3. HOUSING PRICES AND MORTGAGE CREDIT IN LUXEMBOURG

Sara Ferreira Filipe[90]

ABSTRACT

This paper investigates the interaction between residential housing prices and mortgage credit in Luxembourg over the period 1980Q1-2016Q3. We use a vector error correction framework to model this interaction and allow for feedback effects between the two variables. In the long-run, higher housing prices lead to a mortgage credit expansion, which in turn puts upward pressure on prices. The growing demand for mortgage credit is also sustained by positive net migration to Luxembourg. Construction activity is another important determinant of housing prices, in line with existing supply-side limitations on dwelling availability. While price dynamics are partially explained by these structural factors, our results suggest that residential housing prices are currently characterized by a moderate overvaluation with respect to market fundamentals. This overvaluation is estimated at 5.7% in 2016Q3. Results also show that housing prices have a slow rate of adjustment to deviations from fundamentals (only 2.3% of the misalignment is corrected each quarter) and they do not directly adjust to disequilibria in the mortgage market.

1 INTRODUCTION

The recent financial crisis has demonstrated that developments in the residential real estate market may have severe repercussions on the financial system and the real economy. In addition, more credit-intensive expansions tend to be followed by deeper recessions. This understanding has brought the interaction between housing prices and mortgage credit into the center of the economic policy debate. A growing literature documents the importance of credit growth to housing market dynamics and, in particular, the existence of feedback effects between housing prices and credit in several countries. The work of Fitzpatrick and McQuinn (2007) for Ireland, Oikarinen (2009) for Finland, Brissimis and Vlassopoulos (2009) for Greece, Gimeno and Martinez-Carrascal (2010) for Spain, Anundsen and Jansen (2013) for Norway, or Turk (2015) for Sweden provide country-level studies. For Luxembourg, Di Filippo (2015b) provides an overview of the risks stemming from the mortgage market (both for households and lenders) although credit variables are not directly included in the modeling framework.

This paper contributes to the literature by modeling the interaction between residential housing prices and mortgage credit in Luxembourg over the period 1980Q1-2016Q3. Thus the main variables of interest are the real housing price index and flows of real mortgage loans. The set of fundamentals used in the analysis also includes proxies for construction activity, the real mortgage rate, and demographic variables. Standard unit root tests reveal that the variables are integrated of order one and results from the cointegration tests suggest the existence of two cointegrating relations. We therefore follow the vector error correction model (VECM) approach and interpret the two cointegrating relations as long-run equations for housing prices and credit. A first estimation based on initial identification restrictions suggests that the real construction cost index is weakly exogenous. The main results are then obtained with a restricted VECM analysis. In the long-run, higher housing prices lead to an expansion of mortgage credit, which in turn puts upward pressure on prices. The analysis also confirms the importance of structural factors in the Luxembourg housing market: first, construction activity is an important long-run determinant of property prices, reflecting supply-side limitations on dwelling availability;

90 Financial Stability Department, Banque centrale du Luxembourg

second, demographic factors should be taken into account, as positive net migration to Luxembourg helps sustain the demand for mortgage credit.[91]

While price dynamics are partially explained by these structural factors, we estimate that residential housing prices are currently characterized by a moderate overvaluation with respect to market fundamentals. To this end, we follow the literature and calculate a valuation measure based on the misalignment of the actual price series from the long-run fitted values of the restricted VECM estimation. Since the beginning of 2015, the average overvaluation in the Luxembourg residential real estate market is estimated to be 8.5%, with a value of 5.7% in 2016Q3. For comparison purposes, Turk (2015) estimates that housing prices in Sweden were between 5.5% and 12% above the long-run equilibrium in 2015Q2.

In terms of short-term dynamics of housing prices, the adjustment coefficient is estimated to be 2.3%, which implies that price deviations from fundamentals are corrected at a slow pace. Caldera Sanchez and Johansson (2011) show that there are wide differences across countries in the implied speed of price adjustment, estimating quarterly corrections to be between 2.7% (for Japan and Denmark) and 77.6% (for Poland). These estimates, however, do not consider the inclusion of a long-run equation for mortgage credit. Similarly, the speed of adjustment estimated here is considerably lower than the value of 7.7% documented for Luxembourg by Di Filippo (2015a). Again, this is most likely due to the inclusion of mortgage credit in the analysis. In fact, we find that property prices do not directly adjust to disequilibria in the mortgage market, i.e. the coefficient on the mortgage error correction term is insignificant. On the other hand, regarding the short-term dynamics for mortgages, both error correction terms are statistically significant and negative. The speed of adjustment of mortgage loans is estimated to be 36% per quarter, while a positive deviation of housing prices from their long-run equilibrium leads to a decrease of 13.8% in mortgage loans over the next period. The results therefore suggest that the equilibrium in the mortgage market is restored faster than is the case for housing prices.

The rest of the paper is organized as follows. Section 2 describes the data. Section 3 discusses the methodology. Section 4 presents the initial VECM estimation and the main results. Section 5 concludes.

2 DATA

Data is collected from different sources on residential real estate prices, construction activity and housing supply, mortgage loans and interest rates, as well as demographic factors. The final quarterly sample covers the period between 1980Q1 and 2016Q3. The data on housing price indices for Luxembourg is made available at a quarterly frequency by STATEC. We use the index for new and existing dwellings that has been published online since 2007Q1. Given the short time span, we complete the time-series using historical data compiled from the Central Bank of Luxembourg (BCL) and the *Observatoire de l'Habitat*.

Regarding construction activity and housing supply, we use STATEC information on dwelling permits, housing stock values, and construction cost. The number of dwelling permits includes only residential buildings and it is available at a monthly frequency since 1979M01. Monthly permits are summed over each quarter to obtain a quarterly series. As permits proxy the construction activity, we calculate their moving average over four quarters to account for construction delays and the volatility in the series.

91 The limited supply of dwellings, insufficient to meet demographic pressures, has been highlighted by other studies. Peltier (2011) estimates that, in order to meet the increasing housing demand, 6,500 new dwellings should be built each year between 2010 and 2030. According to STATEC, the number of completed dwellings per year was on average 2,483 between 2010 and 2013.

We also calculate a housing stock series, using lagged permits and available housing stock values.[92] Moreover, we include in the analysis the bi-annual construction cost index and interpolate the series to obtain a quarterly variable.

With respect to mortgage credit, we use BCL data on new mortgage loans granted to domestic households. The data is available quarterly from 1992Q1 onwards, and annually for the period 1978-1991. The annual series is interpolated to a quarterly frequency (using a quadratic match sum approach) and then used to extend the current series backwards. For data on mortgage interest rates, which are available at a monthly frequency starting in 2003M01, we use quarter averages. Moreover, we extend the data backwards by using the growth rates of the quarterly three-month interbank lending rate for Belgium.

The housing market dynamics in Luxembourg are strongly influenced by demographic pressures, with housing demand being driven by an increasing population and a sustained net migration to Luxembourg. To capture this effect, we collected STATEC data on household size, population, and net migration. The average size of resident households is obtained from census data; the information is available every 10 years since 1970, so we linearly interpolate the data to obtain a quarterly series. Annual population estimates are also available since 1970; we apply a quadratic match average method to obtain a quarterly population variable. The average number of households is calculated as the ratio between total population and average size of resident households. Finally, data on annual net migration to Luxembourg is available since 1980 and it is converted to a quarterly frequency using a quadratic match sum process.

The series are seasonally adjusted, rebased to 2010 where applicable, and measured in real terms, i.e. the housing price index, mortgage loans, mortgage rate, and construction cost index are deflated by the consumer price index for Luxembourg. Following the literature, all variables are measured in logs, with the exception of the real mortgage rate, which is measured in per cent *p.a.*[93] The final variables are: real housing price index ($rhpi_t$), building permits (bp_t), housing stock (h_t), real construction cost index (cc_t), real new mortgage loans granted to domestic households (mg_t), real mortgage rate (r_t), average number of households (hh_t) and net migration (mi_t). Table 1 provides summary statistics on the variables, both in levels and first-differences.

92 Although information on the number of existing dwellings is not regularly published by STATEC, this number was estimated to be 135,760 at the end of 1979 and 227,326 in 2015Q1.

93 As net migration equals the number of people migrating to Luxembourg over those who leave, it can in principle be negative. In practice, the only sample year registering a negative value is 1982. Hence, we first linearly interpolate the net migration series between the two adjacent years and then apply the log transformation.

Table 1:

Summary Statistics

PANEL A: VARIABLES IN LEVELS		OBS	MEAN	STDDEV	MIN	MAX	CORR
Real housing price index	$rhpi_t$	147	4.085	0.469	3.291	4.801	0.987**
Building permits	bp_t	147	6.640	0.335	5.923	7.260	0.977**
Housing stock	h_t	147	12.077	0.162	11.822	12.363	0.981**
Real construction cost index	cc_t	147	4.551	0.067	4.402	4.627	0.983**
Real new mortgage loans	mg_t	147	6.069	0.869	4.511	7.303	0.983**
Real mortgage rate	r_t	147	5.577	4.736	-1.285	17.684	0.954**
Average households	hh_t	147	5.129	0.198	4.849	5.520	0.980**
Net migration	mi_t	147	6.690	1.173	2.970	7.989	0.985**
PANEL B: VARIABLES IN FIRST-DIFFERENCES		**OBS**	**MEAN**	**STDDEV**	**MIN**	**MAX**	**CORR**
Real housing price index	$rhpi_t$	146	0.009	0.017	-0.045	0.052	0.580**
Building permits	bp_t	146	0.005	0.056	-0.224	0.239	0.523**
Housing stock	h_t	146	0.004	0.001	0.002	0.011	0.560**
Real construction cost index	cc_t	146	0.001	0.006	-0.014	0.018	0.135
Real new mortgage loans	mg_t	146	0.016	0.075	-0.244	0.269	-0.060
Real mortgage rate	r_t	146	-0.111	0.979	-4.007	3.513	0.054
Average households	hh_t	146	0.005	0.002	0.001	0.011	0.665**
Net migration	mi_t	146	0.013	0.169	-1.066	0.862	0.566**

*Source: BCL calculations. 'Corr' stands for the first-order autocorrelation and ** denotes statistical significance at the 1% level.*

The order of integration was also analyzed, with the results of Augmented Dickey-Fuller (ADF) unit root tests presented in Table 2. The results suggest that the variables are non-stationary in levels. Most variables are stationary in differences, except for the average number of households and the housing stock.

Table 2:

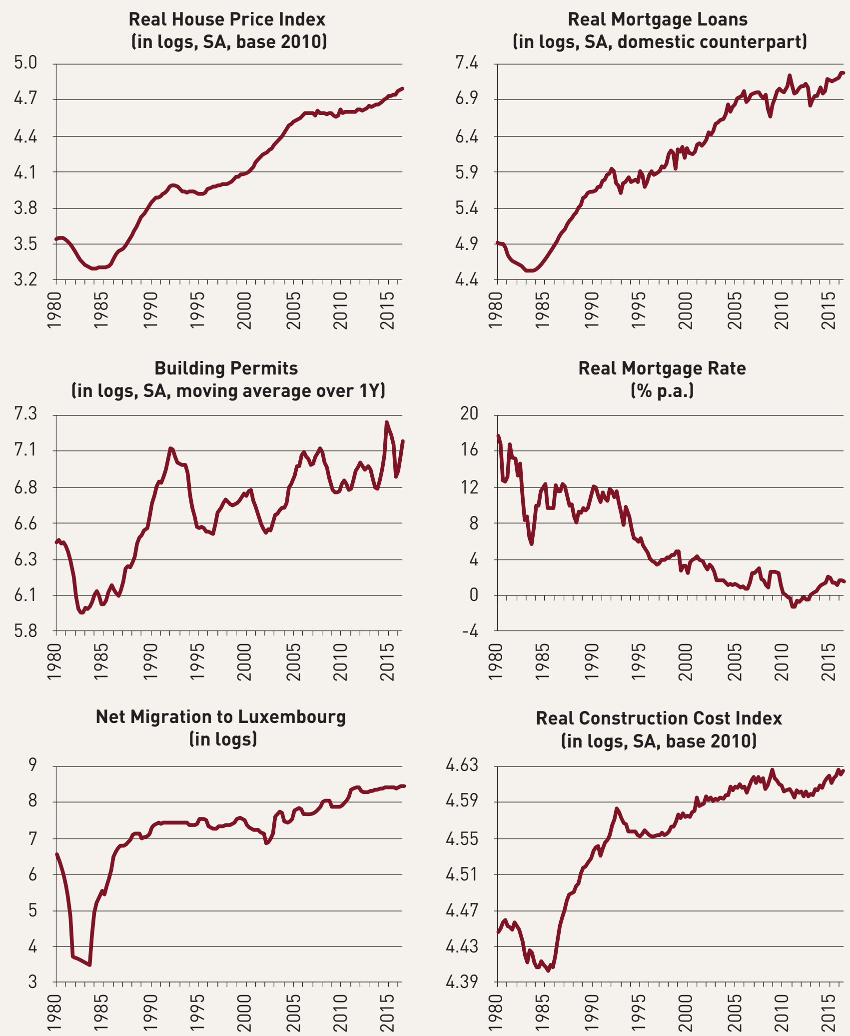
Unit Root Tests

	CONSTANT		CONSTANT + TREND	
	LEVEL	1ST DIFF.	LEVEL	1ST DIFF.
Real housing price index, $rhpi_t$				
Lags	2	1	2	1
Test Statistic	-0.220	-3.621	-3.262	-3.651
Probability	**0.932**	0.006	**0.077**	0.029
Building permits, bp_t				
Lags	5	4	5	4
Test Statistic	-1.387	-3.982	-3.055	-3.998
Probability	**0.587**	0.002	**0.121**	0.011
Housing stock, h_t				
Lags	3	2	3	2
Test Statistic	0.731	-2.773	-3.320	-2.929
Probability	**0.992**	**0.065**	**0.067**	**0.157**
Real construction cost index, cc_t				
Lags	4	3	4	3
Test Statistic	-1.140	-4.102	-2.128	-4.070
Probability	**0.699**	0.001	**0.526**	0.009
Real new mortgage loans, mg_t				
Lags	0	0	0	0
Test Statistic	-0.424	-12.786	-2.391	-12.744
Probability	**0.901**	0.000	**0.383**	0.000
Real mortgage rate, r_t				
Lags	0	0	0	0
Test Statistic	-2.047	-11.429	-3.033	-11.447
Probability	**0.267**	0.000	**0.127**	0.000
Average households, hh_t				
Lags	4	3	4	3
Test Statistic	2.523	-0.868	-1.204	-2.847
Probability	**1.000**	**0.796**	**0.906**	**0.183**
Net migration, m_t				
Lags	1	0	1	0
Test Statistic	-1.566	-6.338	-2.821	-6.315
Probability	**0.497**	0.000	**0.192**	0.000

Source: BCL calculations. Lags represent the optimal lag length according to the Schwarz information criterion. The probability is the p-value associated with the ADF null hypothesis of existence of unit root. Numbers in bold represent the cases where we cannot reject the null.

The finding that housing stock and demographic variables are $I(2)$ is common in the literature and often discarded due to data availability constraints. In this case, alternative measures seem to be a better option: in terms of construction activity, building permits and construction cost are good proxies and stationary in differences; regarding demographic variables, net migration effectively captures the increase in population in Luxembourg and is also $I(1)$. According to Turk (2015), net migration is preferred over other demographic factors, as immigration typically generates more immediate housing needs compared to the natural increase in population. Given these results, we opt for dropping housing stock and the number of households from the analysis. This ensures that all variables included in the econometric modeling are integrated of order one. Figure 1 displays their time-series, covering the sample period 1980Q1 to 2016Q3.

Figure 1
Evolution of Main Variables



Source: BCL calculations

3 MODEL

3.1 Modeling Housing Prices

In general, the relationship between housing prices and fundamentals can be analyzed under the life-cycle model of housing. We follow Anundsen and Jansen (2013) and augment this model with a term capturing the presence of credit constraints. Market efficiency requires that, in equilibrium, the cost of owning a given dwelling should be equal to the real imputed rental price for housing services, Q_t (i.e. what it would have cost to rent a dwelling of similar quality). It follows that:

$$RHPI_t = \frac{Q_t}{\left[(1-\tau_t)i_t - \pi_t + \delta - \frac{\dot{RHPI}}{RHPI} + \frac{\lambda_t}{\mu_c}\right]} \quad (1)$$

where $RHPI_t$ is the real housing price index, τ_t is the marginal tax deduction rate, i_t is the nominal mortgage rate, π_t is the inflation rate, δ is the housing depreciation rate (which is assumed to be constant), $\dot{RHPI} / RHPI$ is the expected real rate of appreciation for housing prices, λ_t is the shadow price of the credit constraint and μ_c is the marginal utility of consumption. The term in brackets is commonly referred to as the real user cost of housing, in this case augmented with the credit constraint. As Q_t is unobservable, one common approach in the literature is to assume that it is a function of related variables. This paper uses proxies that are related to housing stock and construction activity, as well as demographic variables. In particular, we use building permits BP_t and real construction cost CC_t, as well as net migration, MI_t. Equation (1) can then be written as:

$$RHPI_t = f\,(BP_t, CC_t, MI_t, r_t, \frac{R\dot{H}PI}{RHPI}, \frac{\lambda_t}{\mu_c}) \qquad (2)$$

where $r_t = (1 - \tau_t)\, i_t - \pi_t$ is the real after tax interest rate. We follow the literature and model price expectations by allowing lagged real price appreciations in the model dynamics. Finally we use mortgage loans MG_t as a proxy for the credit constraint, in the spirit of Anundsen and Jansen (2013). Then a log-linear approximation of equation (2) yields:

$$rhpi_t \approx \tilde{\beta}_{BP} bp_t + \tilde{\beta}_{CC} cc_t + \tilde{\beta}_{MI} mi_t + \tilde{\beta}_r r_t + \tilde{\beta}_{MG} mg_t \qquad (3)$$

where lower-case letters indicate that the variables are measured in logs and r_t is expressed as per cent p.a. Following Anundsen (2015), the equilibrium correction representation of equation (3) can be expressed as:

$$\Delta rhpi_t = \tilde{\gamma} + \tilde{\alpha}_{rhpi}\Big(rhpi_{t-1} - \sum_k \tilde{\beta}_k k_{t-1}\Big) + \sum_{i=1}^{p-1} \tilde{\rho}_{rhpi,i} \Delta\, rhpi_{t-i} + \sum_k \sum_{i=1}^{p-1} \tilde{\rho}_{k,i} \Delta k_{t-i} + \tilde{\epsilon}_t \qquad (4)$$

where $k = \{bp, cc, mi, r, mg\}$ denotes the set of housing market fundamentals used in the analysis and we expect $(rhpi_t - \sum_k \tilde{\beta}_k k_t)$ to be $I(0)$. The adjustment coefficient $\tilde{\alpha}_{rhpi}$ is expected to be negative and statistically significant if housing prices are determined by fundamentals.

3.2 Vector Error Correction Model

To analyze the relationship between residential property prices and housing market fundamentals, we generalize condition (4) above and estimate a multivariate vector error correction model (VECM) of the form:

$$\Delta \mathbf{y}_t = v + \Pi \mathbf{y}_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta \mathbf{y}_{t-i} + \epsilon_t \qquad (5)$$

where $\boldsymbol{y}_t$ is a K × 1 vector of variables, v is a K × 1 vector of parameters, and ϵ_t is a K × 1 vector of disturbances. ϵ_t has mean $\mathbf{0}$, covariance matrix Σ, and is *i.i.d.* normal over time. The variables in $\boldsymbol{y}_t$ are the set $\{rhpi, bp, cc, mi, r, mg\}$ so that $K = 6$. If the variables $\boldsymbol{y}_t$ are stationary in differences, the matrix Π has rank $0 < r < K$, where r is the number of linearly independent cointegrating vectors. Furthermore, if the variables cointegrate, then $0 < r < K$. The tests for cointegration used to determine the rank are based on Johansen's method (see Johansen (1991)).

Given the rank, the matrix Π can be expressed as $\Pi = \alpha\beta'$, where α and β are both $K \times r$ matrices of rank r. Without further restrictions, the cointegrating vectors are not identified; in practice, the VECM estimation requires at least r^2 identification restrictions. The deterministic component can also be expressed as $v = \alpha\mu + \gamma$. Equation (5) can therefore be rewritten as:

$$\Delta \mathbf{y}_t = \alpha(\beta' \mathbf{y}_{t-1} + \mu) + \sum_{i=1}^{p-1} \Gamma_i \Delta \mathbf{y}_{t-i} + \gamma + \epsilon_t \qquad (6)$$

Equation (6) allows for a linear time trend in the level variables and restricts the cointegration equations to be stationary around constant means.

4 ESTIMATION

4.1 Cointegration Tests

Table 3 provides the results of Johansen's cointegration tests, where *K = 6*. The results are mixed. At a 5% confidence level, the max-eigenvalue test suggests the existence of two cointegrating relations, whereas the trace test suggests the existence of three cointegrating relations. We analyze the number of cointegrating equations in more detail using recursive cointegration tests. We find that results are time-varying and that, for most of the sample, a rank of two is a better representation of the data. Hence, we estimate a model with two cointegrating relationships and, following the literature (see, for example, Gimeno and Martinez-Carrascal (2010)), we identify them as long-run equilibrium relationships for house prices and mortgage loans.

Table 3:

Johansen Cointegration Tests

NO. OF CE(S)	EIGENVALUE	TRACE STATISTIC			MAX-EIGENVALUE STATISTIC		
		TEST STAT	5% C.V.	1% C.V.	TEST STAT	5% C.V.	1% C.V.
$r = 0$	0.329	147.87	95.75	104.96	57.48	40.08	45.87
$r \leq 1$	0.232	90.39	69.82	77.82	38.02	33.88	**39.37**
$r \leq 2$	0.166	52.37	47.86	**54.68**	26.08	**27.58**	32.72
$r \leq 3$	0.107	26.30	**29.80**	35.46	16.28	21.13	25.86
$r \leq 4$	0.049	10.02	15.49	19.94	7.17	14.26	18.52
$r \leq 5$	0.020	2.85	3.84	6.63	2.85	3.84	6.63

Source: BCL calculations. The tests allow for two lags in first-differences and the inclusion of a linear deterministic trend. The columns 5% c.v. (1% c.v.) represent the critical values from surface regressions in MacKinnon et al. (1999) at 5% (1%) level. Numbers in bold denote the first hypothesis that is not rejected for each test and significance level.

4.2 Initial VECM Estimation

4.2.1 Identifying Restrictions

The estimation of the VECM parameters requires at least r^2 identification restrictions in the cointegrating vectors, where $r = 2$ in our case. As discussed in the previous section, we identify the two cointegrating equations as long-run equilibria for house prices and mortgage loans. This implies that, in the first equation, we impose a normalization restriction on housing prices (so that $\beta_{rhpi,1} = 1$) and, in the second cointegrating relationship, we impose a normalization restriction on mortgage loans (so that $\beta_{mg,2} = 1$).

For the third identification restriction, we assume that building permits bp_t do not directly affect the amount of mortgage loans in the long-run, i.e. $\beta_{bp,2} = 0$. This is in accordance with e.g. Fitzpatrick and McQuinn (2007), where the housing stock variable is excluded from the long-run equation for credit. It should be noted that there is still a second-round effect, via the impact of construction activity on housing prices and their effect on mortgage credit.

Regarding the last identification condition, we start by restricting the coefficient of the interest rate r_t on the price equation and imposing $\beta_{r,1} = -0.1$.[94] Empirically, the derivative of real house prices with respect to the interest rate is often found to be statistically insignificant (see, for example, Caldera Sanchez and Johansson (2011)). Moreover, as argued by Anundsen and Jansen (2013), its sign is theoretically ambiguous when controlling for disposable income and mortgage loans, as the main effects of a change in the interest rate work through these variables, and the remaining substitution effects may be of either sign. The authors start by estimating long-run equations for housing prices and debt without restricting the interest rate coefficient and find $\beta_{r,1} = -0.13$ (although statistically insignificant). Similarly, Gimeno and Martinez-Carrascal (2010) impose a zero coefficient on interest rates, so that aggregate credit is the variable that captures the impact of financing costs on house prices. In our case, when allowing for one cointegrating equation on housing prices (the only identifying restriction in this case is $\beta_{rhpi,1} = 1$), we obtain a positive effect for the real interest rate. As Fitzpatrick and McQuinn (2007) point out, a possible explanation for the positive sign may be the relatively high correlation with other market interest rates, such as deposit rates. This effect might be particularly important in Luxembourg, where households have high levels of financial assets. Moreover, as shown below, this identifying restriction will be relaxed with very similar results.

4.2.2 Initial VECM Results

Table 4 displays the results of the exactly identified model, using a lag of two periods and a rank of two. Panel A presents the initial estimated cointegrating equations for housing prices (CEq1) and mortgage loans (CEq2), which correspond to the long-run equilibria. Most variables are statistically significant at the 10% confidence level and show the expected signs in both equations (the exceptions are the statistically insignificant net migration, mi_t, in the first relationship, and real construction cost index, cc_t, in the second equation). Our initial results support the hypothesis that housing prices and mortgage credit are mutually dependent. We find that, in the long-run, increases in mortgage credit are associated with increases in real housing prices, which is consistent with a positive effect on housing demand. The number of building permits, a proxy for construction activity and the supply of dwellings, is negatively related with the price level. Similarly, an increase in the construction cost index translates to lower supply and higher housing prices. For the long-run equation on mortgage loans, we find that the positive effect of housing prices is highly statistically significant, confirming the existence of a two-way interaction between prices and credit. Moreover, the real interest rate is negatively related to credit, so that higher financing costs lead to a lower search for house credit by households. Finally, an increase in the number of households caused by net migration to Luxembourg translates to a more significant amount of mortgage loans.

94 The two cointegrating vectors are expressed as $CEqi_t = \sum_y \beta_{y,i} y_t + c_i$, where $y = \{rhpi,bp,cc,mi,r,mg\}$ and $i = \{1,2\}$. Hence, $\beta_{rhpi,1} = 1$ and $\beta_{r,1} = -0.1$ imply a positive long-run relationship between the interest rate and housing prices.

Table 4:

Initial Results: Exactly Identified VECM

PANEL A: COINTEGRATING EQUATIONS	$rhpi_t$	mg_t	bp_t	r_t	mi_t	cc_t	c
CEq1	1	-0.996**	1.523**	-0.1	-0.058	-6.277**	21.355
		[-10.801]	[8.198]		[-1.101]	[-4.434]	
CEq2	-1.412**	1	0	0.022**	-0.100**	-0.270	1.472
	[-16.981]			[4.379]	[-4.928]	[-0.512]	

PANEL B: SHORT-TERM DYNAMICS	$CEq1_{t-1}$	$CEq2_{t-1}$	$\Delta rhpi_{t-1}$	$\Delta rhpi_{t-2}$	Δmi_{t-1}	c	
$\Delta rhpi_t$	-0.011	0.019	0.243*	0.381**	0.015*	0.003*	R^2 = 0.538
	[-1.756]	[1.122]	[2.575]	[4.255]	[1.976]	[2.557]	Adj. R^2 = 0.488
Δmg_t	-0.093*	-0.361**	-	-	-	0.015	R^2 = 0.174
	[-2.502]	[-3.572]				[1.941]	Adj. R^2 = 0.084

*Source: BCL calculations. Panel A displays the estimated cointegrating equations. Panel B presents the (partial) estimated short-term dynamics for $\Delta rhpi_t$ and Δmg_t. T-statistics are shown in brackets and * (**) represents statistical significance at the 5% (1%) level.*

Panel B of Table 4 presents the estimation output of the short-term equations for $\Delta rhpi_t$ and Δmg_t, where for brevity only adjustment coefficients and coefficients that are statistically significant at a 10% cutoff level are displayed. Regarding the first equation, the error correction term $CEq1_{t-1}$ (i.e. the lagged residuals of the long-run equation for prices) is statistically significant at 10% but the second error correction term for mortgages is not. Our initial results suggest that, if housing prices deviate from their long-run equilibrium, they will revert back to the fundamental value at a very slow pace (i.e. with a correction of 1.1% of the disequilibrium per period) and they do not adjust to a disequilibrium in the mortgage market. Regarding the second equation, both error correction terms are statistically significant and negative. The speed of adjustment of mortgage loans is estimated to be 36.1% per quarter, while a positive deviation of housing prices from their long-run equilibrium leads to a decrease of 9.3% in mortgage loans over the next period.

4.3 Main Results

4.3.1 Weak Exogeneity Tests and Restricted VECM

In this section, we investigate the weak exogeneity of the variables with respect to the long-run coefficients. This amounts to testing if the loadings of both cointegrating vectors with respect to each variable y are zero, i.e. $\alpha_{y,1} = \alpha_{y,2} = 0$ (see Johansen (1992)). The only variable for which we find support for the weak exogeneity hypothesis is the real construction cost index, cc_t. The test statistic for the binding restrictions on cc_t is $X^2(2) = 0.47$ with a p-value of 0.79. To illustrate what this implies in terms of the VECM estimation, it is convenient to partition the vector $\mathbf{y}_t$ containing the variables into a vector of endogenous variables, $\mathbf{x}_t$, and a vector of weakly exogenous variables, $\mathbf{z}_t$. The VECM representation of equation (6) can then be expressed as:

$$\Delta \mathbf{x}_t = \alpha(\beta' \mathbf{y}_{t-1} + \mu) + \sum_{i=1}^{p-1} \Gamma_{x,i} \Delta \mathbf{x}_{t-i} + \sum_{i=0}^{p-1} \Gamma_{z,i} \Delta \mathbf{z}_{t-i} + \gamma + \epsilon_t \quad (7)$$

where $\mathbf{y}_t = (\mathbf{x}'_t, \mathbf{z}'_t)$ (see Anundsen (2015) for details and references therein). According to the results of the weak exogeneity tests, we consider $\mathbf{z}_t = cc_t$ and $\mathbf{x}_t = [rhpi_t, mg_t, bp_t, r_t, mi_t]'$.

As Table 4 shows, the estimated coefficient of cc_t in the long-run mortgage equation of the exactly identified VECM is statistically insignificant. Given this result, we also test the hypothesis $\beta_{cc,2} = 0$ in addition to the weak exogeneity restrictions $\alpha_{cc,1} = \alpha_{cc,2} = 0$ and find strong empirical support for the joint test. The test statistic for the three binding restrictions is $X^2(3) = 0.48$ with a p-value of 0.92. Finally, as the coefficient of net migration in the first cointegrating equation CEq1 is statistically insignificant, we impose $\beta_{mi,1} = 0$ and instead estimate the coefficient on the real interest rate. Specifically, the second identifying restriction on CEq1 is now given by the zero constraint on the migration coefficient and $\beta_{r,1}$ is estimated freely. This allows us to confirm our conjecture relative to the positive semi-elasticity of housing prices with respect to the real interest rate.

Therefore, the estimation of the restricted VECM described in equation (7) drops mi_t from the cointegration vector for housing prices (CEq1) and drops cc_t from the cointegrating vector for mortgage loans (CEq2). Moreover, insignificant variables in the second part of the VECM estimation output are sequentially deleted (using a 10% cutoff). In particular, we use the results from the first step Johansen's procedure for the restricted cointegrating vectors and estimate the short-term equations for $\Delta\mathbf{x}_t$ using the Seemingly Unrelated Regressions (SUR) approach.[95] This allows us to find a parsimonious model by using a general-to-specific approach and stepwise elimination of insignificant variables in the system. Table 5 presents the main estimation results.

95 For example, Caldera Sanchez and Johansson (2011) use SUR to jointly estimate both long- and short-run systems of equations for housing prices and residential investment. Unlike this paper, they do not consider the Johansen's procedure for the cointegrating vectors in the long-run, and do not allow for interactions of the error correction terms. As our focus is to model the mutual dependence between housing prices and mortgage loans, we use the results of the cointegration long-run analysis and employ SUR to jointly estimate the short-run system.

Table 5:

Main Results: Restricted VECM Estimation

PANEL A: COINTEGRATING EQUATIONS	$rhpi_t$	mg_t	bp_t	r_t	mi_t	cc_t	c
CEq1	1	-0.872**	0.859**	-0.063**	0	-3.480**	11.691
		[-11.190]	[7.023]	[-6.799]		[-4.344]	
CEq2	-1.410**	1	0	0.022**	-0.115**	0	0.340
	[-21.398]			[4.199]	[-6.559]		

PANEL B: SHORT-TERM DYNAMICS

	$CEq1_{t-1}$	$\Delta rhpi_{t-1}$	$\Delta rhpi_{t-2}$	Δbp_{t-1}	Δmi_{t-1}	Δcc_t	Δcc_{t-1}	c
$\Delta rhpi_t$	-0.023**	0.277**	0.210**	0.041*	0.016**	0.913**	-0.343	0.003**
	[-3.454]	[3.647]	[3.073]	[2.288]	[2.784]	[5.701]	[-1.939]	[3.225]
$R^2 = 0.609$, Adj. $R^2 = 0.589$								

	$CEq1_{t-1}$	$CEq2_{t-1}$	Δbp_{t-1}	c
Δmg_t	-0.138**	-0.360**	0.248*	0.015*
	[-2.899]	[-4.464]	[2.325]	[2.572]
$R^2 = 0.118$, Adj. $R^2 = 0.099$				

	$CEq1_{t-1}$	Δbp_{t-1}	Δr_{t-1}	Δmi_{t-1}
Δbp_t	-0.088**	0.519**	-0.007	0.050*
	[-3.542]	[7.558]	[-1.829]	[2.171]
$R^2 = 0.358$, Adj. $R^2 = 0.344$				

	$CEq1_{t-1}$	$CEq2_{t-1}$	$\Delta rhpi_{t-2}$	Δmg_{t-1}	Δmg_{t-2}	Δmi_{t-1}	Δmi_{t-2}	Δcc_t	Δcc_{t-2}	c
Δr_t	2.950**	-1.712	8.853	2.380*	1.812	1.410**	-1.224**	31.456**	24.405	-0.298**
	[5.232]	[-1.695]	[1.847]	[2.252]	[1.871]	[3.085]	[-2.658]	[2.783]	[1.941]	[-4.014]
$R^2 = 0.332$, Adj. $R^2 = 0.287$										

	$CEq1_{t-1}$	$CEq2_{t-1}$	Δr_{t-2}	Δmi_{t-1}	Δmi_{t-2}	Δcc_t	Δcc_{t-2}
Δmi_t	0.230**	0.579**	-0.041**	0.463**	0.138	-3.752*	6.110**
	[2.620]	[4.159]	[-3.995]	[6.420]	[1.907]	[-2.225]	[3.481]
$R^2 = 0.469$, Adj. $R^2 = 0.445$							

*Source: BCL calculations. Panel A presents the restricted cointegrating equations. Panel B presents the estimated short-term dynamics, where the equations are estimated by SUR and we sequentially eliminate coefficients that are not statistically significant at the 10% level. T-statistics are shown in brackets and * (**) represents statistical significance at the 5% (1%) level.*

4.3.2 Long-Run Analysis

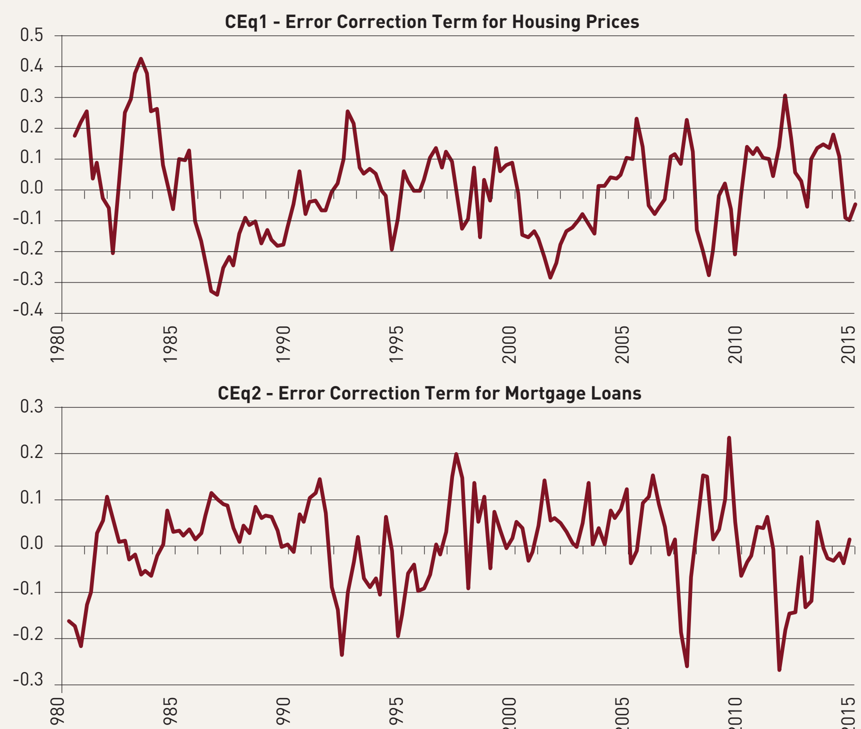
Regarding the cointegrating equations (see Panel A), all variables are highly statistically significant and the results overall confirm the signs and magnitudes of the initial estimation. The results support the hypothesis that housing prices and mortgage credit are mutually dependent. In the long-run, higher housing prices lead to a mortgage credit expansion, which in turn translates to higher housing demand and puts upward pressure on prices.

We report an elasticity of housing prices with respect to mortgage debt of 0.87, similar to the 0.98 documented by Anundsen and Jansen (2013) for Norway. Moreover, the elasticities of prices with respect to housing supply proxies are in line with the literature (respectively, -0.86 for building permits and 3.48 for construction cost). Although not directly comparable, Caldera Sanchez and Johansson (2011) use the stock of dwellings and find high negative elasticity values (i.e. lower than -1) for 15 out of the 21 OECD countries considered. Anundsen and Jansen (2013) estimate an elasticity of housing prices with respect to the stock of dwellings of -3.03 for Norway. Di Filippo (2015a) uses the number of dwellings and estimates a corresponding elasticity value of -4.53 for Luxembourg. Regarding demographics, net migration no longer directly affects the long-run equation for housing prices (recall that, in the initial estimation, the coefficient on net migration was 0.06 but statistically insignificant). For comparison purposes, Turk (2015) documents a corresponding value of 0.07 for Sweden. More importantly, we obtain a positive small effect for the real interest rate on housing prices, supporting the initial identifying restriction on $\beta_{r,1}$. As discussed above, a possible explanation for the sign may be the relatively high correlation with other market interest rates, such as deposit rates. This effect might be particularly important in Luxembourg, where households have high levels of financial assets. In the same line, Arestis and Gonzalez (2013) find a positive and significant long-run effect of mortgage rates on housing prices for Canada, Sweden, and the United Kingdom.

Regarding the long-run equation for credit, the estimated semi-elasticity of mortgage loans with respect to the real interest rate is -0.02, which implies that a 1 percentage point increase in the real interest rate will decrease mortgage borrowing by 0.02% in the long-run. This value is close to the value of -0.04 documented by Brissimis and Vlassopoulos (2009) for Greece. In turn, Fitzpatrick and McQuinn (2007) find a positive but very small effect of interest rates on credit in Ireland. With respect to net migration, there is a positive effect on the volume of new mortgage loans, with an estimated elasticity of 0.12. Finally, we find that housing prices exercise a greater long-run impact on mortgage credit than does mortgage credit on prices; this result is the opposite of that found by Anundsen and Jansen (2013) for total household borrowing, but is in line with the conclusions of Gimeno and Martinez-Carrascal (2010) for house purchase loans. In particular, we estimate that a 1% increase in housing prices increases mortgage loans by 1.41% in the long-run.

The estimated long-run values can be interpreted as the *fundamental values* of housing prices and mortgage loans. The deviations of the actual series from the estimated values are the error correction terms CEq1 and CEq2. Model inference depends crucially on the stationarity of these long run-residuals. Figure 2 plots their time-series and indicates that both series are stationary and roughly between -40% and 40%. Unreported results further confirm that the existence of unit roots for both series is strongly rejected (using individual or group unit root tests).

Figure 2
Long-Run Residuals



Source: BCL calculations. CEq1 and CEq2 are estimated using the first-step Johansen's procedure for the restricted cointegrating vectors as presented in Table 5.

4.3.3 Short-Run Dynamics

Panel B of Table 5 presents the estimation output of the restricted VECM short-term dynamics, where standard Portmanteau tests indicate no serial correlation in the system residuals.

Regarding the $\Delta rhpi_t$ equation, the housing prices' error correction term $CEq1_{t-1}$ is found to be statistically significant. Whereas the estimated coefficient is higher (in absolute terms) in comparison to the exactly identified VECM, the adjustment of housing prices in Luxembourg to deviations from fundamentals is considered slow, with an estimated correction of 2.3% per quarter. Caldera Sanchez and Johansson (2011) show that there are wide differences across countries in the implied speed of price adjustment, estimating quarterly corrections to be between 2.7% (for Japan and Denmark) and 77.6% (for Poland). This is also corroborated by the findings in Arestis and Gonzalez (2013) but neither paper considered the inclusion of a long-run equilibrium equation for mortgage credit. Similarly, the speed of price adjustment estimated here is considerably lower than the value of 7.7% documented for Luxembourg by Di Filippo (2015a), most likely due to the inclusion of mortgage credit in the analysis. In fact, we find that the coefficient on the mortgage error correction term is *positive* but insignificant (and therefore $CEq2_{t-1}$ is dropped from the equation). This result contrasts with the findings of Gimeno and Martinez-Carrascal (2010) and Anundsen and Jansen (2013), who document a negative coefficient for Spain and Norway respectively; nonetheless it is in line with the results of Brissimis and Vlassopoulos (2009), who also show that property prices do not adjust to the disequilibrium in the mortgage lending market in Greece. With respect to other variables, we document a positive effect of lagged house price changes on $\Delta rhpi_t$ (in line with the literature) and similarly for building permits, a positive (negative) contemporaneous (lagged) effect of changes in construction cost, and a positive coefficient for lagged net migration changes. Overall, the fit of the first short-term equation is noticeable, with an adjusted R^2 of 58.9%.

In the Δmg_t equation, both error correction terms are statistically significant and negative. The speed of adjustment of mortgage loans is now estimated to be 36.0% per quarter, while the effect of $CEq1_{t-1}$ is more important in comparison to the unrestricted case. In particular, a positive deviation of housing prices from their long-run equilibrium leads to a decrease of 13.8% in mortgage loans over the next period. It seems therefore that the equilibrium in the mortgage market in Luxembourg is restored faster than for the case of housing prices. For comparison purposes, the same values estimated by Gimeno and Martinez-Carrascal (2010) for Spain are 10.9% and 2.8%, respectively. Anundsen and Jansen (2013) find a lower speed of adjustment for real household debt in Norway (the estimated coefficient is -0.046) and an insignificant effect of the price error correction on the debt equation.

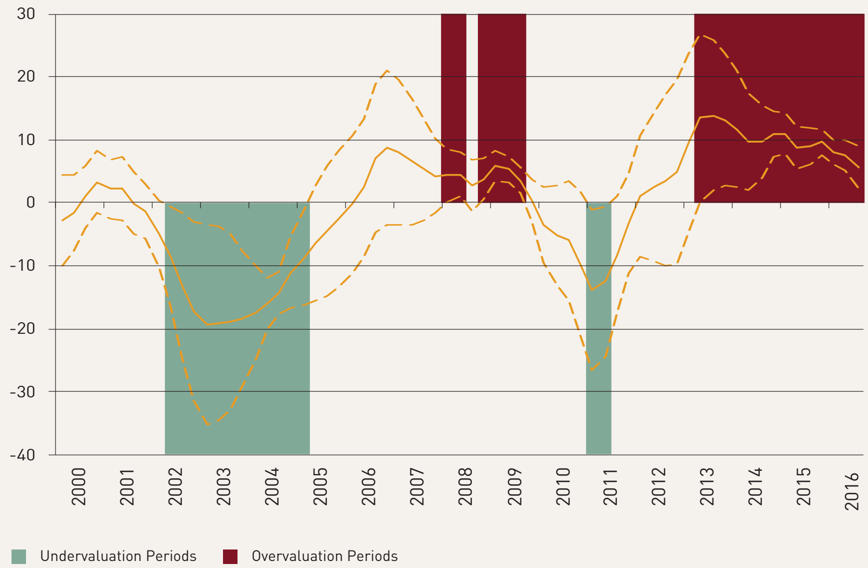
Regarding other interesting short-term effects, we find a negative and significant effect of lagged CEq1 on building permits Δbp_t. This implies that positive housing price deviations from fundamentals contribute, in the short-run, to a decrease in construction activity. These dynamics may contribute to magnify the existing supply constraints on dwelling availability.

4.3.4 Valuation Measure of Residential House Prices

The results suggest an important role for the interaction between residential housing prices and mortgage credit in Luxembourg. While the adjustment of housing prices to long-term deviations from fundamentals is done at a slow pace, property prices do not directly adjust to disequilibria in the mortgage market. Against this background, an important question refers to the degree of overvaluation or undervaluation of housing prices. To investigate this issue, we follow the literature and calculate a valuation measure based on the misalignment of the actual price series from the fundamental values estimated with the restricted cointegrating vectors. In particular, we use smoothed long-run residuals, calculated as a moving average of CEq1 over eight quarters, as our valuation measure. Figure 3 displays the results for the period between 2000Q1 and 2016Q3.

Overall the evidence suggests the existence of an undervaluation period between 2002Q2 and 2005Q1. This is consistent with the observation of a sharp decline in building permits and construction activity in the early 2000's (see Figure 1). The deceleration of construction activity would be reflected in a more limited supply of dwellings and, therefore, a jump in the fundamental value of housing. As the actual prices were growing at a steady rate, the dynamics are consistent with the estimated undervaluation. Furthermore it should be noted that, although net migration to Luxembourg also decreased, this drop was less significant and its long-run effect on housing prices is of a second-round nature (as it acts through a positive impact on mortgage credit).

Figure 3
Housing Prices - Overvaluation and Undervaluation Periods
(in %)



Source: BCL calculations. The solid line represents the smoothed deviations of housing prices from fundamentals. The dotted lines represent a confidence band around the estimated misalignment. Overvaluation (undervaluation) periods are signaled by the shaded red (green) areas.

The model also identifies two major overvaluation periods, the first roughly around 2008-2009 and coinciding with a decline in new mortgage loans after the onset of the financial crisis, and the second since 2013Q2. The analysis of the endogenous variables since 2013Q2 reveals a continuous increase in housing prices, an expansion of mortgage credit, a rise in construction cost, a stabilization of net migration to Luxembourg and some fluctuation in building permits and mortgage rates. Both the expansion of mortgage credit and the rise in construction cost directly contribute to a higher estimated fundamental value of housing prices. At the same time, $rhpi_t$ is increasing at a steady pace. Overall this evolution translates to a moderate overvaluation of housing prices. Over 2015 and the first three quarters of 2016, the average overvaluation in the Luxembourg residential real estate market is estimated to be 8.5%, with a value of 5.7% in 2016Q3. For comparison purposes, Turk (2015) estimates that housing prices were between 5.5% and 12% above the long-run equilibrium in Sweden in 2015Q2 using a similar approach. The analysis therefore confirms that the sustained increase in housing prices in Luxembourg is partially explained by structural factors, such as supply-side constraints (reflected in high construction cost and an insufficient level of building permits) and changes in demographics (with mortgage demand being heavily influenced by net migration to Luxembourg).

5 CONCLUSION

This paper investigates the interaction between housing prices and mortgage loans in Luxembourg. To this end, we estimate a restricted VECM that allows for feedback effects between the two variables. In line with the literature results for other countries, we confirm the existence of such interaction. In the long-run, higher housing prices lead to an expansion of mortgage credit, which in turn puts upward pressure on prices. Our analysis also confirms the importance of structural factors in the Luxembourg housing market: first, construction activity is an important long-run determinant of property prices, reflecting supply-side limitations on dwelling availability; second, demographic factors should be taken into account, as positive net migration to Luxembourg helps sustain the demand for mortgage credit.

While price dynamics are partially explained by these structural factors, we estimate that residential housing prices are currently characterized by a moderate overvaluation with respect to market fundamentals. Our valuation measure is based on the misalignment of the actual price series from the fundamental long-run fitted values. Since the beginning of 2015, the average overvaluation in the Luxembourg residential real estate market is estimated to be 8.5%, with a value of 5.7% in 2016Q3.

In terms of short-term dynamics of housing prices, we find that the adjustment coefficient is 2.3%, which implies that price deviations from fundamentals are corrected at a slow pace when comparing to other countries. This is most likely due to the inclusion of mortgage credit in the analysis. In fact, we find that property prices do not directly adjust to disequilibria in the mortgage market. Therefore, an increase in mortgage credit that is not explained by fundamentals may sustain the already strong housing demand in Luxembourg and contribute to a further short-term increase in housing prices. On the other hand, the speed of adjustment of mortgage loans is estimated to be 36.0% per quarter, while a positive deviation of housing prices from their long-run equilibrium leads to a decrease of 13.8% in mortgage loans over the next period. The results therefore suggest that the equilibrium in the mortgage market is restored faster than for the case of housing prices.

REFERENCES

Anundsen, A. (2015). "Econometric regime shifts and the US subprime bubble", *Journal of Applied Econometrics*, Vol. 30, pp. 145-169.

Anundsen, A., and Jansen, E. (2013). "Self-reinforcing effects between housing prices and credit", *Journal of Housing Economics*, Vol. 22, pp 192-212.

Arestis, P., and Gonzalez, A. (2013). "Modeling the Housing Market in OECD countries", Levy Economics Institute, *Working Paper* No. 764.

Brissimis, S.N., and Vlassopoulos, T. (2009). "The interaction between mortgage financing and housing prices in Greece", *Journal of Real Estate Finance and Economics*, Vol. 39, pp. 146-164.

Caldera Sanchez, A., and Johansson, A. (2011). "The price responsiveness of housing supply in OECD countries", OECD Economics Department, *Working Paper* No. 837.

Di Filippo, G. (2015a). "Residential Property Price Dynamics in Luxembourg: Lessons from ratio-based and model-based analyses", *Working paper.*

Di Filippo, G. (2015b). "An assessment of Luxembourg's Residential Real Estate Market", Central Bank of Luxembourg, *Financial Stability Review*, pp. 112-126.

Fitzpatrick, T., and McQuinn, K. (2007). "House prices and mortgage credit: empirical evidence for Ireland", *The Manchester School*, Vol. 75, pp. 82-103.

Gimeno, R., and Martinez-Carrascal, C. (2010). "The relationship between house prices and house purchase loans: The Spanish case", *Journal of Banking and Finance*, Vol. 34, pp. 1849-1855.

Johansen, S. (1991). "Estimating and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models", *Econometrica*, Vol. 59 (6), pp. 1551-1580.

Johansen, S. (1992). "Cointegration in partial systems and the efficiency of single-equation analysis", *Journal of Econometrics*, Vol. 52, pp. 389-402.

MacKinnon, J., Haug, A., and Michelis, L. (1999). "Numerical Distribution Functions of Likelihood Ratio Tests for Cointegration", *Journal of Applied Econometrics*, Vol. 14 (5), pp. 563-577.

Oikarinen, E. (2009). "Interaction between housing prices and household borrowing: the Finnish case", *Journal of Banking and Finance*, Vol. 33, pp. 747--756.

Peltier, F. (2011). "Projection des ménages privés et des besoins en logements 2010-2030", STATEC *Working Paper*, No. 55.

Turk, R. (2015). "Housing Price and Household Debt Interactions in Sweden", IMF *Working Paper Series*, WP/15/276.