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MONETARY POLICY TRANSMISSION AND MACROECONOMIC DYNAMICS IN LUXEMBOURG: RESULTS FROM A VAR ANALYSIS

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MONETARY POLICY TRANSMISSION AND MACROECONOMIC DYNAMICS IN LUXEMBOURG: RESULTS FROM A VAR ANALYSIS[*]

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Abstract

The aim of this work is to study the interactions between monetary policy, credit, house prices and the macroeconomy in Luxembourg using a VAR model with quarterly data in levels from 1986 to 2009. The results of the structural analysis provide valuable information concerning the monetary policy transmission mechanism, the interactions between credit and house prices, and the importance of foreign shocks for the behaviour of domestic variables. Some tentative explanations related to the particular economic and financial structures of the Luxembourg economy are moreover suggested to interprete this empirical evidence. More specifically, the structural analysis leads to the following conclusions: (1) In accordance with the existing VAR literature, a contractionary monetary policy shock leads to a temporary decrease in output and to a gradual decline in prices. (2) Monetary policy transmission to the real economy is relatively strong in Luxembourg, a result that could be associated with the variable interest rate structure of loans to the private sector, the high degree of openness and the preponderance of the financial services industry. (3) The response of credit and GDP following a residential property price shock provides some scope for the existence of a house price channel of monetary policy transmission in Luxembourg. (4) Finally, domestic variables respond strongly to foreign shocks, as evidenced by both the impulse response functions and the forecast error variance decomposition.

Keywords: Monetary policy, small open economy, VAR, macroeconomic shocks.

JEL classification: C32, E52, F41.

[*] The author is grateful to BCL colleagues for their helpful comments. The views expressed in this paper are personal views of the author and do not necessarily reflect those of the Banque centrale du Luxembourg or the Eurosystem. Author address: Romuald Morhs, Banque centrale du Luxembourg, 2, Boulevard Royal L-2983 Luxembourg. E-mail:romuald.morhs@bcl.lu.
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Content

Résumé non-technique

La méthodologie VAR constitue un outil économétrique particulièrement adapté pour modéliser les interactions dynamiques entre variables macroéconomiques à partir d'une représentation sommaire de l'économie. L'objectif de ce cahier d'études est d'estimer un modèle VAR pour le Luxembourg de manière à étudier les effets de la politique monétaire et l'influence des chocs externes sur les développements économiques au Grand-Duché. Ce modèle, qui est estimé à partir de données trimestrielles couvrant la période 1986 à 2009, comporte un ensemble de variables domestiques et étrangères. Le bloc de variables domestiques comprend l'indice des prix à la consommation, le PIB réel, le crédit au secteur privé et le prix de l'immobilier résidentiel au Luxembourg, tandis que le bloc de variables étrangères inclut l'indice des prix à la consommation, le PIB réel, le taux d'intérêt nominal de court terme et l'indice du prix des actions de la zone euro. Afin de prendre en compte de manière appropriée les interactions entre le Luxembourg et la zone euro, le cadre d'analyse retenu décrit par ailleurs une petite économie ouverte dans laquelle les variables domestiques n'exercent pas d'influence sur la détermination des variables étrangères.

Les principaux résultats obtenus dans cette étude sont les suivants : (1) Conformément à la littérature existante, un choc de politique monétaire restrictif exerce un effet temporaire sur l'activité économique et un effet plus persistant sur le niveau de prix. (2) L'impact de la politique monétaire sur le PIB réel luxembourgeois est relativement élevé, une hausse du taux d'intérêt nominal de court terme de 32 points de base se traduisant par une contraction du PIB réel de 0,35% après six trimestres. Ce résultat pourrait notamment s'expliquer par la structure à taux variable des crédits au secteur privé, mais aussi et surtout par les effets indirects de la politique monétaire qui s'exercent par le biais du PIB réel et du prix des actions de la zone euro. (3) Les réactions positives et significatives du crédit et du PIB réel au Luxembourg suite à un choc sur le prix de l'immobilier résidentiel suggèrent en outre la présence d'un effet collatéral et/ou d'un effet de richesse, indiquant par là l'existence d'un canal du prix de l'immobilier par lequel les effets de la politique monétaire se transmettent à l'activité économique. (4) L'économie luxembourgeoise apparaît enfin très sensible à l'évolution de l'environnement international, les fluctuations à long terme des variables domestiques provenant à plus de 60% des chocs sur les variables de la zone euro. Plus particulièrement, un choc de près de 0.5% sur le PIB de la zone euro exerce un impact de même ampleur sur le PIB luxembourgeois après un an, tandis qu'un choc de 9% sur le Dow Jones Euro STOXX exerce un effet plus immédiat pour une hausse maximale de 0.62% du PIB luxembourgeois.

Non-technical summary

The vector autoregressive (VAR) methodology provides a flexible technique for assessing relationships between macroeconomic variables. This paper builds a VAR model to study the effects of monetary policy and external shocks on the Luxembourg economy. This model, which is estimated with quarterly data covering the period 1986 to 2009, includes a set of domestic and foreign variables. The set of domestic variables consists of real GDP, consumer prices, nominal credit to the private sector, and nominal residential property prices. The set of foreign variables contains euro area real GDP, the euro area consumer price index, the euro area share price index, and the short-term nominal interest rate. In order to provide an appropriate treatment of the relationships between the Luxembourg economy and the euro area economy, we moreover adopt a small open economy framework in which domestic variables exert no influence on the determination of foreign variables.

The main results obtained in this study are the following: (1) In conformity with the existing VAR literature, a contractionary monetary policy shock leads to a temporary decrease in output and to a more gradual decline in prices. (2) Monetary policy transmission to the real economy is relatively strong in Luxembourg, a 32 basis points increase of the short-term nominal interest rate generating a fall of real GDP of -0.35% after six quarters. This result could be associated with the variable interest rate structure of loans to the private sector, but also and especially with the indirect effects of monetary policy transiting through the euro area GDP and share price index. (3) The positive response of credit and GDP following a residential property price shock suggests the presence of a collateral and/or a wealth effect in Luxembourg, providing some scope for the existence of a house price channel of monetary policy transmission in Luxembourg. (4) Finally, the Luxembourg economy appears to be highly sensitive to the evolution of the international environment, innovations in euro area variables accounting for more than 60% of the fluctuations of domestic variables in the long run. More specifically, after a shock of 0.5% on the euro area GDP, the Luxembourg GDP reaction reaches a peak after four quarters that is close to the size of the initial shock. A shock of 9% on the Dow Jones Euro STOXX has a more immediate effect, translating into a maximum increase of Luxembourg GDP of 0.62% after one quarter.

1. Introduction

The vector autoregressive (VAR) methodology provides a flexible technique for assessing relationships between macroeconomic variables. This paper builds a VAR model of the Luxembourg economy taking into account the specificities of the country, which is a small open economy dominated by the financial sector. This adaptation of the model is highlighted by the inclusion of a set of foreign variables containing, among others, the euro area output and share price index. To my knowledge, this is the first time that such a model is used to study macroeconomic relationships in Luxembourg and, more particularly, the effects of monetary policy. The aim of this paper is to fill this gap, thus contributing to the existing applied literature in this field for the euro area countries.

The seminal work of Sims (1980) launched an abundant literature using the VAR methodology to study the macroeconomic effects of monetary policy decisions (e.g. Christiano et al., 1999, for the United States, Peersman and Smets, 2003, and Mojon and Peersman, 2003, for the euro area). This work adopts this approach to analyse the impact of monetary policy on some macroeconomic variables of interest in Luxembourg, namely GDP, consumer prices, credit to the private sector and house prices. Furthermore, the model is used to analyse the interactions between credit, house prices and the macroeconomy in Luxembourg, as well as the impact of some foreign shocks on the behaviour of the domestic variables, including shocks to euro area GDP and the Dow Jones Euro STOXX index. The empirical results are then interpreted in light of the specificities of the Luxembourg economy.

From the point of view of the monetary transmission mechanism, it is worth noting that this paper completes to some extent the study of Mojon and Peersman (2003) who present the results of a VAR model, *« the most widely used empirical methodology to analyse the [monetary] transmission mechanism »*, for all the euro area countries except Luxembourg and Portugal. The value added brought by this work to previous research carried out at the BCL on this topic is thus straightforward. Indeed, whereas Guarda (2005) uses a traditional structural macroeconomic model to quantify the effects of a two-year increase in the interest rate by 100 basis points, the remaining studies focus on the disaggregated transmission channels of monetary policy. Lünnemann and Mathä (2002) use micro data to analyse the interest rate and the credit channel in Luxembourg firms' investment behaviour, and Wicky (2008) provides an empirical estimate of the interest rate pass-through in Luxembourg banks on both an aggregate and an individual basis.

Overall, the VAR results for Luxembourg suggest a strong and highly significant multi-directional relationship between monetary policy, credit, house prices and the macroeconomy. More specifically, the structural analysis leads to the following conclusions: (1) In conformity with the existing VAR literature, a contractionary monetary policy shock leads to a temporary decrease in output and to a more gradual decline in prices. (2) Monetary policy transmission to the real economy is relatively strong in Luxembourg, a result that could be associated with the variable interest rate structure of loans to the private sector, the high degree of openness and the preponderance of the financial services industry. (3) The response of credit and GDP following a residential property price shock provides some scope for the existence of a house price channel of monetary policy transmission in Luxembourg. (4) Finally,

domestic variables respond strongly to foreign shocks, as indicated by both the impulse response functions and the forecast error variance decomposition.

The remainder of the paper is organized as follows. The second section introduces the key characteristics of the Luxembourg economy as well as its main macroeconomic developments, in order to set the framework of the VAR analysis. The third section presents the structure of the VAR model for Luxembourg and the fourth section summarizes the results obtained with the structural analysis, putting forward some tentative explanations for this empirical evidence. Finally, the last section concludes before identifying some avenues for further work on this topic.

2. Some stylized facts and specificities of the Luxembourg economy

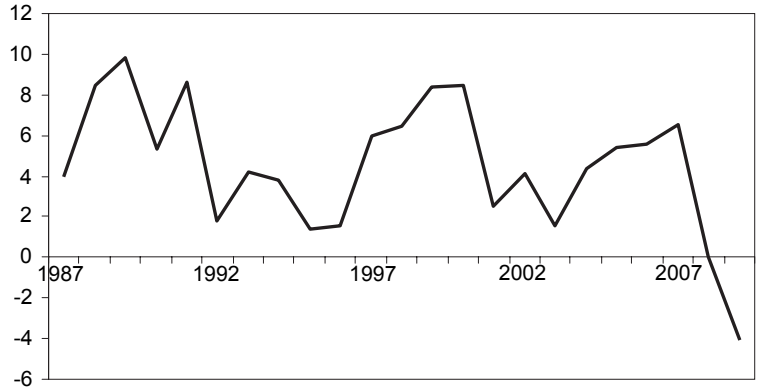
The aim of this section is to present the key characteristics of the Luxembourg economy as well as its main recent macroeconomic developments, in order to set the framework of the VAR model and put forward the main arguments related to the interpretation of the results obtained from the structural analysis[1].

2.1 The Luxembourg economic structure: an overview

Luxembourg is, as many other countries, a small open economy. Its share of the euro area GDP is less than 0.4% and its overall degree of openness, measured by the average of imports and exports divided by GDP, is almost 165%. At the same time, the Luxembourg economy is deeply integrated into the euro area with about ¾ of its external trade taking place with the member states of the monetary union.

Furthermore, Luxembourg is characterized by a relatively large financial sector. Indeed, the rapid expansion of the economy since the mid-1980s has been largely driven by the development of financial services. In 2009, these accounted for 25.0% of nominal gross value added, compared to 8.7% for industry, 0.3% for agriculture, 5.5% for construction, 24.2% for retail trade, tourism, etc., 21.2% for real estate, lending and business activities, and 15.2% for other services.

Figure 1 : GDP annual growth rate of the Luxembourg economy
(Source: STATEC)

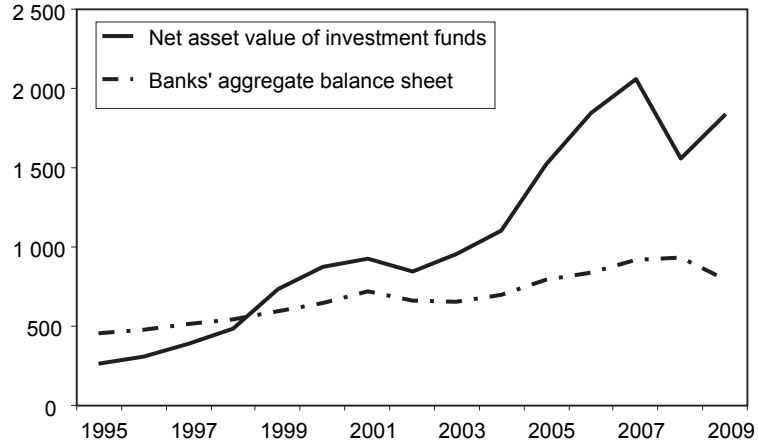


Besides its important share of GDP, the financial services industry has also been generating several positive externalities for the Luxembourg economy through related activities (consulting, accountancy, business law…) or more basically through construction, hotels and restaurants, transport and so on. According to a study by Deloitte (2008), the direct and indirect impact of the financial sector in Luxembourg for the year 2007 represented 45% of total value added, 21% of total employment and 34% of total fiscal revenues.

[1] Readers familiar with the Luxembourg economy may wish to skip directly to the following section.

In contrast to Luxembourg's limited economic weight in euro area GDP, the size of its financial sector is relatively large, as illustrated by the aggregate balance sheet of banks and, more importantly, by the net asset value of the investment funds industry. At the end of 2009, the latter represented about 30% of the outstanding amount in the euro area, Luxembourg being the largest European centre for UCIs administration and distribution, with a total of 3463 UCIs divided into 12232 subfunds and totalizing a net asset value of roughly 1840 billion euros.

Figure 2 : Bank and investment fund activity in Luxembourg
(Source: BCL, billions of euros)



To sum up, Luxembourg is a small open economy where the financial services industry plays a predominant role, making it highly vulnerable to external shocks, especially those related to financial markets.

2.2 The Luxembourg financial structure: an overview

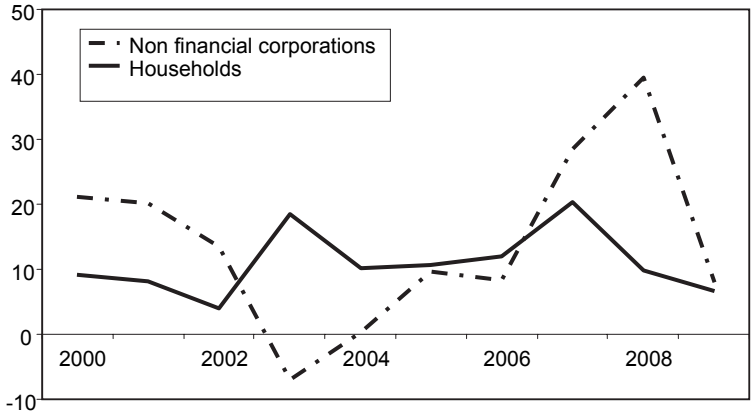
As in other euro area countries, the financial structure in Luxembourg is clearly more bank-oriented than market-oriented. Bank credit plays a fundamental role in financing non-financial corporations and households, thus rendering investment and consumption decisions highly dependent on the banking system's behaviour.

Data availability is fairly limited concerning the source of financing for the non-financial corporate sector in Luxembourg due to the absence (to date) of financial accounts. However, strong bank-lending relationships are suggested by the large outstanding amount of loans to this sector which, in the 2000s, exceeded total gross fixed capital formation to reach a share in GDP slightly above 25%. On the other hand, the stock market is only of secondary importance, as reflected by the low number of publicly traded companies. Only 31 out of 26 621 Luxembourg firms were listed on the Luxembourg stock exchange in 2009, while about 90% of the domestic market capitalisation was accounted for by three multinational corporations, namely Arcelor Mittal, SES and RTL Group. Similarly, the bond market plays only a minor role in the financing of the Luxembourg non-financial corporate sector, as the Luxembourg stock

exchange is mainly used for issuance and quotation by foreign companies and their Luxembourg-based holdings[2].

Figure 3 : Growth rate of credit to the domestic non financial corporations and households sectors in Luxembourg

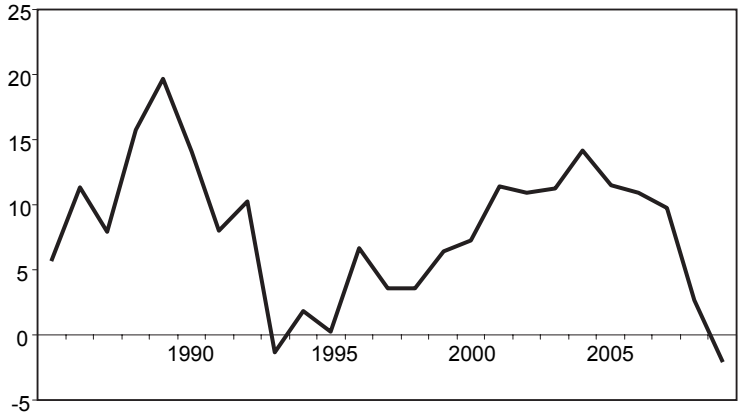
(Source: BCL)



The banking sector is also the most important lender to Luxembourg households. The bulk of household indebtedness is issued as bank loans and large part of the debt is at long-term maturity, including substantial amounts of long-term mortgages. In 2008, housing loans in Luxembourg accounted for roughly ¾ of the outstanding household debt. Between 2000 and 2009, the average annual growth rate of the latter reached almost 13%. This increase can be attributed in part to the effects of the sustained rise of house prices in Luxembourg which averaged 10% per year during the 2000s. As a consequence, the household indebtedness ratio has almost doubled since 1999, reaching about 49% of nominal GDP in 2009, whereas at the same time, banks have modified their lending practices by extending both the loan repayment duration and the loan-to-value ratio (BCL, 2009).

[2] Another indication of the importance of credit for the financing of non-financial corporations in Luxembourg is the large contribution of small and medium enterprises to the economy, which represented 74% of total value added and 72% of total employment in 2000, according to the *Observatory of European SMEs*. Indeed, SMEs are usually more prone to information asymmetry problems and thus more dependent on long-term credit relationships for the development of their activities.

Figure 4: Growth rate of residential property prices in Luxembourg
(Source: STATEC, BCL calculation)



Given the importance of credit for the financing of economic activity in Luxembourg, the structure of the banking system in terms of competition, openness and specialisation should be a key determinant of the monetary transmission mechanism and the credit channel in particular. Both the Herfindahl index and the share of the five largest credit institutions in total assets suggest that the Luxembourg banking system is characterized by a very low level of concentration (ECB, 2008). However, only a small number of the 149 banks officially registered in Luxembourg at the end of 2009 supply their services on the domestic market. The banking sector is actually dominated by foreign banks mainly operating internationally, with a specialisation centered around three activities: (1) private banking, which consists in providing portfolio management services for high net worth individuals, (2) custodian and central administration activities for the investment fund industry, as reflected in the growing share of fees and commissions in bank non-interest revenues, and (3) liquidity hub for other entities of the banking group, using the competitive advantage inherent to the favourable fiscal environment and the presence of Clearstream (the international clearing house) for interbank and monetary policy operations.

Another important characteristic of the Luxembourg financial system for the monetary transmission mechanism, and more particularly for the interest rate channel, is the floating rate structure of the loans to non-financial corporations and households (with the exception of consumer loans). The transmission of monetary policy decisions to bank lending rates (i.e. the pass-through of official and market interest rates to retail bank interest rates) is thus quite rapid and complete in Luxembourg[3]. This in turn exerts a powerful impact on economic activity through different channels (Sellon, 2002). On the one hand, the cost of financing constitutes one of the main determinants of borrowers' indebtment behaviour and (residential) investment decisions, and on the other hand, changes in monetary policy translate into a faster response of the cost of debt servicing and, consequently, of firm cash flows and household disposable income, thus establishing an important channel through which interest rate changes affect investment and consumption expenditures[4].

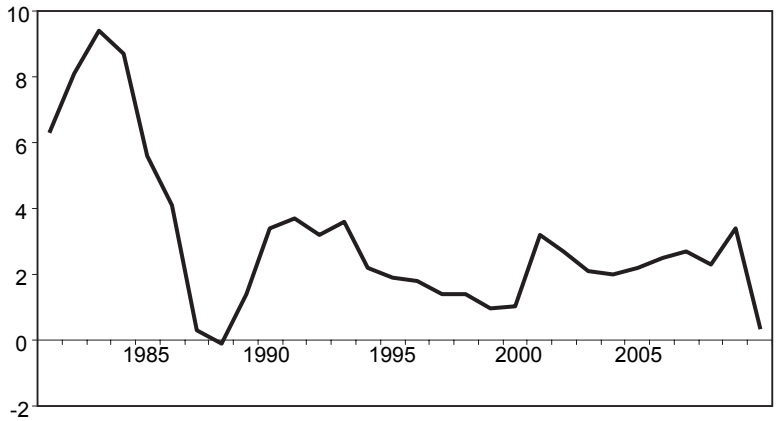
[3] See Wicky (2008) for an empirical study of the interest rate pass-through in Luxembourg.
[4] See Lünnemann and Mathä (2002) for a study of the determinants of firms' investment behaviour in Luxembourg based on microeconomic data.

2.3 Monetary policy in historical perspective

Another specificity of Luxembourg is the absence until recently of any national central bank. The *Banque centrale du Luxembourg* (BCL) was created in June 1998, just before its decision powers were transferred to the European Central Bank (ECB). Before 1999, Luxembourg was a member of the Belgo-Luxembourg Economic Union (BLEU) which included a protocole relative to the monetary association between the two countries. The *Institut Monétaire Luxembourgeois* (IML), the predecessor of the BCL, was limited to issuing Luxembourg Francs and supervising the banking sector. The Banque Nationale de Belgique (BNB) was responsible for monetary policy operations and the liquidity of banks, as well as foreign exchange operations.

Both Belgium and Luxembourg were members of the European Monetary System (EMS) between 1979 and 1998[5]. During this period, the main objective of the BNB was to guarantee exchange rate stability between the Belgium Franc and the Deutsche Mark. The scope for an independent monetary policy was therefore limited. Indeed, the EMS functioned asymetrically ; whereas the Bundesbank enjoyed a degree of freedom in the conduct of its monetary policy, the other member states had to align their interest rate on the German one in order to maintain the exchange rate parity defined within the European exchange rate mechanism (ERM). Like many other countries of the euro area, Belgium and Luxembourg progressively passed from a fixed but adjustable exchange rate system to a system without realignments between 1987 and 1992[6]. According to the *credibility transfer thesis* (e.g. Giavazzi et Pagano, 1988, Dhyne, 2005), this transition from a 'soft ERM' to a 'hard ERM' played a prominent role in shaping the inflation dynamics of the Luxembourg economy during the mid-1980s.

Figure 5 : Inflation rate in Luxembourg
(Source: European Commission, AMECO database)



[5] See Buys et al. (2005) for a detailed history of the Belgian monetary policy over this period.
[6] After the readjustments of the exchange rate parity in 1982 (devaluation of 8.5% in February and 4.25% in June), 1983 (4%), 1986 (2%) and 1987 (1%), the years 1987-1992 were characterized by a period of stability between the Belgium Franc and the Deutsche Mark. The Belgium Franc has moreover been anchored to the Deutsche Mark from May 1990.

Besides the tensions encountered by the Belgium Franc during the speculative attacks on the EMS currencies[7], the 1990s have been characterized by a period of monetary stability and nominal convergence. The ratification of the Maastricht Treaty in 1993 paved the way for the adoption of the euro in 1999 and its corollary, the creation of an independent central bank with the explicit primary objective of price stability. Within the current institutional framework, the BCL, along with the other national central banks of the Eurosystem, implements the monetary policy decisions taken by the ECB's Governing Council and executes the missions of the European System of Central Banks (ESCB), including monetary policy operations and management of reserves as well as the supervision of the payment and settlement systems.

This section described the main characteristics and macroeconomic developments of the Luxembourg economy. Before turning to the empirical analysis of the interactions between monetary policy, house prices, credit and the macroeconomy in Luxembourg, the next section presents the framework of the VAR model estimated for that purpose.

3. Specification of the VAR model

The VAR process has the following general representation[8]:

$$(1) \qquad Y_t = A_0 + A_1(L)Y_t + B_0X_t + \varepsilon_t,$$

where Y_t is a vector of endogenous variables, X_t is a vector of exogenous variables, A(L) is a matrix polynomial in the lag operator and ε_t is a vector of normally distributed i.i.d. errors.

The vector of endogenous variables, Y_t, comprises a set of domestic and foreign variables. The set of domestic variables (Y_t^{LUX}) consists of real GDP (y_t^{LUX}), consumer prices (p_t^{LUX}), nominal credit to the private sector ($credit_t^{LUX}$), and nominal residential property prices ($prop_t^{LUX}$). The set of foreign variables (Y_t^{EA}) contains euro area real GDP (y_t^{EA}), the euro area consumer price index (p_t^{EA}), the euro area share price index ($shares_t^{EA}$), and the short-term nominal interest rate (sri_t^{EA}). All the variables are expressed in logarithms, except the interest rate which is in levels[9].

In order to take into account the size of the Luxembourg economy with respect to the euro area, we adopt a small open economy framework as in Cushman and Zha (1997):

$$(2) \qquad \begin{pmatrix} Y_t^{LUX} \\ Y_t^{EA} \end{pmatrix} = \begin{pmatrix} A_{10} \\ A_{20} \end{pmatrix} + \begin{pmatrix} A_{11}(L) & A_{12}(L) \\ 0 & A_{22}(L) \end{pmatrix} \cdot \begin{pmatrix} Y_t^{LUX} \\ Y_t^{EA} \end{pmatrix} + \begin{pmatrix} 0 \\ B_{20} \end{pmatrix} \cdot X_{t-1} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}$$

[7] In 1993, these tensions lead the BNB to increase its official interest rate substantially from 6.7% in mid-July to 10.7% in the beginning of September and to intervene massively on the exchange rate market in order to defend the parity of the Belgium Franc.
[8] The VAR methodology is presented in Appendix 1.
[9] See Appendix 2 for a detailed presentation of the data used in this work.

The restriction $A_{21}(L) = 0$ implies that the foreign block Y_t^{EA} is exogenous to the domestic block Y_t^{LUX} both contemporaneously and for lagged values of the variables, thus providing a more appropriate treatment of the relationships between the Luxembourg economy and the euro area economy.

Within this framework, the monetary policy shock is identified within the euro area block, this latter being estimated separately. In order to get closer to Peersman and Smets (2003), we also allow euro area variables to be affected with a lag by a vector of exogenous variables (X_t) including a world commodity price index (wcp_t), US real GDP (y_t^{US}) and the US short-term nominal interest rate (sri_t^{US})[10]:

The VAR model represented by equation (2) is estimated in levels using quarterly data over the period 1986-2009[11], thus allowing for implicit cointegrating relationships in the data (Sims et al., 1990). The standard lag selection criterion lead us to retain a VAR of order three. Five dummies for the quarters 1992:3, 1999:1, 2008:2, 2008:4 and 2009:2 were added to the deterministic component of the system in order to avoid non-normality of the residuals. The first two dummies correspond to the interest rate reactions during the speculative attacks against the EMS currencies that lead to the withdrawal of the Pound Sterling and the Lira in September 1992, and to the change in definition of the credit series[12] (as indicated in Appendix 2). The other dummies are justified by the high volatility induced by the subprime crisis on the variables of the model.

To identify the structural shocks, we use a standard Choleski decomposition with the variables ordered as follows[13]:

$$(4) \qquad Y_t' = [p_t^{EA} \quad y_t^{EA} \quad sri_t^{EA} \quad shares_t^{EA} \quad p_t^{LUX} \quad y_t^{LUX} \quad credit_t^{LUX} \quad prop_t^{LUX}]$$

Following the existing literature (e.g. Assenmacher-Wesche and Gerlach, 2008b), the short-term interest rate is ordered after the euro area consumer prices and euro area GDP but before the equity price index because, on the one hand, monetary policy does

[10] The VAR process estimated for the euro area is thus quite close to the one estimated by Peersman and Smets (2003) except that the real effective exchange rate is replaced by the share price index. This choice is motivated by the importance of this latter variable for the macroeconomic dynamics in Luxembourg.

[11] We are fully aware that the sample 1986:1-2009:4 is subject to data limitations (as illustrated, for example, by the need to interpolate Luxembourg real GDP prior to 1995) and to the possible existence of parameter instability (due, for example, to a structural change in the monetary policy regime). However, the choice of a sufficiently long span was required to overcome the curse of dimensionality inherent to the estimation of a VAR model with eight variables.

[12] The inclusion of this latter dummy in the block of euro area variables is also motivated by the launch of the euro.

[13] The Choleski decomposition represents the most widely used strategy to identify structural shocks in a VAR model. However, alternative identification schemes have been applied to study the monetary transmission mechanism: (1) Cushman and Zha (1997) and Kim and Roubini (2000) use the methodology proposed by Bernanke (1986) and Sims (1986) and impose a non-recursive structure to the identification matrix based on short-run restrictions. (2) Gerlach and Smets (1995), following Blanchard and Quah (1989), use an identification scheme based on short- and long-run restrictions, assuming that aggregate demand/supply shocks have transitory/permanent effects on real GDP. (3) Finally, Uhlig (2005) proposes an identification scheme based on the imposition of sign restrictions on the impulse responses of variables following a monetary policy shock.

not respond in practice to contemporaneous changes in asset prices, and on the other hand, because equity prices respond contemporaneously to all the information available in the economy. Concerning the ordering of domestic variables, the underlying assumption is that output shocks have no contemporaneous effects on prices due to their intrinsic persistence, and the same holds true with respect to the relationship between credit and house prices. Finally, output and prices are assumed to react to credit only with a lag which is also quite a standard assumption in the existing literature (e.g. Assenmacher-Wesche and Gerlach, 2008b, Goodhart and Hofmann, 2008). However, the results obtained with this identification strategy are highly robust to a change in the ordering of the domestic variables.

4. Results of the structural analysis

In this section, we discuss the results of the structural analysis obtained from the estimation of the VAR described above. First, the impulse response functions are used to analyse monetary policy transmission, the interactions between credit, house prices and the macroeconomy, and the impact of foreign shocks on the behaviour of domestic variables. Then, the forecast error variance decomposition is carried out for the domestic variables of the VAR process, providing some information on the source of fluctuations of the Luxembourg economy over different horizons. The robustness of the results presented in this section has been explored through different specifications of the VAR model. In particular, results proved to be very stable both qualitatively and quantitatively to a change in the ordering of the variables, the lag structure and the starting point of the sample period, as well as the introduction of a linear trend in the deterministic component of the system.

4.1 Monetary policy transmission in Luxembourg

Figure 6 displays the impulse responses to an orthogonalized one standard deviation monetary policy shock together with the one standard error confidence bands based on 10000 bootstrap replications[14]. Following an exogenous increase in the interest rate, the fall of the Luxembourg price level becomes statistically significant after the fourth quarter and displays strong persistence, whereas the drop in Luxembourg GDP occurs more quickly to reach a trough after five to seven quarters before recovering slowly. Overall, according to the point estimates, an unexpected and temporary increase of the short-run nominal interest rate of 32 basis points generates after two years a fall of real GDP of -0.35% and a fall of CPI of -0.15%. Concerning the other domestic variables, credit starts to fall significantly after one year to reach a trough of -1.1% about eight quarters after the shock, while residential property prices start to fall gradually during the first year and show the same persistence as CPI, reaching a maximum decrease of about -0.82% after two years.

These findings suggest strong transmission of monetary policy to the Luxembourg economy and warrant several comments. First, the reactions of prices and output following a contractionary monetary policy shock are similar to those found in the existing VAR literature for the (countries of the) euro area, in the sense that

[14] The impulse response functions are reported in Appendix 3.

« contractionary monetary policy shocks lead to a temporary decrease in output and to a gradual decline in prices » (Mojon and Peersman, 2003, p.56). Compared to the results obtained by Peersman and Smets (2003) for the euro area as a whole and with a very similar monetary policy shock[15], the pattern of the CPI reaction is the same in Luxembourg except that the size of the reaction is much larger. However, it is worth noting that most of the impulse response functions presented by Mojon and Peersman (2003) for the other euro area countries taken individually also display a stronger CPI reaction, notably when considering the case of Germany, Austria, Belgium, Netherlands and France[16]. By contrast, the fall (and subsequent recovery) of real GDP in Luxembourg is slower compared to the euro area while the size of the reaction is also much larger. Actually, the peak of the effect for Luxembourg GDP lags the maximum impact on euro area GDP by two to three quarters and the size of the reaction is about two times larger. According to the results obtained by Mojon and Peersman (2003), this would classify Luxembourg among the most sensitive euro area countries, along with Belgium, the Netherlands and Finland. As pointed out in the second section, the variable interest rate structure of the financial system in Luxembourg could contribute to such a strong transmission to the real economy. The high degree of openness and the driving role played by the financial services industry in the growth process constitute other explanations for this result. Indeed, in the estimated VAR process, the interest rate also affects real GDP through the fall in euro area output and share price index, meaning that the effects of monetary policy in Luxembourg partly reflect its impact on the euro area variables included in the model[17].

Second, the responses of Luxembourg GDP, residential property prices and credit to the private sector show approximatively the same pattern, but GDP reaches its minimum more quickly. Moreover, whereas most of the decline in credit occurs within the second year, the reaction of house prices appears to be both faster and much more persistent. Overall, after two years, the size of the reaction is about two to three times larger for credit and property prices than for real GDP. As emphasized by Assenmacher-Wesche and Gerlach (2008b), these results suggest that for Luxembourg, a *leaning against the wind* policy would be very costly in terms of forgone output. Indeed, for the central bank to offset a 15% rise in residential property prices, *« which is not an unusually large increase by the standards of many recent property price booms »*, the required tightening of monetary policy would generate, *et caeteris paribus*, a 6.4% contraction of real GDP.

Finally, compared to the results obtained by Assenmacher-Wesche and Gerlach (2008b) for a panel of 17 OECD countries, Luxembourg falls in the category of countries where

[15] The monetary policy shock identified in this work is broadly similar to the one presented by Peersman and Smets (2003), although it displays slightly more persistence.

[16] The comparison with the results of Mojon and Peersman (2003) should however be taken carefully given the differences in the model specification, the sample period used and the identified monetary policy shocks.

[17] Results obtained for the euro area (countries) using traditional structural macroeconometric models and a two-year increase of the short-term policy interest rate by 100 basis points depict a more similar picture in terms of length and size of the GDP and CPI reactions (e.g. McAdam and Morgan, 2003, Van Els et al., 2003). Simulations carried out with these models classify Luxembourg in the moderately sensitive category of countries (see Guarda, 2005). However, these models impose monetary policy shocks through reduced form equations so they are not directly comparable with the identified monetary policy shocks from VAR models. In addition, the traditional model simulations rely on the counterfactual assumption of no indirect effects of monetary policy via the reactions of foreign variables.

nominal house prices are quite responsive to monetary policy[18]. Several authors have investigated the role played by the institutional features of the mortgage financing system in the house price dynamics and the monetary transmission mechanism (e.g. MacLennan et al., 1998, Tsatsaronis and Zhu, 2004, Calza et al., 2007, Assenmacher-Wesche and Gerlach, 2008a). Again, according to these studies, the floating rate structure of mortgage loans appears to be one of the most important explanatory factors underlying such an empirical result. This peculiarity of the Luxembourg financial system could moreover explain the fact that most of the decrease occurs during the first year following the shock, variable interest rates being often associated with a high variability of house prices (e.g. Tsatsaronis and Zhu, 2004).

4.2 Impact of foreign shocks on the domestic economy

The reaction of the Luxembourg economy to foreign shocks is presented in figures 7a to 7c. As expected, the reaction of Luxembourg GDP following a shock to euro area GDP (the proxy for foreign demand) is significantly positive and occurs relatively quickly (figure 7b). The peak of the effect is reached after four quarters and is close to the size of the initial shock, thus reflecting the high degree of openness and the economic integration of Luxembourg within the euro area[19]. The reaction of domestic credit and property prices to this shock is also significantly positive which, according to Goodhart and Hofmann (2008), clearly identifies the innovation in euro area GDP as an aggregate demand shock. Conversely, the euro area CPI shock (figure 7a) should mainly capture supply-side disturbances, a result that is however only suggested by the associated impulse response functions of real GDP and house prices.

The output response to a shock to the euro area share price index (figure 7c) is virtually immediate and significantly positive for the first year. The maximum effect on Luxembourg GDP is about 0.62% one quarter after a persistent 9% increase in European stock prices, a reaction that is almost three times larger than for the euro area as a whole[20]. Given the structural evolution of the Luxembourg economy over the last decade, characterized by the substantial development of the investment funds industry, one could expect this effect to be even larger in the second part of the sample. Furthermore, the response of credit to an innovation in the equity price index is also significantly positive in the short run, peaking around 0.8% in the following year. However, this result is difficult to interpret given that our identification scheme is not adequate to disentangle the effects coming from the demand side (i.e. through Tobin's Q) and from the supply side (i.e. through banks' capital position) of the market.

[18] Although results are not directly comparable, these authors obtain a decrease of nominal house prices of 1.5% after a 75 basis points increase in the interest rate which would imply, *et caeteris paribus*, a decrease of -0.64% associated with the corresponding identified monetary policy shock of 32 basis points.
[19] Although not strictly comparable, this result is similar to those obtained from traditional structural macroeconometric models of Luxembourg. The GDP response is slightly higher in Guarda (2005) and slightly lower in Adam (2007) which uses Modux, the structural macroeconomic model of STATEC.
[20] However, this is slightly weaker that the result in table 6 of Adam (2007) which suggests that a permanent 5.2% increase in the European share price index raises Luxembourg GDP by 0.4% after one year and a similar amount in years two and three.

4.3 Interactions between credit, house prices and the macroeconomy

The impulse responses presented in Figures 8a to 8d provide some indications of the interactions between credit, house prices and the macroeconomy in Luxembourg. After a GDP shock (figure 8b), the CPI response becomes significantly positive after only a few quarters and reaches a maximum after two years. The reaction of credit appears with the unexpected sign, whereas residential property prices rise significantly and persistently. A persistent CPI shock (figure 8a) generates a temporary decrease of real GDP after one year and a transitory increase of credit and house prices, which is not a very surprising result given that these latter variables are both expressed in nominal terms.

A positive shock to credit (figure 8c) doesn't trigger the expected increase in domestic variables, except for CPI in the short run[21]. The same doesn't hold true for the dynamic effects of a property price shock (figure 8d), following which the increase in CPI becomes significant in the very short run, while GDP increases significantly after only six quarters to reach a peak after two years. The response of credit, which is statistically significant after three quarters, exhibits the same profile as the house price shock but with a small lag of two quarters, peaking after one and a half years at 0.68%, more than two-thirds the size of the initial shock.

These results warrant several comments. On the one hand, the reaction of house prices to a credit shock is hardly in line with the findings of empirical research that have emphasized the role of credit in asset boom prices (e.g. Borio et al., 1994, Adalid and Detken, 2007), a topic that has recently seen a renewal of interest following the subprime crisis. On the other hand, the response of credit to a house price shock suggests the presence of a collateral effect in bank lending decisions, property often acting as loan collateral for both households and firms (e.g. Bernanke et al., 1999). According to this argument, higher house prices in Luxembourg should enable consumer and firms to spend more by enhancing their borrowing capacity, a result which seems to be confirmed by the positive lagged reaction of real GDP following the house price shock. This empirical result, which provides some scope for a house price channel of monetary policy transmission in Luxembourg, should not be overstated for households. Indeed, despite a relatively high owner-occupancy rate in Luxembourg[22], the absence of a mortgage equity withdrawal mechanism suggests a limited wealth effect of house prices on consumption[23]. Finally, the relatively strong response of credit to house prices could also be partially explained by the existence of a high loan-to-value ratio in bank lending practices (Tsatsaronis and Zhu, 2004).

[21] This non-significant result could be explained by measurement errors in the credit series. Indeed, prior to 1999, this series incorporates both loans to non-residents and loans to financial corporations, which are largely unrelated to the financing of economic activity in Luxembourg.

[22] The owner-occupancy rate in Luxembourg reached almost 75% in 2007. See ECB (2009) for an international comparison with the euro area countries.

[23] Equity withdrawal increases the liquidity of housing assets since it allows households to obtain credit lines either for a consumption purpose or with the aim of renegotiating the interest rate on existing debt contracts. The wider use of mortgage equity withdrawal in countries like the United States and the United Kingdom contributes to a more important wealth effect of house prices on consumption than in the euro area (Slacalek, 2006, Muellbauer, 2007).

4.4 Forecast error variance decomposition

To complete this analysis, Table 1 reports the forecast error variance decomposition for the domestic variables included in the VAR process, thus identifying the source of fluctuations of the Luxembourg economy over different horizons[24]. Overall, the results indicate a rich set of interactions between the variables of the model. As expected, the short-run variability of the domestic variables comes mainly from their own innovations (a typical result in the VAR literature), while innovations in foreign variables become a dominant source of fluctuations in the long run, accounting for more than 60% of the forecast error variance at an horizon of five years. More precisely, the forecast error variance decomposition analysis leads to the following results.

Table 1: Forecast error variance decomposition

Decomposition of Variance for Series *gdp*						
Step	Std Error	gdp	cpi	credit	prop	foreign variables
1	0.011	88.2	1.63	0.00	0.00	10.1
4	0.015	59.8	1.27	0.36	1.88	36.7
8	0.018	43.8	2.53	0.98	2.55	50.2
12	0.020	36.4	2.47	2.53	4.64	54.0
20	0.025	28.3	1.89	5.26	4.22	60.4
Decomposition of Variance for Series *cpi*						
Step	Std Error	gdp	cpi	credit	prop	foreign variables
1	0.003	0.00	35.8	0.00	0.00	64.2
4	0.006	1.26	37.9	1.31	3.67	55.9
8	0.009	10.0	33.7	1.06	8.52	46.7
12	0.011	16.8	21.6	3.22	7.97	50.4
20	0.017	16.0	9.80	8.63	5.40	60.2
Decomposition of Variance for Series *credit*						
Step	Std Error	gdp	cpi	credit	prop	foreign variables
1	0.017	0.59	4.80	86.9	0.00	7.67
4	0.037	4.24	8.80	48.1	0.90	38.0
8	0.068	2.43	8.70	20.0	2.97	65.9
12	0.081	2.22	10.5	14.9	3.25	69.1
20	0.090	4.12	9.76	12.1	3.03	70.9
Decomposition of Variance for Series *prop*						
Step	Std Error	gdp	cpi	credit	prop	foreign variables
1	0.004	4.17	0.03	6.07	76.6	13.2
4	0.018	5.91	0.27	7.39	41.6	44.9
8	0.038	15.0	0.47	8.83	21.8	53.9
12	0.059	16.0	0.28	9.25	11.2	63.3
20	0.100	11.7	1.45	9.63	5.10	72.2

[24] The variance decomposition determines the proportion of the variability of a variable at time t+s that is due to its own shocks and to the shocks occuring on the other variables of the system. If the shocks to the other variables explain little of the forecast error variance of a $\{y_t\}$ sequence at all forecast horizons, we can say that the $\{y_t\}$ sequence is relatively exogenous.

First, GDP fluctuations in Luxembourg depend primarily on their own innovations in the short run, and, from the second year, on the foreign variable innovations, external shocks becoming the dominant source of output fluctuations. For the 20th quarter, the forecast error variance of Luxembourg GDP is due to 20.1% to innovations on the Dow Jones EURO STOXX index, 13.9% to innovations on the interest rate, and 11.8% to innovations on euro area GDP. The dominant influence of foreign variables in the long-run variability of GDP is consistent with the results obtained from the impulse response functions.

Second, the Luxembourg price level appears to be more sensitive than GDP to foreign shocks in the short-run, because of the influence of euro area consumer prices (and the possible incorporated *cost-push* effect) which accounts for more than 50% of Luxembourg's CPI forecast error variance during the first year. On the demand side of the economy, CPI fluctuations appear to be mainly driven by innovations in both euro area and Luxembourg GDP during the second and the third year, the former accounting for about 20-25% of the CPI forecast error variance at this horizon. Residential property prices explain on average more than 5% of the CPI forecast error variance at an horizon above four quarters. In the long run, nearly two thirds of CPI movements come from foreign variable innovations, the euro area consumer price shocks still representing the dominant source of CPI variability during the fifth year.

Third, credit, which exhibits strong persistence, depends mainly on its own fluctuations during the first year. From the second year on, external factors begin to play a prominent role, with the euro area GDP, the interest rate and the Dow Jones EURO STOXX index accounting for the bulk of credit fluctuations over longer horizons, with a respective share of 43.8%, 11.9% and 7.4% at an horizon of five years. The contribution of residential property prices lies below 5% over the whole decomposition period, while CPI innovations account for about 10% of credit fluctuations at an horizon longer than three years.

Finally, residential property prices depend essentially on their own innovations during the first year. From the second year on, house price movements are mostly determined by foreign variable shocks, with the euro area HICP, GDP and the interest rate explaining almost half of house price variability at the fifth quarter. In the long run, foreign variables become even more dominant with euro area CPI, GDP, share prices and the interest rate accounting respectively for 41.8%, 11.4%, 12.0% and 6.9% of the forecast error variance at an horizon of five years. On the domestic side, GDP and credit explain on average more than 20% of the residential property prices forecast error variance at an horizon above four quarters.

5. Conclusion

To conclude, the results obtained with the VAR model suggest a strong and highly significant multi-directional relationship between monetary policy, credit, house prices and the macroeconomy in Luxembourg. More specifically, the structural analysis lead to the following conclusions: (1) In conformity with the existing VAR literature, a contractionary monetary policy shock translates into a temporary decrease in output and to a more gradual decline in prices. (2) Monetary policy transmission to the real economy is relatively strong in Luxembourg, a result that could be associated with the variable interest rate structure of loans to the private sector, the high degree of openness and the size of the financial services industry. (3) The reaction of credit and GDP following a residential property price shock provides some scope for the existence of a house price channel of monetary policy transmission in Luxembourg. (4) Finally, domestic variables respond strongly to foreign shocks, as indicated by both the estimated impulse response functions and the forecast error variance decomposition.

Considering this work as a starting point to study the monetary transmission mechanism and, more generally, macroeconomic relationships in Luxembourg, three avenues are open for future research. (1) The first is to estimate a small open economy model with Bayesian techniques (following, for example, Cushman and Zha, 1997) in order to focus on a smaller sample beginning in 1995 on. Indeed, there are good reasons to conjecture that the relationships between monetary policy, house prices, credit and the macroeconomy have changed over the sample beginning in 1986 due to structural changes in the financial and economic structures as well as in the monetary policy regime. The use of a FAVAR model may also be very promising from this point of view, since it would allow us to study the monetary transmission mechanism through a larger set of variables (e.g. Bernanke et al., 2005, Boivin and Giannoni, 2008) (2) Second, this paper has adopted a macroeconomic approach in the sense that the individual strands of monetary transmission (namely, the interest rate channel, the exchange rate channel, the credit channel, and the asset price channel) have not been investigated in detail (e.g. Kok Sorensen and Werner, 2009, Ciccarelli et al., 2010). Thus, a future avenue for research would be to fill this gap, with a particular interest for the asset price channel given the structural features of the Luxembourg economy. (3) Finally, given possibly non-linear effects of monetary policy in economic downturns and upswings, the estimation of a time series model incorporating a Markov-switching process could be more appropriate, especially to study the dynamic relationships between credit, house prices and the macroeconomy (e.g. Kaufmann and Valderrama, 2007).

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Appendix 1: The VAR methodology

The VAR methodology derives from a critique of structural macroeconomic models based on simultaneous equations systems. According to Sims (1980), these models relied too much on untested hypotheses that lead the modeller to impose too strong *a priori* restrictions compared to what the economic theory can suggest, notably concerning the distinction between exogenous and endogenous variables.

A VAR is a dynamic system in which each variable is regressed on its own past values and the present and past values of the other variables. The model for a VAR(1) with two variables is given by:

$$(1) \qquad \begin{cases} y_{1t} = \gamma_{10} - \beta_{12} y_{2t} + \gamma_{11} y_{1t-1} + \gamma_{12} y_{2t-1} + \varepsilon_{1t} \\ y_{2t} = \gamma_{20} - \beta_{21} y_{1t} + \gamma_{21} y_{1t-1} + \gamma_{22} y_{2t-1} + \varepsilon_{2t} \end{cases}$$

with ε_{1t} and ε_{2t} being *pure innovations* identically and independently distributed with a zero mean and a finite variance.

Using matrix algebra, the structural form of the VAR(1) can be written:

$$(2) \qquad \begin{pmatrix} 1 & \beta_{12} \\ \beta_{21} & 1 \end{pmatrix} \begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix} = \begin{pmatrix} \gamma_{10} \\ \gamma_{20} \end{pmatrix} + \begin{pmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{pmatrix} \begin{pmatrix} y_{1t-1} \\ y_{2t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}$$

which, in a more usable way, leads to the expression:

$$(3) \qquad BY_t = \Gamma_0 + \Gamma_1 Y_{t-1} + \varepsilon_t$$

If the matrix B is invertible, the VAR(1) process can be rewritten in the following reduced form:

$$(4) \qquad Y_t = A_0 + A_1 Y_{t-1} + e_t$$

where $A_0 = B^{-1}\Gamma_0$, $A_1 = B^{-1}\Gamma_1$ and $e_t = B^{-1}\varepsilon_t$.

The reduced form of the VAR can be estimated by OLS if the system is stationary, i.e. if the eigenvalues of the matrix A_1 have a modulus less than 1. In this case, the Wold theorem shows that this process can be transformed into a vector moving average (VMA) representation:

(5) $$Y_t = \mu + \sum_{i=0}^{\infty} \psi_i e_{t-i} \qquad \begin{cases} \mu = (I - A_1)^{-1} A_0 \\ \psi_0 = I,\ \psi_i = (I - A_1 L)^{-1} \end{cases}$$

The coefficients ψ_i represent the dynamic multipliers which quantify the effects of the shocks e_{it} on the variables y_{it}. However, these coefficients have no economic interpretation since the elements of the vector e_t are correlated. In fact, the error terms e_t of the reduced form are linear combinations of the two structural shocks ε_{1t} and ε_{2t}:

(6) $$e_t = \begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix} = \frac{1}{1 - \beta_{12}\beta_{21}} \begin{pmatrix} \varepsilon_{1t} - \beta_{12}\varepsilon_{2t} \\ \varepsilon_{2t} - \beta_{21}\varepsilon_{1t} \end{pmatrix}$$

Given that the economic interpretation comes from the elements of the vector ε_t, the structural analysis based on the impulse response functions and the forecast error variance decomposition is carried out through the orthogonal form of the VMA[25]:

(7) $$Y_t = \mu + \sum_{i=0}^{\infty} \theta_i \varepsilon_{t-i}\ , \qquad \theta_i = \frac{\varphi_i}{1 - \beta_{12}\beta_{21}} \begin{pmatrix} 1 & -\beta_{12} \\ -\beta_{21} & 1 \end{pmatrix}$$

To identify the structural innovations ε_t from the estimated vector e_t, it is necessary to impose some restrictions on the VAR structure. In the case of a VAR(1) with two variables, the structural form contains 10 parameters against 9 parameters for the reduced form, which implies that it is necessary to impose *a priori* one identifying constraint to derive the structural parameters[26]. One common solution is to use the Choleski decomposition to solve the identification problem by imposing short-run restrictions on the matrix B that orthogonalize the shocks, ensuring they are uncorrelated. This method requires ordering the variables from the most exogenous one to the most endogenous one, which imposes a lower triangular structure on the matrix B:

(8) $$B = \begin{pmatrix} 1 & 0 \\ \beta_{21} & 1 \end{pmatrix}$$

[25] The impulse response functions can be used to analyse, for example, the percentage deviation in output over time following a shock to the short-term interest rate. The forecast error variance decomposition determines the proportion of the variability of a series over different horizons that is due to its own shocks and to the shocks occuring on the other variables of the system.

[26] In the general case, it is necessary to impose n(n-1)/2 orthogonalization constraints on the model in order to estimate the structural VAR. The identification of the structural shocks therefore represents the weakness of the VAR methodology given that the number of *a priori* restrictions increases quickly with the number of variables used in the model.

The restriction $\beta_{12} = 0$ means that y_{2t} has no contemporaneous effect on y_{1t}, i.e. that the second structural innovation has no impact on the first one. In virtue of this restriction, we now have:

$$e_t = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} - \beta_{21}\varepsilon_{2t} \end{pmatrix} \tag{9}$$

The restrictions placed on the structural form identify the parameters from the estimated reduced form. The variance/covariance matrix of the reduced form is then estimated, which unables us to obtain β_{21} and, consequently, to calculate the impulse response functions and the forecast error variance decomposition from the dynamic multipliers of the orthogonal VMA.

Appendix 2: Presentation of the data

All the data (except the nominal short-run interest rates, the world commodity price index and the euro area share price index) are seasonally adjusted using the *Census X12 multiplicative* method.

The *Luxembourg consumer price index* is the quarterly average of monthly values for the national CPI prior to 1999 and the HICP thereafter (Source: STATEC).

Luxembourg real GDP is at constant market prices (millions of euros, working day and seasonally adjusted) from 1995 on. To construct quarterly data prior to 1995, annual real GDP has been interpolated using the Chow-Lin procedure with employment and industrial production as the reference series (Source: STATEC).

Credit to the private sector is the quarterly average of end of month outstanding amounts of loans to residential non-financial corporations and households from 1999 on. Prior to 1999, these data have been linked to a series including all outstanding loans (millions of euros, Source: BCL).

The *nominal residential property price index* is interpolated from an annual series until 2007 (Source: STATEC, BCL calculation), using the *cubic match last* procedure available in Eviews. The original annual index is based on the average price of actual transactions but does not take into account the surface or the quality of the goods sold. Because of this limitation, an aggregate property price index including commercial property prices proved too volatile for use. This series has been linked to the quarterly hedonic acquisition price index of apartments estimated by the STATEC from 2008 on.

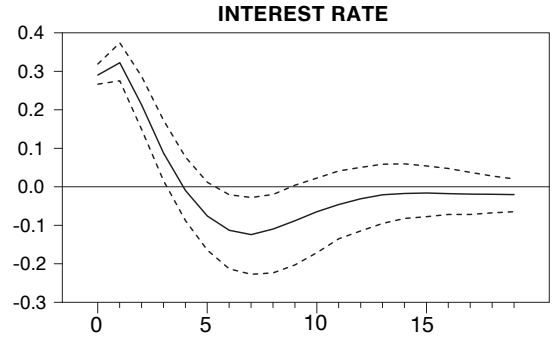
The *nominal short-run interest rate* is the euro area three-month money market rate prior to 1999 (Source: Fagan et al., 2001), and the three-month Euribor afterwards (Source: ECB).

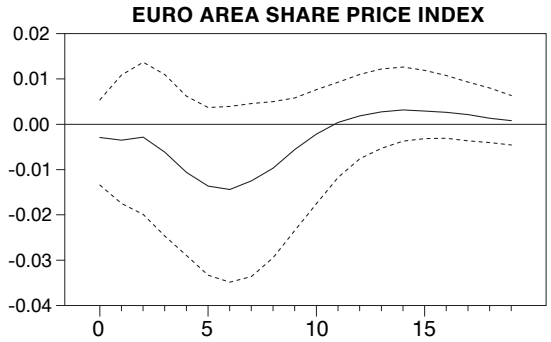
The *euro area share price index* is the Dow Jones Euro STOXX (broad price index, Source: ECB). It is extrapolated prior to 1986:4 using the weighted national index of Germany, France, Italy and Spain (Source: BIS). The weights used for this purpose are those used for the euro area database by Fagan et al. (2001).

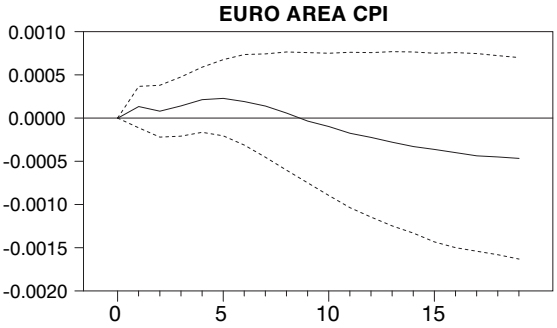
Finally, the *world commodity price index*, the *euro area HICP* and the *euro area real GDP* are taken from the updated database of Fagan et al. (2001) available on eabcn.org until 2008:4. These series have been respectively linked to the IMF world commodity price index and to the Eurostat database for the year 2009. The *US short-run nominal interest rate* (i.e. the Federal funds rate) and *US real GDP* come from the FRED database of the Federal Reserve Bank of St. Louis.

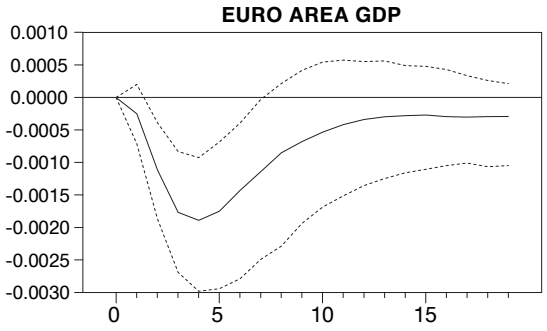
Appendix 3: Impulse response functions

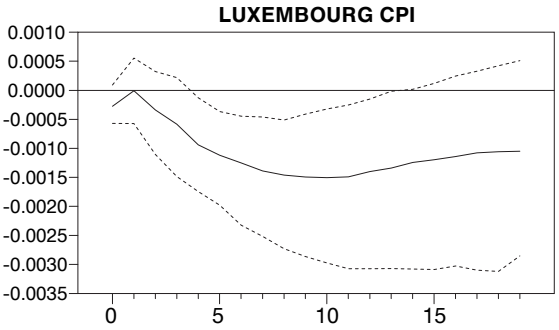
Figure 6: Impulse responses to a monetary policy shock

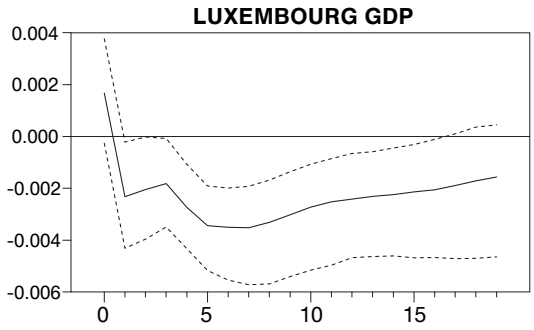


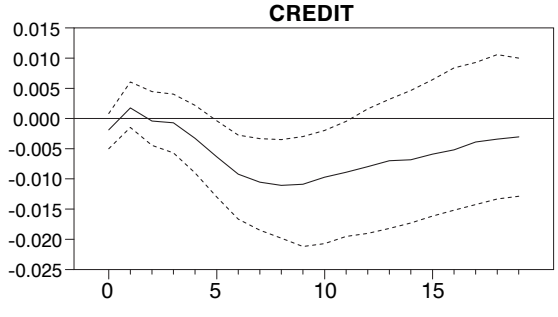












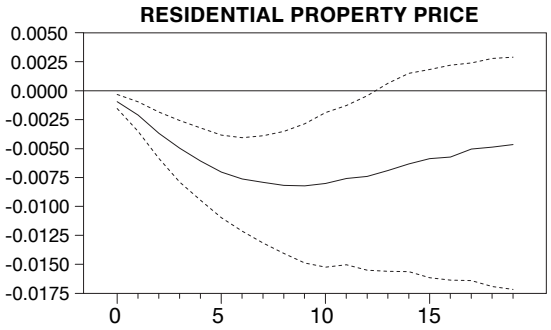


Figure 7a: Impulse responses to a shock on the euro area CPI

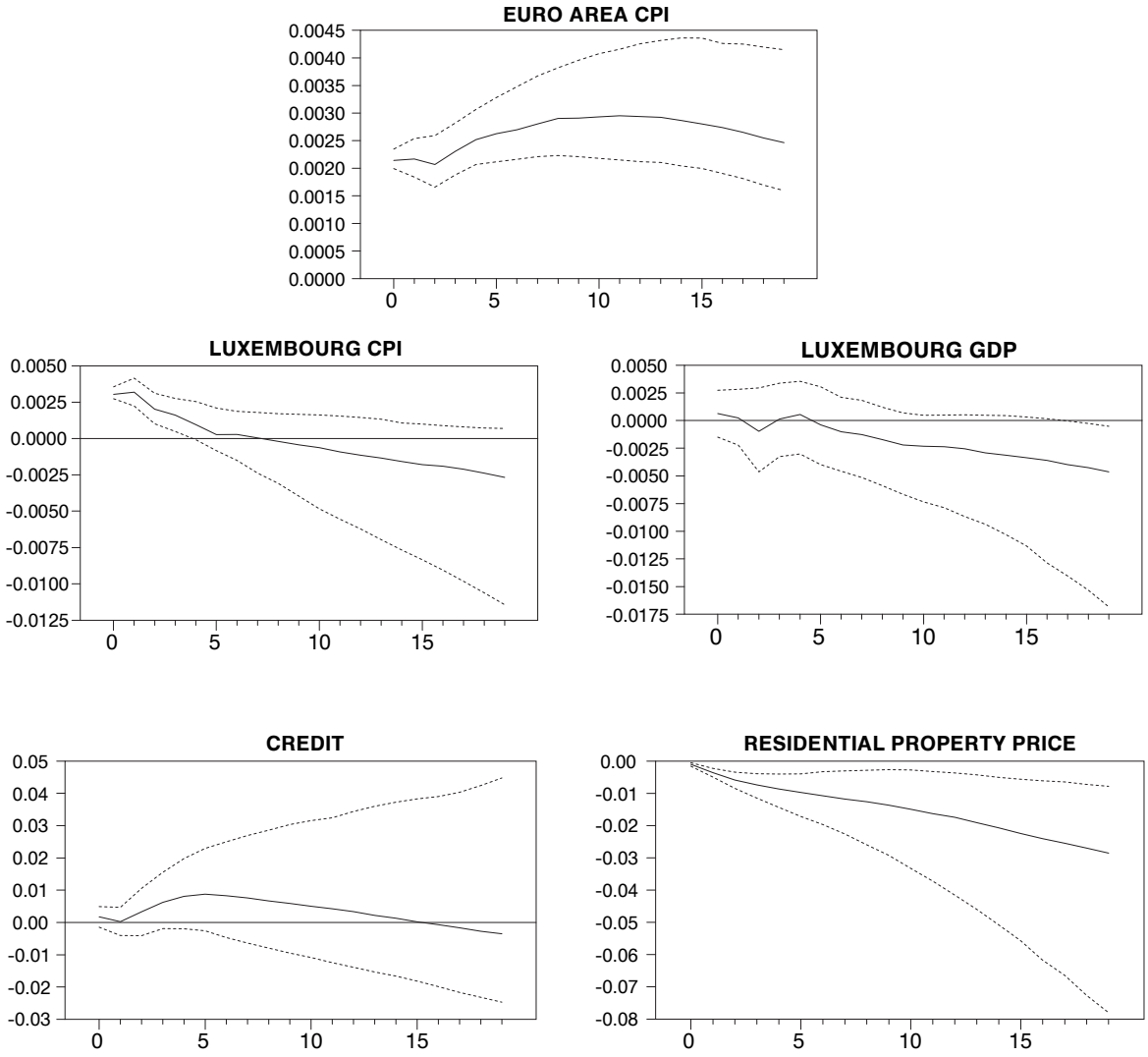


Figure 7b: Impulse responses to a shock on the euro area GDP

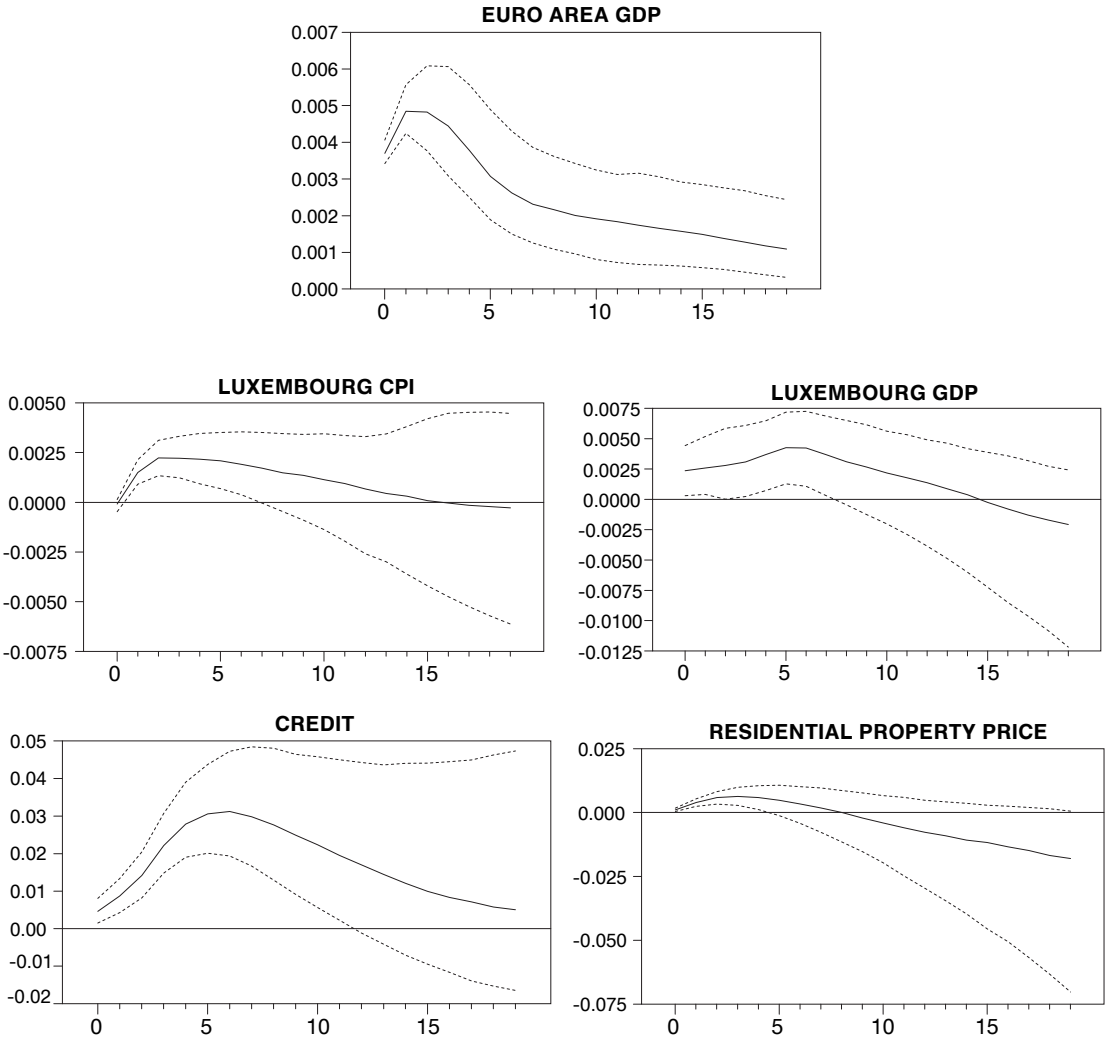


Figure 7c: Impulse responses to a shock on the euro area share price index

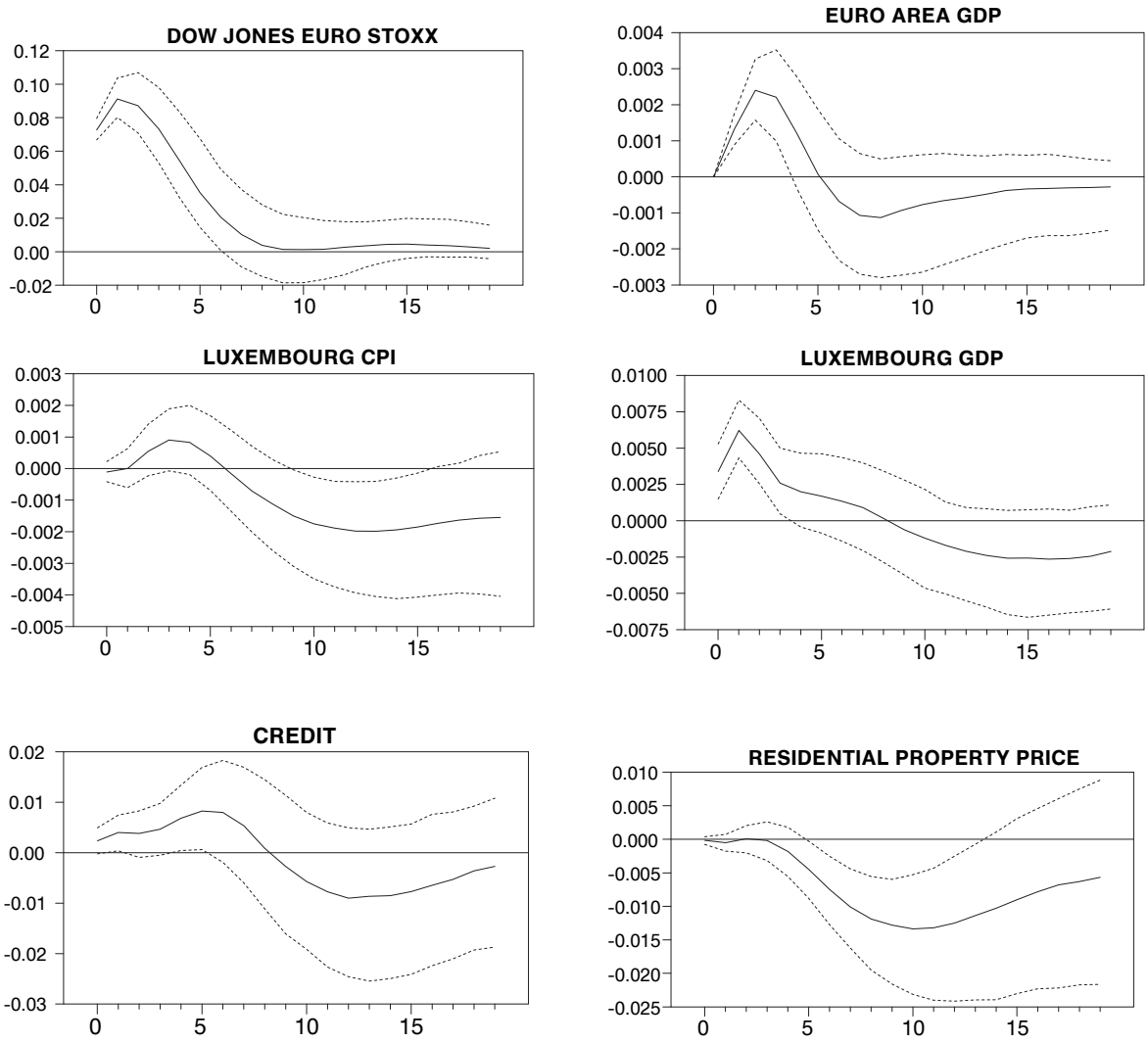


Figure 8a: Impulse responses to a shock on the Luxembourg CPI

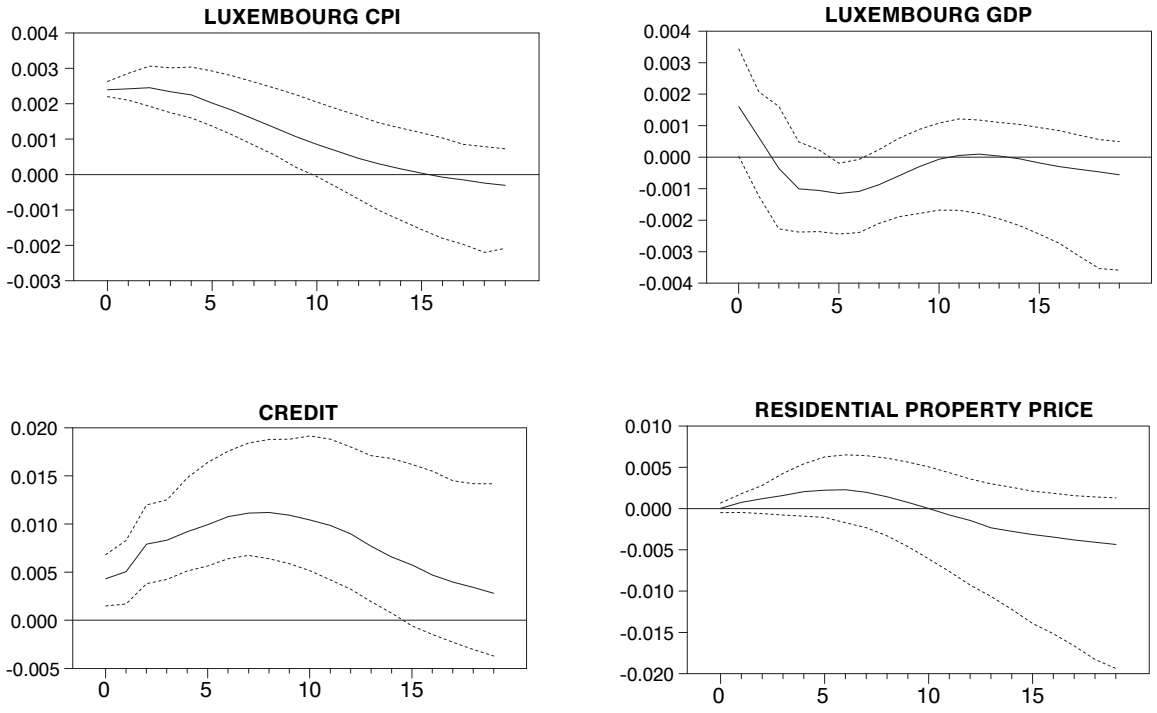


Figure 8b: Impulse responses to a shock on the Luxembourg GDP

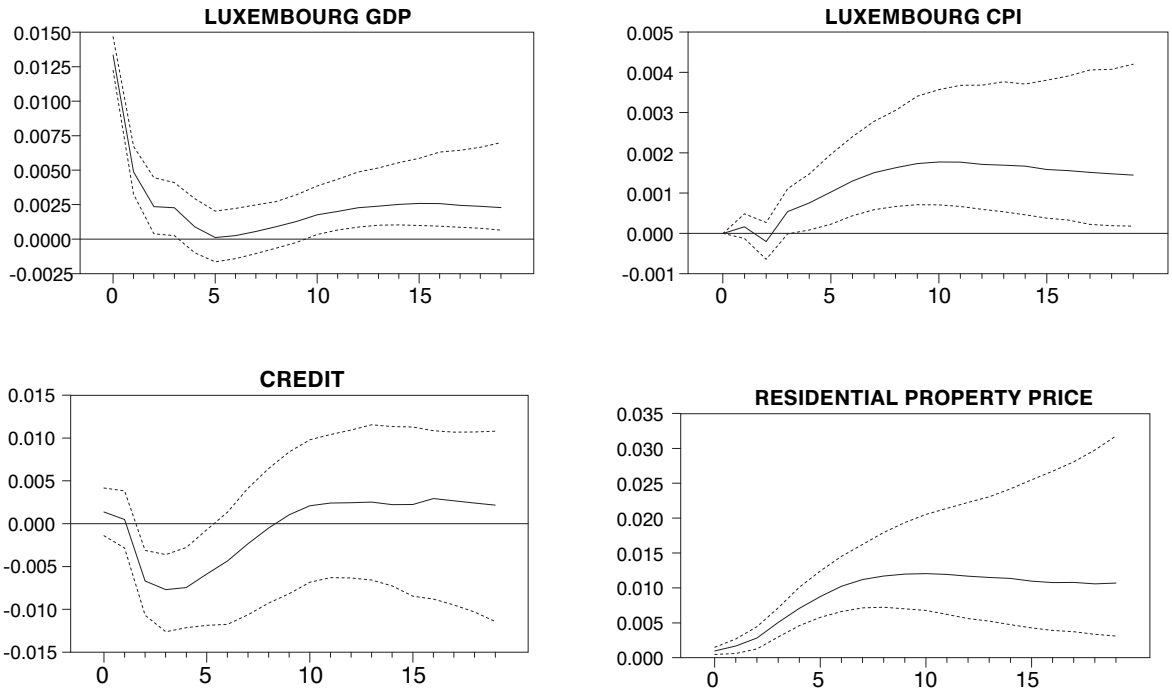


Figure 8c: Impulse responses to a credit shock

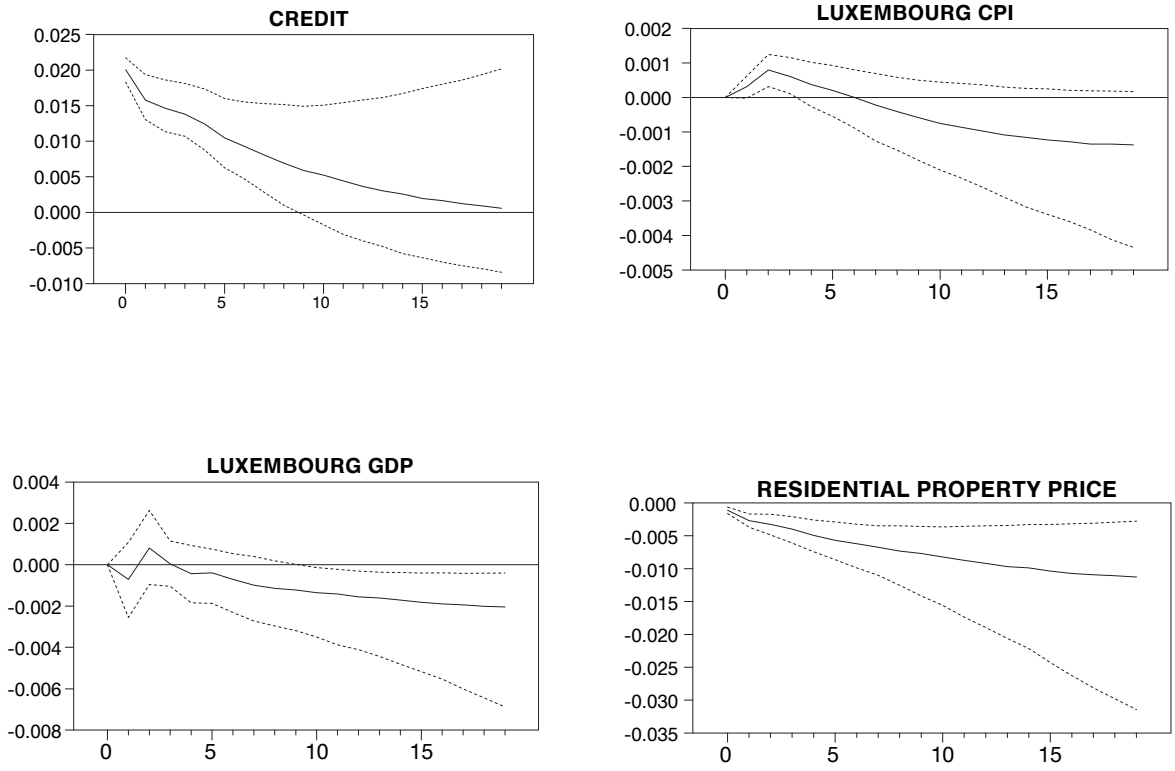
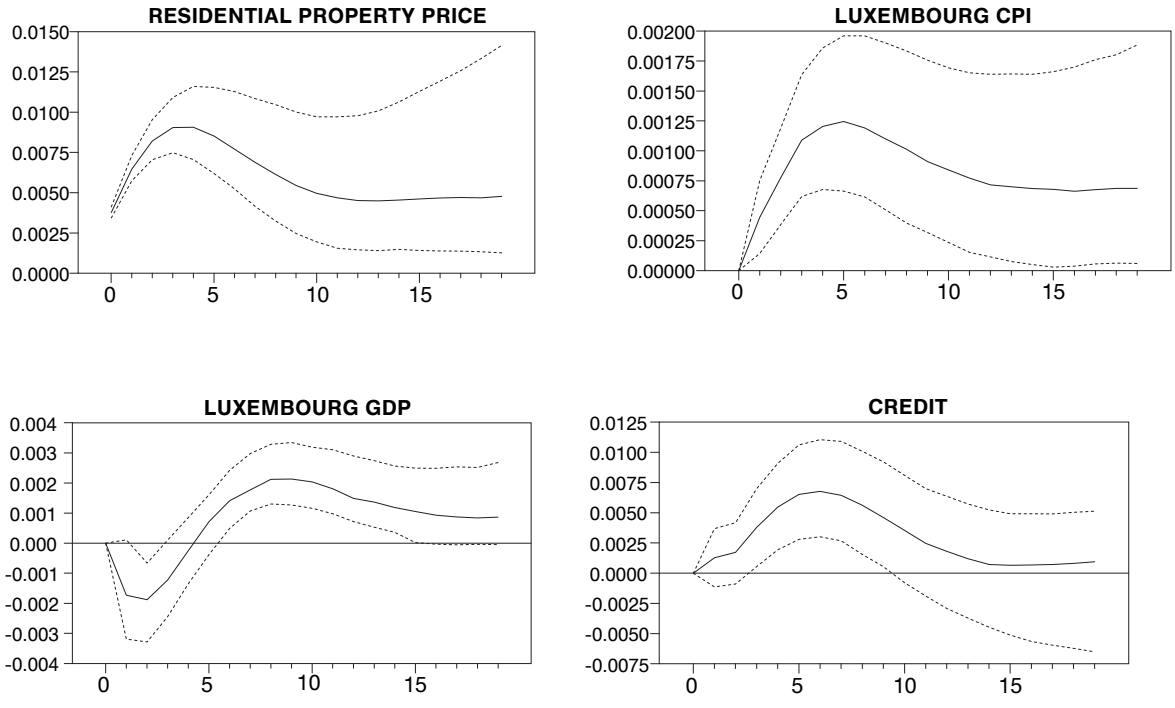


Figure 8d: Impulse responses to a house price shock



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