaire included, for the first time, an ad hoc question on the impact of the ECB's negative deposit facility rate (DFR) on their net interest income, lending conditions and lending volume. Banks were asked to consider both the direct and indirect effects of the negative DFR, as there may be indirect effects on banks' financial situation and lending conditions even if the respective bank has no excess liquidity.

to be in a transition phase toward new income sources.

Forecasting bank profitability in a low interest rate environment and the profound structural changes that it can induce is a challenging task because Luxembourg banks, at the aggregate level, may diverge from traditional intermediation activities. In many aspects the Luxembourg banking system displays distinct specificities regarding its size and internationally oriented nature, the importance of the inter-bank and intra-group market and the coexistence of various business models.

As shown in Figure 6, traditional retail banking activities, primarily those which are domestically oriented, represent a moderate fraction of the Luxembourg banking system (17%). Other business

Figure 6

Total banking sector asset breakdown by type of business models

- Investment banking/Corporate finance
- Custodian banking
- Activities linked to investment funds and firms
- Private banking
- Covered bonds
- Other activities
- Retail and commercial banking
- Intragroup liquidity management
- Clearing and settlement

Source: CSSF

models focus on niche activities or specific client types by providing financial services to international corporations (investment/corporate banks; 26%), portfolio managers and institutional investors (custodian banks; 14%) or wealthy clients (private banks; 21%). In fact, Luxembourg banks are mostly branches and subsidiaries of global banking groups (93% of 144 banking licenses in 2016) which are internationally oriented (75% of the total amount of loans is granted to foreign entities) and maintain strong relations with their parent banks.

As suggested in Table 1, the inter-bank market plays an important role in Luxembourg banking transactions (see loans to deposit taking corporations). Around 50% of the aggregate total assets of the banking sector are composed of inter-bank loans, of which 80% are intra-group loans.[84] These types of loans usually have a very short maturity and provide either interest income or commission income. For these reasons, Luxembourg banks are often described as net liquidity providers which draw on their deposit base to channel funds to parent banks. From a financial stability perspective the risks related to intra-group loans are mixed. On one hand these risks may be considered very low because the level of liquidity mismatch is practically nonexistent and the default probability of the parent remains low. Moreover, academic literature (Reinhardt and Riddiough (2014)) shows that the intra-bank market contributes to dampen adverse shocks by constituting an alternative source of funding to the inter-bank market when the latter dries up during liquidity or solvency crises. On the other hand, intra-group transactions increase the cross-border interconnectedness of the financial system and represent a possible channel of external contagion. The return of such activities is presumably low since the risk

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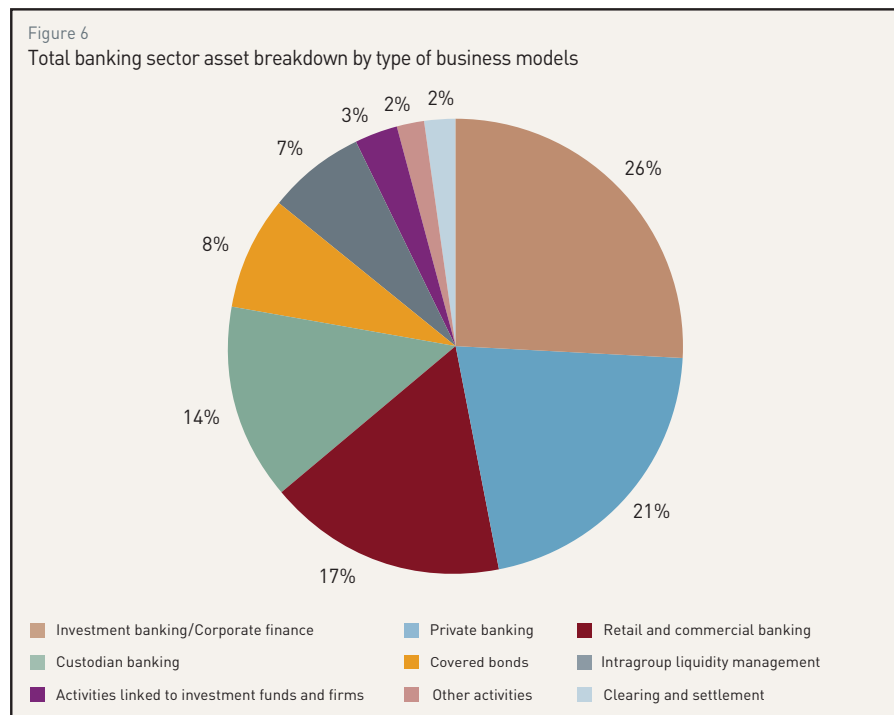
84   BCL (2016). Revue de stabilité financière. Section 3, page 49.

premium and the term premium are likely marginal. However, large banking groups may find it profitable to manage liquidity in various jurisdictions. Hence, the impact of the low interest rate environment is *a priori* difficult to assess and may be neutral on a significant share of the banking book.

Table 1:

Average total asset breakdown by main balance-sheet items and share of loans with an initial maturity superior to one year

	RETAIL BANKS	M>1 YEAR	PRIVATE BANKS	M>1 YEAR	CUSTODIAN BANKS	M>1 YEAR	INVESTMENT/CORPORATE BANKS	M>1 YEAR
LOANS	**70.5%**		**76.4%**		**53.7%**		**89.3%**	
Government	3.8%	72%	0.04%	27%	0.01%	100%	0.3%	96%
NFCs	16.4%	75%	11.6%	64%	1%	64%	24.8%	68%
Households	32.8%	95%	10.9%	32%	1%	43%	1.4%	74%
Central Bank	1.9%	2%	9.4%	0%	22%	0%	6.2%	0%
Deposit taking corporations	31.9%	49%	54.9%	24%	64%	12%	62.5%	14%
Financial companies	13.3%	77%	13.1%	45%	12%	0%	4.8%	58%
DEBT SECURITIES HELD	**24%**		**16.9%**		**38.6%**		**7.5%**	
EQUITY	**3%**		**2.5%**		**3.4%**		**1.3%**	
NON FINANCIAL ASSETS	**1%**		**0.5%**		**0.4%**		**0.1%**	
REMAINING ASSETS	**1%**		**1.4%**		**1%**		**1.0%**	
OFF-BALANCE SHEET EXPOSURES TO AVERAGE TOTAL ASSET	**14%**		**5%**		**3.6%**		**35.6%**	

Source: BCL, sample 2015Q3. Off-balance sheet exposures are the sum of credit lines and guarantees.

The Luxembourg domestic banking sector is dominated by several well-established players which correspond to the classical view of retail banks operating in an oligopolistic market. The mortgage credit market is fairly concentrated among the top five banks which account for around 80% of the loans to households for house purchases. This business model typically allows banks to extract monopoly rents through the use of mark-ups and mark-downs since households usually posses little bargaining power. However, as previously stated, those sources of income tend to decline with a flatter yield curve.

As shown in Figure 7b, banks' NIM has been trending downward since 2003. Since most of the stock of mortgage loans (77.5% on average for new loans issued between January 2009 and December 2016) are denominated at a floating rate, the return of those investments decreases and may not be compensated by the reduced losses on an already low level of nonperforming loans and a lesser need for provisions. In fact, households managed to lock in low rates with a higher proportion of fixed rate loans which went from 15% of the new loans issued in January 2003 to 59% in December 2016. It is still possible that banks will continue to expand their loan portfolios due to the strong demand for credit stemming from the residential real estate market. However, as the collateral prices increase, the risk premium shrinks and the net effect is unclear.

Finally, while retail lenders have diversified their banking books, they still rely primarily on maturity transformation (see table 1, column 1 and 2) and are likely to suffer from the low interest rate environment. As a consequence, the slight increase of NONII at the end of the period (Figure 7c) might suggest that retail banks are looking for other sources of revenues.

Corporate/investment banks usually provide funding solutions to large global firms by underwriting financial instruments (bonds and equity issuance) or syndicated loans, giving support and advice for

mergers-acquisitions and accommodating investors' trades via tailored hedging strategies and through their brokers, market making and proprietary trading desks. Table 1 (column 7 and 8) suggests that the corporate banking model dominates in Luxembourg compared to investment banking. Indeed, 89% of banks' balance sheets are composed of loans of which 24.8% are granted to nonfinancial companies. Moreover, their trading books (debt securities held and equity) do not seem to be large enough to conduct significant market based activities. While they have the highest level of off-balance sheet exposures (35.6%) those are credit lines and guarantees presumably granted to NFCs.

As shown in Figure 7b, NIM of corporate banks has approximately halved since 2010 while NONII has not increased significantly over the same period leading to a significant decrease of ROA since 2014. Hence, corporate banks in Luxembourg have not benefited from the positive valuation effects in financial markets and increased securities issuance induced by the low interest rate environment.

Custodian banks collect deposits and assets from corporate and institutional investors. A large part of their activities consists of providing related services to their clients like the collection of incomes from securities (dividends and interest), the execution of transactions, accounting and compliance services and financial reporting for investment funds (computation of net asset value

Figure 7
Profitability by business models
(in %)
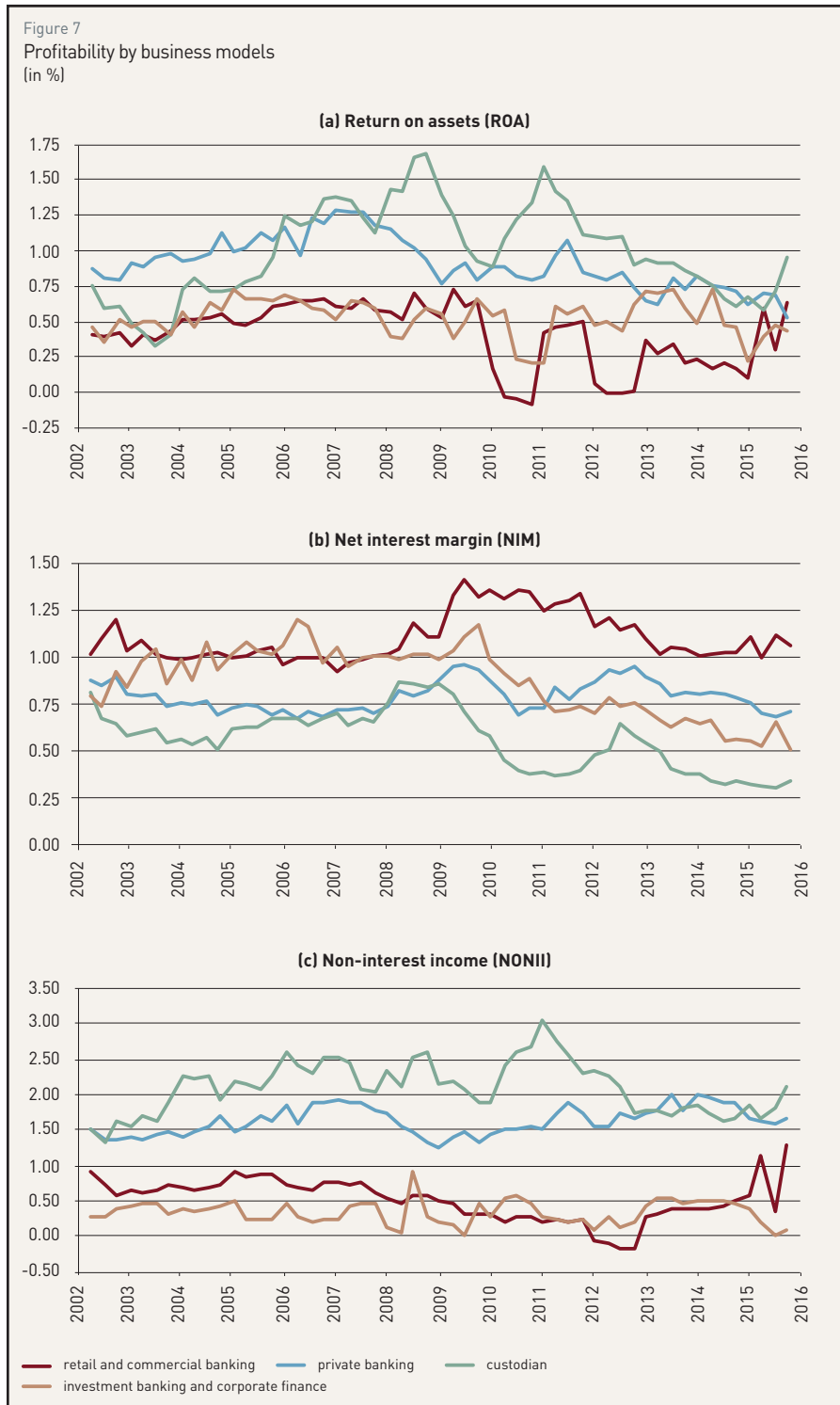
Source: BCL

and performance indicators). Custodian services play an important role in the Luxembourg financial sector, particularly for investment funds, which account for a significant portion of financial activity. Luxembourg banks hold a total of 3.5 trillion euros in assets under custody, half of which are held by four entities.

Even if custodian banks may profit from increased investment fund activities, the low interest rate environment is likely to have a negative impact on their profitability as the decrease in ROA suggests (Figure 7a). Indeed, custodian banks do not engage in significant liquidity transformation because of the high volatility of their deposit base and the low level of risk they need to attract clients. Hence, they invest in very liquid short maturity assets as shown in Table 1 and even deposit cash at the central bank (22% of the banking book). Custodian banking is likely the business model most impacted by negative central bank deposit rates and money market rates to the point where they may be reluctant to accept additional deposits as negative rates would be passed on to clients. For this reason, the dynamic of custodian banks NIM closely follows the trajectory of the short term rate (see Figure 4 and Figure 7b).

Finally, private banks are usually smaller structures which provide investment solutions and investment advice to wealthy clients. Table 1 (column 3 and 4) suggests that private banks tend to hold diversified portfolios with balanced maturities in the banking book. While, NIM and NONII seem robust, ROA is clearly on a decreasing trend since the GFC. Their biggest challenge in a low interest rate environment may come from the increased competition from investment funds and universal banks which could be tempted to aggressively attract their client base.

2   EMPIRICAL APPROACH

To evaluate the impact of the low interest rate environment on bank profitability at the aggregate level, we construct a database using quarterly bank-level balance sheet and income statement data from 2002Q1 to 2015Q3 as well as a set of macro-financial variables over the same time period. The dataset contains a sample of 172 banks which cover on average over 75% of total Luxembourg banking sector assets.

We estimate a dynamic panel model with a two-step system GMM[85] estimator proposed by Blundell and Bond (1998) with the Windmeijer's correction (2005) for robust standard errors.[86] The specification has been intensively tested with different panel estimators and control variables. In equation (1) we provide the definitive and robust specification. The model is of the form:

$$y_{i,t} = c + \alpha y_{i,t-1} + \beta_0 r_t + \beta_1 \Delta r_t + \beta_2 \Delta r_{t-1} + \beta_3 s_t + \beta_4 \Delta s_t + \beta_5 \Delta s_{t-1} + \beta_6 k_{i,t} + \beta_7 a_{i,t}$$
$$+ \beta_8 a\_vol_{i,t} + \beta_9 hhi_t + \beta_{10} gdp_t + \beta_{11} hp_t + \beta_{12} stx_t + \beta_{13} stx\_vol_t + \varepsilon_{i,t} \qquad (1)$$

with $y_{i,t}$ a measure of annual profitability (ROA, NIM, NONII), which is based on the last four quarterly values. ROA uses pre-tax net income, which ensures that differences in taxation across banks do not impact the results. NIM is interest income minus interest expenses over interest bearing assets; NONII is fees and commission income as well as foreign exchange income. Each of the profitability measures is normalized by average total assets (ROA, NONII) or average interest bearing assets (NIM).[87]

85   The Hausman test, the Baltagi-Wu test and the Likelihood ratio test suggest respectively the presence of a fixed effect, autocorrelation and heteroskedasticity. Therefore, the lagged dependent variable is correlated with the error term which introduces dynamic panel bias into the estimation process (Nickell, 1981). To overcome this limitation, we use the system GMM estimator.

86   We use the Stata package xtabond2 developed by Roodman (2009).

87   Average total assets for a given bank is defined as [assets(t) + assets(t-4)]/2. Average interest bearing assets for a given bank is defined as [loans and fixed income securities(t) + loans and fixed income securities(t-4)]/2.

The short-term rate r_t is the 3 month euro LIBOR, and s_t is the slope of the yield curve, defined as the German 10-year government bond yield minus the 3 month euro LIBOR. Following Alessandri and Nelson (2015), we introduce the variation of the rates Δr_t and the slope of the yield curve Δs_t at time t and t-1 to capture short run repricing effects. We control for bank-specific variables by adding the ratio of total capital to assets, the natural logarithm of total assets and the volatility of total asset denoted respectively by $k_{i,t}$, $a_{i,t}$ and $a\_vol_{i,t}$. The variable hhi_t is the Herfindahl-Hirschman index, which captures the level of concentration in the banking sector, and is calculated using total assets for each bank. We introduce a set of macro-financial variables to measure the impact of economic activity: gdp_t is the annual growth rate of nominal GDP in the euro area, hp_t is the annual growth rate of Luxembourg home prices, stx_t is the annual growth rate of the Euro Stoxx 50 index, and stx_vol_t is the implied volatility of 30 day options on the Euro Stoxx 50. Financial market data is taken from Bloomberg for stock index returns, implied volatility, and interest rates, and euro area nominal GDP growth is obtained from the ECB Statistical Data Warehouse (SDW), while the residential real estate price index comes from Statec.

We treat bank specific variables as well as lagged dependant variables as predetermined but potentially endogenous and they are introduced as GMM style instruments. All macro-financial variables are considered exogenous and are instrumented by themselves such as in the case for traditional instrumental variables. We run the model on the full sample from 2002Q1 to 2015Q3 to measure the "average" contribution of the rates to the profitability and then investigate the parameters' dynamics and nonlinearities through a rolling window of 22 quarters.

3   RESULTS

Full sample regressions

Since the time span of the sample is large and the instrument count is quadratic in T, we overcome inflation in the instrument count by collapsing the matrix of instruments and restricting the number of lags, so the number of instruments remains below the number of groups. [88] The results on the full sample are displayed in Table 2.

The specification tests demonstrate results close to previous studies. The Hansen test, as well as the separate Difference-in-Hansen tests (named GMM Inst. p and IV inst. p in Table 2) fails to reject the null hypothesis of the validity of instruments. The Arellano-Bond test (A-B AR(2) in Table 2) also fails to reject the null of no autocorrelation of order 2 in the regression residuals.

Net interest margin

For NIM (column 1), both the short term rate and the slope of the yield curve are significant and positive. This shows that higher rates and a steeper yield curve are associated with higher NIM. Hence, a 1 percent increase in the level of the short term rate leads to an increase of NIM by around 0.05% in the long run. This estimate is consistent with Alessandri and Nelson (2015) who find 0.035% increase over a quarter. The increase in the slope of the yield curve has a similar impact compared to the level of the short term rate with a 0.06% increase of NIM following a rise of 1% of the slope. This indicates that Luxembourg banks tend to make significant profits from maturity transformation activities.

Consistent with Alessandri and Nelson (2015), we find that in the short run unexpected changes in rates and the slope of the yield curve have a negative impact on NIM with at least a one period lag persistency

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88   The number of lags varies between 32 and 39 over a maximum default value of 55 time periods.

in the case of rates with estimated parameters of similar magnitude. Hence, Luxembourg banks' profitability suffers in the short run from repricing frictions suggesting that following an increase in interest rates, interest bearing liabilities tend to reprice faster than interest bearing assets, leading to a temporary margin compression. Over the long run, Luxembourg banks still profit from higher rates.

Bank specific variables (k, a, a_vol) are significant and positive. This is consistent with the view that bigger banks profit from economies of scale and are better able to handle negative shocks due to a higher degree of portfolio diversification. Moreover, strong capital positions allow banks to roll over short term debt at a lower cost on the money market, leading to a lower level of interest rate risk on the liability side.

The Herfindahl-Hirschman index is significant at the 10% level with an expected positive sign. Indeed, higher concentration gives banks higher market power and the ability to extract monopoly rents from mark-ups of loan rates and mark-downs of deposit rates.

Finally, most of the macroeconomic variables have good explanatory power. GDP growth is significant and positive while market returns and volatility are significant and negative. However, house prices do not seem to be significant.

Return on assets

The results for ROA (column 2) are broadly consistent with the parameters estimated for NIM. The level of the short term rate and the slope of the yield curve are positive and significant with similar magnitude. However, the negative short run repricing effects are less pronounced with Δr_t only significant at the 15% level. This may indicate that, at the portfolio level, interest rate risk is hedged and more difficult to capture with econometric models. However, it does not seem to be possible for Luxembourg banks to counteract the strong decreasing trend in the level of the rates.

Again, bank-specific variables are significant with positive signs. Interestingly the Herfindahl-Hirschman index and GDP are not significant, while home prices are significant at the 10% level and positive. Hence, despite the international orientation of some Luxembourg banking activities, certain banks still profit sufficiently from the residential real estate market to impact the results of the model.

Non-interest income

For NONII most of the rate variables are not significant at any conventional level. Only bank specific variables, GDP growth and market volatility have some explanatory power. While this may be linked to the fact that NONII is an aggregate measure of different sources of income, which can have different sensitivities to rates, this also suggests that Luxembourg banks did not adjusted significantly their business models. This is an important finding as it indicates that banks do not try to compensate lower NIM by increasing revenues from less stable activities. Although, profitability concerns remain, systemic vulnerabilities do not seem to build up outside traditional banking activities.

The concentration measure of the banking system (*hhi*) is significant and negative. This is consistent with Moshirian et al. (2011) who find that a high concentration level leads to lower non-interest income. This negative relationship holds because a high degree of competitiveness in traditional banking activities (deposit and loan market) acts as a push factor for banks to focus more on noninterest income based activities.

Table 2:

System GMM estimation results

	NIM	ROA	NONII
y_{t-1}	**0.700***	**0.734***	**0.758***
	10.84	14.30	15.50
r	**0.047**	**0.053***	0.006
	2.73	1.85	0.25
Δr	**-0.104***	-0.066+	-0.016
	-3.61	-1.58	-0.34
Δr_{t-1}	-0.04+	-0.018	-0.05
	-1.56	0.54	-1.22
s	**0.062***	**0.073***	0.033
	2.77	1.81	0.95
Δs	**-0.06**	-0.018	-0.001
	-2.93	-0.51	-0.04
Δs_{t-1}	-0.016	-0.005	-0.009
	-0.72	-0.20	0.31
k	**0.016**	**0.040***	**0.035***
	2.26	3.14	3.19
a	**0.256***	**0.533***	**0.286***
	4.38	3.35	1.94
a_vol	**0.002***	**0.001***	**0.001***
	3.76	1.88	1.82
hhi	**0.042***	-0.040	**-0.068***
	1.84	-1.22	-2.24
gdp	**0.016**	0.002	0.0013
	2.52	0.31	0.11
hp	-0.004	**0.012***	**0.01***
	-1.20	1.80	1.76
stx	**-0.002***	-0.001+	-0.001
	-4.59	-1.46	-1.31
stx_vol	**-0.003***	**-0.004***	**-0.002**
	-4.53	-2.87	-2.17
$cons$	**-6.667***	**-11.63***	**-5.979***
	-4.69	-2.87	-1.83
No. Obs	5.162	5.162	5.162
No. Banks	172	172	172
No. Instr	171	168	168
A-B AR(2)	0.800	0.478	0.937
Hansen p	0.517	0.457	0.387
GMM Inst. p	0.440	0.565	0.375
IV inst. p	0.378	0.310	0.323

*Note: += $p < 0.15$, * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$. The NIM equation uses the log value of NIM and has one more lagged value of NIM as an independent variable with parameter estimate of 0.1 and p=0.048. In this case, y_{t-2} is treated as a GMM style instrument, pushing the instrument count up.*
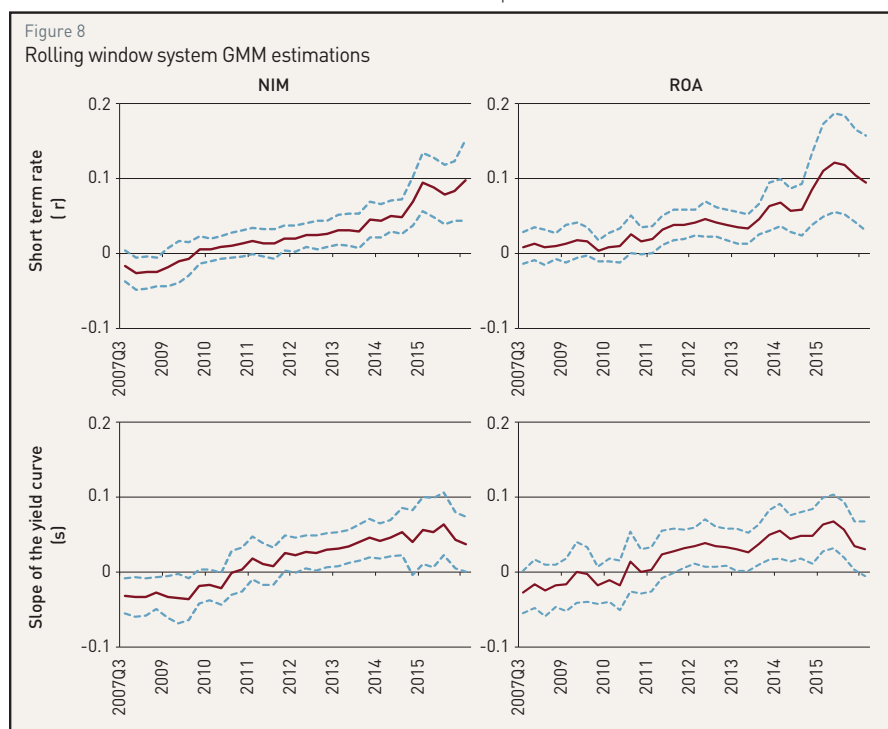
Finally, real estate prices are significant and positive suggesting that the positive impact detected at the portfolio level (ROA) mainly results from commissions related to real estate transactions and not directly from mortgage loans.

Rolling window regressions

According to Borio et al. (2015) the relationships between the rates and profitability measures are highly non-linear; i.e. positive and concave for NIM, negative and convex for NONII and positive and concave for ROA. In the case of NIM, this implies that, as the short term rate converges to the zero lower bound and the yield curve gets flatter, the compression of NIM becomes stronger. On the opposite side, with a sufficiently high level of interest rates, this relationship largely fades away.

We propose to investigate this phenomenon by adopting a different approach compared to Borio et al. (2015) who introduced squared values of the short term rate and the slope of the yield curve in a linear specification. We chose to estimate the same model as equation (1)[89] on a rolling window of 22 quarters, which allows us to track the dynamics of the parameters through time and verify if the relationship has become stronger at the end of the period. The results are presented in Figure 8.

The results show an upward trend in the expected values of the estimated parameters. This is particularly true for the relationship between the short term rate and NIM and/or ROA. In fact, hardly any link is detected between rates and profitability measures in sub-samples starting before 2005. This is consistent with Rouabah (2006) who does not find a significant relationship between the rates and profitability in his sample period. Hence, interest rates did not significantly impact profits before the GFC meaning that other structural bank-specific and macroeconomic

Figure 8
Rolling window system GMM estimations

Note: the figure reports the 22 quarters rolling window system GMM estimates of the parameters associated with the short-term rate and the slope of the yield curve with more parsimonious specifications compared to equation (1). The point estimate is placed at the end of the period. The first data point is 2007Q3; i.e. 2002Q1+22 quarters. The dashed lines represent the 15% confident interval.

factors were driving Luxembourg banks' profitability. However, as the rolling window advances, the parameters become different from zero and increase to a level two times above the average estimates on the whole sample. This shows that this relationship is indeed non-linear and that lower rates have impacted bank profitability more as time has passed.

89 To assure the quality of the estimations, the number of instruments is dynamically adjusted in the routine by keeping the number of instruments below the number of groups. Moreover, we use the orthogonal deviation transform to maximize the sample size considering the unbalanced nature of the sample.

CONCLUSION

This article studies the link between interest rates and bank profitability in Luxembourg, with a linear specification estimated on panel data with system GMM over the period 2002Q1 to 2015Q3. Following the approach developed by Alessandri and Nelson (2015) and Borio et al. (2015), we study the impact of the modification in the interest rate structure, the short term rate and the slope of the yield curve on two major elements of banks' income statements; net interest margin, non-interest income, and overall profitability as determined by return on assets. In our analysis we control for macroeconomic factors and bank specific characteristics. We find that in the long run, higher interest rates and a steeper yield curve increase bank profitability. As a consequence, this study reveals that low interest rates have an unequivocally negative effect on bank profits in the long run. However, in the short run, due to asset and liability repricing frictions, we find that a decrease in market rates leads to temporary higher profitability. This study also reveals that Luxembourg banks' NONII does not react at the aggregate level to the rates. Hence, we do not find any evidence of increased systemic risk linked to a surge in non-core banking activities. However, a continued low interest rate environment may eventually raise challenges for banks' resilience and the stability of the financial system in the long run.

As mentioned in section 1, Luxembourg banks have been able to build strong capital positions. Hence, there is no immediate vulnerability for the Luxembourg banking system stemming from the low interest rate environment. Moreover the entry into force of the second pillar of the Banking Union on the resolution of credit institutions on December 2015 provides Luxembourg authorities with the instruments to manage bank solvency issues in an orderly manner. Furthermore, the national macro-prudential authority, the *Comité du risque systemique* (CdRS), closely monitors the buildup of vulnerabilities in the banking system and has at its disposal new macro-prudential instruments (such as the O-SII buffer and the counter-cyclical capital buffer) to improve the resilience of the banking system.

Finally, it is important to recall that the low interest rate environment has implications which go far beyond the scope of monetary and macro-prudential policy. Global imbalances, productivity issues and ultimately the lower growth potential of the advanced economies will likely have to be addressed by structural reforms at the international and European level.

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