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MODELLING THE HOUSING MARKET IN LUXEMBOURG

Abstract

A system of equations is identified which allows to capture the most important developments in the housing market in Luxembourg. The econometric set-up takes explicitly into account demand and supply aspects and the trade-off between renting and buying alike. Key supply factors considered comprise land supply, construction activity and the residential capital stock. Demand factors involve, among others, effective demand captured by the average number of households and latent demand proxied by the number of cross-border workers. The extended model allows for an analysis of the developments in the housing market in Luxembourg from a macroeconomic point of view taking into account various feedback effects from other sectors. It can then be used for structural analysis, policy analysis and macroeconomic forecasting alike.

1. Introduction

Housing market activity (residential investment) contributes about three percent to the gross domestic product (GDP) in Luxembourg. This seemingly small share hides the major role this sector plays for the aggregate economy and financial stability related aspects alike.

Economists have investigated the interplay of housing and the macroeconomy for the obvious reasons that housing accounts for a large fraction of household wealth. In addition, housing has some unique features that distinguish it from other assets. Specifically, (a) housing is infrequently traded and trades are subject to search frictions and large transaction costs (b) the dividends that housing provides are unique to housing in the sense that only a structure can provide shelter and in the case of owner-occupancy are hard to quantify, (c) the value of the asset class is enormous, and (d) the federal government interferes significantly in housing and mortgage markets. The sheer size of housing and mortgage markets suggests these peculiarities might affect macroeconomic outcomes and various other asset prices.

The variable which best describes the developments going forward in the housing market is real estate prices (henceforth *housing prices*). As they are an equilibrium concept, they reflect both demand and supply side shocks. First, house prices affect activity in the construction sector. For instance, a house price increase signals higher future profitability to construction firms which in turn incentives them to expand supply. Hence, housing prices stimulate housing construction activities and housing investment and hence the aggregate goods market and labour market alike. Second, housing prices affect household demand. This effect can be further decomposed into a change in the demand for housing and a change in the demand for overall consumption. As regards the first, increases in housing prices usually induce the demand for housing to drop. The drop in demand eventually leads to excess supply which in turn exerts downward pressure on prices and the housing market stabilizes. As regards the second, higher housing prices give rise to an increase in housing wealth. This effect has consequences for the real economy once home owners raising mortgage-secured loans to extract part of the increase in housing wealth to increase consumption. Hence, the presence of a wealth effect arising from changes in housing prices gives rise to a direct link between housing prices and the real economy. Once increases in housing prices spur indebtedness, then also financial stability related aspects arise. This link comes most apparent once a decline in housing prices is considered. In reaction to that, collateral values drop which in turn increases household leverage ratios. This raises the risk of loan losses for banks which banks will react to by increasing lending rates for both new borrowers and already existing ones – this applies in particular in case of mortgages based on variable lending rates. If the share of mortgages based on variable lending rates is high, spikes in lending rates deteriorate households' debt servicing ability which is likely to reinforce household loan default and hence banks' losses on their loan portfolio (i.e. rising non-performing loans). This interaction of loan-losses and higher lending rates has the potential of a downward spiral bringing about the consequences observed during the financial crisis of 2008/2009.

In Luxembourg, house prices have risen at a comparatively high pace. In addition to this, they have been growing fast since the global financial crisis. This development is likely to reflect the increasing gap between housing demand and supply. Strong population growth and a comparably large rise in the number of single-households has shaped housing demand within the last ten years. The limited supply of land for construction and the widespread practice of land hoarding constrains supply. In particular, a low price elasticity of housing supply is a typical feature of the Luxembourgish housing market. Hence, the supply of housing has not been able to keep up with demand which in turn is reflected in rising equilibrium housing prices. In this context, the steady rise in housing prices is likely to reflect changes in economic fundamentals. For instance, there is the potential that the reinforced monetary stimuli efforts by the ECB—well seen in the by now highly negative shadow rate—has contributed to the rise in prices as housing investment might now be more attractive than investing into financial assets (portfolio effect). Furthermore there is the possible impact of demographic developments as well as traffic related aspects related to commuting on the housing market. Not least we can also expect wages, employment and governmental subsidies directed to the housing market to shape fundamentals and prices alike.

In contrast to that, the sharp rise in house prices especially in the most recent episode (2018 until today) may prompt the issue of the existence of a bubble in the housing market, i.e. whether housing prices exceed their fundamental value which is determined by interest rates, income and other factors. Several developments can give rise to house price bubbles of which the most important one concerns the decision to purchase a dwelling today (putting an upward pressure on prices) when house prices are expected to rise in the period ahead. This expectation driven demand has the potential to trigger an in-proportionately strong increase in demand and prices alike. In contrast to that, prices may decline sharply once price expectations change. In this case, banks may experience that the value of the collateral falls below the value of the loan and that households increasingly have difficulties repaying their debt.

Hence, having at hand a tool-kit that allows assessing whether house prices are overvalued in relation to fundamentals, or whether the fundamentals have been responsible for the high house prices, is useful when monitoring the housing market, financial stability and the macroeconomy as a whole. An understanding as regards how and to what extent housing prices depend on different fundamentals is also important for projecting house price developments.

To assess developments in the housing market, the ratio of house prices to income and the ratio of housing prices to house rents comprise commonly used measures to assess whether house prices are overvalued or undervalued in relation to economic fundamentals. However, these measures are incomplete as they do not allow to identify whether housing prices are high (in relation to income or house rents) due to a bubble or due to developments in fundamentals. The only valid approach in this context is to estimate an econometric model of housing prices using fundamental variables as explanatory factors. Then, under certain conditions, one can use the deviation between actual and fitted house prices as a measure of whether or not housing prices are overvalued in relation to fundamental explanatory factors. This set-up, though, does not only allow for an assessment of housing prices being under- or overvalued, one can use this model then also for purposes related to economic forecasting and policy analysis. As regards the latter, this set-up then allows for an evaluation of the possible consequences of particular governmental policies for the housing market on the housing market itself but also on other sectors and the economy as whole.

Against this background, this project identifies an econometric set-up which allows to capture the most important developments in the housing market in Luxembourg. This set-up is considered as an extension for Modux, a structural macroeconometric model of the Luxembourgish economy. This in turn provides the necessary toolkit for being able to assess the consequences of shocks originating in the housing market for the aggregate economy and vice versa. The econometric set-up comprises nine equations for the following endogenous variables: housing prices, rent prices, housing capital stock, valued added in construction, construction prices (captured by means of the deflator of value added in the construction sector), land prices, new dwellings supply, building permits and mortgages. The set-up takes explicitly into account demand and supply aspects and the trade-off between renting and buying alike. Since this system of equations is built with the purpose of (among others) extending Modux, several compromises arise which are in turn discussed. The equation system allows for an analysis of developments in the housing market in Luxembourg from a macroeconomic point of view taking into account various feedback effects from other sectors. Hence, the extended model can then be used for structural analysis, policy analysis and macroeconomic forecasting alike. Eventually the equation system will be incorporated into Modux—a structural macroeconomic model used at Statec/Luxembourg. This project extends previous work on the housing market in Luxembourg (Glocker, 2017; Adam and Glocker, 2018 and Filipe, 2018).

2. Modelling the housing market – Literature review

The recent literature on macro-housing has emphasized the contribution of housing to the traditional business cycle through various channels such as residential investment (i.e., Davis and Heathcote 2005, Leamer 2007, Fisher 2007, Kydland, Sustek, and Rupert 2012, Boldrin, Garriga, Peralta-Alva, and Sanchez 2013), collateral constraints (i.e., Iacoviello 2005, Iacoviello and Neri 2010, and Liu, Wang, and Zha 2011), and nominal mortgage contracts (i.e., Garriga, Kydland, and Sustek, 2013) to name a few. An extensive summary of the state of this literature is provided by Davis and Van Nieuwerburgh (2015) and Piazzesi and Schneider (2016). While these papers measure the importance of housing to high frequency movements of the economy, in general, these models fail to reproduce less frequent episodes characterized by large swings in housing prices, like the recent boom-bust cycle observed in a number of developed economies.

The cyclical nature of housing has been a topic of interest for decades and many economists have written on the topic. A vivid empirical literature studies lead-lag relationships of housing with other macroeconomic aggregates, i.e. Green (1997), Leamer (2007) and Ghent and Owyang (2010), and the relationship of housing prices and housing wealth to consumption, for example Muellbauer and Murphy (1997), Davis and Palumbo (2001) and Case, Quigley, and Shiller (2005).

2.1. **Theoretical contributions.** Most of the theoretical work utilizes dynamic stochastic general equilibrium (DSGE) models in some form.

The first class of models in this context are classical real business cycle (RBC) models. Housing variables entered as objects of interest in the form of home production (Benhabib, Rogerson, and Wright, 1991; Greenwood and Hercowitz, 1991). These models are two-sector extensions of the canonical real business cycle model of Kydland and Prescott (1982). The key extension of these models relative to the original RBC model is that households are assumed to have three uses of time: market work and leisure, as in the standard model, and work at home. A justification for this approach (see McGrattan, Rogerson, and Wright (1997)) is that in time-use surveys, households on average spend about 25 percent of discretionary time on activities that can be classified as home work (see Greenwood, Rogerson, and Wright, 1995; McGrattan, Rogerson, and Wright, 1997).

Other papers that have adopted a similar housing production are Kahn (2008), Iacoviello and Neri (2010), Kiyotaki, Michaelides, and Nikolov (2011) and Dorofeenko, Lee, and Salyer (2013) to name just a few recent examples. These models have great success replicating—with a view to the US economy—the fact that residential investment is about twice as volatile as non-residential investment. Additionally, these models replicate the positive contemporaneous correlation of nonresidential and residential investment. This result arises from the fact that land acts as an adjustment cost to building new housing rapidly. As noted by Fisher (1997), these kinds of adjustment costs are necessary to generate positive co-movement of residential and non-residential investment. In contrast to that, these models fail to match the housing data along three dimensions. First, residential investment tends to lead GDP and non-residential investment tends to lag GDP. These models fails to replicate this finding. Second, these models under-predict the volatility of housing prices. Third, these models predict a negative correlation of residential investment and housing prices, whereas in the data the correlation is positive for nearly all countries.

A second class of theoretical models examines the role of housing in households' portfolios of assets. Housing is not only an important asset in the portfolio, it also has several features that make it different from investments in financial assets. First, it is illiquid in the sense that changing the quantity of housing may take time and/or require incurring substantial transaction costs. Second, it is indivisible: A limited assortment of types and sizes is available for purchase at any time (including a minimum size). Third, home ownership and housing consumption are typically intimately linked. Most households own only one home and live in the house their own. Fourth, housing represents the main source of pledge-able capital against which households can borrow. Investment in housing is much more leveraged than investments in other financial assets and the value of owned housing limits the amount of leverage in households' portfolios. In this context, Fernandez-Villaverde and Krueger (2011) argue that a key implication of these models is that the interaction of borrowing constraints and consumer durables induces young agents to accumulate durables early in life and increase non-durable spending and financial asset positions later in life. Yang (2009) revisits the work of Fernandez-Villaverde and Krueger (2011) and argues that consumption of housing first increases over the life cycle but fails to decline in old age, unlike non-durable spending. Nakajima and Telyukova (2012) show in this context that retired home owners spend down their wealth more slowly than renters. Halket and Vasudev (2014) show that these models can account for the increase in home ownership, increase in wealth, and decline in mobility over the life cycle. All these contributions address the topic of *Home ownership over the life-cycle*. There are several other research issues which have commonly been analysed using these models. This addresses among others *Housing collateral to smooth consumption* (see for instance, Hurst and Stafford (2004), Ejarque and Leth-Petersen (2008), Hryshko, Luengo-Prado, and Sorenson (2010)), *House price risk and demand for housing* (see for instance Han (2008), Sinai and Souleles (2005), Halket and Amior (2013)), *the role of housing on the financial portfolio* (see for instance Flavin and Yamashita (2002), Yao and Zhang (2004), Cocco (2005)).

2.2. **The role of supply constraints.** If housing supply inadequately adjusts to changes in housing demand, this might lead to large swings in housing prices for an extended period of time (Capozza, 2002). In the literature, the presence of a low supply elasticity is often associated with physical supply constraints related to topological conditions (Saiz, 2010) or a rigid planning system (Hilber and Vermeulen, 2016). For Luxembourg, both are likely to be relevant. In various, mostly urban areas, new construction is restricted because a considerable share of land is already developed (physical constraints). In addition, new housing supply is further hampered by a planning system that is fairly restrictive (Strasky, 2020). In the equation system proposed in Section 5, a look is taken at supply constraints as a whole without distinguishing between physical and regulatory constraints due to lack of data on the extent of rigidity of the planning system.

It has been found in the literature that shocks to household income trigger stronger effects on housing prices when supply constraints weigh heavily. Hilber and Vermeulen (2016) create an index for the extent of supply constraints in a given region. They do that for all regions in the UK by relating the amount of already developed land to total available developable land. Glaeser et al. (2008) show that areas with stronger supply constraints are likely to experience a larger housing boom. Moreover, during a boom phase the adaptive expectations of those who aspire to buy a house lead to overshooting of prices in the more supply-constrained areas, exacerbating the busts that are due to follow. Heebøll and Anundsen (2016) argue further that besides adaptive expectations, the financial accelerator effect is also more pronounced in more restricted areas. As a result, increasing (decreasing) housing prices lead to more (less) optimistic beliefs on future housing prices and more (less) collateral to borrow against.

2.3. **Buying versus renting.** An important element in the context of housing addresses the choice of buying versus renting. Perhaps the most important dimension of heterogeneity in models of housing involves this choice. Most authors assume that finite-lived households receive utility from non-housing consumption, the quantity of housing services, and whether or not those services are acquired through owning or renting. The discrete choice is whether or not to receive housing services by owning or renting. Li and Yao (2007) show that the relationship between the housing prices and the probability of home ownership is ambiguous and depends on the degree of household risk aversion. Additionally, they highlight that old home owners benefit from an unanticipated positive increase in housing prices, while renting households are strictly worse off after this shock. Similarly, an increase in wealth prompts a switch from renting to owning.

Yao and Zhang (2004) study how households optimally choose their portfolio of financial assets in an environment in which they can also decide whether to rent or to own residential property. They show that renters and owners choose substantially different portfolios of financial assets, highlighting that conclusions drawn about optimal portfolio allocations over the life-cycle from models that do not include a rental/own housing choice may be misleading. For example, when a household transitions from renting to owning in the model, the share of stocks in total wealth falls, but the share of stocks in liquid wealth increases. The reason is that the low correlation of stocks and houses and the high equity risk premium make holding stocks relatively attractive.

Coleman and Scobie (2009) develop a simple model that captures the essential features of the supply and demand for housing, and incorporates elements describing the demand to rent or purchase residential properties. The key feature of the model is that it allows both rental and ownership tenure options. The results suggest that despite the widespread attention, owner occupancy rates have attracted, they are not a particularly helpful guide to the state of the housing market. Typically they are quite insensitive to policy interventions, a result that follows from the integrated view of both the rental and ownership market, adopted in that study.

In a similar context, Rubaszek and Rubio (2019) provide evidence that the response of housing prices to macroeconomic fundamentals is attenuated by the size of the private rental market. They propose a DSGE model in which households satisfy housing needs both by owning and by renting. By simulating the model, they show that reforms enhancing the rental housing market contribute to macroeconomic stability.

With a view on empirical contributions, Davis and Ortalo-Magne (2011) use micro data on renting households from the 1980, 1990 and 2000 Decennial Censuses of Housing to show that, across metro areas and over time, the median ratio for renters of rental expenditures and utilities to household income is nearly constant at 24 percent.

2.4. **Housing in large scale models.** A number of large scale simulation models built also feature housing sector related elements with varying details. Notable among these are Meen and Andrew (2008) for the U.K., and Wood, Watson and Flatau (2003) for Australia. The U.K. model allows for population growth, different types of households, household formation, tenure choice, interregional migration, housing supply, and earnings. The model can be used to simulate the effect of changes in policies such as an increase in the supply of land for new construction. The Australian Housing Market Microsimulation (AHMM) model captures the housing supply and demand decisions of consumers and investors and allows for the effect of taxation. Policies such as a grant to first home buyers or changes to the depreciation allowances for new construction can be assessed for their impact on tenure choice and home ownership rates. The model captures the effect of government interventions on incomes, costs, and prices paid by decision makers on both the demand and supply side of the housing market.

The contributions most relevant for the present study are explained in what follows. All these studies involve structural macroeconometric models featuring the housing sector in some form.

DNB (2011) provide an overview for a macroeconomic model for the Dutch economy used for forecasting and policy analysis. It features housing wealth and housing prices as they are important determinants of the consumption pattern of Dutch households. The supply of mortgage credit to households in turn determines the path of housing prices in the long run. The model considers mortgages and housing prices as co-integrated variables, with developments in mortgage credit causing changes in housing prices. The short-run dynamics of housing prices depend on mortgage interest rates and the unemployment rate. As a starting point for modelling households' mortgage borrowing, it is assumed that in the long run, after-tax mortgage interest payments are a fixed fraction of the households' disposable income. This assumption reflects the current practice of mortgage lending in the Netherlands. The long-run determinants of mortgage debt are therefore disposable income and the mortgage interest rate net of the tax rate in the highest income tax bracket. In the short run, mortgage borrowing is also affected by changes in unemployment and housing investment. In addition, changes in housing wealth affect consumption spending in the short-run. Finally DNB (2011) takes into account that housing investment and private consumption co-move one-to-one in the long run. Housing investment is increasing in the number of building permits issued. In the short term, the change in housing investment is impacted by an error-correction term, the change in the number of productive hours worked per employee in the construction sector and the change in housing wealth. The latter variable can be motivated by the fact that part of (surplus) housing wealth is used for home improvement. The user cost of housing capital is a conventional function of the long term interest rate, depreciation and capital gains from (backward looking) expectations of price changes. The stock of dwellings cumulates according to a perpetual inventory condition, with a constant depreciation rate.

Bergin et al. (2017) build a model for the Irish economy which is called *COSMO: A new COre Structural MOdel for Ireland*. The significant contribution of COSMO is that it incorporates the interaction between credit markets (mortgages and consumer credit), macroprudential policy and the housing market, thus linking the real and financial dimensions of economic activity. Since the macroprudential tools are set to target new mortgage lending, mortgage demand is modelled in terms of the volume of new mortgage lending rather than the outstanding stock of mortgage credit. It is assumed to be a function of repayment capacity, given by income levels and the mortgage interest rate, and housing prices, which represent the value of household collateral. The supply of mortgage credit is represented by the mortgage interest rate and is modelled as a mark-up over deposit and money market funding costs (Davis and Liadze, 2012). The intuition for this is that the riskiness of mortgage lending to the household sector should reflect the loss-given-default associated with this type of lending as well as the ability of households to service this debt. The former is captured by the equity households have in their homes while the unemployment rate is used to approximate the latter. Household equity is given by the residual proportion of housing wealth net of the mortgage stock. Housing prices are modelled as an inverted demand function for housing, which relates real housing prices to income levels, the per capita housing stock, and the user cost of housing. The unemployment rate is also included in the house price equation as a proxy for market sentiment. On the supply side, housing investment is modelled as a function of Tobin's Q, cyclical factors, and the cost and availability of credit. Tobin's Q reflects the profitability of residential investment and is approximated by the ratio of housing prices to construction costs. Similar to the model for housing demand, there are two credit channels in the model of housing supply. The first channel is the cost of credit to construction firms given by the interest rate on corporate credit while the second channel reflects the availability of credit as approximated by the growth rate of construction credit. Finally, building costs, the unemployment rate and the corporate insolvency rate are included in the model as indicators of sentiment that may proxy for uncertainty about the future path of housing prices (Duffy et al, 2016a; McInerney, 2016). The total stock of dwellings then evolves according to the perpetual inventory method where current residential investment accumulates on to the depreciated stock from the previous period (Duffy et al, 2016a).[1]

Ballantyne et al. (2019) construct a macroeconometric model to capture the key economic relationships relevant for the conduct of monetary policy in Australia. The model consists of a series of estimated equations. Most of them are modelled in an error correction framework, which allows to impose a theoretically coherent structure on the long-run properties of the model while retaining the flexibility to account for the short-run empirical relationships observed in the data. The model features equations for the housing sector. Equations for housing (residential) investment, housing price and rents capture the demand for and supply of housing services—they

[1]Time series data on the stock of commercial property are not available for Ireland. Instead, and following Whitely and Windram (2003), COSMO assumes that the supply of commercial property can be approximated by the private sector capital stock. The price, or capital value, of commercial property is then modelled as an inverted demand function that is similar to the house price model. Capital values are assumed to be a function to real GDP, the private sector capital stock and the cost and availability of credit. Importantly, COSMO allows housing prices to affect commercial property capital values in the short run as construction firms compete for the same resources to complete both residential and commercial property investment.

hence, capture equilibrium conditions. The behavioural dynamics underlying these equations reflect households' decisions about whether to buy, sell or build dwellings. The equation for housing investment contains consumption, real mortgage interest rates and the relative price of housing investment. In the long run, households are assumed to allocate a stable share of their expenditure to housing and non-housing consumption, conditional on the level of interest rates. This implies that the ratio of nominal housing investment to nominal consumption expenditure will fluctuate around a constant mean, which conforms with the data. A decrease in real interest rates lowers the cost of borrowing to construct new housing as well as the cost of new housing relative to established housing. This makes housing investment more profitable and raises its expenditure share relative to consumption. Housing investment can deviate from its long-run equilibrium because of short-run movements in the nominal mortgage interest rate and real housing prices. Along a balanced growth path, real housig investment grows at the economy's trend growth rate. The model features housing prices using an ECM similar to that in Fox and Tulip (2014). Housing prices are expected to tend towards their fundamental value, which is the price where households are indifferent between owning and renting. Ballantyne et al. (2019) assume that variation in the user cost of owning a home is driven by movements in the real mortgage interest rate.[2] In the long run, if the real mortgage rate is constant, nominal housing prices will grow in line with rents. Like Fox and Tulip (2014), Ballantyne et al. (2019) find that the rents-user cost framework can account for much of the growth in housing prices over recent decades. In the short run, changes in housing prices have a large inertial component, and are also influenced by movements in nominal mortgage interest rates. As regards housing rents, in the long run, real rents depend on the demand for and supply of housing. Ballantyne et al. (2019) measure the demand for housing using real compensation of employees – the wage component of real household income. The supply of housing is given by the housing stock. This relationship can account for a large part of the low frequency movements in rents over recent decades. Because rent inflation is a highly persistent series, much of its short run behaviour is accounted for by its own lag.

[2]This implies that other components of the cost of owning are stable and captured by a constant in the long-run levels equation.

Another contribution in this context is Cambridge Econometrics (2019) which describes a macroeconometric model for the UK. Given that investment in dwellings is a big component of investment it was felt that the industrial investment equation was inadequate in explaining investment in dwellings and should be treated separately due to the different factors driving the decision-making process. For the long-run part of the equation the demand for housing is expected to have a positive relationship with real gross disposable income. Since most of the housing market is financed through borrowing, e.g. mortgages, the demand for housing also seems likely to be sensitive to variations in the real rate of interest. Variables covering child and old-age dependency rates are included to capture changes in investment in dwellings caused by changing demography. For the dynamic equation the unemployment rate is included, to capture the variation in the labour market, as well as the total consumer price deflator. Compared to the detailed specification of various other sectors, the housing sector is still kept small in the model.

OBR (2013) also considers a macroeconometric model for the UK which features distinct elements of the housing market. The equation for particulars delivered (housing turnover) is based on the assumption that turnover is negatively related to the difference between actual and expected housing prices. Expected housing prices are assumed to be determined by the user cost of housing, consumer prices and real disposable income. The equation also contains a demographic term, the number of people aged 20-29 (this age group is characterised by a greater mobility giving rise to a greater potential in explaining regional house price disparities). Private sector housing investment covers both investment in new dwellings and home improvements. Private sector housing investment is modelled using a long-term relationship with housing transactions (as a proxy for the demand for housing), and real housing prices and real interest rates (proxies for the profitability of house building). The equation was estimated using a housing transactions series excluding transactions of new dwellings, to reduce endogeneity problems. A lag of the growth in housing investment is also included in the equation to improve model fit. Finally, private housing rents are assumed to grow in line with the CPI.

Grech et al. (2013) build a macroeconometric model for Malta which contains a block of equations for the housing sector. Private housing investment is modelled as a constant share of real private sector GDP in the long run. Its short-run dynamics are driven by the housing permits issued, real housing credit, and real housing prices. housing prices are also modelled separately via a behavioural equation, given their importance within the local context. In the long run, to ensure the affordability of housing, the elasticity of housing prices with respect to disposable income per capita is restricted to one. In the short run, the provision of mortgage loans plays an important role in driving house price inflation, while the elasticity of changes in disposable income per capita is lower than one. The financial block models credit and interest rates, albeit in a rudimentary fashion. The model distinguishes between two types of credit – consumer and other credit, and housing credit – each of which is modelled through a behavioural equation. The financial block contains three other behavioural equations that determine a range of interest rates: the lending rate to non-financial corporations, the interest rate on consumer and other credit, and the interest rate on housing credit. Real housing credit in the long run depends on real housing prices with an elasticity of one, and on the real interest rate on mortgages. Its short-run dynamics are driven by real disposable income and real housing prices.

3. The data, their sources and alike

The following section provides a quick overview on the data used within the analysis. Where possible a comparison of Luxembourg data with those of the Greater Region (explained in more detail below) is made. The variables selected closely follow previous work in line with the overview provided in Section 2. The section ends with a discussion on data related shortcomings and the subsequent drawbacks for macroeconomic modelling. Additional details are provided in Section 5.2.4.

3.1. **The variables considered.** The data used are gathered from different sources. For some variables the historical information for Luxembourg dates back to the early 1970s, however, this is not the case for most series. Moreover, the frequency availability also differs across variables. In line with the current version of Modux, an annual frequency is used in what follows. While most series considered are already specified as annual data, all other series are transformed to an annual frequency. Table 2 provides an overview on the data used within the analysis. The table provides information on the particular coding of a variable in the Eviews-code of Modux and the source (name of institution). Some of the series are already contained in the Eviews database of Modux; though most variables listed in Table 2 are new. The variables outlined in Table 2 are used either in (log-)levels or in some other transformed way, possibly in the form of ratios with other variables. In what follows we provide a discussion on a few important variables.

Supply side factors

Building permits: Building permits are an important variable in housing. They are a type of authorization that must be granted by a municipality, government or other regulatory body before the construction of a new or existing building can legally occur. Since all related factors associated with the construction of a building are important economic activities (for example, financing and employment), the building permit data can give a major hint as to the state of the housing sector and the economy alike. The granting of housing permits can be a barometer of consumer confidence and solvency. Building permits for new housing can range from apartment buildings to single-family homes. A general increase in building permits could indicate a need for more housing. An increase in building permits specifically for single-family houses may indicate that more citizens have accumulated enough wealth to be able to afford their housing. Building permits are commonly evaluated relative to population growth (ratio of building permits to population growth); this shows the extent to which the change in the number of buildings is related to demographic trends. In case of Luxembourg it is also attractive to relate building permits to the amount (or growth rate) of commuters as commuters might eventually settle in Luxembourg by which they create a demand for housing.

Construction activity: It is a building activity indicator and provides information about the present and future levels of supply for residential, commercial, and industrial buildings. Building activity indicators provide important information on the health of the broad economy, largely because the level of construction activity plays such a key role in how the overall economy performs. In this context, current price trends and construction activity, when considered jointly, can provide important insights to potential supply bottlenecks, or sector specific imbalances in more general.

Construction costs: It is a supply specific indicator and provides information about price developments related to construction. High construction activity might exert upward pressure on construction prices which will eventually be passed on to home buyers in form of higher housing prices. Against this background, constructions costs (and construction prices in more general terms) provide one explanation of house prices to increase despite supply being expanded. This is a crucial transmission channel as a priori one might expect housing prices to decline once supply thereof increases. A key element here concerns the question of how quick is the pass-through from construction prices to housing prices. This effect naturally confines the analysis to newly built dwellings and affects prices of the existing housing stock only indirectly.

Share of developed land, developed land per capita, land prices: These variables are considered and utilized to assess the effects of the extent of supply constraints on housing prices. It is to be noticed that scarcity of land as such does not necessarily constrain housing supply since the altitude of houses determines the amount of housing services at the end of the day. The reason why land scarcity is still likely to be an important determinant for housing supply in Luxembourg is due to the fact that housing specific regulations constrain the altitude of houses which in turn constrains the number of flats per unit of land.

Vacancy rate: The extent of supply that is held back from demand (to be purchased or rented) is captured by the so called vacancy rate. In case of excess demand the vacancy rate should be low, however, there is still the potential for excessive vacancy rates. This can arise, for instance, from high regulatory protection of those who rent rendering the supply less attractive for owners, etc.

Demand side factors

Ratio of housing prices to rent prices: The price-rental ratio is the ratio of housing prices to the annual rent at a given location and serves as a benchmark for evaluating whether it is cheaper to rent or to own a property. The price/rent ratio is used as an indicator of whether the real estate markets are characterized by pricing in line with fundamentals or whether they are excessive in some form. For instance, the significant increase of this ratio in the US prior to the housing market crash of 2008-2009 was, in retrospect, a red flag for the property bubble. In many countries, statistical authorities nowadays produce a price-to-rent ratio which compares the total cost of owning a home with the total cost of renting a similar residential property. This ratio is commonly used as a benchmark for assessing whether it is cheaper to rent or own a property and therefore compares the economics of buying and renting - but it though provides no information as regards the affordability of either.

Ratio of housing prices to income: This measure is often used as a proxy for the extent of housing affordability. It lays out whether an individual is able to afford a property based on housing prices and income levels. This particular form of a housing affordability measure is also commonly used as a means to judge the quality of banks' mortgages and hence serves as a measure for systemic risk in the financial sector. Extensions of the housing affordability index often compare the cost of purchasing a home in different locations. As housing is often one of the largest expenses an individual faces, a housing affordability measure is considered as an overall indication of the costs of living in a particular area.

Total cost of home-ownership: This composite variable contains mortgage principal and interest, property taxes, insurance, closing costs, mortgage insurance, and tax advantages such as the mortgage interest deduction or public subsidies within the acquisition of a property.

Interest rates, mortgage rates: A low interest rate environment can rise demand for housing along two channels. On the one hand, low interest rates give rise to low mortgage rates which in turn expands borrowing capacity of households as debt servicing costs decline. Housing demand and credit demand hence increase which are likely to exert upward pressure on housing prices. On the other hand, low interest rates dis-incentive investment into fixed income assets (bonds, etc.) as profitability is low. As a result, funds might in turn be shifted into other assets, among them housing. This in turn gives rise to an increase in housing demand and housing prices alike. Hence, the interventions of big investment funds in the household sector can be captured indirectly by means of an interlinkage between interest rates and housing prices. The latter in fact comprise a portfolio effect concerning investment into housing versus financial assets of households and/or financial and non-financial corporations. This form of investment comprises an important factor especially in an environment of a build-up of a bubble as a purchase of a residential property occurs with the pure intention to re-sell it in the future at a presumably higher price. Buying and selling decisions are based upon the aspiration of steady housing price appreciations. In this context, the volume of financial assets could in principle be used to complement the interest rate in an attempt to capture portfolio effects in the model.

LTV and DSTI: The loan-to-value (LTV) and debt-service-to-income (DSTI) ratios address the borrowing capacity and debt servicing capacity of households and hence comprise important variables for capturing loan demand and hence housing demand and housing prices. These measures could be computed using data of the Household Finance and Consumption Survey (HFCS). The HFCS is conducted every three years in most Euro area countries. Following this idea, Carpantiera et al. (2018) compute the LTV ratio as the ratio between the amount of the loan and the value of the house at the time of acquisition of the property.

Commuters, population growth and other demographic factors: The share of cross-border workers has increased steadily in Luxembourg since the global financial crisis. Currently, nearly half of employed workers commute across borders. This large contingent of daily cross border workers from neighbouring countries creates a significant latent demand for housing in Luxembourg. This latent demand is complemented by demand arising from high population growth and the growing number of single-person households.

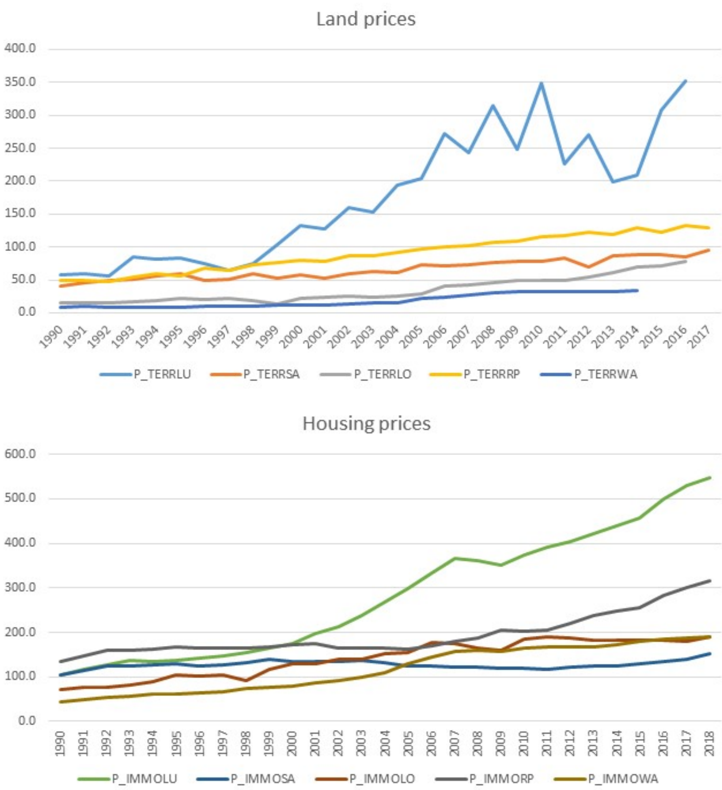
Return on housing: In the case that house purchases are made solely for investment purposes, the return on housing is an important variable especially in relation to the return on alternatives as for instance investment in fixed income assets (bonds), in stocks, etc. In this context Alberts and Kerr (1981) assess the rate of return from residential investment taking into account (i) annual gross rental savings, (ii) annual operating costs, (iii) beginning-of-the-year investment costs, (iv) beginning-of-the-year equity investment, (v) annual debt service, and (vi) tax rates. The household's after-tax rate of return on this cumulative equity investment consists of two components: (1) the rental yield and (2) the capital gains yield. The first component arises from renting a property or from the net savings in rental payments in case the owner lives in the property. The second component captures the capital gain or loss that arises from changes in housing prices that would accrue if the property were sold. In this context, Alberts and Kerr (1981) point out that changes in the return on housing are mainly due to changes in housing prices. In particular, the second component (capital gains yield) dominates the first (rental yield) up to a factor of ten. Hence, inclusion of the return on housing might quickly introduce an endogeneity problem: high housing prices because of a high demand thereof due to high returns on housing; or high returns on housing due to high capital gains as housing prices increase significantly.

There are several further variables that would naturally be considered in an application within this context, though data scarcity impedes the use. This concerns for instance housing investment by Investmentfunds and alike. Attempts have been made to address these variables indirectly by means of prices of alternative assets—more on this in Section 5.

4. Housing prices, rent prices and land prices—a look at the data

Luxembourg is economically strongly embedded in the surrounding regions of Belgium, Germany and France. Above all, the good transport network shapes the interaction and thus the commuter volume as well as price dynamics of land and real estate. The upper subplot in Figure 1 shows the trajectory of land prices in Luxembourg and the neighbouring provinces (Wallonie in Belgium, Saarland and Rheinland-Pfalz in Germany and Lorraine in France henceforth *Greater Region*) from 1990 to the most recent data vintage. Land prices indicated in the figure refer to the sales price in EUR per square-meter of land. In the 1990s land prices increased at a low pace in all of the five regions with prices in Luxembourg surpassing those of the remaining regions throughout slightly. However, since the year 2000, land prices in Luxembourg have increased at two-digit rates. From 2000 until the outbreak of the global financial crisis in 2008, the average annual increase was 15% which compares to an average increase of only 8% in case of the other regions. The post-crisis period shows an excessively high volatility pattern in the case of Luxembourg, which arises, among other things, most likely from aspects related to adjustments in data collection and changes in definitions rather than pure economic aspects.

Figure 1. Land and housing prices in Luxembourg and the Greater Region

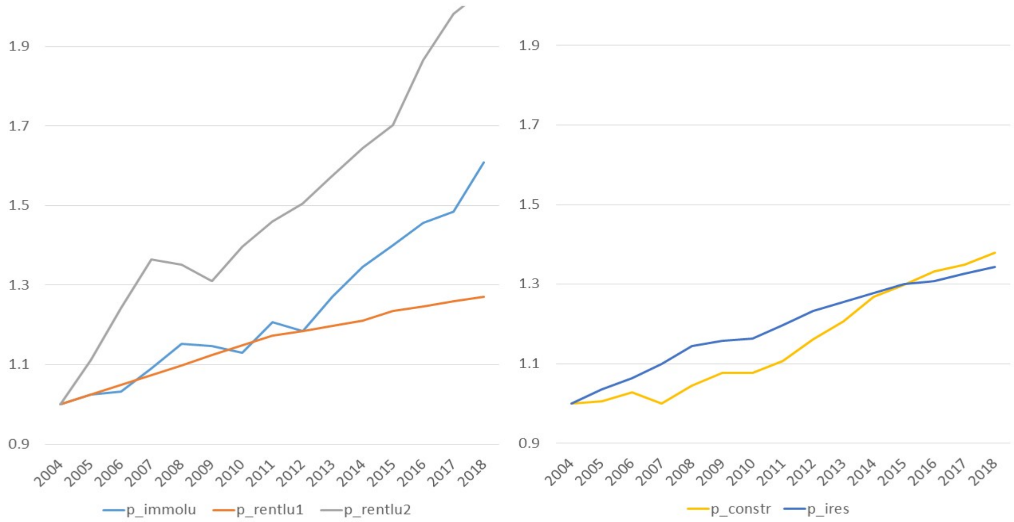


Note: The values on the y-axis refer to the average sales prices, in EUR 1000, per unit sold.

The lower subplot in Figure 1 shows the path of housing prices in the five regions. The price is average sales prices, in EUR 1,000, per unit sold. The pattern conforms with the one of land prices. A rather flat path in the 1990 stands in contrast to two-digit growth rates in the time thereafter. The average annual increase in housing prices in Luxembourg was 5% in the 1990s (same average annual increase in the Greater Region) which compares to an average annual increase of around 7% in Luxembourg and 3% in the Greater Region from 2001 until 2018. Hence, land and housing prices have been diverging since the year 2000 which has resulted in large differences in prices of land and housing in per square-meter and per house-unit terms.

The left subplot in Figure 2 compares housing and rent prices in Luxembourg. There are two sources of rent prices; one is from the Observatoire de l'Habitat (referred to as $p\_rentlu2$ in the figure) while the other measure is a taken from the

Figure 2. Rent, housing and construction prices in Luxembourg



Note: The values on the y-axis refer to Index-values.

CPI data (as rent prices are part of the CPI, the index hence features (monthly) data on rent prices; referred to as *p_rentlu*1 in the figure).[3]

The difference among the two indices for rent prices is that the one of the CPI refers to the rent of existing tenancies, while the second one refers primarily to new tenancies. Both increase over time though the one capturing new tenancies tends to grow at a faster pace especially from the 2012 onwards. The increase outpaces the rise in housing prices throughout.

In what follows, the focus will be on housing prices and rent prices of existing tenancies (*p_rentlu*1, sub-component of the CPI). The reason for using CPI based data on rent prices is due to the fact that Modux features the CPI index already at various places. Hence, modelling a particular sub-component allows to capture the overall fluctuations in the headline index more precisely.

The right subplot in Figure 2 shows the path of construction prices (*Price index (implicit deflator)*, NACE_R2 Construction; *p_vabconstr*) and prices of residential investment (*p_ires*). They increased in line with the other prices, though less than housing prices and significantly less than rent prices of new tenancies. While a gap between these two price measures occurred between 2006 and 2013, it was closed thereafter and the two series are currently moving in tandem.

[3]The notation in Modux is slightly different: *p_rentlu* for the measure from the CPI and *p_rentlu*2 for the other.

5. The econometric set-up

In what follows, a set of equations is specified with the intention to extend Modux. The extension is limited to the real estate market. This limits the range of available variables, since each new variable should be represented in the form of an independent equation to be able to represent it endogenously in the model. Furthermore, the equation specification also takes place against the background of the plausibility of the results resulting from the extended model. Instabilities, a too strong oscillatory behaviour but also results that cannot be reconciled with economic theory are some of the aspects that are taken into account in the equation specification exercise. As a result, the best equation specification from a pure econometric point of view is not always the one most adequate from the point of view of its usefulness within Modux. This shows the trade-off between high econometric precision and good estimation properties on the one hand and economic plausibility and coherence with the other equations in Modux on the other. Against this background, the appendix shows several additional equation specifications which were found to be good in the econometric specification, but which were rated inferior in the economic analysis.

The attempt of establishing a housing block for Modux discussed here has been designed and estimated following a pragmatic view. Thus, neither a pure top-down approach where data is allowed to determine the outcome of the new equation system all alone, nor a pure bottom-up approach where a structure motivated by economic theory is imposed on the equation system without taking proper account of data has been adopted. Instead something in between has been considered where the data and the theory are combined in an attempt to identify the structure that best explains the observed fluctuations in the data. In this set-up, theory contributes by constructing a possibility set, while the data play a role in choosing among the alternatives spanned by the theoretically motivated possibility set.

The following lists the equations in their error-correction (EC) representation. We start with an expression for housing prices (p_immolu_t):

Housing prices (p_immolu_t)

$$\Delta \log\left(\frac{p\_immolu_t}{p\_ires_t}\right) = -\underset{[-7.16]}{4.08} - \underset{[-3.48]}{0.02} \cdot \Delta(r\_ugrl_t) - \underset{[-4.41]}{0.11} \cdot \Delta \log\left(\frac{stoxx50_{t-1}}{p\_ires_{t-1}}\right) \tag{1}$$

$$- \underset{[-7.23]}{0.35} \cdot \left[\log\left(\frac{p\_immolu_{t-1}}{p\_ires_{t-1}}\right) + 5.44 \cdot \log\left(\frac{capbres_{t-1}}{poptot_{t-1}/persmen_{t-1}}\right) - 0.45 \cdot \log(frin_{t-1}) - 0.18 \cdot \log\left(\frac{p\_terrlu_{t-1}}{p\_ires_{t-1}}\right)\right]$$

$$+ \underset{[4.98]}{0.91} \cdot \Delta_2 \log(empbnq_t) + DV_t + \epsilon_t^{p\_immolu}$$

$OLS, \qquad \bar{R}^2 = 0.84$

$T = 1984:2018, \qquad DW = 1.57$

where DV_t denotes dummy variables, $\Delta_2 = 1 - L^2$ and L is the lag-operator. r_ugrl_t denotes the unemployment rate in the Greater Region, $stoxx50_t$ the Eurostoxx50 stock price index, $capbres\_r_t$ the real housing capital stock, $poptot_t$ the population size, $persmen_t$ the average number of persons per household, $frin_t$ the number of commuters between Luxembourg and the Greater Region and $empbnq_t$ the number of employees in the financial sector. The equation for housing prices uses the housing capital stock per average number of households ($capbres_t/(poptot_t/persmen_t)$), the amount of commuters $frin_t$ and the price of land p_terrlu_t within the cointegration relation for real housing prices.

An increase in the average number of households (either by means of an increase in the population and/or a drop in the average number of persons per household), a decline in the housing capital stock, an increases in the amount of commuters and an increase in land prices (also expressed in relative terms) exert upward pressure on real housing prices in the long run. More specifically, the cointegration relation captures demand along two components: the first is effective demand proxied by the average number of households. The second is latent demand which is proxied by the volume of commuters. The cointegration relation captures supply along two dimensions as well: the first is the residential capital stock. An increase thereof gives rise to an increase in housing supply which exerts downward pressure on prices. The second dimension concerns land prices. Since data availability of land use poses a challenge, we hence use land prices as a proxy of the extent of scarcity in land supply.[4] An increase in land scarcity is proxied by an increase in land prices. This in turn limits the expansion of the supply of housing as the scarcity of land impedes supply side activity. These supply side constraints give rise to increases in housing prices too.

The error correction term is negative and less than unity in absolute terms giving rise to stability, i.e. a gap between current and long-run equilibrium real housing prices vanishes. This occurs rather quickly as the error correction coefficient is rather high. In fact, if there is a gap between current and equilibrium real house price values, then the error correction coefficient implies that half of this gap will be gone after 1.4 years. Finally, the error correction expression implies that increases in real housing prices are triggered by a reduction in the unemployment rate of the Greater Region, a decline in the EuroStoxx50 stock market index and an increase in the growth rate of employment in the financial sector in Luxembourg. The dependency of housing prices on the Eurostoxx50 give rise to house purchases being a substitute for financial investment; this captures a portfolio effect involving stock market investment and residential investment. The fact that employment in the banking sector is a major contributor to housing prices shows that this sector that has been the source of the success of the Luxembourgish economy over the last decades. The fit of the econometric specification could be improved further by considering, for instance, construction prices ($p\_vabconstr$) instead of residential investment prices (p_ires); consider the Appendix for further details on that.

Equation (2) provides details on the specification for new dwellings ($dwell_t$):

Dwellings ($dwell_t$)

$$
\begin{aligned}
(2)\qquad \Delta\log(dwell_t) = {} & \underset{[8.69]}{7.61} + \underset{[1.99]}{0.18}\cdot\Delta\log(con\_perm\_dwel_{t-1}) - \underset{[-3.13]}{2.50}\cdot\Delta\log\left(\frac{p\_rentlu_{t-2}}{p\_pib_{t-1}}\right) \\
& - \underset{[-8.46]}{0.91}\cdot\Big[\log(dwell_{t-1}) - 0.88\cdot\log(ires\_r_{t-1}) + 0.01\cdot t\Big] \\
& + \underset{[5.15]}{0.10}\cdot(ticteur_t - tilteur_t) + DV_t + \epsilon_t^{dwell} \\
& OLS, \qquad \bar{R}^2 = 0.94 \\
& T = 1998:2017, \qquad DW = 1.79
\end{aligned}
$$

[4]While data for land use is available and also used hereinafter, its time span is very short. Hence, preference is given to land prices at this stage.

where $con\_perm\_dwel_t$ denotes building permits, p_terrlu_t land prices in Luxembourg, $ires\_r_t$ real residential investment and $ticteur_t$ and $tilteur_t$ denote a short and long term interest rate. The cointegration, i.e. long-run, relationship represents a relation between new dwellings, real residential investment and a deterministic time trend t. The coefficient of 0.88 is estimated, though, imposing a unity coefficient would work nearly equally well. The coefficient of the error correction term is comparably large in absolute terms which gives rise to a fast error correction. In particular, the estimated error correction value implies that half of the gap between current and long-run equilibrium values will be gone after about four months. The error correction part of the equation implies that the amount of new dwellings increases with the building permissions (lagged), an interest rate differential representing financial market conditions (now from the point of view of fixed income investors as opposed to stock markets as considered in equation (1)) and with rent prices. The latter shows in how far suppliers of housing react to rent prices: increases in rent prices act as a signal to suppliers since price increases give rise to increases in profits which in turn incentivizes suppliers to expand housing supply. This conforms with standard supply theory (firm theory) and comprises an important model specific aspect that guarantees stability of the model. Equation (2) features rent prices, though one could also consider housing prices in this context instead of rent prices.

The next equation we look at concerns rent prices (sub-index from CPI):

Rent prices (p_rentlu_t)

$$
\begin{aligned}
(3)\qquad \Delta\log\left(\frac{p\_rentlu_t}{p\_immolu_t}\right) = &-\underset{[-3.27]}{0.93} + \underset{[4.78]}{0.01}\cdot sldmigr_{t-1} - \underset{[-3.13]}{0.03}\cdot\Delta_2\log(dwell_t) \\
&- \underset{[-3.94]}{0.27}\cdot\Bigg[\log\left(\frac{p\_rentlu_{t-1}}{p\_immolu_{t-1}}\right) - 0.01\cdot\left(\frac{tihyp_{t-2}}{100} - \Delta\log(p\_cfin_{t-2})\right) + \\
&\qquad 2.86\cdot\log\left(\frac{rdmen_{t-2}}{poptot_{t-2}}\right)\Bigg] \\
&- \underset{[-6.24]}{0.05}\cdot(tihyp_{t-1} - ticteur_{t-1}) + DV_t + \epsilon_t^{p\_rent\_lu} \\
&OLS, \qquad \bar{R}^2 = 0.86 \\
&T = 1997:2017, \qquad DW = 1.19
\end{aligned}
$$

where $sldmigr_t$ denotes net migration flows, $tihyp_t$ the lending rate on mortgages, p_cfin_t the consumer price index (CPI) and $rdmen_t$ denotes disposable income expressed in nominal terms. The cointegration relationship determines rent prices to depend on the real mortgage lending rate and per capita disposable income. In particular, higher lending rates give rise to increases in rent prices. The intuition is the following: higher lending rates render external finance more costly. This discourages potential house buyers from acquiring real estate in a credit-financed form. Hence, in response to increases in lending rates, house purchases contract while renting a residential property becomes more attractive. This in turn exerts upward pressure on rent prices but downward pressure on housing prices. This trade off is reinforced by per capita disposable income. An increase thereof gives rise to a drop in rent prices. The intuition is that increases in income incentives tenants to switch from renting to owning. This trade-off is likely to be reinforced by macroprudential regulation in form of changes in debt-to-income ratios (DTI) etc. The corresponding increase in demand for house purchases and increasing excess supply of houses to be rented triggers an increase in housing prices relative to rent prices. Hence, the cointegration relationship captures two aspects people face when confronted with the decision whether to buy or rent: re-financing costs and disposable income. The error correction coefficient is small giving rise to a sluggish adjustment of deviations of current rent prices to their long-term equilibrium level. In particular, in case of a gap, half of it will be gone only after around 2.2 years. The error correction part of the equation extends the equation along various dimensions. First higher net migration exerts upward pressure while an economic slack—expressed by means of the output gap—exerts downward pressure on rent prices (this variable is omitted in equation (2) but it could easily be added as outlined in Appendix A). Additionally, the error correction part also contains an interest rate differential to capture financial market conditions: higher mortgage rates exert downward pressure on rent prices in the short run undermining the crucial role of financial markets in determining both rents as well as housing prices.

A possible economic explanation for the negative sign of mortgage rates in the error correction part is the following: if the purchase of a property is financed by credit and the house is purchased with the sole intention of renting it out later, then this establishes a direct link between the mortgage interest rates and the rent prices. To see this, consider the following: in the event of an increase in the mortgage interest rates, the owner's cost of capital increase. He will then try to pass on the increased cost of capital to the tenant in order to maintain his original level of profitability. Depending on how much of the the rise in mortgage interest rates is passed on to rent prices, they will rise. Finally, observe that the signs of the partial effect of dwellings and migration in the error correction part of the equation for rent prices align with supply and demand effects from the view of rent prices: an expansion in dwellings implies an increase in supply, hence rent prices decline; if migration inflows increase, this comprises an expansionary demand shock which in turn exerts upward pressure on rent prices. Apparently, to the extent that the signs of these demand and supply shocks are correct from the point of view of rent prices, the opposite applies in case of housing prices. This, though, should not be interpreted as a mis-specification since the dependent variable captures the ratio between rent and housing prices. The key implication is that the pass-through of supply and demand shocks tends to occur significantly quicker for rent prices than for housing prices. Put differently, the degree of price stickiness is higher in case of housing than for rent prices.

As the trade-off between renting and buying concerns also the costs for external financing, credit related aspects hence play a crucial role. In this vein, the next equation addresses mortgages:

Mortgages $(credresmen_t)$

$$
\begin{aligned}
(4) \qquad \Delta \log(credresmen_t) = &\underset{[7.10]}{4.74} - \underset{[-3.57]}{0.03} \cdot riskmen_t \\
&- \underset{[-6.86]}{0.97} \cdot \Big[\log(credresmen_{t-1}) - 0.69 \cdot \log(capbres\_r_{t-1} \cdot p\_immolu_{t-1}) - \\
&\qquad 0.86 \cdot (\log(rdmen_{t-1}))\Big] \\
&- \underset{[-2.65]}{0.01} \cdot (tihyp_{t-1} - ticteur_{t-1}) + DV_t + \epsilon_t^{credresmen} \\
&OLS, \qquad \bar{R}^2 = 0.84 \\
&T = 1996:2018, \qquad DW = 1.93
\end{aligned}
$$

where $riskmen_t$ denotes a mortgage related risk measure, $capbres\_r_t \cdot p\_immolu_t$ is the value of the residential capital stock evaluated at sales prices. The cointegration relationship determines mortgages as a function of the value of the residential capital and disposable income. The intuition is that increases in the amount of housing supply (i.e. new dwellings), represented by *capbres_r*, or the value of a single unit thereof, represented by the housing price index imply that a higher value for the overall residential housing stock has to be financed, among others by means of mortgages. On the other hand, increases in disposable income induce people to switch from renting to buying—consider also equation(3)—which in turn creates demand for mortgages. The error correction coefficient is large giving rise to a comparably quick adjustment to the long run equilibrium. In case of a gap between the current mortgages and the long run value, half of it will be gone after around eight months. This seemingly rapid adjustment masks the fact that this occurred at an even higher pace before the global financial crisis while is now significantly more sluggish. The reason for this is related to a structural break in the stochastic patterns of the time series which occurred in the vein of the global financial crisis. It cannot be conclusively clarified whether this was due to economic or purely statistical (i.e. data specific) aspects. The error correction term involves two variables. Mortgages increase when the overall level of risk in the mortgage related credit sector decline and mortgages drop when mortgage rates increase. The two are related in the sense that a lower risk environment gives rise to easier access the mortgages and lower mortgage rates alike. The equation is extended by a dummy variable controlling for a data specific peculiarity which induced a significant outlier in the year 1998.

The equation we consider next concerns building permissions:

Building permissions $(con\_perm\_dwel_t)$

$$
\begin{aligned}
&\Delta \log\left(con\_perm\_dwel_t\right) = \underset{[4.65]}{2.42} + \underset{[3.65]}{1.42} \cdot \Delta \log\left(\frac{p\_immolu_{t-1}}{p\_vabconstr_t}\right) \qquad (5)\\
&\quad - \underset{[-4.74]}{0.62} \cdot \left[\log\left(con\_perm\_dwel_{t-1}\right) - 0.81 \cdot \left(\frac{poptot_{t-1}}{persmen_{t-1}}\right)\right]\\
&\quad + DV_t + \epsilon_t^{con\_perm\_dwel}\\
&\quad OLS, \qquad \bar{R}^2 = 0.78\\
&\quad T = 1996:2018, \qquad DW = 1.63
\end{aligned}
$$

where $p\_vabconstr_t$ denotes construction prices. The cointegration relation gives rise to building permits rising with the average number of households $(poptot_{t-1}/persmen_{t-1})$. The degree of co-movement is 0.81 only, however, imposing a unit coefficient would also work. The long-run relation implies that an increase in demand for housing, proxied by the average number of households, leads to a rise in building permits. The error correction coefficient is of similar size as for mortgages. As before, in case of a gap between the current level of building permits and the long run value, half of it will be gone after around eight months. In contrast to mortgages the stochastic properties of the time series for building permits are rather stable over time. The error correction part features the ratio of housing prices to construction prices only (ignoring one dummy variable). This control variable implies that building permits increase with housing prices and decrease with construction prices. The intuition is that increases in demand give rise to increases in housing prices in case they are not met by supply sufficiently. Hence, housing prices proxy housing demand in this case. Higher demand eventually leads to an increase in building permits. Supply related aspects are captured by construction prices in this specification. An increase in construction prices dis-incentivizes suppliers to expand supply as profitability drops once input prices increase, ceteris paribus. From a theoretical aspect, the relation between housing prices and construction prices corresponds to Tobin's Q for the housing sector. In general terms, Tobin's Q is the relation between a physical asset's market value and its replacement value. In the present context, a measure for the market value is the housing price index while construction prices for the replacement value (see Section 2.4 and Bergin et al. (2017) for further details). Hence, the numerator is the market valuation: the current price in the market when selling or buying. The denominator captures the replacement or reproduction cost: the price in the market for newly produced houses. Considering investment theory, an increase in Tobin's Q promotes investment, while a drop triggers the opposite. Equation (5) captures this theoretical concept within an empirical context.

The next equation addresses construction prices:

Construction prices ($p\_vabconstr_t$)

$$\Delta \log(p\_vabconstr_t) = \underset{[4.56]}{0.12} + \underset{[3.05]}{0.05} \cdot \Delta \log(dwell_{t-1}) \tag{6}$$

$$- \underset{[-3.08]}{0.15} \cdot \left[\log(p\_vabconstr_{t-1}) - \log(p\_vabprvo_{t-1}) - 0.15 \cdot \log\left(\frac{migrin_{t-1}}{dwell_{t-1}}\right)\right]$$

$$+ \quad DV_t + \epsilon_t^{p\_vabconstr}$$

$$OLS, \qquad \bar{R}^2 = 0.70$$

$$T = 1996:2018, \qquad DW = 1.69$$

where $p\_vabprvo_t$ denotes the deflator for the private sector related value added and $migrin_t$ captures migration. The cointegration relationship is characterized by a similar specification as for residential investment prices (p_ires, not shown here). In the long run, construction prices depend on average prices (proxied by means of the GDP deflator)—they co-move one-to-one—and a variable that captures pressure on the housing sector arising from migration. The latter is specified as net migration in relation to the current level of residential investment captured here by new dwellings. If net migration inflows exceed residential investment, then upward pressure on construction prices arises. The error correction coefficient is rather small giving rise to a sluggish adjustment to the long run equilibrium. This conforms with the notion of sticky prices in general. In case of a gap between the current level of construction prices and the long run value, half of it will be gone after around 2.3 years. The error correction part features as most important control variable the number of new dwellings. An increase there in gives rise to higher construction prices. This relates to a simple demand effect—an increase in dwellings requires a pick up in construction activity. This in turn exerts upward pressure on construction prices.

The specification for the (real) value added in the construction sector reads:

Real value added of the construction sector ($vabconstr\_r_t$)

(7)
$$\begin{aligned}
\Delta \log\left(vabconstr_r_t\right) = & -\underset{[-5.17]}{3.35} + \underset{[3.12]}{0.11} \cdot \Delta \log\left(con_perm_dwel_t\right) \\
& - \underset{[-5.23]}{0.86} \cdot \left[\log\left(vabconstr_r_{t-1}\right) - 0.05 \cdot \log\left(\frac{con_perm_dwel_{t-1}}{p_terrlu_{t-2}}\right) - \right. \\
& \left. 1.06 \cdot \log\left(empconstr_{t-1}\right)\right] \\
& + \underset{[6.03]}{0.01} \cdot og_t + \underset{[2.88]}{1.47} \cdot \Delta \log\left(\frac{p_rentlu_{t-1}}{p_ires_{t-1}}\right) \epsilon_t^{vabconstr_r} \\
& OLS, \qquad \bar{R}^2 = 0.84 \\
& T = 1997:2018, \qquad DW = 1.71
\end{aligned}$$

where $empconstr_t$ denotes employment in the construction sector. The long run relation identifies a link between construction output and dwelling permissions and employment. The latter captures elements of a traditional production function while the former relates to specific sector related impediments for production. The cointegration relation contains a relative price term relating housing prices to construction prices. This relative price term captures profitability related elements: expanding construction output is particularly profitable when housing (=output) prices are high and/or when construction (=input) prices are low. The error correction coefficient is large giving rise to a comparably quick adjustment to the long run equilibrium. In case of a gap between the current output level and its long run value, half of it will be gone after around eight months. The error correction part of the equation features the output gap (og_t). By this a link between activity in the construction sector and the economy as a whole is established. The second variable in the error correction part is the permission of new dwellings: a rise therein implies an increase in construction activity.

An important variable depicting supply side elements is given by residential capital stock. The specification for it reads as follows:

Real residential capital stock ($capbres\_r_t$)

$$\begin{aligned}
(8) \quad \Delta \log(capbres_r_t) = &- \underset{[-2.35]}{1.12} + \underset{[7.03]}{0.75} \cdot \Delta \log(capbres_r_{t-1}) + \underset{[2.96]}{0.43} \cdot \Delta \log(poptot_t) \\
&- \underset{[-2.34]}{0.28} \cdot \Bigg[\log(capbres_r_{t-1}) - 0.01 \cdot \log\left(\frac{pucres_{t-1}}{p_ires_{t-1}}\right) - 1.02 \cdot \log(poptot_{t-1}) - \\
&\quad 0.07 \cdot \log\left(\frac{credresmen_{t-1}}{p_immolu_{t-1}}\right) - 0.05 \cdot \log(vabconstr_r_{t-1}) \Bigg] \\
&+ \underset{[2.25]}{0.02} \cdot \Delta \log\left(\frac{p_immolu_{t-1}}{p_vabconstr_{t-1}}\right) + \underset{[3.80]}{0.04} \cdot \Delta \log(vabconstr_r_t) + \epsilon_t^{capbres_r}
\end{aligned}$$

$OLS, \quad \bar{R}^2 = 0.89$

$T = 1996:2018, \quad DW = 2.48$

where $pucres_t/p\_ires_t$ denotes the capital user cost in the residential sector. The long run relation of this equation contains capital user cost, the size of the population, nominal credit deflated by housing prices and construction activity. The latter represents the build-up of the residential capital stock by means of construction activity. The former elements are explained in Adam (2004) and Glocker (2017). The error correction coefficient is small, giving rise to a comparably slow adjustment to the long run equilibrium. The error correction part of the equation contains an autoregressive term, the change in population, construction activity and a profitability measure. The intuition for the specific measure of profitability used is the same as for equation (7).

Finally, the last equation addressing supply side elements concerns land prices (p_terrlu) which is given by the following specification:

$$\textbf{Land prices } (p\_terrlu_t)$$

$$\Delta \log\left(\frac{p\_terrlu_t}{p\_pib_t}\right) = -\underset{[-0.48]}{0.02} + \underset{[1.86]}{0.69} \cdot \Delta \log\left(ires\_r_{t-2}\right) \tag{9}$$
$$- \underset{[-2.10]}{0.51} \cdot \left[\log\left(\frac{p\_terrlu_{t-1}}{p\_pib_{t-1}}\right) + 0.18 \cdot \log\left(\frac{land\_pot_{t-1}}{poptot_{t-1}}\right)\right]$$
$$+ \epsilon_t^{p\_terrlu}$$
$$OLS, \qquad \bar{R}^2 = 0.44$$
$$T = 2005 : 2018, \qquad DW = 2.55$$

where p_pib_t, $ires\_r_t$ and $land\_pot_t$ denote the GDP deflator, residential investment (in real terms) and land potential. In particular, the latter captures available land potential for housing in hectares which is composed of 100% of available surfaces in residential areas and 75% of available surfaces in mixed areas. The methodology used to analyse the land potential is described in detail in Liser (2018). The Housing Observatory (*Observatoire de l'Habitat*) at the Ministry of Housing in collaboration with the LISER (*Luxembourg Institute of Socio-Economic Research*) determines the land potential for housing in Luxembourg. An attempt is made to measures the land area potentially available for residential construction at the municipal level. These data are being used in equation (9) to explain land prices. The data for land potential are available on a three-year periodicity starting in 2004. The years within the three-year period were set using the value of the last available year. This means that the time series $land\_pot_t$ records variation within a three-year period, but none within these three years. The variable for land potential is used in the equation describing land prices within the long run (i.e. cointegration) relation. In the long run, land prices are assumed to move one-to-one with general prices which are proxied by means of the GDP deflator. Additionally, land prices increase with the size of the population ($poptot_t$). Finally, increases in land potential give rise to lower land prices. The latter describes a typical supply side phenomenon on the side of land availability. In principle, the variable capturing land potential could be used in the equation for construction activity, construction prices and housing prices. However, to the extent that the variable $land\_pot_{t-1}/poptot_{t-1}$ expresses supply side constraints at the side of land potential, the extent of land scarcity can equivalently be proxied by the relative price of land. Since the time series for land prices is observed at an annual basis starting in 1980, preference has been given to land prices in expressing supply side constraints in the equation system. The error correction part of the equation contains (real) residential investment as sole explanatory variable. As can be seen from Table 1, it improves the model fit by 66%. This seemingly high value confirms the intuition that residential investment activity relates to a small extent to renovations, while the major part thereof falls on new buildings. The latter though requires building land which constitutes the key factor for investment in housing and residential construction activity.

5.1. **On the explanatory power of the regressors.** The explanatory variables in equations (1) to (9) are all in line with economic theory—both from the sign of the coefficients and their sizes —and show reasonable t-values highlighting their statistical importance. However, the t-values alone and also the size of the coefficients say little about the contribution of a single explanatory variable to explaining the variation of the endogenous variable. Although R^2 statistics added to the equations provide information about the share of the variation of the endogenous variable that is explained by the explanatory variables in sum, it does not give information about the individual contribution of one particular explanatory variable. Against this background, the following attempt is made to determine the individual content of the explanatory variables. The focus will be on R^2 statistics—alternatively one could also choose the SSR (sum of squared residuals), etc. The exercise is as follows. To estimate the contribution of a variable, an equation is estimated where the variable of interest is missing. From this regression, the R^2 is then determined and compared with the R^2 of the complete regression equation. The difference of the R^2 of the two regressions gives information about the contribution of the explanatory variable of interest. This exercise is carried out for all explanatory variables of the short-run part in equations (1) to (9). In particular, for the explanatory variables in the error correction part, however, not for those in the cointegration relationship. Table 1 provides the results thereof. The values in the table indicate the gain of an exogenous variable to explain the variation of the endogenous variable. For instance, considering the output gap (og_t) in the equation for the value added

Table 1. Contribution in explanatory variables in explaining respective endogenous variables

$EQ: VABCONSTR\_R$				
og	con_perm_dwel	$\frac{p\_rentlu}{p\_ires}$		CI
0.73	0.13	0.11		0.46
$EQ: P\_IMMOLU$				
r_ugrl	$\frac{stoxx50}{p\_vabconstr}$	$empbnq$	DV	CI
0.18	0.44	0.45	0.16	1.91
$EQ: DWELL$				
con_perm_dwel	$ticteur - tilteur$	$\frac{p\_rentlu}{p\_pib}$	DV	CI
0.01	0.15	0.06	0.11	0.28
$EQ: P\_RENTLU$				
$tihyp - ticteur$	$sldmigr$	$dwell$	DV	CI
0.75	0.34	0.12	0.16	0.17
$EQ: CREDRESMEN$				
$tihyp - tilteur$	$riskmen$		DV	CI
0.08	0.16		0.19	1.07
$EQ: CON\_PERM\_DWEL$				
$\frac{p\_immolu}{p\_vabconstr}$			DV	CI
0.29			0.65	0.50
$EQ: P\_VABCONSTR$				
$dwell$			DV	CI
0.27			4.23	0.50
$EQ: CAPBRES\_R$				
$capbres\_r$	$poptot$	$\frac{p\_immolu}{p\_vabconstr}$	$vabconstr\_r$	CI
0.62	0.07	0.04	0.13	0.04
$EQ: P\_TERRLU$				
$ires\_r$				CI
0.66				1.87

in the construction sector ($vabconstr\_r$)—the value of 0.73 implies that when the output gap is included in the equation, then the model fit (measured by means of the R^2) improves by 73%. The last column (CI) indicates the contribution of the cointegration relationship in explaining the variation of the explanatory variables. The contribution of the cointegration relationship is especially large for land prices (p_terrlu), mortgages ($credresmen$) and housing prices (p_immolu), and noticeably smaller for the remaining variables. Table 1 also indicates the contribution of the time-dummy variables (DV). Their contribution is especially high in case of building permissions ($con\_perm\_dwel_t$), the deflator of value added in the construction sector ($p\_vabconstr_t$) and construction prices ($p\_vabconstr_t$) which amounts even up to 423%; this significant gain is most likely related to changes in the composition and definition of the time series, rather than economically related aspects.

5.2. **Some remarks on the equations.** The following discussion addresses several problems that arose within the econometric analysis and describes the role of alternative and/or additional explanatory variables that have been tested. Possible extensions are discussed as concerns alternative measures for rent prices. Finally, the role of data bottlenecks is discussed in the context of housing market related modelling.

5.2.1. *Additional explanatory variables considered.* Equations (1) - (9) describe central elements of the housing sector involving both demand and supply side relevant components and financial market specific elements alike. Within the specifications, emphasis was placed on parsimony. This was mainly done against the background of annual data and a short time horizon. Therefore the degrees of freedom strongly limit the scope of the explanatory variables in the equations. Nevertheless, the variables listed in Table 2 have been tested in the equation system. These variables describe various, very different, aspects. On the one hand, they capture public interventions in the form of direct support payments within the framework of housing rent, but also supply-oriented forms. Furthermore, an attempt has been made to include measures that allow macro-prudential policies to be taken into account. The attempt was limited primarily to debt-to-income (DTI) and loan-to-value (LTV) ratios on the side of borrowers. On the side of lenders, bank-specific variables such as the return on assets, capital ratios, etc. were included in the equations. In all cases, it turned out that these variables were neither useful in the cointegration relationship, nor in the error correction part of the equations. In almost all cases this is due to the fact that the additional variables have a relatively short time horizon. As a consequence, the number of available observations in the estimated equations is drastically reduced. Ultimately, the shortening of the time horizon does not simply give rise to the newly included variables having t-statistics that are close to zero, but it also implied that the other explanatory variables no longer have a statistically relevant contribution for explaining the variation of the endogenous variables. In general, this problem indicates instabilities in relation to subsamples. However, due to the short time series, this problem cannot be further investigated.

Further variables from Table 2 concern characteristics of the Greater Region. Although the equation for housing prices takes into account the unemployment rate in the Greater Region, it is obvious that other variables may also have explanatory power in the equations (1) - (9). In addition to housing prices in the Greater Region, an attempt was made to take into account additional supply characteristics. This concerns primarily additional measures of construction activity. To this purpose, key figures on the gross value added of the construction industry in the Greater Region were considered. This also takes up on the idea that construction companies of the Greater Region could be active in Luxembourg and thus have a decisive influence on the supply of housing in Luxembourg. However, this high level of activity in the construction sector would, from a statistical data collection point of view, be attributed to the value added of the Greater Region's construction sector, but not the one of Luxembourg. In Luxembourg, the supply of housing would in this case simply be higher without this being taken into account in the construction activity of Luxembourg as this would be captured in the statistics of the Greater Region. On the other hand, other demand-relevant indicators were also tested. In addition to the population in the Greater Region, this also concerns the volume of daily commuters from a disaggregated (i.e. country specific) point of view. These components address both effective and latent demand components. All these variables were included and tested with regard to their explanatory power in the cointegration relationship as well as in the error correction part. In all cases, the inclusion of these variables proved to be of little benefit. In some cases, the problem of multicollinearity also arose very strongly.

5.2.2. *Alternative measures for rent prices.* The equations for housing prices and rent prices are specified using official data (Eurostat compliance) for both series. As regards rent prices the official series is part of the CPI and constitutes a sub-component capturing inflationary pressure tenants are confronted with. The series for rent prices primarily captures rent prices on existing tenancies. There exist, however, other series for rent prices. In particular, alternative series capture rent prices for newly rented apartments and houses as highlighted in Section 3. The two series for rent prices addressing apartments and houses are merged into one series only (henceforth $p\_rentlu2_t$) by means of a weighted average where the weight attached to apartments in 0.85 and the one for house is 0.15. Attempts have been made to establish an econometric specification for this alternative measure for rent prices. It is not being considered within the system of equations given by (1) – (9). Some possible specifications are provided in Appendix A.7. As can be seen, the cointegration relation specifies the trade-off between renting and buying as a function of mortgage rates and disposable income in line with equation (3). The error correction part though tends to work better if disposable income (in real terms) is used instead of dwellings ($dwell_t$). In principle, both equations, i.e. the one for $p\_prentlu_t$ and $p\_prentlu2_t$ tend to perform equally well, even if the form of tenancies underlying the prices is different, motivating a careful use of these price measures and the corresponding econometric equations. At this point, priority has been given to $p\_prentlu_t$ and hence to equation (3) as this price measure is already part of Modux, though only indirectly by means of the consumer price index (CPI, p_cfin_t).

5.2.3. *Adaptive expectations and the build-up of bubbles.* Another important aspect that has been checked concerns the assessment of a likely build-up of bubbles. The analysis in this context is confined to the equation for housing prices. In principle, it could be extended to rent prices and land prices too. The build up of a bubble generally aligns with adaptive (or static) expectations.[5] Economic theory proposes several forms of expectation formation of which adaptive expectations has been commonly found as a form which generally conforms well with the data, though it is perceived as inferior in relation to several alternative forms of expectation formation since it gives rise to expectation errors being serially correlated. The adaptive expectations hypothesis states that individuals adjust their expectations

[5]Adaptive expectations are an extension to static expectations. As regards static expectations, let the expectation of the value of some variable x_t at time t be denoted by x_t^e. Then static expectations state that the expected value for time t depends on the previous periods value: $x_t^e = \vartheta x_{t-1}$ with $\vartheta > 0$. The expectation error is given by: $x_t^e - x_t$. Adaptive expectation formation extends static expectations by taking into account the expectation (i.e. forecast) error from the previous period: $x_t^e = \vartheta x_{t-1} + \lambda(x_{t-1}^e - x_{t-1})$. Next to static and adaptive expectation formation, some more commonly used alternatives are *rational expectations* and *adaptive learning*.

of the future based on past experiences and events. In mathematical terms: $x_t^e = x_{t-1}+\lambda(x_{t-1}^e-x_{t-1})$ where the superscript ^{e} refers to the expectation of some variable x_t and λ captures the extent to which the forecast error is taken into account for the current expected value of x_t. The intuition is that if an asset has been trending upward, people will likely expect it to continue to trend that way because that is what it has been doing in the recent past. The tendency to think this way can be harmful as it can cause people to lose sight of economic fundamentals and focus instead on recent activity and the expectation that this trend will continue. However, in this case, trends are believed to persist simply because this pattern has been observed in the recent past which can lead to overconfidence and the trend being assumed to continue indefinitely—this can lead to an asset bubble. For example, before the U.S. housing bubble burst, housing prices had been appreciating and trending upward for a considerable length of time. Given this recurrent observation, people increasingly perceived this pattern to continue, possibly indefinitely, so they leveraged up and purchased assets with the assumption that a price reversion was not a possibility because this would contradict the recent past behaviour of housing prices. Eventually, the cycle turned and prices fell as the bubble burst. Hence, the build-up of a bubble translates into expectations formation being characterized by adaptive (or static) expectations. This aspect has been checked in the equation for housing prices. The adaptive expectation hypothesis motivates to model price expectations in the form of allowing lagged real price appreciations in the model dynamics. Real house price appreciation has been used both in the cointegration relation and the error-correction part. In this context, Abraham and Hendershott (1996), refer to a *bubble builder* effect, represented by lagged real housing price appreciations in the cointegration relation, and a *bubble burster* effect through the use of real house price appreciation in the error correction term. In both cases the coefficient for lagged real house price appreciation was comparably small and had a t-value of less than 0.5. Hence, this variable has been omitted from the equation. This provides useful information on the extent to which the build up of a bubble has most likely not taken place in Luxembourg.

5.2.4. *Data specific bottlenecks.* The analysis uses data which are to a large part freely available and cover a relatively long period of time. Since many interesting alternative variables do not meet at least one of these two requirements, they were only partially considered in the econometric specifications. A much more important aspect in this context concerns the availability of seemingly important variables. For example, for Luxembourg, as for many other EU countries, there is little reliable data on vacancies in real estate. It is evident that a time series reflects important information in this respect. It is usually a central feature of an assessment of supply and demand effects on property prices. In addition to the vacancy rate, there is also only limited information on the owner of newly acquired properties. Knowledge of this information is also central to a better understanding of the fluctuations in the real estate market, as it allows a better assessment of the sensitivity of the real estate market to other investment opportunities (financial market, etc.). Another point regarding the lack of data is the availability and knowledge of the risks inherent in the respective real estate loans. Knowledge of these risks allows to better model risk premiums and thus to better reflect the tendency to buy or rent. Moreover, it would also allow to assess systemic risks. Last but not least, additional supply-side measures of capacity utilisation could also provide valuable information on supply-side bottlenecks. Variables covering this could not only be used to better describe construction and housing prices, but could also provide valuable information for the macroeconomy as a whole.

6. Simulations

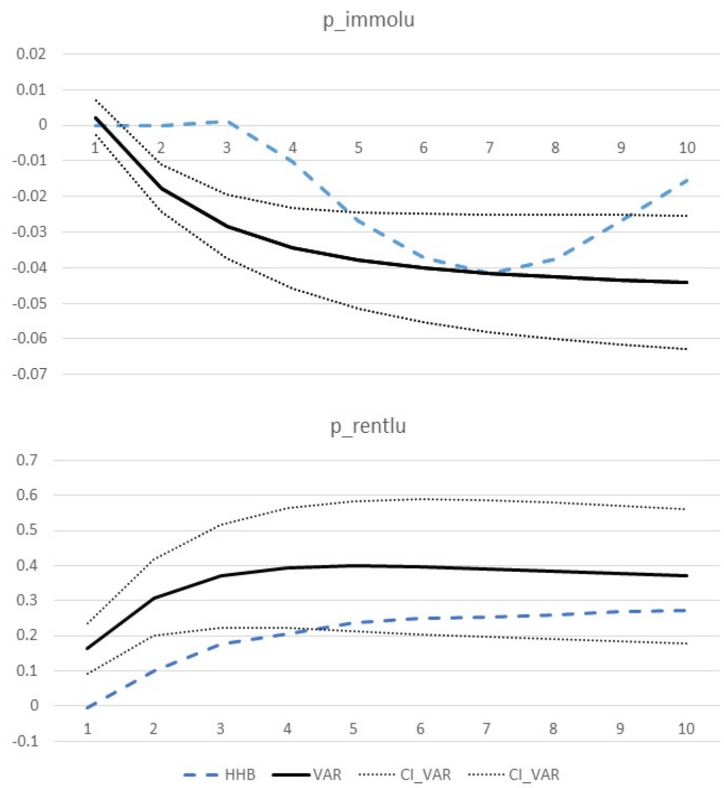
This section uses the equation system—henceforth referred to as *housing block* of the previous section and considers simulations. The simulations of the housing block will be compared to the results of a standard Bayesian vector auto-regressive (VAR) in order to judge plausibility of the results. In general, any alternative approach, among others dynamic stochastic general equilibrium (DSGE) models, ect. could be used, though VAR models are the most convenient one in this context as they allow to adequately capture the stochastic properties of the time series of the variables considered in Section 5 while also offering the tools for structural analysis.

The following considers the effects of a transitory, though persistent increase in the short term rate on housing prices and rent prices. The short term rate is captured by the variable $ticteur_t$ in the system of equations. The pattern of the shock is constructed such that after an initial increase of one percentage point, the shock is phasing out inertially. The extent of inertia is aligned with the degree of serial correlation of the short term rate. Figure 3 shows the impulse response functions of housing prices and rent prices, i.e. the effects of the surprise increase in the short term rate on housing and rent prices. The blue dashed lines refer to the effects as implied by the equations comprising the housing block. The black solid line is the median response of a Bayesian VAR where the stochastic search variable algorithm has been used as a hierarchical prior density. The thin black dotted lines display error bands (20th and 80th percentile of the posterior distribution).

In response to the spike in the short term rate, housing prices decline. The housing block equations propose a fairly delayed reaction in housing prices — the drop occurs in the fourth year after the shock. Within the adjustment to the shock, a trough is reached after around seven years. Afterwards, housing prices tend to converge back to the steady state (i.e. baseline result). The drop in housing prices as implied by the housing block equations conforms with the evidence of the BVAR model. However, there are still noticeable deviations. These concern the initial phase of the impulse response function and the medium term horizon, i.e. horizon beyong nine years. For these episodes, the impulse response function as implied by the housing block equations is outside the credible intervals of the BVAR model. Only the responses of the fifth to ninth year after the shock are statistically not different from the BVAR model.

The lower plot shows the implications for rent prices. Considering first the reaction as implied by the housing block equations highlights that rent prices increase. This increase sets in with a delay of one year. The positive reaction prevails beyond the short term giving rise to a highly sluggish adjustment pattern of rent prices. The impulse response function conforms with the evidence of the BVAR model qualitatively. But there are noteworthy differences. First of all, the BVAR model proposes a significantly quicker reaction of rent prices at the early stage of the responses. Hence, there a statistically significant differences arising between the first and fourth years of the horizon. Second, the overall degree of inertia as proposed by the BVAR model tends to be smaller than the one of the housing block equations.

FIGURE 3. Interest rate shock



Note: The values on the y-axis refer to the deviation relative to the baseline.

In particular, while the BVAR model proposes a downward trajectory in rent prices from the seventh year onward, the housing block equations still features a rise.

Hence while qualitatively the response of the housing block equations conform with the evidence of the BVAR model, some differences remain. They are likely due to the fact that the BVAR model implies a full dynamic system with all its variables being endogenous. In contrast to that, the housing block equations comprise nine endogenous variables but thirty exogenous ones. Hence there is a likely emergence of a significant model specific rigidity which is due to the fact that most of the variables in the system are not allowed to have a feedback on the variables of interest, i.e. the endogenous variables. This strongly constrains the extent of dynamics in the adjustment path, giving rise to, for instance, housing prices to react with a delay of four years only. This deficiency also casts doubts on the quantitative implications of the impulse response functions of the housing block equations.

These limitations arise due to that fact that the housing block equations are not yet integrated into Modux, while they can still be used for simulation analysis. The limitations one faces in this regard constrain the current use of the new equations. Against this background, the results presented here should be taken with great care as some important elements of dynamic interaction are ignored in this exercise. These shortcomings could be accounted for when integrating the equations of the housing block into Modux, that is, when a full incorporation of the housing block within Modux is considered. While this brings about the need to change various existing variables and equations in the model, however, once done, this then allows for a fully fledged analysis of the housing market within a macroeconomic context taking into account interactions with various distinct supply and demand components, the labour market and the financial market alike.

7. Conclusion

This project identified a set of equations with the aspiration to capture key factors relevant for explaining fluctuations in the housing market of Luxembourg. To this end, a focus has been made on supply and demand factors and the trade-off between renting versus buying, a decision that is key for understanding household behaviour in the context of fluctuations in the housing market. In total, a set of nine equations has been specified for housing prices, rent prices, land prices, construction prices (deflator of value added of construction), construction activity (value added in construction), newly completed properties, building permits, residential capital stock and mortgages. The set of nine equations involves additional 30 exogenous variables for explaining the nine endogenous variables.

The equation set-up features several important aspects, as for instance – portfolio specific aspects related to the decision of housing versus financial market investment (i.e. stock market investment in particular); – the influence of developments of the Greater Region on the housing market in Luxembourg; – economic policy specific aspects in form of short term policy rates and building permits. Not the least, the equation set-up also takes into account financial market specific aspects in conjunction with labour market developments.

In its current form, the system of equations is of limited use as nine endogenous variables are opposed to thirty exogenous variables. This implies that the intrinsic dynamics of the system is rather limited. This problem can be solved in an elegant way by integrating the system of equations into a larger macroeconometric model, such as Modux. This would then allow a full macroeconomic analysis of the real estate market. This aspect is still missing though planned for future work.

References

[1] Abraham, J.M., and Hendershott, P.H, (1996), Bubbles in metropolitan housing markets, Journal of Housing Research, Vol. 7 (2), pp. 191–207.

[2] Adam, Ferdy (2004) Modeling a small open economy: What is different? The case of Luxembourg, available at:
http://www.statistiques.public.lu/en/methodology/definitions/M/Modux/Modux.pdf

[3] Adam, F. and C. Glocker, (2018) A simple financial accelerator in a standard macroeconometric model, STATEC Working paper Économie et statistiques No. 101/2018.

[4] Alberts, William W. and Halbert S. Kerr (1981) The Rate of Return from Investing in Single-Family Housing, Land Economics, vol. 57(2), pages 230–242.

[5] Ballantyne, Alexander , Tom Cusbert, Richard Evans, Rochelle Guttmann, Jonathan Hambur, Adam Hamilton, Elizabeth Kendall, Rachael McCririck, Gabriela Nodari and Daniel Rees (2019), MARTIN Has Its Place: A Macroeconometric Model of the Australian Economy, Reserve Bank of Australia, Research Discussion Paper RDP 2019-07.

[6] Benhabib, J, R Rogerson, and R Wright (1991), Homework in Macroeconomics: Household Production and Aggregate Fluctuations, Journal of Political Economy, 99(6), 1166-1187.

[7] Bergin, Adele, Niall Conroyd, Abian Garcia Rodrigueza, Dawn Hollandc, Niall McInerneya, Edgar Morgenrotha, and Donal Smithe (2017), COSMO: A new COre Structural MOdel for Ireland, Working Paper No. 553.

[8] Braid, Ralph (1981), The short-run comparative statics of a rental housing market. Journal of Urban Economics 10, pp. 280-310.

[9] Braid, Ralph (1984), The effects of government housing policies in a vintage filtering model. Journal of Urban Economics 16, pp. 272-296.

[10] Boldrin M, Garriga C, Peralta-Alva A, Sanchez J (2013), Reconstructing the Great Recession, Working Paper 2013-006C Federal Reserve Bank of St. Louis

[11] Cambridge Econometrics (2019) E3ME Technical Manual v6.1., Version March 2019.

[12] Carpantier, Jean-Francois, Olivera, Javier and Van Kerm, Philippe (2018) Macroprudential policy and household wealth inequality, Journal of International Money and Finance, Elsevier, vol. 85(C), pages 262-277.

[13] Case, K E, J M Quigley, and R J Shiller (2005), ComparingWealth Effects: The Stock Market Versus the Housing Market, Advances in Macroeconomics, 5(1), 1-32.

[14] Cocco, J, F Gomes, and P. Maenhout (2005), Consumption and Portfolio Choice over the Life Cycle, Review of Financial Studies, 18(2), 491.

[15] Cocco, J F (2005), Portfolio choice in the presence of housing, Review of Financial studies, 18(2), 535-567.

[16] Coleman, A and G M Scobie (2009), A Simple Model of Housing Rental and Ownership with Policy Simulations, Motu Economic and Public Policy Research, Motu Working Paper 09-08.

[17] Dorofeenko, V., G. S Lee, and K D Salyer (2013), Risk Shocks and Housing Supply: A Quantitative Analysis, Working Paper, University of California-Davis

[18] Fisher, J D (1997), Relative Prices, Complementarities and Comovement among Components of Aggregate Expenditures, Journal of Monetary Economics, 39(3), 449-474.

[19] Fernandez-Villaverde, J, and D Krueger (2011), Consumption and Saving over the Life Cycle: How Important are Consumer Durables, Macroeconomic Dynamics, 15(5), 725-770.

[20] Davis, P. and I. Liadze. (2012), Modelling and Simulating the banking sectors of the US, Germany and the UK. NIESR Discussion Paper 396, NIESR: London.

[21] DNB (2011), DELFI—DNB's Macroeconomic Policy Model of the Netherlands, DeNederlandsche Bank (DNB) Occasional Studies Vol.9, No.1.

[22] Duffy, D., McInerney, N., and K. McQuinn. (2016a), Macroprudential Policy in a Recovering Property Market: Too Much Too Soon?, International Journal of Housing Policy, first published online August 2016.

[23] Duffy, D., McQuinn, K., Morley, C., and D. Foley (2016b), Quarterly Economic Commentary, Summer 2016. Dublin: Economic and Social Research Institute.

[24] Davis, M A, and M Palumbo (2001), A Primer on the Economics and Time Series Econometrics of Wealth Effects, Federal Reserve Board of Governors Working Paper FEDS 2001-09.

[25] Davis M, and Heathcote J (2005), Housing and the Business Cycle, International Economic Review, 46(3), 751-784.

[26] Davis M, and Heathcote J (2007), The Price and Quantity of Residential Land in the United States, Journal of Monetary Economics, 54(8), 2595-2620.

[27] Davis M, and Van Nieuwerburgh S (2015), Housing, Finance and the Macroeconomy, Handbook of Urban and Regional Economics, 5, 753-811.

[28] Ejarque, J, and S Leth-Petersen (2008), Consumption and Savings of First Time Owners: How Do They Deal with Adverse Income Shocks, Working paper, Department of Economics University of Copenhagen.

[29] Filipe, Sara Ferreira, (2018). Housing prices and mortgage credit in Luxembourg, BCL working papers 117, Central Bank of Luxembourg.

[30] Fisher, JDM (2007), Why does Household Investment Lead Business Investment over the Business Cycle?, Journal of Political Economy, 115 (1), 141-168.

[31] Flavin, M, and S Nakagawa (2008), A model of housing in the presence of adjustment costs: A structural interpretation of habit persistence, American Economic Review, 98(1), 474-495. 43

[32] Flavin, M, and T. Yamashita (2002), Owner-Occupied Housing and the Composition of the Household Portfolio, American Economic Review, 79, 345-362.

[33] Fox R and P Tulip (2014), Is Housing Overvalued?, RBA Research Discussion Paper No 2014-06.

[34] Garriga C, Kydland FE, and Sustek R (2013), Mortgages and Monetary Policy, NBER Working Paper No. 19744.

[35] Garriga C and Hedlund A (2016), Mortgage Debt, Consumption, and Illiquid Housing Markets in the Great Recession, Working Paper Series 2007-33, Federal Reserve Bank of St. Louis.

[36] Ghent, A C., and M T. Owyang (2010), Is Housing the Business Cycle? Evidence from U.S Cities, Journal of Urban Economics, 67(3), 336-351.

[37] Glocker, C. (2017) Introducing a financial accelerator for the housing sector in Modux, STATEC Working paper Économie et statistiques No. 95/2017 .

[38] Green, R K (1997), Follow the Leader: How Changes in Residential and Non-residential Investment Predict Changes in GDP, Real Estate Economics, 25(2), 253-270.

[39] Grech, Owen, Brian Micallef, Noel Rapa, Aaron G. Grech and William Gatt (2013) A Structural Macro-Econometric Model of the Maltese Economy, Central Bank of Malta, Working Paper No. WP/02/2013.

[40] Greenwood, J, and Z. Hercowitz (1991), The Allocation of Capital and Time over the Business Cycle, Journal of Political Economy, 99(6), 1188-1214.

[41] Greenwood, J, R Rogerson, and R Wright (1995),Frontiers of Business Cycle Researchchap. Household Production in Real Business Cycle Theory. Princeton University Press

[42] Han, L. (2008), Hedging House Price Risk in the Presence of Lumpy Transaction Costs, Journal of Urban Economics, 64(2), 270-287.

[43] Halket, J, and M Amior (2013), Do Households Use Homeownership to Insure Themselves? Evidence Across U.S Cities, Working paper, University of Essex.

[44] Halket, J, and S Vasudev (2014), Saving Up or Settling Down: Home Ownership Over the Life Cycle, Review of Economic Dynamics, 17(2), 34-366.

[45] Hryshko, D, M J Luengo-Prado, and B. E Sorenson (2010), housing prices and Risk Sharing, Journal of Monetary Economics, 57(8), 975-987.

[46] Iacoviello, M (2005), housing prices, Borrowing Constraints, and Monetary Policy in the Business Cycle, American Economic Review, 95(3), 739-764.

[47] Iacoviello M, and Neri S (2010), House Market Spillovers: Evidence from an Estimated DSGE Model, American Economic Journal: Macroeconomics, 2(2), 125-164.

[48] Kaneko, Mamoru (1982), The Central Assignment Game and the Assignment of Markets . Journal of Mathematical Economics 10, 205-232.

[49] Kahn, J A (2008), What Drives Housing Prices, Federal Reserve Bank of New York, Staff Report no. 345.

[50] Kiyotaki N, Michaelides A, and Nikolov K (2011), Winners and Losers in Housing Markets, Journal of Money Credit and Banking, 43(2-3), 255-296.

[51] Kydland FE, Sustek R, Rupert P (2012), Housing Dynamics over the Business Cycle, NBER Working Paper No. 18432.

[52] Kydland, F E, and E C. Prescott (1982), Time to Build and Aggregate Fluctuations, Econometrica , 50(6), 1345-1370.

[53] Leamer, E E (2007), Housing is the Business Cycle, NBER Working Paper No. 13428.

[54] Li, W, and R Yao (2007), The Life-Cycle Effects of House Price Changes, Journal of Money, Credit and Banking, 39(6), 1375-1409.

[55] Liser—Luxembourg Institute of Socio-Economic Research (2018), Note méthodologique sur l'identification du potentiel foncier et des Baulücken résidentielles , available at: http://observatoire.liser.lu/pdfs/Methodologie_potentiel_foncier_2018.pdf

[56] Liu Z, Wang P, and Zha T (2011), Land-Price Dynamics and Macroeconomic Fluctuations, Federal Reserve Bank of San Francisco Working Paper

[57] McInerney, Niall. (2016), A Structural Model of Macroprudential Policy and the Banking Sector. Mimeo.

[58] Meen, G and M Andrew (2008), Planning for housing in the post-barker era: Affordability, household formation, and tenure choice, Oxford Review of Economic Policy 24(1), 79-98.

[59] Muellbauer, J N., and A Murphy (1997), Booms and Busts in the UK Housing Market, Economic Journal, 107, 1701-1727.

[60] Nakajima, M, and I. A Telyukova (2012), Home Equity in Retirement, Working paper, Federal Reserve Bank of Philadelphia.

[61] OBR – Office for Budget Responsibility (2013) The macroeconomic model, Briefing paper No. 5.

[62] Ortalo-Magne, F., and A. Prat (2010), Spatial Asset Pricing: A First Step, Working Paper.

[63] Ortalo-Magne, F, and S Rady (2006), Housing Market Dynamics: On the Contribution of Income Shocks and Credit Constraints, Review of Economic Studies, Volume 73, Issue 2, 459-485.

[64] Piazessi M, and Schneider M (2016), Housing and Macroeconomics, Chapter 19 in Handbook of Macroeconomics, 2016, vol. 2, 1547-1640.

[65] Rubaszek, Michal and Margarita Rubio, (2017), Does rental housing market stabilize the economy? A micro and macro perspective, Empirical Economics, forthcoming.

[66] Stráský, Jan (2020) Policies for a more efficient and inclusive housing market in Luxembourg, OECD Economics Department Working Papers, No. 1594, OECD Publishing, Paris.

[67] Whitely, J. and R. Windram. (2003), A quantitative framework for commercial property and its relationship to the analysis of the financial stability of the corporate sector, Working Paper No. 207, Bank of England.

[68] Whitely, J. R., Windram and P. Cox. (2004), An empirical model of mortgage arrears, Working Paper 214, Bank of England.

[69] Wood, G, R Watson and P Flatau (2003), A model of the Australian housing market, Melbourne, Australian Housing and Urban Research Institue (AHURI), Research and Policy Bulletin 28.

[70] Yang, F (2009), Consumption Over the Life Cycle: How Different is Housing, Review of Economic Dynamics, 12(3), 423-443.

[71] Yao, R, and H H Zhang (2004), Optimal Consumption and Portfolio Choices with Risky Housing and Borrowing Constraint, Review of Financial Studies, 18(1), 197-239.

Appendix A. Alternative equation specifications

A.1. Housing prices (p_immolu_t).

(1)

```
CI: LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PERSMEN(-1)
↪  ))-0.683*LOG(FRIN(-1))

ECM: DLOG(P_IMMOLU) = -5.925 - 0.375*(LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255*LOG(CAP
↪  BRES_R(-1)/(POPTOT(-1)/PERSMEN(-1)))-0.683*LOG(FRIN(-1))) +
↪  0.368*DLOG(P_IMMOLU(-1)) - 0.022*D(R_UGRL)

R-squared        0.647,     Durbin-Watson stat              2.084
```

(2)

```
CI: LOG(P_IMMOLU(-1)/P_IRES(-1))
↪  +4.045*LOG(CAPBRES_R(-2)/(POPTOT(-2)/PERSMEN(-2))) - 0.818*LOG(FRIN(-1)) +
↪  0.684*LOG(RDMEN(-1)/(P_IRES(-1)*POPTOT(-1)))

ECM: DLOG(P_IMMOLU) = -4.507 -
↪  0.341*(LOG(P_IMMOLU(-1)/P_IRES(-1))+4.057*LOG(CAPBRES_R(-2)/(POPTOT(-2)/PERS
↪  MEN(-2)))-0.7812*LOG(FRIN(-1))+0.684*LOG(RDMEN(-1)/(P_IRES(-1)*POPTOT(-1))))
↪  + 0.580*DLOG(P_IMMOLU(-1)) + 0.033*D(R_UA(-1))

R-squared        0.614, Durbin-Watson stat       2.091
```

(3)

```
CI: LOG(P_IMMOLU(-1)/P_IRES(-1))+7.2557*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PERSMEN(-1
↪  )))-0.683*LOG(FRIN(-1))

EC: DLOG(P_IMMOLU/P_IRES) = -7.111 - 0.451*(LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255*L
↪  OG(CAPBRES_R(-1)/(POPTOT(-1)/PERSMEN(-1)))-0.683*LOG(FRIN(-1))) -
↪  0.048*D(R_UGRL) - 0.078*DLOG(STOXX50(-1)/P_IRES(-1)) - 0.812*DLOG(RDMEN_R)

R-squared        0.733,     Durbin-Watson stat              1.443
```

(4)

```
CI: LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PERSMEN(-1)⌋
↪  ))-0.6831*LOG(FRIN(-1))

EC: DLOG(P_IMMOLU/P_IRES) = -5.827 - 0.369*(LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255*L⌋
↪  OG(CAPBRES_R(-1)/(POPTOT(-1)/PERSMEN(-1)))-0.683*LOG(FRIN(-1))) -
↪  0.032*D(R_UGRL) - 0.070*DLOG(STOXX50(-1)/P_IRES(-1)) -
↪  0.004*D(TIHYP(-2)-@PC(P_CFIN(-1)))

R-squared        0.633

(5)
CI: LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255005278787*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PE⌋
↪  RSMEN(-1)))-0.683093075851*LOG(FRIN(-1))

EC: DLOG(P_IMMOLU/P_IRES) = -5.85025248704 -
↪  0.370622383337*(LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255005278787*LOG(CAPBRES_R(-1⌋
↪  )/(POPTOT(-1)/PERSMEN(-1)))-0.683093075851*LOG(FRIN(-1))) -
↪  0.0251110017835*D(R_UGRL) - 0.102928127878*DLOG(STOXX50(-1)/P_IRES(-1)) +
↪  1.2810543355*D(DLOG(EMP))

R-squared        0.650597

(6)
CI: LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255005278787*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PE⌋
↪  RSMEN(-1)))-0.683093075851*LOG(FRIN(-1))

EC: DLOG(P_IMMOLU/P_IRES) = -6.16368804955 -
↪  0.390490145557*(LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255005278787*LOG(CAPBRES_R(-1⌋
↪  )/(POPTOT(-1)/PERSMEN(-1)))-0.683093075851*LOG(FRIN(-1))) -
↪  0.0325815043137*D(R_UGRL) - 0.107286930019*DLOG(STOXX50(-1)/P_IRES(-1)) +
↪  0.502955463163*D(DLOG(EMPBNQ))

R-squared        0.700997, Durbin-Watson stat                1.79443601

(7)
CI: LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255005278787*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PE⌋
↪  RSMEN(-1)))-0.683093075851*LOG(FRIN(-1))
```

```
EC: DLOG(P_IMMOLU/P_IRES) = -5.68488152621 -
↪  0.360171175058*(LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255005278787*LOG(CAPBRES_R(-1
↪  )/(POPTOT(-1)/PERSMEN(-1)))-0.683093075851*LOG(FRIN(-1))) -
↪  0.0242187760506*D(R_UGRL) - 0.104164062325*DLOG(STOXX50(-1)/P_CONSTR(-1)) +
↪  1.79837886905*D(DLOG(EMP))

R-squared        0.753015,     Durbin-Watson stat              1.471350

(8)
CI: LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255005278787*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PE
↪  RSMEN(-1)))-0.683093075851*LOG(FRIN(-1))

EC: DLOG(P_IMMOLU/P_IRES) = -5.88156788364 -
↪  0.372611635559*(LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255005278787*LOG(CAPBRES_R(-1
↪  )/(POPTOT(-1)/PERSMEN(-1)))-0.683093075851*LOG(FRIN(-1))) -
↪  0.0310379235813*D(R_UGRL) - 0.120150489197*DLOG(STOXX50(-1)/P_CONSTR(-1)) +
↪  0.763363155595*D(DLOG(EMPBNQ))

R-squared        0.771801,     Durbin-Watson stat              1.251413

(9)
CI: LOG(P_IMMOLU(-1)/P_IRES(-1)) +
↪  5.4441943007*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PERSMEN(-1))) -
↪  0.45764676523*LOG(FRIN(-1)) - 0.180940933978*LOG(P_TERRLU(-1))

EC: DLOG(P_IMMOLU/P_IRES) = -5.30473363973 - 0.461196379625*(LOG(P_IMMOLU(-1)/P_
↪  IRES(-1))+5.4441943007*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PERSMEN(-1)))-0.4576467
↪  6523*LOG(FRIN(-1))-0.180940933978*LOG(P_TERRLU(-1))) -
↪  0.0220846685853*D(R_UGRL) - 0.0885532658991*DLOG(STOXX50(-1)/P_CONSTR(-1)) +
↪  0.807990541361*D(DLOG(EMPBNQ))

R-squared        0.772823,     Durbin-Watson stat              1.036048

(10)
```

```
CI: LOG(P_IMMOLU(-1)/P_IRES(-1)) +
↪  5.4441943007*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PERSMEN(-1))) -
↪  0.45764676523*LOG(FRIN(-1)) - 0.180940933978*LOG(P_TERRLU(-1))

EC: DLOG(P_IMMOLU/P_IRES) = -5.37119354044 - 0.466758822021*(LOG(P_IMMOLU(-1)/P_⌋
↪  IRES(-1))+5.4441943007*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PERSMEN(-1)))-0.4576467⌋
↪  6523*LOG(FRIN(-1))-0.180940933978*LOG(P_TERRLU(-1))) -
↪  0.0210851829936*D(R_UGRL) - 0.0864901119394*DLOG(STOXX50(-1)/P_CONSTR(-1)) +
↪  0.792998518912*D(DLOG(EMPBNQ)) + 0.0390747926672*DLOG(P_TERRLU/P_CONSTR)

R-squared        0.818661,         Durbin-Watson stat               1.148003

(11)
CI: LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255005278787*LOG(CAPBRES_R(-1)/(POPTOT(-1)/PE⌋
↪  RSMEN(-1)))-0.683093075851*LOG(FRIN(-1))

EC:
DLOG(P_IMMOLU/P_IRES) = -5.92935145849 -
↪  0.375500288208*(LOG(P_IMMOLU(-1)/P_IRES(-1))+7.255005278787*LOG(CAPBRES_R(-1⌋
↪  )/(POPTOT(-1)/PERSMEN(-1)))-0.683093075851*LOG(FRIN(-1))) -
↪  0.0305754215959*D(R_UGRL) - 0.141121070986*DLOG(STOXX50(-1)/P_IRES(-1)) +
↪  0.816982616218*D(DLOG(EMPBNQ)) +
↪  0.0464562244396*DLOG(P_TERRLU(-1)/P_CONSTR(-1))

R-squared        0.854242,     Durbin-Watson stat               1.356441
```

A.2. **New Dwellings** ($dwell_t$).

```
(1)
CI: LOG(DWELL(-1))-0.881239513271*LOG(IRES_R(-1))+0.00878428883721*@TREND

EC: DLOG(DWELL) = -0.836517116032*(LOG(DWELL(-1))-0.881239513271*LOG(IRES_R(-1))⌋
↪  +0.00878428883721*@TREND) + 0.118947821308*D(DLOG(CON_PERM_DWEL)) +
↪  0.103475885228*(TICTEUR-TILTEUR) +
↪  2.03911472708*DLOG(P_RENTLU(-2)/P_PIB(-1)) + 6.95863392596 -
↪  0.341694343977*D00 - 0.186610635314*D05

R-squared        0.951733,     Durbin-Watson stat               1.737945

(2)
CI: LOG(DWELL) - 0.950154463748*LOG(CAPBRES_R)

EC: DLOG(DWELL) =
↪  -0.536232823758*(LOG(DWELL(-1))-0.950154463748*LOG(CAPBRES_R(-1))) +
↪  0.315276820393*LOG(CON_PERM_DWEL(-2)) + 0.105318542554*(TICTEUR-TILTEUR) -
↪  0.244314644598*DLOG(P_TERRLU(-1)/P_IMMOLU(-1))

R-squared        0.647420, Durbin-Watson stat        2.394433

(3)
CI: LOG(DWELL(-1)) - 13.2521813406*DLOG(CAPBRES_R) - 0.0105275381247*@TREND

EC: DLOG(DWELL) = -0.304041108451*(LOG(DWELL(-1))-13.2521813406*DLOG(CAPBRES_R)-⌋
↪  0.0105275381247*@TREND) + 2.40109370924 +
↪  0.254413493363*DLOG(CON_PERM_DWEL(-2)) + 0.111788734333*(TICTEUR-TILTEUR) -
↪  0.181668071534*DLOG(P_TERRLU(-1)/P_IMMOLU(-1)) - 0.544411909979*D00

R-squared        0.819648,     Durbin-Watson stat               1.571244

(4)
CI: OG(DWELL(-1)) - 13.2521813406*DLOG(CAPBRES_R) - 0.0105275381247*@TREND
```

```
EC: DLOG(DWELL) = -0.388*(LOG(DWELL(-1))-13.252*DLOG(CAPBRES_R)-0.010*@TREND) +
↪  2.966 + 0.445*DLOG(CON_PERM_DWEL(-2)) + 0.091*(TICTEUR-TILTEUR) -
↪  0.206*DLOG(P_TERRLU(-1)/P_IMMOLU(-1)) - 0.327*(D00+D05-D17)

R-squared        0.855787,     Durbin-Watson stat                2.662261
```

A.3. **Rent prices** (p_rentlu_t).

```
(1)
CI: LOG(P_RENTLU(-1)/P_IMMOLU(-1)) -
↪  0.0126767095739*(TIHYP(-2)-DLOG(P_PIB(-2))*100) +
↪  2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))

EC: DLOG(P_RENTLU/P_IMMOLU) =
↪  -0.271595295527*(LOG(P_RENTLU(-1)/P_IMMOLU(-1))-0.0126767095739*(TIHYP(-2)-D⌋
↪  LOG(P_PIB(-2))*100)+2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))) -
↪  0.0478295272994*(TIHYP(-1)-TICTEUR(-1)) + 0.0063352444253*SLDMIGR(-1) -
↪  0.0060747617645*OG - 1.50177206704

R-squared        0.754836,                 Durbin-Watson
↪  stat                 2.333921

(2)
CI: LOG(P_RENTLU(-1)/P_IMMOLU(-1)) -
↪  0.0126767095739*(TIHYP(-2)-DLOG(P_PIB(-2))*100) +
↪  2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))

EC: DLOG(P_RENTLU/P_IMMOLU) =
↪  -0.205247000294*(LOG(P_RENTLU(-1)/P_IMMOLU(-1))-0.0126767095739*(TIHYP(-2)-D⌋
↪  LOG(P_PIB(-2))*100)+2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))) -
↪  0.0590462374791*(TIHYP(-1)-TICTEUR(-1)) + 0.00889635786176*SLDMIGR(-1) -
↪  1.14252060586

R-squared        0.640855,             Durbin-Watson stat                1.951437

(3)
CI: LOG(P_RENTLU(-1)/P_IMMOLU(-1)) -
↪  0.0126767095739*(TIHYP(-2)-DLOG(P_PIB(-2))*100) +
↪  2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))
```

```
EC: DLOG(P_RENTLU/P_IMMOLU) =
↪  -0.219895336447*(LOG(P_RENTLU(-1)/P_IMMOLU(-1))-0.0126767095739*(TIHYP(-2)-D⌋
↪  LOG(P_PIB(-2))*100)+2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))) -
↪  0.0649318294577*(TIHYP(-1)-TICTEUR(-1)) + 0.00907061726594*SLDMIGR(-1) +
↪  0.257282514306*DLOG(P_RENTLU(-2)/P_IMMOLU(-2)) - 1.20546320251

R-squared        0.693103,             Durbin-Watson stat                2.294940

(4)
CI: LOG(P_RENTLU(-1)/P_IMMOLU(-1)) -
↪  0.0126767095739*(TIHYP(-2)-DLOG(P_PIB(-2))*100) +
↪  2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))

EC: DLOG(P_RENTLU/P_IMMOLU) =
↪  -0.154569753513*(LOG(P_RENTLU(-1)/P_IMMOLU(-1))-0.0126767095739*(TIHYP(-2)-D⌋
↪  LOG(P_PIB(-2))*100)+2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))) -
↪  0.0628815122056*(TIHYP(-1)-TICTEUR(-1)) + 0.00950288529393*SLDMIGR(-1) -
↪  0.0411307072828*D(DLOG(DWELL)) - 0.865380824023

R-squared        0.741515,          Durbin-Watson stat                1.841404

(5)
CI: LOG(P_RENTLU(-1)/P_IMMOLU(-1)) -
↪  0.0126767095739*(TIHYP(-2)-DLOG(P_PIB(-2))*100) +
↪  2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))

EC: DLOG(P_RENTLU/P_IMMOLU) =
↪  -0.221343148562*(LOG(P_RENTLU(-1)/P_IMMOLU(-1))-0.0126767095739*(TIHYP(-2)-D⌋
↪  LOG(P_PIB(-2))*100)+2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))) -
↪  0.0641410433599*(TIHYP(-1)-TICTEUR(-1)) + 0.00969778443291*SLDMIGR(-1) -
↪  0.0547277021891*DLOG(DWELL) - 1.22722049767

R-squared        0.721937,         Durbin-Watson stat                2.136703
```

A.4. **Construction prices** ($p\_vabconstr_t$).

(1)

```
CI: LOG(P_VABCONSTR(-1))-LOG(P_VABPRVO(-1))-0.31*LOG(MIGRIN(-1)/IRES_R(-1))

EC: DLOG(P_VABCONSTR) = -0.269419748811*(LOG(P_VABCONSTR(-1))-LOG(P_VABPRVO(-1)) ⌋
↪  -0.31*LOG(MIGRIN(-1)/IRES_R(-1))) - 0.2299302973 +
↪  0.0520068116206*DLOG(DWELL(-1)) + 0.0732502578026*(D01-D07)

R-squared        0.774152,     Durbin-Watson stat                2.054272
```

(2)

```
CI: LOG(P_VABCONSTR(-1))-LOG(P_VABPRVO(-1))-0.15*LOG(MIGRIN(-1)/DWELL(-1))

EC: DLOG(P_CONSTR) = -0.200757180873*(LOG(P_VABCONSTR(-1))-LOG(P_VABPRVO(-1))-0. ⌋
↪  15*LOG(MIGRIN(-1)/DWELL(-1))) + 0.150225421674 +
↪  0.0480962543551*DLOG(DWELL(-1)) + 0.0707702236459*(D01-D07)

R-squared        0.732116,     Durbin-Watson stat                1.828871
```

(3)

```
CI: LOG(P_VABCONSTR(-1))-1.0*LOG(P_VABPRVO(-1))-0.15*LOG(MIGRIN_0(-1)/DWELL(-1))

EC: DLOG(P_VABCONSTR) = -0.201217155754*(LOG(P_VABCONSTR(-1))-1.0*LOG(P_VABPRVO( ⌋
↪  -1))-0.15*LOG(MIGRIN_0(-1)/DWELL(-1))) + 0.150541380389 +
↪  0.0482115308162*DLOG(DWELL(-1)) + 0.0708195839065*(D01-D07)

R-squared        0.732511,     Durbin-Watson stat                1.830572
```

(4)

```
CI: LOG(P_VABCONSTR(-1))-0.8*LOG(P_PIB(-1))-0.15*LOG(MIGRIN_0(-1)/DWELL(-1))

EC: DLOG(P_VABCONSTR) = -0.236828180241*(LOG(P_VABCONSTR(-1))-0.8*LOG(P_PIB(-1)) ⌋
↪  -0.15*LOG(MIGRIN_0(-1)/DWELL(-1))) + 0.17177993437 +
↪  0.0593931261827*DLOG(DWELL(-1)) + 0.0708260379132*(D01-D07)

R-squared        0.736092,     Durbin-Watson stat                1.763705
```

A.5. **Value added construction [real]** ($vabconstr\_r_t$).

```
(1)
CI: LOG(VABCONSTR_R(-1)) - 0.16940698975*LOG(CON_PERM_DWEL(-1)) -
↪  0.740075982987*LOG(EMP(-1))

EC: DLOG(VABCONSTR_R) = -0.751779279491*(LOG(VABCONSTR_R(-1))-0.16940698975*LOG(⌋
↪  CON_PERM_DWEL(-1))-0.740075982987*LOG(EMP(-1))) + 0.00298696810685*OG -
↪  0.0210173949505*D(MIGRIN_0(-2)) + 1.52662387613 + 0.145101283556*D07

R-squared        0.745073,     Durbin-Watson stat              2.058760

(2)
CI: LOG(VABCONSTR_R(-1))-0.12145953438*LOG(CON_PERM_DWEL(-1))-0.53725198757*LOG(⌋
↪  EMP(-1))-0.180090871315*LOG(P_IMMOLU(-1)/P_VABCONSTR(-1))

EC: DLOG(VABCONSTR_R) = 4.25903833602 -
↪  1.18721105976*(LOG(VABCONSTR_R(-1))-0.12145953438*LOG(CON_PERM_DWEL(-1))-0.5⌋
↪  3725198757*LOG(EMP(-1))-0.180090871315*LOG(P_IMMOLU(-1)/P_VABCONSTR(-1))) +
↪  0.0106899978436*OG - 0.0686763624153*DLOG(P_TERRLU/(POPTOT/PERSMEN)) -
↪  0.0904755319604*D13

R-squared        0.687552,     Durbin-Watson stat              1.696773

(3)
CI: LOG(P_VABCONSTR(-1))-1.0*LOG(P_PIB(-1))-0.15*LOG(MIGRIN_0(-1)/DWELL(-1))

EC: DLOG(VABCONSTR_R) = 4.25903833602 -
↪  1.18721105976*(LOG(VABCONSTR_R(-1))-0.12145953438*LOG(CON_PERM_DWEL(-1))-0.5⌋
↪  3725198757*LOG(EMP(-1))-0.180090871315*LOG(P_IMMOLU(-1)/P_VABCONSTR(-1))) +
↪  0.0106899978436*OG - 0.0686763624153*DLOG(P_TERRLU/(POPTOT/PERSMEN)) -
↪  0.0904755319604*D13

R-squared        0.687552,     Durbin-Watson stat              1.696773

(4)
CI: LOG(P_VABCONSTR(-1))-1.0*LOG(P_PIB(-1))-0.15*LOG(MIGRIN_0(-1)/DWELL(-1))
```

```
EC: DLOG(VABCONSTR_R) =
↪  -0.811261320138*(LOG(VABCONSTR_R(-1))-0.12145953438*LOG(CON_PERM_DWEL(-1))-0⌋
↪  .53725198757*LOG(EMP(-1))-0.180090871315*LOG(P_IMMOLU(-1)/P_VABCONSTR(-1)))
↪  + 0.0109238067774*OG + 0.149344321773*DLOG(CON_PERM_DWEL) + 2.91192710114

R-squared        0.739021,     Durbin-Watson stat                1.547041
```

A.6. **Residential capital stock [real] ($capbres\_r_t$).**

(1)

```
CI: LOG(CAPBRES_R(-1))-0.00688573978168*LOG(PUCRES(-1)/P_IRES(-1))-1.02655068999⌋
↪   *LOG(POPTOT(-1))-0.0724759779999*LOG(CREDRESMEN(-1)/P_IMMOLU(-1))-0.05979138⌋
↪   09542*LOG(VABCONSTR_R(-1))

EC: DLOG(CAPBRES_R) = 0.758174110671*DLOG(CAPBRES_R(-1)) +
↪   0.437327518559*DLOG(POPTOT) - 0.287157188844*(LOG(CAPBRES_R(-1))-0.006885739⌋
↪   78168*LOG(PUCRES(-1)/P_IRES(-1))-1.02655068999*LOG(POPTOT(-1))-0.07247597799⌋
↪   99*LOG(CREDRESMEN(-1)/P_IMMOLU(-1))-0.0597913809542*LOG(VABCONSTR_R(-1))) +
↪   0.0275340488388*DLOG(P_IMMOLU(-1)/P_VABCONSTR(-1)) +
↪   0.0374412289044*DLOG(VABCONSTR_R) - 1.12621632602

R-squared        0.889604,     Durbin-Watson stat                2.484442
```

A.7. **Alternative measure for rent prices ($p\_rentlu2_t$).**

(1)

```
CI: LOG(P_RENTLU2(-1)/P_IMMOLU(-1))-0.0126767095739*(TIHYP(-2)-DLOG(P_PIB(-2))*1
↪  00)+2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))

EC: DLOG(P_RENTLU2/P_IMMOLU) =
↪  -0.644836361064*(LOG(P_RENTLU2(-1)/P_IMMOLU(-1))-0.0126767095739*(TIHYP(-2)-
↪  DLOG(P_PIB(-2))*100)+2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))) -
↪  0.0228897495067*(TIHYP(-1)-TICTEUR(-1)) + 0.0140187541006*SLDMIGR(-1) -
↪  0.0548566853808*DLOG(DWELL) - 3.46170902271 - 0.0637247015508*(D07-D08)

R-squared        0.715655,     Durbin-Watson stat               2.849341
```

(2)

```
CI: LOG(P_RENTLU2(-1)/P_IMMOLU(-1))-0.0126767095739*(TIHYP(-2)-DLOG(P_PIB(-2))*1
↪  00)+2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))

EC: DLOG(P_RENTLU2/P_IMMOLU) =
↪  -0.661895905113*(LOG(P_RENTLU2(-1)/P_IMMOLU(-1))-0.0126767095739*(TIHYP(-2)-
↪  DLOG(P_PIB(-2))*100)+2.86868196571*LOG(RDMEN_R(-2)/POPTOT(-2))) -
↪  0.0267254599715*(TIHYP(-1)-TICTEUR(-1)) + 0.0162791338844*SLDMIGR(-1) -
↪  1.02556867622*DLOG(RDMEN_R) - 3.5380742303 - 0.0497801622188*(D07-D08)

R-squared        0.800955,     Durbin-Watson stat               2.664228
```

(3)

```
CI: LOG(P_RENTLU2(-1)/P_IMMOLU(-1)) -
↪  0.015540343089*(TIHYP(-2)-DLOG(P_PIB(-2))*100) +
↪  1.73747548802*LOG(RDMEN_R(-2)/POPTOT(-2))

EC: DLOG(P_RENTLU2/P_IMMOLU) =
↪  -0.765240701209*(LOG(P_RENTLU2(-1)/P_IMMOLU(-1))-0.015540343089*(TIHYP(-2)-D
↪  LOG(P_PIB(-2))*100)+1.73747548802*LOG(RDMEN_R(-2)/POPTOT(-2))) -
↪  0.0271230421862*(TIHYP(-1)-TICTEUR(-1)) + 0.00959969436193*SLDMIGR(-1) -
↪  1.01291245168*DLOG(RDMEN_R) - 1.0156141397 - 0.0470974976583*(D07-D08)

R-squared        0.839968,     Durbin-Watson stat               2.433671
```

Table 2: Data overview

	Variable	Description	Source
1	p_immolu	Property prices Luxembourg - total	Statec own calculations from Tableau 1: Les ventes 'd'immeubles résidentiels
2	p_immolo	Property prices total Lorraine-	DREAL Lorraine, Direction Régionale de l'Environnement, de l'Aménagement et du Logement
3	p_immorp	Property prices Rheinlandpfalz - total	Immobilien Verband Deutschland, Regionalverband West; www.ivd-west
4	p_immosa	Property prices Saarland - total	Immobilien Verband Deutschland, Regionalverband West; www.ivd-west.
5	p_immowa	Property prices Belgium Luxembourg Province - total	statbel.fgov.be
6	P_TERRLU	Selling prices for Land Luxembourg - total	Statec. Requested by mail
7	P_TERRSA	Selling prices for Land Saarland - total	Saarland: saarland.de/61430.htm
8	P_TERRLO	Selling prices for Land Lorraine-total	developpement-durable.bsocom.fr
9	P_TERRRP	Selling prices for Land Rheinlandpfalz - total	developpement-durable.bsocom.fr
10	P_TERRWA	Selling prices for Land Belgium Luxembourg Province - total	statbel.fgov.be/fr
11	AUTBATRES	Autorisations for residential building, volume	Statec
12	AUTBATNRES	Autorisations for non-residential building, volume	Statec
13	IMMO_SALES	Number of sales	Statec own calculations from Tableau 1: Les ventes 'd'immeubles résidentiels
14	GCS_RESTOT	Gross capital stock of dwellings at current replacement cost	Statec
15	TIHYP	Interest rates over 5 years initial maturity loans for house purchase (See also TIHYP)	

Table 2: Data overview

	Variable	Description	Source
16	CREDRESMEN	Credit granted by credit institutions for real estate located in Luxembourg	
17	APOP_BE33	Active population in Belgium NUTS BE33	Eurostat, Macrobond
18	APOP_BE34	Active population in Belgium NUTS BE34	Eurostat, Macrobond
19	APOP_DEB2	Active population in Germany NUTS DEB2	Eurostat, Macrobond
20	APOP_DEC	Active population in Germany NUTS DEC	Eurostat, Macrobond
21	APOP_FR41	Active population in France NUTS FR41	Eurostat, Macrobond
22	APOP_FR411	Active population in France NUTS FR411	Eurostat, Macrobond
23	APOP_FR413	Active population in France NUTS FR413	Eurostat, Macrobond
24	FRIN_BE33	Cross border worker from in Belgium NUTS BE33	ADEM, Macrobond
25	FRIN_BE34	Cross border worker from in Belgium NUTS BE34	ADEM, Macrobond
26	FRIN_DEB2	Cross border worker from in Germany NUTS DEB2	ADEM, Macrobond
27	FRIN_BDEC	Cross border worker from in Germany NUTS DEC	ADEM, Macrobond
28	FRIN_FR41	Cross border worker from in France NUTS FR41	ADEM, Macrobond
29	FRIN_FR411	Cross border worker from in France NUTS FR411	ADEM, Macrobond
30	FRIN_FR413	Cross border worker from in France NUTS FR413	ADEM, Macrobond
31	GVACON41	Gross value added, Construction of buildings	Statec National Accounts

Table 2: Data overview

	Variable	Description	Source
32	GVACON43	Gross value added, Specialised construction activities	Statec National Accounts
33	GVACON41_rp	Gross value added, Construction of buildings. Previous Year Prices	Statec National Accounts
34	GVACON43_rp	Gross value added, Specialised construction activities. Previous Year Prices	Statec National Accounts
38	IP_RES	Price index for Dwellings	Statec INDICATEURS RAPIDES - SÉRIE C
39	IP_HOUSE_buy	Price index announced sells prices for houses	Observatoire de l'Habitat
40	IP_Appart_buy	Price index announced sells prices for appartments	Observatoire de l'Habitat
41	IP_HOUSE_rent	Price index announced rental prices for houses	Observatoire de l'Habitat
42	IP_Appart_rent	Price index announced rental prices for apparment	Observatoire de l'Habitat
43	IP_RES_Q	Price index for Dwellings	Statec INDICATEURS RAPIDES - SÉRIE C
44	DIV_LU	Divorce rate	Statec Table: b2111
45	POPAVERAGE	Average age of population	Statec Table: b1102
46	Dwell	Number of new dwellings	Statec Table: d4200
47	Dwell_sqm	Total surface of new dwellings	Statec Table: d4200
48	CREDRES_TOT_FL	Total real estate loans credits granted by credit institutions for real estate located in Luxembourg (flow)	BCL Macrobond
49	CREDRES_HOUSE_TOT_FL	Credit granted by credit institutions for Single family homes located in Luxembourg (flow)	BCL Macrobond
50	CREDRES_APPART_TOT_FL	Credit granted by credit institutions for appartments located in Luxembourg (flow)	BCL Macrobond

Table 2: Data overview

	Variable	Description	Source
51	CREDRES_PROMO_TOT_FL	Credit granted by credit institutions to promoters for real estate located in Luxembourg (flow)	BCL Macrobond
52	ASS_CAP_RISK	Regulatory capital to risk-weighted assets	BCL table 17.01 - Financial Soundness Indicators form 2010 macrobond
53	ASS_CAP_RISK_TIER1	Regulatory Tier 1 capital to risk-weighted assets	BCL table 17.01 - Financial Soundness Indicators form 2010 macrobond
54	ASS_Return	Return on assets	BCL table 17.01 - Financial Soundness Indicators form 2010 macrobond
55	PERSMEN	Average size of a household	Statec
56	GVACON_BE341	Belgium, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, BE341 Arr. Arlon, EUR	Eurostat, Macrobond
57	GVACON_BE342	Belgium, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, BE342 Arr. Bastogne, EUR	Eurostat, Macrobond
58	GVACON_DEB21	Germany, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, DEB21 Trier, Kreisfreie Stadt, EUR	Eurostat, Macrobond
59	GVACON_DEB22	Germany, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, DEB22 Bernkastel-Wittlich, EUR	Eurostat, Macrobond
60	GVACON_DEB23	Germany, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, DEB23 Eifelkreis Bitburg-Prim, EUR	Eurostat, Macrobond
61	GVACON_DEB24	Germany, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, DEB24 Vulkaneifel, EUR	Eurostat, Macrobond

Table 2: Data overview

	Variable	Description	Source
62	GVACON_DEB25	Germany, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, DEB25 Trier-Saarburg, EUR	Eurostat, Macrobond
63	GVACON_FRF3	France, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, FRF3 Lorraine, EUR	Eurostat, Macrobond
64	GVACON_FRF31	France, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, FRF31 Meurthe-Et-Moselle, EUR	Eurostat, Macrobond
65	GVACON_FRF32	France, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, FRF32 Meuse, EUR	Eurostat, Macrobond
66	GVACON_FRF33	France, Gross Value Added at Basic Prices by NUTS 3 Regions, Construction, FRF33 Moselle, EUR	Eurostat, Macrobond
67	HOUSE_PRICE_INCOM	Price to income ratio	OECD, Macrobond
68	HOUSE_PRICE_RENT	Price to rent ratio	OECD, Macrobond
69	PROPER_PRICE_INCOM	Developed land per capita	OECD, Macrobond
70	CON_PERM_Build	Luxembourg, Construction Status, Buildings, Total, Number of Buildings, Permits	STATEC Macrobond
71	CON_PERM_DWEL	Luxembourg, Construction Status, Buildings, Total, Number of Dwellings, Permits	STATEC Macrobond
72	CON_PERM_VOL	Luxembourg, Construction Status, Buildings, Total, Built Volume, Permits	STATEC Macrobond
73	SUBMEN_INTER	Individual housing assistance: interest charge participation	Budget of Luxembourg Government

Table 2: Data overview

	Variable	Description	Source
74	SUBMEN_SUSTAIN	Individual housing assistance: premiums in relation to sustainable housing	Budget of Luxembourg Government
75	HPI_LU	Luxembourg, Real Estate Prices, Houses, Current Prices, Index, Luxembourg Housing Ministry, Residential, Price Index	Housing Ministry Macrobond
76	ECB_SHADOW_Rate	Euro Area, Policy Rates, European Central Bank Shadow Rate (Wu-Xia)	ECB Macrobond
77	p_rentlu	Rent prices Loyers d'habitation réels	STATEC (CPI sub component)
78	p_vabconstr	Construction prices: Price index (implicit deflator), NACE2: Construction	Eurostat, Macrobond
79	Sub_HOUS_Sup_1	Participation in interest charges for the development of sustainable housing	Budget of Luxembourg Government
80	Sub_Soc_RENT_1	Participation in the operating costs of a social rental management: assistance to non-profit associations and foundations working in the field of housing (Non-limiting credit and without distinction of exercise)	Budget of Luxembourg Government
81	Sub_HOUS_Sup_2	Subsidies to associations and institutions working in the field of housing	Budget of Luxembourg Government
82	Ind_aid	Individual aid for housing: Participation in the interest burden (Non-limiting loan and without distinction of exercise)	Budget of Luxembourg Government

Table 2: Data overview

	Variable	Description	Source
83	Sub_Soc_RENT_2	Participation in the costs of acquisition, construction and fitting out of rental housing	Budget of Luxembourg Government
84	Sub_Soc_RENT_3	Participation in the costs of acquisition, construction and fitting out of rental housing	Budget of Luxembourg Government
85	Sub_HOUS_Sup_3	Contribution to the construction costs of care and education facilities in the context of housing projects	Budget of Luxembourg Government
86	Sub_HOUS_Sup_4	Participation in the acquisition, construction and renovation costs of housing for foreign workers alone	Budget of Luxembourg Government
87	Sub_HOUS_Sup_5	Participation in acquisition, construction and renovation costs for the development of sustainable housing	Budget of Luxembourg Government
88	Sub_HOUS_Sup_6	Participation in the costs of construction, acquisition and fitting out of rental housing	Budget of Luxembourg Government
89	VABCONSTR_R	Gross value added Construction, NACE2: Construction	STATEC