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ALIENOR, a Macrofinancial Model for Macroprudential Policy

Cyril Couaillier[1], Thomas Ferrière[1] and Valerio Scalone[1]

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Abstract

ALIENOR is an econometric model built to provide macroeconomic scenarios and conduct macroprudential analysis, in particular for larger stress-test exercises. In the model design, we pay particular attention to the link between financial variables and the real economy, to estimate the potential impact of the materialization of financial systemic risk, and to perform policy exercises. In addition, we quantify the impact of the macroeconomy on financial variables, with a focus on households' credit, Non-Financial Corporates' credit, and real estate prices, given the key role played by those variables during the crisis. Finally, we analyse the consequences on the economy of an exogenous increase in the long-term interest rates and a decrease in real estate prices.

Keywords: macroprudential policy, macrofinancial stress-test

JEL classification: E17, E5827, E47

[1] Financial Stability dept. cyril.couaillier@banque-france.fr; thomas.ferriere@banque-france.fr; mailto:valerio.scalone@banque-france.fr

NON-TECHNICAL SUMMARY

The Great Recession highlighted the strong linkages between the financial sector and the real economy. The increased attention paid to macrofinancial risks and the development of this new regulation, going under the name of macroprudential policy, create the need to develop a set of tools to run the different stages of macroprudential analysis: risk assessment, ex-ante calibration of macroprudential instruments and ex-post evaluation of their effectiveness. In particular, pre-crisis macroeconometric models often paid little attention to macrofinancial variables, such as credit or real estate prices, which have become key variables for macroprudential regulators.

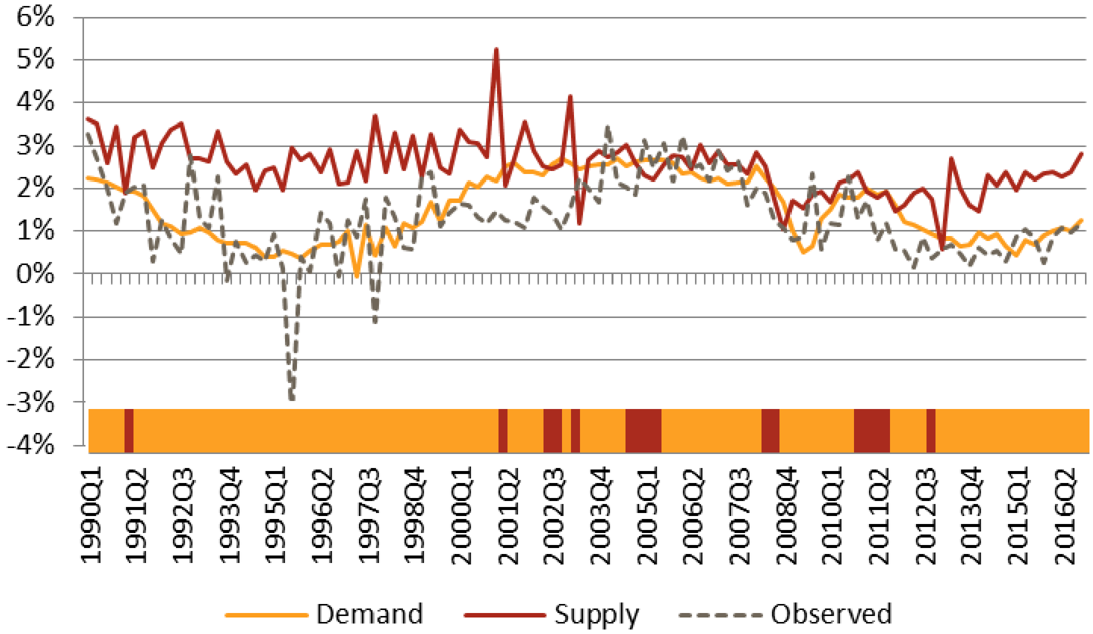
In this work, we develop a macro-financial econometric model named ALIENOR aiming to support macroprudential analysis regarding: (i) risk assessment, for example by producing macroeconomic adverse scenarios to be used as input in stress tests models evaluating banks' solvency and (ii) calibration of instruments, by assessing the impact of macroprudential measures on the real economy. This model is composed of a set of econometric and accounting equations, describing the dynamics of the macroeconomic and financial aggregates for the French economy, focusing on interactions among financial and macroeconomic variables. This relatively parsimonious model is able to produce adverse scenarios in which the financial developments play a crucial role in determining macroeconomic dynamics.

It is important to note that, while usable in a purely standalone way, we intend to articulate ALIENOR with stress tests exercises of bank capital. In those exercises, banks' resilience is tested considering different macroeconomic scenarios derived from ALIENOR. To avoid redundancy, bank capital is thus absent of the ALIENOR.

The results quantitatively support the key role of the transmission channels between financial and macroeconomic variables. Regarding the impact of financial variables on real ones, the model is specified in order to obtain a financial accelerator: a deceleration in credit growth has a negative impact on spending and on asset prices. The slowdown in the real economy further decreases asset prices and banks propensity to lend.

Regarding the impact of real variables on financial ones, we put the emphasis on three macrofinancial variables that have proved critical in financial cycles and systemic crises: households' credit, Non-Financial Corporates' (NFC) credit, and real estate prices. For households' credit, we develop a credit disequilibrium model (Maddala and Nelson (1974), Laroque, and Salanié (1994)). This modelling choice allows disentangling demand and supply-driven regimes, delivering interesting insights on the effectiveness of macroprudential policies. In our estimated model, in normal times the regime is demand driven, meaning that credit supply is in excess with respect to demand. Conversely, during crises, the regime is supply-driven: banks supply less credit than demanded by households, triggering aggregate credit rationing. For firms' credit, we exploit the information provided by the evolution of firms' aggregate balance sheet. This design results in a clear narrative of the underlying factors of the momentum of corporate debt. For the housing sector, the equation for real estate prices includes households' Debt-Service Ratio (DSR) as the main driving factors. The DSR is the fraction of income that agents use to repays their debt (principal and interests), thus capturing households' purchasing power.

The model is used to produce adverse scenarios: we analyze the effects on the economy of two different types of shocks: (i) a 100 basis points exogenous increase in the long term interest rates; (ii) a negative housing shock equal to an initial reduction of -10% of the real estate prices. Under the long-term interest rate hike, the financial sector goes through a generalized increase of the interest rates. Overall, the total credit in the economy decreases, with negative effects on the real economy. In addition, the increase in the interest rates and the fall in revenues cause a substantial decrease of housing prices. Under the house price shock, the model shows a decline in households' spending, triggering a deceleration on the aggregate demand side. Moreover, this decrease further lowers house prices amplifying the initial negative shock and activating an important financial accelerator mechanism.



Credit demand (yellow lined) and credit supply (red line) for France, estimated according to the households' credit disequilibrium model contained in ALIENOR.

ALIENOR, un Modèle Macrofinancier pour la Politique Macroprudentielle

Résumé

ALIENOR est un modèle économétrique construit pour développer des scénarios macroéconomiques et conduire des analyses macroprudentielles, en particulier en s'inscrivant dans des exercices plus larges dits de « stress test ». Dans la conception du modèle, nous nous attachons particulièrement aux liens entre variables financières et de l'économie réelle, afin d'estimer l'impact potentiel d'une matérialisation du risque financier systémique et de mener des simulations de politiques économiques. De plus, nous quantifions l'impact de la macroéconomie sur des variables financières, en particulier le crédit des ménages, la dette des entreprises et les prix de l'immobilier résidentiel, du fait de leur rôle important durant la crise. enfin, nous analysons les conséquences économiques d'une hausse des taux d'intérêt de long terme et d'une baisse des prix de l'immobilier.

Mots-clés : politique macroprudentielle, stress-test macrofinancier,

1. Introduction

The Great Recession highlighted the strong linkages between the financial sector and the real economy. On one side, disruptions in the financial sector played a key role in the downturn observed in in the real sector between 2007 and 2009. On the other side, evolutions in the real economy, for example in the real estate market, substantially contributed to the build-up of systemic risks, whose materialization brought to the disruptions observed during the financial crisis.

In the aftermath of the Great Recession, the accrued awareness on the risks coming from the linkages between financial and real sectors paved the way for the design of a new set of tools to tackle the insurgence of financial systemic risks or to foster the resilience of the financial sector in case of risks materialization. The increased attention paid to macrofinancial risks and the development of this new regulation, going under the name of macroprudential policy, create the need to develop a set of analytical tools to run the different stages of macroprudential analysis: risk assessment, ex-ante calibration of macroprudential instruments and ex-post evaluation of their effectiveness. In particular, pre-crisis macroeconometric models often paid little attention to macrofinancial variables, such as credit or real estate prices, which have become key variables for macroprudential regulators.

In this work, we develop a macro-financial econometric model named ALIENOR aiming to be a support for macroprudential analysis regarding the first two of those building blocks: (i) risk assessment, for example by producing macroeconomic adverse scenarios to be used as input in stress tests models evaluating banks' solvency and (ii) calibration of instruments, by assessing the impact of macroprudential measures on the real economy. This model is composed of a set of econometric and accounting equations, describing the dynamics of the macroeconomic and financial aggregates for the French economy, with a focus on the interactions among macroeconomic and financial variables. In a relatively parsimonious framework, thanks to these linkages, the model is able to produce adverse scenarios in which the financial sector plays a crucial role in determining macroeconomic dynamics. It is important to note that, while usable in a purely standalone way, we intent to articulate ALIENOR with stress tests exercises of bank capital. In those exercises, banks are affected by macroeconomic shocks derived from ALIENOR, and adjust optimally depending on their losses and the reaction function. To avoid redundancy, bank capital is thus absent of the ALIENOR. Directly integrating a fully modelled financial sector with specific constraint is left for future research.

The semi-structural approach used in ALIENOR strikes a balance between structural models (e.g. DSGE models) and agnostic time series models. With respect to structural models, semi-structural models are estimated equation by equations, allowing : i) to plug different blogs in a flexible way, a feature that can be very useful in policy analysis; ii) to take into account econometric performance in the development phase and when correcting misspecification errors. Additionally, with respect to the pure time series approaches (e.g. VAR), the semi-structural approach is based on the use of macroeconomic theory and of intuition in the selection of the regressors. This allows an easier economic interpretation to the estimated coefficients and to the transmission channels. As shown in the forecast performance comparison, ALIENOR performs better than a VAR to forecast GDP and real estate prices.

The results coming out of the estimation of the model quantitatively support the key role of the transmission channels between financial and macroeconomic variables. Regarding the impact of financial variables on real ones, the model is specified in order to obtain a financial accelerator : a deceleration in credit growth has a negative impact on spending and on asset prices. The slowdown in the real economy further decreases asset prices and banks propensity to lend. This modelling choice is to obtain a dynamic similar to what produced by the presence of borrowing constraints in standard macroeconomic models (Kiyotaki and Moore, 1997). [1]

Regarding the impact of real variables on financial ones, we put the emphasis on three macrofinancial variables that have proved critical in financial cycles and systemic crises: households' credit, Non-Financial Corporates' (NFC) credit, and real estate prices. For the households' credit sector, we develop a credit disequilibrium model (Maddala and Nelson (1974), Laroque, and Salanié (1994)). In disequilibrium models, price variations do not guarantee the market clearing between demand and supply: the observed quantity is equal to the lowest between demand and supply. In our estimated model, in normal times the regime is demand driven, meaning that credit supply is in excess with respect to demand. Conversely, during crises, the regime is driven by supply: banks supply less credit than what is demanded by households, triggering aggregate credit rationing. This model thus allows for demand and supply-driven regimes, delivering interesting insights on the effectiveness of macroprudential policies. For firms' credit, we exploit the information provided by the evolution of firms' aggregate balance sheet. More specifically, we follow a two-step approach. First, we estimate firms' external funding needs with respect to the main macroeconomic and financial variables. Second, we study how firms choose their capital structure, in terms of new equity, bond issuance and new loans. This design results in a clear narrative of the underlying factors of the momentum of corporate debt. For the housing sector, the equation for real estate prices includes the households' Debt-Service Ratio (DSR) as the main driving factors for real estate price dynamics. The DSR is the fraction of income that agents use to repays their debt (principal and interests), thus capturing households' purchasing power.

ALIENOR also displays important feedback effect of financial variables on real ones. NFC investment is negatively affected by corporate DSR, while it depends positively on equity prices. The first effect creates a natural negative effect of debt and interest rate on investment. It also amplifies shocks on corporate profits, as the latter negatively affects the DSR. The positive effect of equity prices is coherent with a financial accelerator narrative and constitutes a channel from financial market sentiment and appetite for risk to the real economy. Household's investment, consisting mainly of new residential building, is negatively affected by housing prices and interest rates, creating an additional transmission channel from asset prices and monetary policy to the real economy. Finally, lending rates negatively affect households' consumption. Overall, those channels result in sizeable impact of financial variables on the macroeconomy, making of ALIENOR a useful tool to analyze and simulate macrofinancial systemic risk.

Conversely, financial variables affect the real economy. The price of debt (interest rate), the price of assets and the quantity of credit available all impact investment and consumption.

The model is used to produce adverse scenarios: we analyze the effects on the economy of two different types of shocks: (i) a 100 basis points exogenous increase in the long term interest rates; (ii) a negative housing shock equal to an initial reduction of -10% of the real estate prices.

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[1] Despite the French economy does not feature the same type of dynamics found in for US economy, as the possibility for French agents to run a strategic default, nonetheless asset prices and income growth are key features affecting credit availability.

Under the long term interest rate hike, the financial sector goes through a generalized increase of the interest rates. Overall, the total credit in the economy decreases, with negative effects on the real economy. In addition, the increase in the interest rates and the reduction in revenues cause a substantial decrease of housing prices. Under the house price shock, the model shows that households' spending declines, triggering a deceleration on the aggregate demand side. Moreover, this decrease further lowers house prices amplifying the initial negative variation and activating an important financial accelerator mechanism.

This work can be framed in the stream of literature developed among central banks and economic institutions, to produce macroeconomic forecasts, adverse scenarios and policy exercises. At Banque de France, MASCOTTE (Baghli et al., (2004)) provides an example of econometric model used to produce forecasts and macroeconomic scenarios. Other examples of large scale econometric models in the Euro-area national central banks are: Busetti et al. (2005) for Italy, Jeanfils (2000) for Belgium, the DELFI model by the Nederlandsche Bank (2011) for Nederland. For the US, the FRB/US (F. Brayton et al. (1996)) is the main reference for large scale econometric models. Lastly, the NIGEM model, developed by the National Institute of Economic and Social Research, has been widely adopted for the construction of macroeconomic scenarios among several central banks and institutions. With respect to these models, ALIENOR differs for the two following aspects. First, the model has been designed to emphasize the interactions of financial and real variables. Second, ALIENOR has a smaller scale with respect to the models used for forecasts. To this extent, the model is more conceived as a tool to assess risks rather than as a pure forecasting tool.

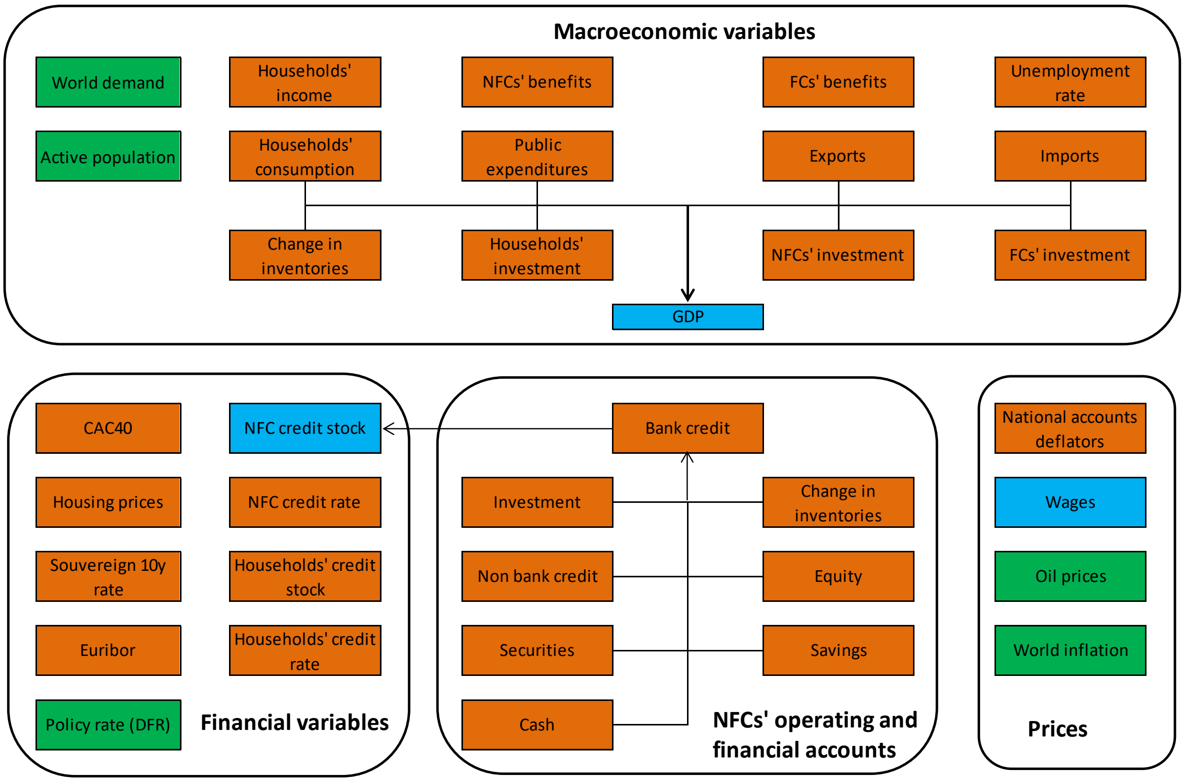
The remainder of the paper is as follows. In Section 2, we present the general structure of the model. Section 3 exposes the key equations reflecting the channels of transmission between financial and macroeconomic variables. Section 4 discusses the accuracy of the model assessed by performance tests. In Section 5, we show the results of the model under the two adverse scenarios. Section 6 concludes. The Appendix provides a more exhaustive list of variables, equations and performances tests of the model.

2. General presentation of the model

The model contains 22 ordinary least squares linear regressions, 11 error correction regressions, 1 disequilibrium model for household's credit, and 37 accounting relationships.

The variables can be divided into four blocks, as reported in scheme 1: 1) the macroeconomic block; 2) the price block; 3) the Non-Financial Corporates (NFC) block; 4) the financial block. The endogenous variables can be obtained either by an econometric equation (in orange), or by an accounting equation (blue). Finally, the model includes a set of exogenous variables (in green).

Scheme 1: overview of the variables contained in the model



Orange : variables econometrically regressed on other lagged variables ; Green : exogenous variables ;
Blue : variables computed from other variables through an accounting relation

The macroeconomic block is structured around the accounting equation of GDP, broken down into its demand subcomponents:

$$Y = G + C + I_{HH} + I_{NFC} + I_{FC} + X - M + \Delta S$$

where Y is the GDP, G are public expenditures (consumption and investment), I_{HH} households' investment, I_{NFC} the Non-Financial Corporates' (NFC) investment, I_{FC} the Financial Corporates' (FC) investment, X the exports, M the imports and ΔS the change in inventories.

Each subcomponent of GDP is modeled and forecasted individually, while the GDP forecast is computed by exploiting the accounting equation, adding the forecasts of subcomponents in the accounting equation[2]. To ensure the long-term consistency of those variables, each equation includes the lagged log-ratio of the component of interest over GDP, as long-term correction parameters. In addition to the subcomponents of the GDP, the macroeconomic block also contains variables related to institutional sector accounts (operating surplus of corporates and disposable income of households), the unemployment rate, the labor force and the world demand addressed to France.

The price block includes deflators of GDP subcomponents, the GDP deflator, wages, oil prices and the world inflation, the last two being exogenous variables. This block produces the forecasts for the deflators used to convert the projections for the GDP components obtained in real terms into their nominal counterparts for the GDP accounting equation, expressed in nominal values. As for GDP components, we ensure long-term consistency by using an error-correction setting for the price block. Nevertheless, a comprehensive modelling of prices and their interaction with the real economy is

[2] This accounting relationship applies to variables expressed in nominal terms (current prices), whereas almost all the forecasting equations of the model are based on variables in real terms (chained prices). Deflators of the variables are modeled in the price block and allow switching from current prices to chained prices.

beyond the scope of this paper, since the Banque de France already has MASCOTTE (Baghli et al., (2004)), a macroeconometric model dedicated to the links between monetary policy, prices and the real economy.

The NFC block models the evolutions of the different components of NFCs' balance sheet. More precisely we exploit two different accounting equations. In the first accounting equation, we compute the net new external funding of the NFC, obtained as the difference between the retained earnings of NFC and their expenditures (investments and change in inventories). The forecast for the expenditures is produced by in the macroeconomic block. The second accounting equation breaks down the net external funding in the different sources: credit, securities and equity. In this way, we exploit the link between financial uses and resources, with a direct channel from the real economy to the financial world. Moreover, this specification allows identifying the existing trade-off between the different sources of external funding, in particular regarding corporate leverage.

Finally, the financial block includes all the other variables of the financial sphere. These variables are outstanding stocks of debt (household and NFC), interest rates (policy rate, 10 years sovereign yield, Euribor, household and NFC lending rates) and asset prices (index of the stock exchange and real estate prices). The monetary policy is exogenous and is not modeled.

All the variables used in ALIENOR are expressed at quarterly frequency and seasonally adjusted. The model is estimated with data available in September 2017 and on an estimation sample ending on Q4 2016.Starting dates depend on data availability and are detailed equation by equation in the Appendix 2. The forecast horizon of the model can vary between two and three years and is constrained by the presence of exogenous variables (reported in green in Scheme 1). In our exercises, for these variables, we use the official projections produced by the European Central Bank. Appendix 1 provides more details on the variables and their source.

Overall, the coding and structure of the model is conceived to facilitate the integration of additional equations and the interaction with other models, such as stress test models (Bennani et al. 2017) or other macroeconomic models.

3. Main equations

In this section we discuss the main interactions between financial variables and the real economy at the core of our model. First, we focus on the impact of macroeconomic variables on the financial ones, by studying the effect that real variables have on households' credit, real estate prices and NFCs credit. Second, we show how those financial variables affect the real economy (i.e. consumption and investment in the macroeconomic block).

Credit to households:

In modelling households' credit we focus on mortgages for three reasons. First, mortgages account for more than 80% of credit to households in France in 2016. Second, mortgage has experienced a remarkable increase, from 17% of GDP in 1995 to 40% in 2016, while non-mortgage-credits have been stable as a share of GDP for at least 25 years. Third, its development is closely linked to the evolution of house prices, whose evolution plays a key role in the determination of the financial cycle, as seen during the financial crisis.

In order to describe the evolution of household's credit, we exploit a credit disequilibrium model. In this type of models (Maddala and Nelson (1974), Laroque, and Salanié (1994)) the interest rate acts as exogenous variable since it affects both credit demand and credit supply even though its movements do not guarantee the market clearing between demand and supply. The departure from the equilibrium theory is based on two main observations. First, when setting interest rates to households' credit, banks closely track the monetary policy rate. The spread between two rates can vary over time, but not enough to necessarily ensure market clearing. Second, banks do not necessarily manage their credit risk only through the interest rate. They decide whether to lend or not on the basis of additional criteria, as such information on the solvency of the borrower. This behavior can be explained by the fact that in a world with imperfect information, banks are not able to correctly price the risk of the different borrowers. As an example, French banks pay particular attention to the Debt Service Ratio, which is an indicator of the sustainability of the debt service for the borrower and thus of its probability of default[3].As a result, the interest rate loses its function of "fully endogenous" price variable co-determined with quantity in equilibrium.

In the disequilibrium model, the observed credit is the minimum between two unobservable variables: demand and supply. An excess of demand at the macro level means that bankers apply non-interest rate credit standards that push them to reject part of credit demand. Vice versa, an excess of supply means that bankers have lending standards that are loose enough to absorb all the demand.

This approach has two interesting features for policy purposes. First, we can disentangle between supply and demand driven regimes. For this reason, some shocks can be more relevant under a regime than under another. This non-linearity can be crucial in the quantification of costs related to the introduction of macroprudential instruments. For instance, a tightening in capital requirements related to housing loans will have strong effect on the economy if it is implemented when the regime is supply-driven, but virtually no effect when supply is already above demand. On the contrary, limiting the households' borrowing capacity would be efficient in a demand-driven regime. Second, the difference between estimated supply and demand can be interpreted as a proxy of the tightness of the mortgage market.

Formally, the system is the following:

$$\begin{cases} Demand_t & = \alpha_0 + \alpha_1 * \Delta i.hh_{t-1} + \alpha_2 * u_{t-1} + \alpha_3 * \Delta rre_{t-1} + \varepsilon_t \\ Supply_t & = \beta_0 + \beta_1 * DSR.hh_{t-1} + \beta_2 * \Delta gdi.hh + \beta_2 * (\Delta i.hh_{t-1} - \Delta oat10_{t-1}) + \epsilon_t \\ Credit_t & = min\left(Demand_t; Supply_t\right) \end{cases}$$

We provide the details of the econometric approach in Appendix.

Table 1: estimation of the credit to households disequilibrium model
dependent variable: dlog(households' debt)

	Demand	Supply
constant	0.05***	0.04
	(3.58)	(1.97)
HH lending rates$_{t-1}$	-0.03	
	(-0.48)	
unemployment rate$_{t-1}$	-0.39***	
	(-2.93)	
Δlog(real estate prices)$_{t-1}$	0.31***	

[3] See « Taux d'apport personnel et taux d'effort : comment les banques françaises limitent leurs risques en matière de crédit immobilier », 2017, Rue de la Banque, Dietsch et Welter-Nicol

	(3.07)	
HH DSR_{t-1}		-0.37 (-1.02)
Δlog(nominal GDI)$_{t-1}$		0.86* (1.84)
$spread_{t-1}$ (HH lending rate - 10y gov bond yield)		0.42 (0.80)
R^2	40%	
Durbin Watson	1.87	
Sample	1990Q1-2016Q4	

In our specification, demand is driven by the change in nominal interest rate, unemployment rate and residential real estate prices growth. This last variable is the main driver of mortgage demand. When house prices increase, agents need to increase their demand of credit to buy their house. To this extent, in the equation modelling house prices growth, the latter is influenced by household debt. This link generates a financial accelerator mechanism that amplifies fluctuation of macroeconomic aggregates thanks to this link, in a similar logic of the borrowing constraints used in DSGE models (Kiyotaki and Moore, 1997). Unemployment rate provides useful information about the cycle of the economy. With respect to GDP, unemployment can be a better proxy of the share of the working population excluded from mortgage. Supply depends on three elements: the Debt Service Ratio, the gross disposable income, and the spread between households' interest rates and the long term sovereign one. In this model, credit supply tries to mimic banks' observed behavior: when opening new loans, banks' decision is affected by the profitability of the alternative options (as such as investing on securities): here this alternative is represented by the use of the spread among regressors.

Another determinant of credit supply growth is the Debt to Service Ratio (DSR) is the fraction of income that is used to repay the debt, considering both the principal and the costs related to the interest rates. We compute it according to the following formula:

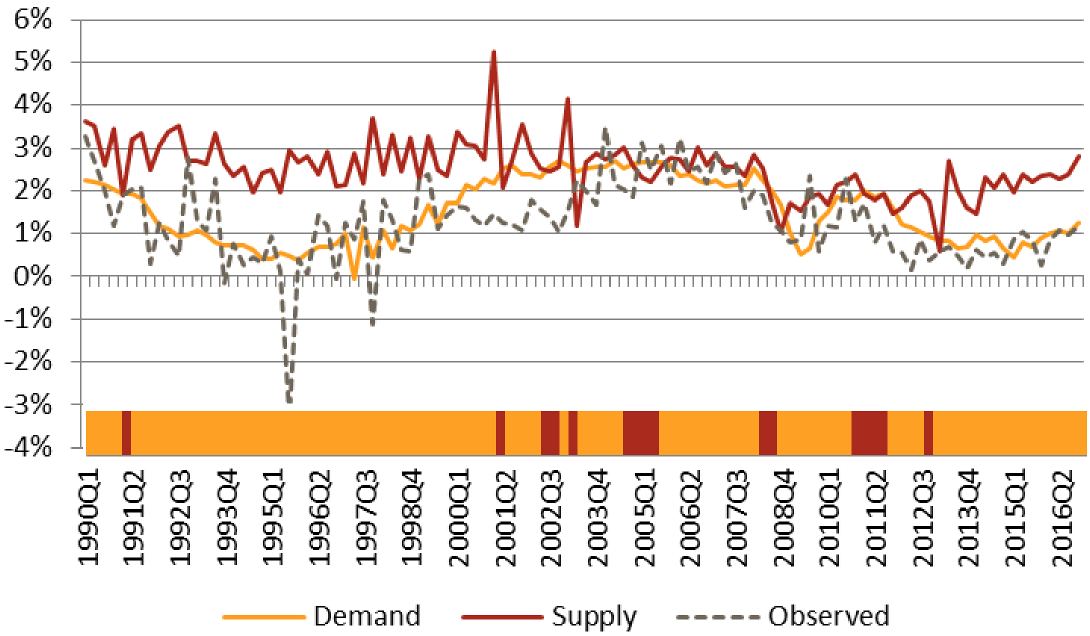
$$DSR_t = \frac{i_t}{1-(1+i_t)^{-M}} * \frac{D_t}{Y_t}$$

with i the interest rate, M the maturity, D the amount of debt and Y the income. In our calculation, we set maturity constant at 20 years. Income is defined as the nominal gross disposable income of households. Finally debt is the outstanding amount of household debt.

The DSR provides information on the ability of the borrower to repay debt. To this extent, when computed at individual level, this DSR is a key indicator considered by French banks when assessing the risk of a household. In our model, DSR is computed at aggregate level, in order to provide information on the aggregate costs related to debt repayment in the economy. In conformity with its use at micro level, in our estimates, DSR has a negative (but non-significant) effect on credit supply.

Overall, the fitted variable, i.e. the minimum of supply and demand, tracks well the narrative around households' credit growth, in particular concerning dates where the regime switches from demand-driven to supply–driven (and vice-versa). Overall, demand is binding during growth periods whereas supply during recessions. During the pre-crisis decade, houses prices growth sustained the demand of credit. Banks were keen to supply to finance housing purchases, even though increasing DSR was signaling a build-up of risk. During the crisis period, supply became binding, falling even more than demand and signaling a period of credit tightening. After the 2008-09 economic crisis, supply recovered more quickly than demand. While supply has bounced back to it 2005-06 high, propped up by ultra-low interest rate and thus decreasing DSR and risk of default, demand has taken more time to recover, affected by high unemployment and decreasing real estate prices. Consistently with many works focusing on the Zero Lower bound (Christiano et al. 2015), low interest rates have not been enough to re-ignite demand.

Figure 1: estimation of demand and supply of credit to households with the disequilibrium model



Source: authors' calculation

Note: the tick line at the bottom of the graph indicates whether credit is supply or demand-constrained: blue (red) indicates demand (supply) constraint

Real estate prices:

Real estate prices depend on a series of macroeconomic and financial variables. First of all, we introduce the DSR as the main determinant of residential real estate prices, since it captures households' purchasing power. As expected, it has a sizeable negative impact on house prices variations: a 1pp increase in households' DSR reduces house price growth by more than 1pp. To account for short-term dynamics, we add in the regression the three components of the DSR in the quarterly variations: i) gross disposable income, ii) the nominal interest rates on households and iii) credit growth. The last two variables play a significant role and create direct channels to real estate prices from the financial and macroeconomic world respectively.

Table 2: estimation of the real estate prices equation
dependent variable: dlog(real estate prices)

Dependent variable : Δlog(real estate prices)$_t$

constant	0.06*** (6.92)
Δlog(stock of HH debt)$_{t-1}$	0.43*** (4.03)
Δlog(nominal GDP)$_{t-1}$	0.39* (1.79)
Δlog(nominal GDI)$_{t-1}$	0.27 (1.64)
HH DSR$_{t-1}$	-1.16***

	(-8.32)
Δ(HH lending rate)$_{t-1}$	-0.01
	(-1.54)
R^2	63%
Durbin Watson	1.10
Sample	1991Q3-2016Q4

Credit to NFCs:

To determine the evolution of the capital structure of Non-Financial Corporates, we use a two-step process: (i) we compute their needs in external funding and (ii) we assess the breakdown of those funding between the three main categories of firms' liabilities: equity, bonds and loans. In order to do that, we use the following accounting identity that links NFCs' source of funding to their use[4]:

$$GFCF + \Delta Cash + \Delta Inventories = Savings + \Delta Credit + \Delta Bonds + \Delta Equity + \Delta Other\ Financial\ Sources$$

Where savings corresponds to profits after cost of labor and capital (including dividend) [5]and is very close to the microeconomic notion of retained earnings.[6]. GFCF stands for Gross Fixed Capital Formation: For the sake of simplicity, we put capital transfers[7] in savings and net acquisition of non-produced assets (typically land) in Gross Fixed Capital Formation. "Other financial sources" are mainly trade credits, which derive from economic activity and cannot be considered as purely financial management products. The accounting equation can be re-written as follows:

Equation 1

$$GFCF + \Delta Cash + \Delta Inventories - Savings - \Delta Other\ Financial\ Sources$$

$$= \Delta Credit + \Delta Bonds + \Delta Equity = External\ Funding$$

The first step is to determine the need for external funding, i.e. the left-hand side of the accounting identity. Once the net external funding has been identified, we can break down the contribution of each different source of the funding: equity, loans or bonds, in plugging this gap with the left-hand side. This strategy assumes a clear hierarchy between uses and resources of funds: at each period, uses are set before resources, which are thus econometrically constrained. In reality, uses and resources are co-determined. Nevertheless, it is not possible to model such co-determination in a tractable way. Moreover, in ALIENOR the funding needs depend on the lagged values of credit and interest rate, introducing a feedback loop from resources to uses. The hierarchical assumption allows for a clear narrative of the determinants of debt growth since the latter is directly linked to both funding needs and a trade-off with equity.

In the second step of the procedure, we determine the capital structure according to the different sources of funding. After net external funding is obtained, we decompose the sources of funding

[4] from the ESA 2010
[5] In financial account terms, it is equal to disposable income minus adjustment for the change in pension entitlement, the latter being null in France
[6] In France pension entitlement is null since NFC do not provide pension plans.
[7] Defined capital transfers require the acquisition or disposal of an asset, or assets, by at least one of the parties to the transaction. Whether made in cash or in kind, they result in a commensurate change in the financial, or non-financial, assets shown in the balance sheets of one or both parties to the transaction.

through two equations. In the first equation, we estimate how the ratio between equity and debt evolves over time. After that, we further decompose firms' debt between loans and bonds issued. This strategy is meant to recognize the higher proximity between the two sources of debt relative to equity: at the macro level, the trade-off is thus first between equity and debt, and only after between both sources of debt. In the first step, we consider the flow of debt as a share of (lagged) outstanding debt and equity. The flow of equity is then defined as the difference between net external funding and debt flow. This implicitly creates a trade-off between debt and equity. According to our estimates, the difference between the net accumulation of debt and equity is mainly driven by the lagged leverage ratio, capturing a mean reverting process. This variable could suggest that firms have a target of leverage when setting their capital structure. Finally, higher interest rates applied to NFC and higher spread between long and short term-interest rates encourage NFC to prefer equity over debt instruments, whereas the opposite holds for GDP growth.

Table 3: estimation of debt-equity trade-off

Dependent variable : flow of $debt_t$ / (stock of $debt_{t-1}$ + stock of $equity_{t-1}$)

constant	0.02*** (3.82)
needs of debt or equity : ($investment_t$ + change in $inventories_t$ + change in $cash_t$ + flow of securities $assets_t$ – other financial $ressources_t$ – $savings_t$) / stock of $debt_{t-1}$ + stock of $equity_{t-1}$)	0.20*** (2.6)
Δ(NFC lending $rate)_{t-1}$	-0.002* (-1.40)
leverage rate of the stock : stock of deb_{t-1} / (stock of deb_{t-1} + stock of $equity_{t-1}$)	-0.02** (-2.19)
$spread_{t-1}$ (10y gov bond – Euribor)	-0.002*** (-3.75)
$\Delta\log(GDP)_{t-1}$	0.23** (2.49)
R^2	40%
Durbin Watson	1.63
Sample	1996Q1-2016Q4

- Credit-bonds trade-off

In the second step, we model the trade-off between bonds and credit. This trade-off operates along two lines. First, we assume that the relative cost of issuing bond with respect to buying new loans negatively depends on the spread between the interest rate applied to NFC and the long term interest rates, in our specification 10y government bond yield[8]. Second, a higher spread between the domestic GDP growth and the world demand addressed to France encourages NFC plays in favor of bond issuance. This could reflect that relatively better domestic conditions attracts foreign capital, which occur mainly in the form of bonds, Moreover better GDP growth transmits faster to corporate bond yields than corporates lending rates.

Table 4: estimation of credit-bond ratio

Dependent variable : flow of $credits_t$ / stock of $debt_{t-1}$

constant	-0.003*** (-3.00)
$\Delta\log(GDP)_{t-1}$ - $\Delta\log(\text{world demand})_{t-1}$	-0.14*** (-2.99)
flow of $debt_t$ / stock of deb_{t-1}	0.71*** (11.54)
$\Delta spread_{t-1}$ (NFC lending rate - 10y gov bond)	-0.01 (-0.50)
R^2	65%

[8] Time series on corporate bond yields for France are not long enough

Durbin Watson	1.10
Sample	1996Q1-2016Q4

NFCs' investment:

NFCs investments depend on GDP growth, NFC Debt to Service Ratio, and quarterly variations of the stock prices. The DSR captures the credit worthiness of NFC, and thus their ability to borrow to finance investment. This ensures a feedback channel from financial variables to the real economy and an amplification effect of shocks to corporate profits: negative (positive) shocks on their profit increase (reduce) their DSR and thus reduce (increase) their ability to invest. We include equity prices growth in order to capture both wealth effects and, given their forward-looking nature, the economic sentiment. All variables have significant effects of the expected sign.

Table 5: estimation of the NFCs' investment

Dependent variable : $\Delta\log(\text{NFC investment})_t$

constant	0,03* (1,81)
$\Delta\log(\text{GDP})_{t-1}$	0,99*** (2,97)
$\Delta\log(\text{GDP})_{t-2}$	0,87*** (2,80)
$\Delta\log(\text{CAC 40})_{t-1}$	0,03* (1,91)
NFC DSR_{t-1}	-0,01* (-1,92)
R^2	49%
Durbin Watson	1,92
Sample	1996Q2-2016Q4

Overall, as expected financial conditions are crucial to determine NFC investment: financial disruptions have sizeable effects on the willingness and ability of NFCs to conduct investment projects.

Households' investment:

Household investment consists mostly of new housing. Real estate price growth provides an indication for the return on housing investment: if households expect growth in residential real estate prices, they anticipate housing to be a profitable investment and thus boost construction. Higher interest rates negatively affect investment through two channels: they increase the costs of financing the investment, and reduce the relative profitability of housing compared to financial investment. Finally, unemployment reduces investment, capturing both a negative phase of the business cycle and a higher share of households that are excluded from bank credit.

Table 6: estimation of the households' investment

Dependent variable : $\Delta\log(\text{HH investment})_t$

constant	-0,13*** (-3,89)
$\Delta\log(\text{real estate prices})_{t-1}$	0,45*** (8,12)
$\Delta(\text{lending rate to HH})_{t-1}$	-0,02*** (-3,30)
$\Delta(\text{unemployment rate})_{t-1}$	-0,01*** (-2,67)
$\log(\text{HH investment / GDP})_{t-1}$	-0,04***

	(-3,77)
R^2	62%
Durbin Watson	1,01
Sample	1996Q1-2016Q4

Households' consumption:

Household consumption depends on three main elements: the consumption-to-income ratio, households' investment and interest rates to households. First, the log of the consumption-to-income ratio is equivalent to fitting an error correction model with a long term elasticity of consumption to income constrained at one. The constraint is not rejected by estimates and makes strong economic sense, implying a constant long term consumption-to-income ratio. First, on the short run, first, consumption has a positive elasticity to disposable income and a negative one to change in unemployment Second, real estate prices have a positive (insignificant) impact on consumption, through wealth effect and expenditures associated to construction. Third, higher interest rates encourage savings. These last two channels allow a quick transmission of financial developments to the real world.

Table 7: estimation of the households' consumption

Dependent variable : Δlog(HH conusmption)$_t$

constant	-0.01 (-1.09)
log(HH consumption / GDI)$_{t-1}$	-0.08 (-1.43)
Δlog(GDI)$_{t-1}$	0.17** (2.08)
Δlog(real estate prices)$_{t-1}$	0.05 (1.50)
Δ(lending rate to HH)$_{t-1}$	-0.38** (-2.10)
Δ(unemployment rate)$_{t-1}$	-0.39 (-1.40)
R^2	16%
Durbin Watson	2.17
Sample	1990Q1-2016Q4

4. Performance tests

The model ALIENOR has been developed to run adverse scenarios for macroprudential analyses. The model is thus more oriented to highlight the transmission channels between macroeconomic and financial variables rather than maximizing the forecast performance. Nonetheless, in this section, we show that the model is also satisfactory in this regard.

We run performance tests to evaluate the accuracy of the model. Forecasts are provided by running the complete model but we only focus on forecasts for six variables, with forecast horizons ranging between 1 and 12 quarters. The benchmark model consists in the vector autoregression of these six variables with four lags estimated by a multivariate least squares approach We have tried to estimate coefficients of this VAR with a Bayesian method but it does not significantly improve the accuracy of forecasts. In this exercise we compare the forecasting performance of our semi-structural model to a reduced-form, thus *a priori* better equipped for in-sample performance.

We simulate forecasts over a three-year horizon, for each quarter from Q1 2011, and compare the results with the data observed until Q4 2016.[9]

In producing forecasts, we used the data available (and possibly revised) in 2017, and not the true real-time data. Simulations are based on the coefficients estimated on the whole sample (until the end of 2016) and not re-estimated on a sample ending at the period of the forecasted horizon. This is based on the fact that, by doing this, forecast errors can highlight specification issues of the model rather than other sources of error.

Variables for which accuracy tests are performed are the quarterly growth rate of:

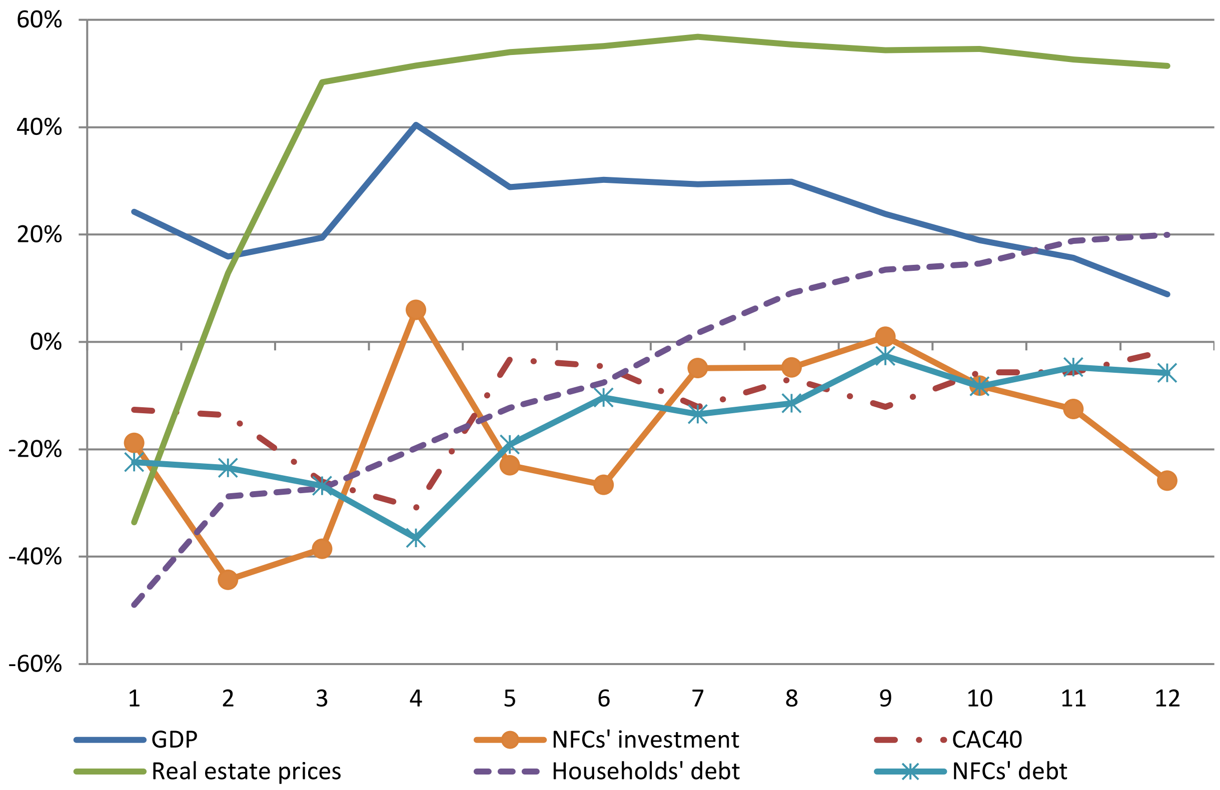
- The GDP in chained prices
- The NFCs' investment in chained prices
- The CAC40 index
- Real estate prices
- The outstanding amount of households' debt
- The outstanding amount of NFC's debt

For each variable, we calculate the root mean square forecast error (RMSFE), for all forecast horizons between 1 and 12 quarters. The gain of accuracy compared to the benchmark model is equal to $1 - \frac{RMSFE_{Alienor}}{RMSFE_{Benchmark}}$. Appendix 3 provides more details on the performance tests.

Overall, relatively to benchmark models, the model ALIENOR allows a significant improvement in forecast accuracy, ranging from 9% to 57% depending on the forecast horizon, for GDP and real estate prices (except a loss of accuracy of 34% for the 1-quarter ahead forecast of real estate prices, see Figure 2). Concerning forecasts of households' debt, the accuracy of ALIENOR is lower than that of the benchmark model for a horizon below 2 quarters. The comparison progressively turns in favor of ALIENOR, by increasing the length of the horizon, to reach a gain of 20% for the final horizon. However, ALIENOR performs globally worse than the benchmark in forecasting the NFCs' investment, the CAC40 and the NFCs' debt. The gain of accuracy of ALIENOR is especially negative at short-term but progressively converges towards zero when the horizon increases.

Figure 2: gain of accuracy according to the forecasting horizon in quarters

[9] The start date of performance tests is constrained by the export forecasting equation in ALIENOR, estimated from Q2 2009



In addition to the accuracy of the growth rates, we verify that the *level* of the projected variables do not strongly diverge from the observed ones, in order to assess the existence of systematic over or under estimate of growth rates. To this end, we analyze a forecast over a three-year horizon, starting in Q1 2014 and ending in Q4 2016, and compare it to known true values.

After three years, the level of the forecasted GDP is very close to the observed value. NFC investment, NFC debt and household debt follow the dynamics of the observed variables but with an over or under estimation in Q4 2016 of respectively -3.6%, 0.3% and 2.7%. Regarding the CAC40, it is worth to notice that the model ALIENOR cannot predict the sharp rise observed in early 2015 and therefore the level of the index is lower by 6.7% compared to reality in Q4 2016. Finally, the forecast of real estate prices shows a slight but uninterrupted decrease throughout the period; in fact, prices fell more or less in line with the forecasts until an upturn in mid-2015, followed by an increase. Annex 2 provides more details.

5. Applications of the model : two adverse scenarios

In this section we use the model to create two different macroeconomic scenarios. We focus on the main financial variables (credit variables, interest rates, real estate prices and CAC40 index) and on some macroeconomic variables (GDP and investment of NFCs) that are particularly sensitive to the evolution of the financial conditions.

For the sake of clarity, we present those adverse scenarios as deviation from a baseline one. This baseline is the 3 years forecast of the model, conditional on the exogenous variables (oil prices, world demand) obtained from the official forecast of Banque de France. All the variations are reported as percentage variations with respect to the baseline scenario. For this reason, the numbers that we provide can be interpreted as impulse responses of the variables to the shock.

Interest rate shock

In this section we analyze how an exogenous increase in the long term interest rate affects the economy (see Figure 4). An exogenous hike in the long-term interest rate can be motivated by a series of events: for example, the expectation of future monetary policy tightening, a global increase of the risk aversion, or tensions on the sovereign bonds markets[10].

In the exercise, an increase of 100 basis points of the long term interest rate on the 10 years government bond yield hits the economy in the first quarter of 2018. After this hike, we allow this rate to behave endogenously in the model. Overall, the government bond yield hike negatively affects the economy through four main transmission channels (see Figure 3):

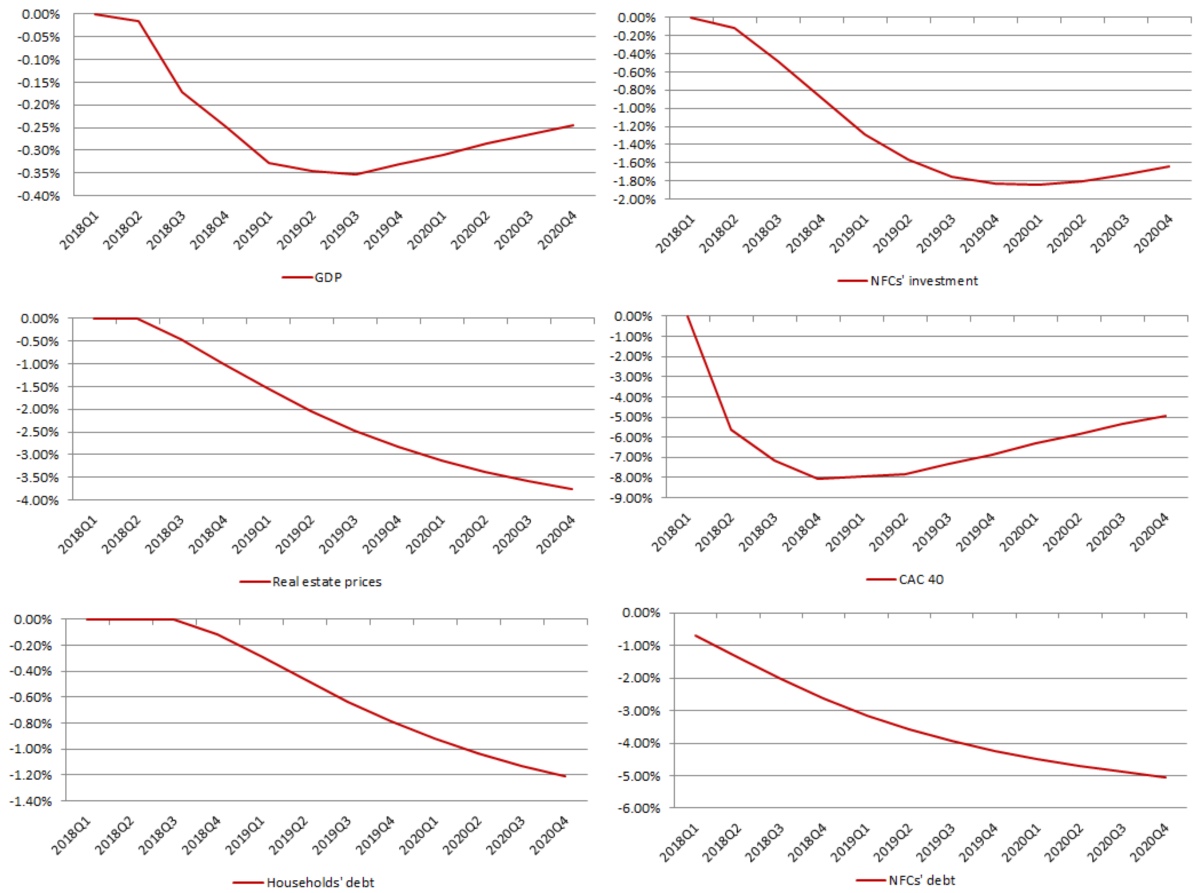
- the nominal interest rate for households' credit, whose maximum variation is equal to + 0.63 pp after one year the shock hits the economy.
- the nominal interest rate for NFCs' credits, increasing by + 0.40 pp with respect to the baseline, one year after the shock;
- the index CAC40 which decreases by -8.0 pp with respect to the baseline, three quarters after the arrival of the shock;
- the demand of bonds for corporates which decreases by -3.98 pp with respect to the baseline, one year after the shock.

Concerning households, the bond yield increase propagates to the interest rates applied on households' credit. This negatively affects households' investments (-1.95 pp two years after the shock) and consumption (-0.29 pp two years after the shock) and causes a positive pressure on the Debt Service Ratio (+0.35 pp one year after the shock). The DSR negatively affects the housing prices (-3.75 pp three years after the shock hits the economy). In the disequilibrium model, households' credit is demand-driven, so this fall in house prices, and marginally higher interest rate, weakens aggregate credit, which decreases by -1.20 pp three years after the shock.

On the corporate side, the increase in the bond yield interest rates negatively affects loans (-5.33 pp three years after the shock) while bonds issuance decreases by -4.60 pp below the baseline scenario three years after the shock. Overall, the corporate total debt decreases by -5.04 pp three years after the shock. The worsening of the financial conditions for firms triggers a reduction of NFCs' investments by -1.63 pp three years after the shock. Besides, the increase in the interest rates directly affects the stock market index (-8.0 pp one year after the shocks), which has further negative effects on corporate activity, in particular investment. The effect on the GDP is of a reduction of -0.35 pp with the respect to the baseline one year after the shock, while unemployment is 0.10 pp higher.

[10] It is worth noticing that the here, the interest rate is not necessarily associated to a deterioration of the fiscal budget. For this reason, the interest rate hike must not be considered as a "sovereign risk" crisis. In that case, other transmission channels could be activated.

Figure 3: gain/loss in the level of key variables with the respect to the baseline



<u>Real estate prices shock</u>

In this sub-section, we analyse the effects of a negative housing shock on the economy (Figure 6). .

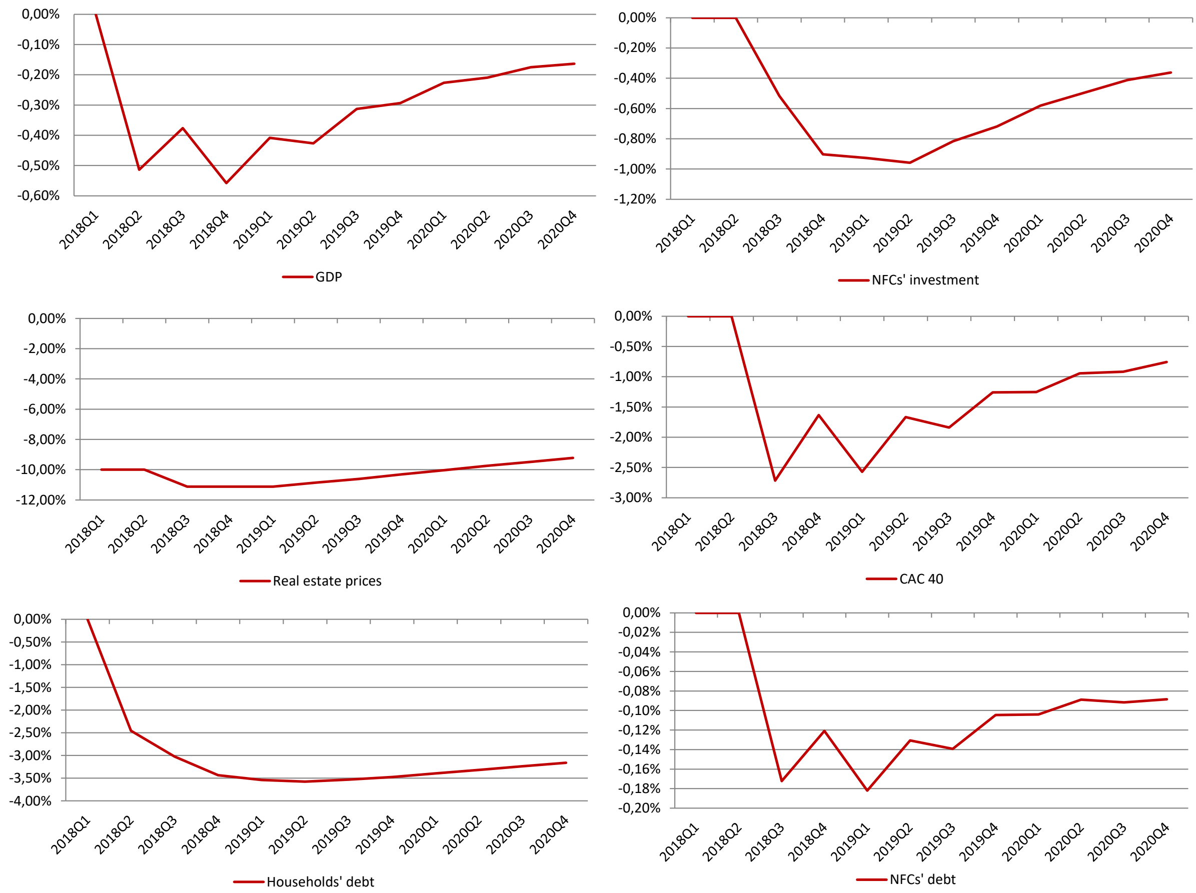
In our exercise, the shock consists in a initial reduction of the housing prices equal to -10%. The initial variation is amplified by the drop in credit (see below) and reachs at the maximum -11.1 pp (compared to the baseline) after one year (Figure 5). The shock predominantly hits the households' sector, through two channels (see Figure 4).

First, the housing price variation affects households' credit (-3.5 pp one year after the shock), by affecting the demand for credit in the households' disequilibrium model, which is demand driven. This effect on credit reinforces the negative pressure on the housing prices, since in the model these depend on the past households' credit.

Second, housing prices have a direct impact on consumption (-0.50 pp after two years) and households' invetsments (-4.69 pp one year after the shock), which mainly consists in new housing, severely affected by falling prices. Overall, by those channels, the negative demand shock negatively affects aggregate demand, reducing the GDP by around -0.52 pp one year after the initial shock. NFC investments decrease by -0.92 pp and stock prices (-2.57 pp), both one year after the initial housing shock. Importantly, the reduction in GDP further reduces housing prices, by affecting the net disposable income of households. NFC debt decreases by -0.18 pp one year after the shock.

Overall, the maximal reduction of GDP growth is equal to -0.55% with respect to the baseline value (one year after the initial shock).

Figure 4: gain/loss in the level of key variables with the respect to the baseline



6. Conclusion

ALIENOR is a macroeconomic model built to provide adverse scenarios and conduct macroprudential exercises. In the model design, we focus on the link between financial variables and the real economy to estimate the potential impact of the materialization of financial systemic risk, and to perform policy exercise to study the impact of macroprudential tools on the economy. Particular attention has been devoted to for econometric equations to provide an intuitive and easily interpretable narrative . For instance, the disequilibrium model used for mortgages disentangles supply and demand. This non-linear structure implies different policy responses depending on the current short side. The design of the financial block for NFCs allows explaining the corporate financial structures through the lens of economic factors, such as economic growth, investment-; and financial factors, as money and leverage). Finally, financial variables have a direct and economically significant impact on the real economy.

This model is flexible enough to accommodate the implementation of various add-ons focusing on particular risks or macro-prudential instruments and to serve as input for larger marcroprudential exercises, such as top-down stress-tests. The way ahead includes the development of add-ins: 1) to assess the macroeconomic impact of more prudential tools such as the Countercyclical capital Buffer (CCyB) or a borrower-based measure, 2) the development of a specific banking sector to better assess the channels between financial and real variables, 3) the exploration of non-linearities, an important feature of systemic financial crises.

References

Agnello, Luca, and Ludger Schuknecht. "Booms and busts in housing markets: determinants and implications." *Journal of Housing Economics* 20.3 (2011): 171-190.

André, Christophe. "A bird's eye view of OECD housing markets." *OECD Economic Department Working Papers* 746 (2010): 0_1.

Andreassen, Leif. Theoretical and Econometric Modeling of Disequilibrium. Central Bureau of Statistics, 1993.

Baghli, M., Brunhes-Lesage, V., De Bandt, O., Fraisse, H. and Villetelle, J. (2004), "Mascotte: Model for analysing and forecasting short term developments", *Notes d'Études et de Recherche*, No 106.

Burdeau, Edwige. "Assessing dynamics of credit supply and demand for French SMEs, an estimation based on the Bank Lending Survey." *IFC Bulletin, April 2015* 39 (2015): 1-18.

Brayton, Flint, and Peter Tinsley, 1996. "A Guide to FRB/US: A Macroeconomic Model of the United States." Finance and Economics Discussion Series 1996-42, Federal Reserve Board.

Busetti, F., Locarno, A. and Monteforte, L. (2005), "The Bank of Italy's quarterly model", in Fagan, G., Morgan, J. (eds), *Econometric Models of the Euro-area Central Banks*, Edward Elgar.

CarbóValverde, Santiago, Francisco Rodríguez Fernández, and Gregory F. Udell. "Trade credit, the financial crisis, and SME access to finance." *Journal of Money, Credit and Banking* 48.1 (2016): 113-143.

Christiano, Lawrence J., Martin S. Eichenbaum, and Mathias Trabandt. 2015. "Understanding the Great Recession." *American Economic Journal: Macroeconomics, 7 (1)*: 110-67.

Čeh, Ana Maria, Mirna Dumičić, and Ivo Krznar. "A Credit market disequilibrium model and periods of credit crunch." *Croatian National Bank, Working Paper W–28* (2011).

De Nederlandsche Bank (2011), "DELFI: DNB's Macroeconomic Policy Model of the Netherlands", *Occasional Studies*, Vol. 9, No 1, De Nederlandsche Bank.

Del Giovane, P., Nobili, A., & F.M., S. (2013). Supply tightening or lack of demand? An analysis of credit developments during the Lehman Brothers and the sovereign debt crises. *Banca d'Italia, Temi di Discussione* .

Dujardin, M., A. Kelber, and A. Lalliard. "Surévaluation et rentabilité des biens immobiliers en zone euro: l'apport des données en euros par mètre carré." *Bulletin de la Banque de France* 199 (2015): 77-88.

Fagan, G. and Morgan, J. (2005), “Econometric Models of the Euro-area Central Banks”, Edward Elgar.

Giovane, P., Eramo, G., & Nobili, A. (2011). Disentangling demand and supply in credit developments: a survey-based analysis for Italy. *Journal of Banking & Finance*.

Jeanfils, P. (2000), “A Model with Explicit Expectations for Belgium”, Working Papers, No 4, Nationale Bank van België/Banque Nationale de Belgique, March 2000.

Kiyotaki, Nobuhiro, and John Moore. "Credit cycles." *Journal of political economy* 105.2 (1997): 211-248.

Kremp, Elisabeth, and Patrick Sevestre. "Did the crisis induce credit rationing for French SMEs?." *Journal of Banking & Finance* 37.10 (2013): 3757-3772.

Lalliard, A. "Détecter autrement les tensions sur le marché immobilier résidentiel." *Bulletin de la Banque de France* 210 (2017): 15-23.

Laroque, G., & Salanié, B. (1994). Estimating the canonical disequilibrium model: Asymptotic theory and finite sample properties. *Journal of Econometrics*, *62* (2), 165-210.

Maddala, G., & Nelson, F. (1974). Maximum likelihood methods for models of markets in disequilibrium. *Econometrica*, 1013-1030.

Vouldis, Angelos T., Credit Market Disequilibrium in Greece (2003-2011) - A Bayesian Approach (June 22, 2015). ECB Working Paper No. 1805.

Appendix 1: variables

Macroeconomic block

Variable	Source	Reference in the Insee online database
Gross Domestic Product	Insee	Current prices: 001690223 Chained prices: 001690224
Consumption expenditures of households (including non-profit institutions serving households)	Insee	Households: Current prices: 001688878 Chained prices: 001688879 NPISH: Current prices: 001688959 Chained prices: 001688960
Expenditures of general government	Insee	Consumption expenditures: Current prices: 001712086 Chained prices: 001712087 Gross fixed capital formation: Current prices: 001689279 Chained prices: 001689280
Gross fixed capital formation of households	Insee	Households: Current prices: 001689377 Chained prices: 001689378 NPISH: Current prices: 001689396 Chained prices: 001689392
Gross fixed capital formation of financial companies	Insee	Current prices: 001689173 Chained prices: 001689174
Gross fixed capital formation of non-financial companies	Insee	Current prices: 001689584 Chained prices: 001689585
Exports	Insee	Current prices: 001689913 Chained prices: 001689914
Imports	Insee	Current prices: 001690115 Chained prices: 001690116
Gross disposable income of households (including sole proprietorships)	Insee	Current prices: 001690072
Gross operating surplus of financial companies	Insee	Current prices: 001689978
Gross operating surplus of non-financial companies	Insee	Current prices: 001689977
Change in inventories	computation	
Unemployment rate (ILO definition for the metropolitan France)	Insee	001688526
Labor force (annual)	Eurostat	
World demand addressed to France	ECB	

Prices block

Variable	Source	Reference in the Insee online database
Oil prices	ECB	
World inflation	ECB	
Wages	computation	Gross disposable income of households / labor force

NFC block (operating account and balance sheet)

Variable	Source	Reference in the Insee online database
Investment	Insee	001689596
Change in inventories	Insee	
Change in cash	Banque de France	
Savings	Insee	001690078
Credit	Banque de France	
Securities liabilities	Banque de France	
Securities assets	Banque de France	
Equity	Banque de France	
Other financial sources	Banque de France	

Financial block

Variable	Source	Reference in the Insee online database
Outstanding amount of households' debt	Banque de France	
Outstanding amount of NFCs' debt	Banque de France	
Deposit facility rate	ECB	
Sovereign 10y rate of France	Banque de France	
Euribor 3 months	Banque de France	
Households' lending rate	Banque de France	
NFCs' lending rate	Banque de France	
CAC40 index	Banque de France	
Real estate prices (price index of second-hand dwellings)	Insee	001587580

Appendix 2: equations

By default, macroeconomic variables are in real terms behind a Δ or Δlog function, and in nominal terms in ratios. T-stat or z-stat are indicated in bracets.

Macroeconomic block

Households' consumption

Dependent variable : $\Delta\log(\text{HH conusmption})_t$

constant	-0.01 (-1.09)
$\log(\text{HH consumption / GDI})_{t-1}$	-0.08 (-1.43)
$\Delta\log(\text{GDI})_{t-1}$	0.17** (2.08)
$\Delta\log(\text{real estate prices})_{t-1}$	0.05 (1.50)
$\Delta(\text{lending rate to HH})_{t-1}$	-0.38** (-2.10)
$\Delta(\text{unemployment rate})_{t-1}$	-0.39 (-1.40)
R^2	16%
Durbin Watson	2.17
Sample	1990Q1-2016Q4

Public expenditures

Dependent variable : $\Delta\log(\text{public expenditures})_t$

constant	-0.04** (-2.83)
$\Delta\log(\text{public expenditures})_{t-1}$	0.43** (4.64)
$\Delta\log(\text{public expenditures})_{t-2}$	0.26** (2.49)
$\Delta\log(\text{public expenditures})_{t-3}$	-0.02 (-0.24)
$\Delta\log(\text{public expenditures})_{t-4}$	-0.16* (-1.77)
$\log(\text{public expenditures/GDP})_{t-1}$	-0.03*** (-2.94)
R^2	45%
Durbin Watson	2.07
Sample	1990Q1-2016Q4

Households' investment

Dependent variable : $\Delta\log(\text{HH investment})_t$

constant	-0,13*** (-3,89)
$\Delta\log(\text{real estate prices})_{t-1}$	0,45*** (8,12)
$\Delta(\text{lending rate to HH})_{t-1}$	-0,02*** (-3,30)
$\Delta(\text{unemployment rate})_{t-1}$	-0,01*** (-2,67)
$\log(\text{HH investment / GDP})_{t-1}$	-0,04*** (-3,77)
R^2	62%
Durbin Watson	1,01
Sample	1996Q1-2016Q4

Financial companies' investment

Dependent variable : $\Delta\log(\text{FC investment})_t$

constant	-0,12 (-1,43)
$\Delta\log(\text{FC investment})_{t-1}$	0,76** (8,35)
$\Delta\log(\text{FC investment})_{t-2}$	-0,29*** (-3,18)
$\Delta\log(\text{GDP})_{t-1}$	0,18 (0,22)

Δlog(GDP)$_{t-2}$	1,70** (2,13)
log(FC investment / GDP)$_{t-1}$	-0,02 (-1,41)
R^2	50%
Durbin Watson	2,13
Sample	1990Q1-2016Q4

Non financial companies' investment

Dependent variable : Δlog(NFC investment)$_t$

constant	0,03* (1,81)
Δlog(GDP)$_{t-1}$	0,99*** (2,97)
Δlog(GDP)$_{t-2}$	0,87*** (2,80)
Δlog(CAC 40)$_{t-1}$	0,03* (1,91)
NFC DSR$_{t-1}$	-0,01* (-1,92)
R^2	49%
Durbin Watson	1,92
Sample	1996Q2-2016Q4

Exports

Long-term equation

Dependent variable : log(exports/world demand)$_t$

constant	11.75*** (300.75)
trend (1980 Q1 = 0)$_t$	0.0003 (1.12)
R^2	8%
Sample	2008Q4-2016Q4

Short-term equation

Dependent variable : Δlog(exports/world demand)$_t$

constant	-0.0004 (-0.27)
residuals$_{t-1}$	-0.37** (-2.73)
R^2	20%
Durbin Watson	1.95
Sample	2009Q2-2016Q4

Imports

Dependent variable : Δlog(imports)$_t$

constant	0,00 (-0,28)
Δlog(GDP)$_{t-1}$	1,78*** (4,88)
Δlog(GDP)$_{t-2}$	0,35 (0,98)
log(imports / GDP)$_{t-1}$	-0,004 (-0,46)
R^2	30%
Durbin Watson	1,93
Sample	1990Q1-2016Q4

Change in inventories

ECM regression : Δchange in inventories$_t$ = c_1 + c_2*(nominal change in inventories$_t$ – c3*trend$_{t-1}$) +c_4*Δlog(GDP)$_{t-1}$ + c_5* Δlog(GDP)$_{t-2}$

Change in inventories are deflated by the GDP deflator.

constant	-1193,26*** (-3,80)
correction factor	-0,40*** (-6,44)
trend (1980 Q1 = 0)$_{t-1}$	33,38***

	(4,39)
$\Delta\log(GDP)_{t-1}$	0,25***
	(3,27)
$\Delta\log(GDP)_{t-2}$	0,22***
	(2,76)
R^2	30%
Durbin Watson	2,36
Sample	1981Q2-2016Q4

Households' gross disposable income

Dependent variable : $\Delta\log(HH\ GDI)_t$

constant	-0.03
	(-1.53)
$\log(HH\ GDI/GDP)_{t-1}$	-0.07
	(-1.63)
$\Delta\log(HH\ GDI)_{t-1}$	0.23*
	(1.73)
R^2	10%
Durbin Watson	2.04
Sample	2004Q1-2016Q4

Financial companies' benefits

Dependent variable : $\Delta\log(FC\ benefits)_t$

constant	-0.13*
	(-1.91)
$\Delta\log(FC\ benefits)_{t-1}$	0.50***
	(6.08)
$\Delta\log(FC\ benefits)_{t-2}$	0.08
	(0.93)
$\Delta\log(GDP)_{t-1}$	1.55
	(1.58)
$\Delta\log(GDP)_{t-2}$	-2.14**
	(-2.22)
$\log(FC\ benefits/GDP)_{t-1}$	-0.03**
	(-1.99)
R^2	34%
Durbin Watson	1.97
Sample	1980Q4-2016Q4

Non financial companies' benefits

Dependent variable : $\Delta\log(NFC\ benefits)_t$

constant	-0.08***
	(-2.66)
$\Delta\log(exports)_{t-1}$	0.31***
	(2.62)
$\Delta\log(GDP)_{t-1}$	0.61
	(1.36)
$\log(NFC\ benefits/GDP)_{t-1}$	-0.04***
	(-2.70)
R^2	16%
Durbin Watson	2.14
Sample	1980Q4-2016Q4

Unemployment rate

Dependent variable : $\Delta(unemployment\ rate)_t$

constant	0.34*
	(1.70)
$\Delta(unemployment\ rate)_{t-1}$	0.13
	(1.07)
$\Delta\log(GDP)_{t-1}$	-18.35***
	(-3.20)
$\Delta\log(GDP)_{t-2}$	-14.15**
	(-2.31)
$unemployment\ rate_{t-1}$	-0.03
	(-1.15)
R^2	50%
Durbin Watson	2.04
Sample	1999Q4-2016Q4

Prices block

Deflators are modelized by error correction models. The upper block corresponds to long term equations, dependent variables are log of deflators. The lower block corresponds to short term equations, dependent variables are Δlog of deflators.

	GDP	**HH consumption**	**Public expenditures**	**HH investment**	**FC invesment**	**NFC investment**	**Imports**	**Exports**
constant	-1,71***	-0,02**		-0,00**	-0,01***	0,00	-0,16*	0,56***
	(-18,48)	(-2,11)		(-0,60)	(-3,51)	(1,15)	(-1,92)	(5,60)
log(GDP deflator)		0,81***		1,89***	0,26***	0,78***		0,50***
		(68,09)		(64,70)	(6,82)	(33,28)		(7,36)
log(imports deflator)		0,10***		0,47***	0,62***	0,16***		0,76***
		(4,96)		(8,57)	(8,61)	(3,74)		(19,11)
log(oil prices)	-0,01**	0,01***					0,07***	-0,03***
	(-2,53)	(2,74)					(16,48)	(-7,98)
log(world inflation)	0,13***			-0,29***	-0,23***	0,09**	0,43***	
	(3,09)			(-6,35)	(-3,51)	(2,33)	(11,18)	-0,18***
log(wages)	0,72***						-0,05	(-3,94)
	(17,41)						(-1,27)	
R^2	99%	100%		100%	94%	100%	98%	99%
Sample	2002Q1-2016Q4	1995Q1-2016Q4		1995Q2-2016Q4	1995Q2-2016Q4	1995Q2-2016Q4	2002Q1-2016Q4	1995Q1-2016Q4
Constant	0,00***	0,00	0,001***	0,00***	0,00	0,00**	-0,00**	-0,00
	(3,600)	(1,05)	(2,77)	(2,66)	(0,27)	(2,28)	(-2,11)	(-0,13)
$residuals_{t-1}$	-0,00	-0,25***		-0,41***	-0,14***	-0,14***	-0,38***	-0,14
	(-0,01)	(-3,06)		(-5,44)	(-2,99)	(-2,78)	(-4,45)	(-1,44)
dependent $variable_{t-1}$	0,53***	0,39***	0,76***		0,45***	0,33***	0,18***	0,23*
	(1,91)	(4,64)	(12,51)		(5,57)	(3,18)	(3,61)	(1,91)
Δlog(GDP $deflator)_{t-1}$		0,36***		0,56*		0,14	0,48**	
		(2,92)		(1,89)		(1,02)	(2,19)	
Δlog(imports deflator $_{t-1}$	0,09***			0,18***		0,06*		0,12*
	(6,24)			(3,36)		(1,89)		(1,82)
Δlog(oil $prices)_{t-1}$		0,01***	0,005***	0,01***	0,01***	0,01***	0,05***	0,02***
		(5,05)	(4,81)	(3,48)	(3,75)	(4,18)	(16,08)	(6,24)
Δlog(world $inflation)_{t-1}$		0,05***			0,08**	0,03	0,26***	0,20***
		(2,95)			(2,55)	(1,53)	(6,10)	(5,85)
$Δlog(wages)_{t-1}$			0,01					
			(0,38)					
R^2	54%	67%	72%	45%	50%	51%	91%	70%
Durbin Watson	1,83	1,99	2,18	1,88	2,37	2,20	2,16	2,13
Sample	2002Q3-2016Q4	1995Q3-2016Q4	1995Q1-2016Q4	1995Q3-2016Q4	1995Q3-2016Q4	1995Q3-2016Q4	2002Q3-2016Q4	1995Q3-2016Q4

NFC block

Flows

Investment

Dependent variable : Δlog(investment)$_t$

constant	0.00 (0.84)
Δlog(NFC investment in national accounts)$_{t-1}$	1.00*** (23.97)
R^2	85%
Durbin Watson	2.43
Sample	1991Q1-2016Q4

Change in cash

Dependent variable : change in cash$_t$

constant	12286.95*** (10.07)
10y gov bond yield$_{t-1}$	-1832.48 (-6.14)
R^2	32%
Durbin Watson	1.89
Sample	1996Q1-2016Q4

Change in inventories

Dependent variable : change in inventories$_t$

constant	-299.41*** (-7.73)
change in inventories in national accounts$_t$	0.94*** (69.79)
R^2	97%
Durbin Watson	1.39
Sample	1980Q1-2016Q4

Savings

Dependent variable : savings$_t$

constant	-0.00 (-0.81)
Δlog(nominal NFC benefits)$_{t-1}$	1.43*** (9.26)
R^2	37%
Durbin Watson	2.22
Sample	1980Q2-2016Q4

Flow of other financial ressources

Dependent variable : other financial ressources$_t$

constant	-2676.76** (-2.28)
other financial ressources$_{t-1}$	-0.39*** (-3.51)
other financial ressources$_{t-2}$	-0.04 (-0.39)
R^2	14%
Durbin Watson	2.00
Sample	1996Q3-2016Q4

1st leverage equation (flow of debt)

Dependent variable : flow of debt$_t$ / (stock of debt$_{t-1}$ + stock of equity$_{t-1}$)

constant	0.02*** (3.82)
needs of debt or equity : (investment$_t$ + change in inventories$_t$ + change in cash$_t$ + flow of securities assets$_t$ – other financial ressources$_t$ – savings$_t$) / stock of debt$_{t-1}$ + stock of equity$_{t-1}$)	0.20*** (2.6)
Δ(NFC lending rate)$_{t-1}$	-0.002* (-1.40)
leverage rate of the stock : stock of deb$_{t-1}$ / (stock of deb$_{t-1}$ + stock	-0.02**

of $equity_{t-1}$)	(-2.19)
$spread_{t-1}$ (10y gov bond – Euribor)	-0.002***
	(-3.75)
$\Delta\log(GDP)_{t-1}$	0.23**
	(2.49)
R^2	40%
Durbin Watson	1.63
Sample	1996Q1-2016Q4

2nd leverage equation (flow of credits)

Dependent variable : flow of $credits_t$ / stock of $debt_{t-1}$

constant	-0.003***
	(-3.00)
$\Delta\log(GDP)_{t-1}$ - $\Delta\log(world\ demand)_{t-1}$	-0.14***
	(-2.99)
flow of $debt_t$ / stock of deb_{t-1}	0.71***
	(11.54)
$\Delta spread_{t-1}$ (NFC lending rate - 10y gov bond)	-0.01
	(-0.50)
R^2	65%
Durbin Watson	1.10
Sample	1996Q1-2016Q4

Revaluations ($stock_t = stock_{t-1} + revaluation_t + flow_t$)

Equity

Dependent variable : revaluations of $equity_t$/GDP $deflator_t$

constant	7 846
	(1.31)
$\Delta\log(CAC40)_{t-1}$	92 324***
	(6.96)
R^2	38%
Durbin Watson	1.97
Sample	1996Q1-2016Q4

Credits

Dependent variable : revaluations of $credits_t$/stock of $credits_t$

constant	0,00
	(0.00)
10y gov bond $yield_{t-1}$	-0.0002
	(-0.91)
R^2	1%
Durbin Watson	1.19
Sample	1996Q1-2016Q4

Securities liabilities

Dependent variable : revaluations of bonds $liabilities_t$/GDP $deflator_t$

constant	-745
	(-1.23)
$\Delta\log(CAC40)_t$	16 139**
	(2.18)
$\Delta\log(CAC40)_{t-1}$	-7 173
	(-0.98)
$\Delta(10y\ gov\ bond\ yield)_{t-1}$	-12 086***
	(-5.79)
R^2	32%
Durbin Watson	1.58
Sample	1996Q1-2016Q4

Financial block

Stock of households' debt

Desequilibrium model : $\Delta\log(\text{stock of HH debt})_t = \min(\text{demand}_t\ ;\ \text{supply}_t)$

	Demand	Supply
constant	0.05*** (3.58)	0.04 (1.97)
HH lending rates$_{t-1}$	-0.03 (-0.48)	
unemployment rate$_{t-1}$	-0.39*** (-2.93)	
Δlog(real estate prices)$_{t-1}$	0.31*** (3.07)	
HH DSR$_{t-1}$		-0.37 (-1.02)
Δlog(nominal GDI)$_{t-1}$		0.86* (1.84)
spread$_{t-1}$ (HH lending rate - 10y gov bond yield)		0.42 (0.80)
R^2	40%	
Durbin Watson	1.87	
Sample	1990Q1-2016Q4	

10y government bond yield

Long-term equation

Dependent variable : 10y governement bond yield$_t$

constant	1.97*** (7.74)
euribor 3 months	0.73 (13.91)
R^2	87%
Sample	1990Q1-2016Q4

Short-term equation

Dependent variable : Δ(10y governement bond yield)$_t$

constant	-0.14*** (-2.67)
residuals$_{t-1}$	-0.05 (-1.46)
Δ(10y governement bond yield)$_{t-1}$	0.33*** (3.36)
Δlog(nominal GDP)$_{t-1}$	12.49** (2.15)
R^2	16%
Durbin Watson	1.78
Sample	1990Q3-2016Q4

Euribor 3 months

Dependent variable : spread$_t$ (euribor – deposit facility rate)

constant	0.00 (0.09)
spread$_{t-1}$ (euribor – deposit facility rate)	0.91*** (24.08)
Δlog(nominal GDP)$_{t-1}$	10.81*** (3.83)
R^2	91%
Durbin Watson	2.05
Sample	1999Q2-2016Q4

Households' lending rate

Dependent variable : HH lending rate$_t$

constant	-1.09*** (-4.82)
10y gov bond yield$_{t-1}$	0.37*** (8.93)
HH lending rate$_{t-1}$	0.77*** (29.77)

1 / HH lending $rate_{t-1}$	2.68*** (4.85)
R^2	99%
Durbin Watson	1.14
Sample	1990Q3-2016Q4

NFCs' lending rate

Dependent variable : NFC lending $rate_t$

constant	-0.89** (-2.14)
10y gov bond $yield_{t-1}$	0.21*** (3.74)
NFC lending $rate_{t-1}$	0.87*** (23.53)
1 / NFC lending $rate_{t-1}$	1.58** (2.05)
R^2	97%
Durbin Watson	1.26
Sample	1990Q3-2016Q4

CAC 40

Dependent variable : $\Delta\log(CAC40)_t$

constant	-0.02 (-1.59)
$\Delta\log(GDP)_{t-1}$	5.34*** (3.19)
Δ(10y gov bond yield. difference)$_{t-1}$	-0.06** (-2.46)
R^2	10%
Durbin Watson	1.46
Sample	1990Q1-2016Q4

Real estate prices

Dependent variable : $\Delta\log$(real estate prices)$_t$

constant	0.06*** (6.92)
$\Delta\log$(stock of HH debt)$_{t-1}$	0.43*** (4.03)
$\Delta\log$(nominal GDP)$_{t-1}$	0.39* (1.79)
$\Delta\log$(nominal GDI)$_{t-1}$	0.27 (1.64)
HH DSR (-1)	-0.01*** (-8.32)
Δ(HH lending rate)$_{t-1}$	-0.01 (-1.54)
R^2	63%
Durbin Watson	1.10
Sample	1991Q3-2016Q4

Appendix 3: performance tests

GDP in chained prices (QoQ growth rate in %)

Sample 2011 - 2016 : Mean = 0.23 ; Standard deviation = 0.29

Horizon (quarters)	1	2	3	4	5	6	7	8	9	10	11	12
RMSFE Alienor	0.22	0.24	0.25	0.21	0.22	0.22	0.21	0.21	0.22	0.21	0.21	0.19
RMSFE Benchmark	0.31	0.26	0.26	0.30	0.30	0.33	0.32	0.33	0.31	0.29	0.27	0.24
Gain of accuracy	24%	16%	19%	40%	29%	30%	29%	30%	24%	19%	16%	9%

NFCs’ investment in chained prices (QoQ growth rate in %)

Sample 2011 - 2016 : Mean = 0.44 ; Standard deviation = 0.80

Horizon (quarters)	1	2	3	4	5	6	7	8	9	10	11	12
RMSFE Alienor	0.88	0.73	0.78	0.80	0.85	0.75	0.71	0.72	0.76	0.74	0.75	0.75
RMSFE Benchmark	0.79	0.55	0.58	0.89	0.73	0.64	0.69	0.68	0.80	0.74	0.71	0.68
Gain of accuracy	-19%	-44%	-39%	6%	-23%	-27%	-5%	-5%	1%	-8%	-13%	-26%

CAC40 index (QoQ growth rate in %)

Sample 2011 - 2016 : Mean = 0.76 ; Standard deviation = 6.70

Horizon (quarters)	1	2	3	4	5	6	7	8	9	10	11	12
RMSFE Alienor	7.73	7.19	7.50	6.12	6.07	5.52	5.21	4.91	5.04	4.97	4.92	5.00
RMSFE Benchmark	6.86	6.73	6.06	4.94	6.19	5.53	4.93	4.87	4.65	4.75	4.71	4.91
Gain of accuracy	-13%	-14%	-26%	-31%	-3%	-5%	-12%	-7%	-12%	-6%	-6%	-2%

Real estate prices (QoQ growth rate in %)

Sample 2011 - 2016 : Mean = -0.07 ; Standard deviation = 0.71

Horizon (quarters)	1	2	3	4	5	6	7	8	9	10	11	12
RMSFE Alienor	0.44	0.44	0.36	0.39	0.40	0.43	0.48	0.53	0.62	0.64	0.66	0.69
RMSFE Benchmark	0.46	0.58	0.83	0.93	1.06	1.14	1.25	1.29	1.28	1.29	1.23	1.16
Gain of accuracy	-34%	13%	48%	51%	54%	55%	57%	55%	54%	55%	53%	51%

Households’ debt (QoQ growth rate in %)

Sample 2011 - 2016 : Mean = 0.72 ; Standard deviation = 0.38

Horizon (quarters)	1	2	3	4	5	6	7	8	9	10	11	12
RMSFE Alienor	0.51	0.48	0.55	0.54	0.59	0.59	0.59	0.52	0.55	0.53	0.52	0.54
RMSFE Benchmark	0.34	0.38	0.43	0.45	0.53	0.55	0.60	0.57	0.63	0.62	0.64	0.67
Gain of accuracy	-49%	-29%	-27%	-20%	-12%	-8%	2%	9%	13%	15%	19%	20%

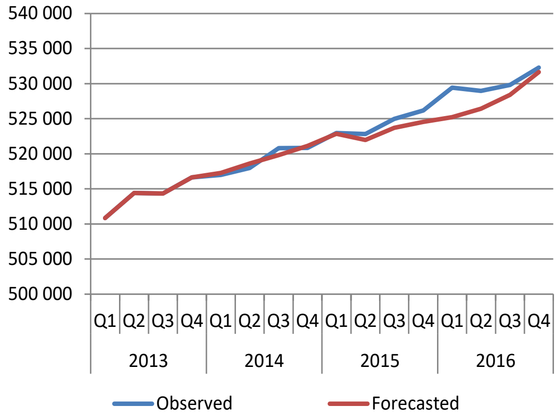
NFCs’ debt (QoQ growth rate in %)

Sample 2011 - 2016 : Mean = 1.27 ; Standard deviation = 1.16

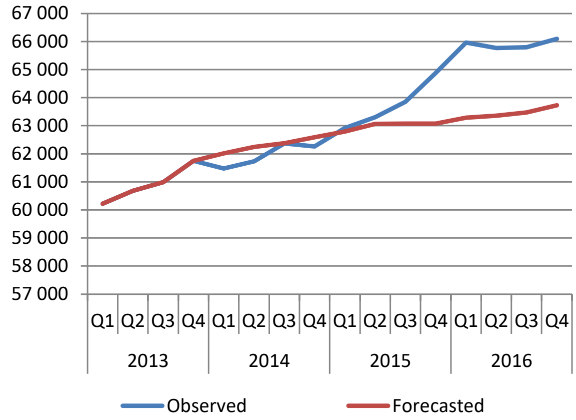
Horizon (quarters)	1	2	3	4	5	6	7	8	9	10	11	12
RMSFE Alienor	1.00	1.08	1.04	1.02	1.00	0.95	0.93	0.96	1.00	1.04	0.89	0.89
RMSFE Benchmark	0.82	0.88	0.82	0.74	0.84	0.87	0.82	0.86	0.97	0.96	0.85	0.84
Gain of accuracy	-22%	-23%	-27%	-37%	-19%	-10%	-13%	-11%	-3%	-8%	-5%	-6%

Example: forecasts from Q1 2014 to Q4 2016

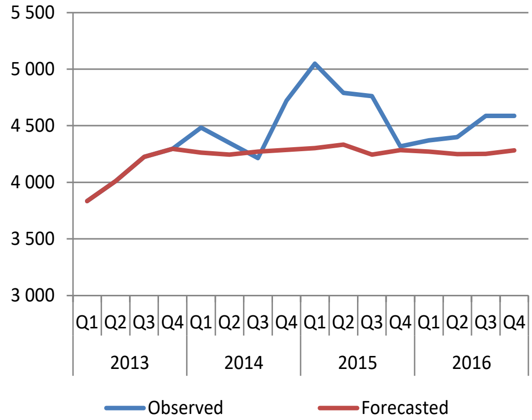
GDP



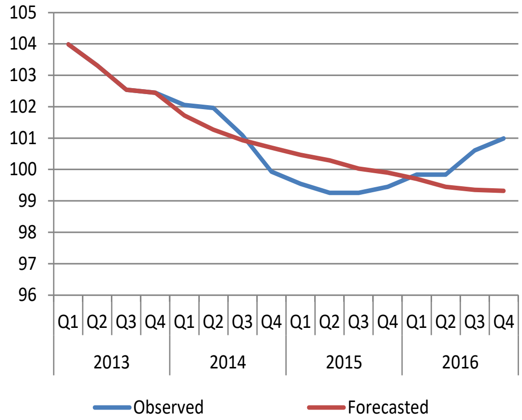
NFCs' investment



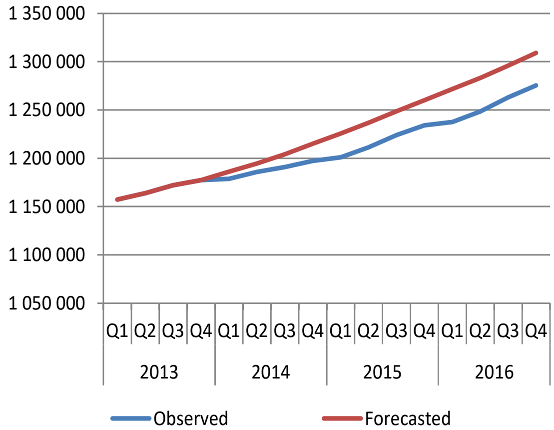
CAC40 index



Real estate prices



Households' debt



NFCs debt