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A GLOBAL PERSPECTIVE ON INFLATION AND PROPAGATION CHANNELS

Luca Gattini, Huw Pill
and Ludger Schuknecht

In 2012 all ECB publications feature a motif taken from the €50 banknote.

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Luca Gattini
at European Investment Bank, 98-100, Boulevard Konrad Adenauer, Luxembourg; L-2950; e-mail: l.gattini@eib.org

Huw Pill
at Goldman Sachs, Research Department; e-mail: Huw.Pill@gs.com

Ludger Schuknecht
at German Ministry of Finance, Wilhelmstraße 97, 10117 Berlin, Germany and European Central Bank;
e-mail: Ludger.Schuknecht@BMF.bund.de

Address
Kaiserstrasse 29, 60311 Frankfurt am Main, Germany

Postal address
Postfach 16 03 19, 60066 Frankfurt am Main, Germany

Telephone
+49 69 1344 0

Internet
http://www.ecb.europa.eu

Fax
+49 69 1344 6000

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Abstract

This paper revisits the evidence on the monetary policy transmission channels. It extends the existing literature along three lines: i) it takes a global perspective with aggregate series based on a broader set of countries (ca 70% per cent of the global economy) and a longer time (1960-2010) than previous studies. It, thereby, internalises potential international transmission channels (i.e. via global commodity prices); ii) it examines the interaction between monetary variables, asset prices (notably residential property) and inflation; and iii) it looks at the role of public debt for consumer price developments. On the basis of a VAR analysis, the study finds that i) global money demand shocks affect global inflation and also global commodity prices, which in turn impact on inflation; ii) global asset/property price dynamics appear to respond to financing cost shocks, but not to shocks to global money demand. Moreover, positive house price shocks exert a significant influence on inflation. From a global perspective, the study suggests recognition of global externalities of commodities and asset values as well as the close monitoring of real estate price developments.

Keywords: VAR, global inflation, global house prices, global money

JEL Codes: E31, E51, E62, C32, F42

Non-technical summary

The reduced form relationship between money and inflation over long periods is well established. However, the structural characterization of the transmission mechanism from monetary expansions to price developments is still an issue of considerable debate. This paper extends this literature in three dimensions: (i) it takes a global perspective (with a broader set of countries than in previous studies and a longer time series), thereby internalizing some potential international transmission channels – e.g. through commodity prices; (ii) it includes encompassing interactions between monetary variables (i.e. liquidity and interest rates), asset prices (specifically residential property prices) and inflation, thereby allowing for a channel of transmission that has been highlighted in the recent literature; (iii) it also includes public debt and credit to the private sector. Public debt may be of particular interest given the fiscal crisis that started in late 2009.

Our analysis covers a time period spanning from 1960 to 2010 and it employs eight quarterly time series: short term interest rate, money, credit to the private sector, real GDP, consumer price index, house prices, public debt and global commodity prices. The country coverage in each period *t* represents at least 68 per cent of world GDP measured in terms of Purchasing Power Parity (PPPs). Following the investigation of statistical properties and Granger causality test across all variables, we apply a vector-autoregressive approach to examine the relationship between all variables and propagation channels.

The study finds that first, global money demand shocks affect inflation and also global commodity prices. Global commodity price shocks in turn affect inflation. These findings highlight an additional global transmission mechanism to inflation, which individual countries cannot control, via commodity prices. Second, asset/property price dynamics appear to be driven primarily by financing cost shocks at the global level (rather than being driven by shocks to global money). Moreover, an increase in house prices exerts a positive influence on inflation at the global level suggesting that an interest rate channel may work via asset values. Third, there appears to be a limited negative relationship between public debt and inflation. This relationship builds on the notion that increased public debt induces private demand to fall in a Ricardian manner, thus reducing inflation.

However, this does not exclude a positive public debt-inflation link looking forward given much increased global public indebtedness.

From a policy perspective, two conclusions emerge. First, from a global perspective, the study suggests recognition of global externalities of commodities and asset values. Notably large monetary and financial players should recognise the implications of their decisions on global inflation dynamics directly, via money growth, indirectly through the effect on commodity prices and on asset/house prices. Second, real property prices should also be monitored closely given their lead relationship for global inflation.

1. Introduction

The reduced form relationship between money and inflation over long periods is well established. However, the structural characterization of the transmission mechanism from monetary expansions to price developments is still an issue of considerable debate. Recently Sousa and Zaghini (2007) and Belke *et al.* (2010a; 2010b) employed in their global models a structural characterisation including monetary variables and inflation developments. Our paper takes a global perspective and brings together most of the experience stemming from previous studies by analysing a more encompassing set of variables and enlarging the sample of countries and the time period. We construct global variables, which have to obey a "representativeness" rule based on a minimum threshold algorithm. By doing so, we also include in our sample a representative group of emerging market economies.

Moreover, this paper extends the literature along three dimensions: (i) it enlarges the set of countries and extends the time series, thereby increasing the representativeness of the aggregated time series and allowing for a more comprehensive internalization of some potential international transmission channels – e.g. through commodity prices; (ii) it includes encompassing interactions between monetary variables (i.e. liquidity and interest rates) and asset prices (specifically residential property prices) ; (iii) it enriches the set of variables including also public debt and credit to the private sector. Public debt may be of particular interest given the fiscal crisis that started in late 2009. The latter variable has already been employed in the literature as an alternative transmission channel of liquidity.

Our analysis covers a time period spanning from 1960 to 2010 and employs eight quarterly time series: money, credit to the private sector, real GDP, consumer price index, house prices, public debt, short term interest rate and global commodity prices. The country coverage in each period *t* represents at least 68 per cent of world GDP measured in terms of Purchasing Power Parity (PPPs). Following the investigation of statistical properties and Granger causality test across all variables, we apply a vector-autoregressive approach to examine the relationship between all variables and propagation channels. Starting from a benchmark structural characterisation similar to previous studies, based on short-term interest rate, inflation, GDP, money and commodity prices, we apply an augmented VAR adding house prices, private credit and public debt. Finally we conducted several robustness checks.

The study finds that first, global money demand shocks affect inflation and also global commodity prices. Global commodity price shocks in turn affect inflation. These findings highlight an additional global transmission mechanism to inflation, which individual countries cannot control, via commodity prices. Second, asset/property price dynamics appear to be driven primarily by financing cost shocks at the global level (rather than being driven by shocks to global money). Moreover, an increase in house prices exerts a positive influence on inflation at the global level suggesting that an interest rate channel may work via asset values. Third, there appears to be a limited negative relationship between public debt and inflation. This relationship builds on the notion that increased public debt induces private demand to fall in a Ricardian manner, thus reducing inflation. However, this does not exclude a positive public debt-inflation link looking forward given much increased global public indebtedness.

After a literature review in section 2, the data construction and a data inspection follow in section 3. Section 4 contains the empirical analysis, including the employed methodology, the results and robustness checks. Section 5 concludes.

2. Literature review

Many previous studies have emphasized the relationship between money growth and inflation. In his seminal article Lucas (1980) applies filters that progressively emphasize the long-run relationship between M1 and the consumer prices in U.S. data. He finds that the relationship becomes more regular, with a coefficient closer to one, the more the filter stresses low frequencies (i.e. the long-run relationship). Lucas (1980, p. 1005) claims that the low-frequency relationship he finds represents "one way in which the quantity-theoretic relationships can be uncovered via a-theoretical methods from time-series which are subject to a variety of other forces." MacCandless *et al.* (2005) found that there is a high (almost unity) correlation between the rate of growth of money supply and the rate of inflation. This result is robust across different definitions of money and across sub-samples of countries. Benati (2009) has shown that, over the last two centuries, the fraction of long-run variation in inflation, which is explained by long-run money growth, has been very high and relatively stable. Moreover, he sheds light on the unity relation associated with the quantity theory of money. He shows that infrequent inflationary outbursts underpin the one-for-one correlation between money growth and inflation.

In the last decade the global dimension in studying the money-inflation transmission channels has gained increasing attention. From a forecasting perspective, Ciccarelli and Mojon (2010) propose evidence that a common international component accounts for 70 per cent of the variance in domestic inflation in industrialized economies. D'Agostino and Surico (2009) stress that global liquidity produces forecasts of US inflation that are significantly more accurate than the forecasts based on US money growth and country specific components only.

Recently a growing number of studies have analysed the transmission channels potentially affecting inflation at a global level via vector autoregression models, in a reduced (VAR) and structural form (SVAR) with aggregated data. Sousa and Zaghini (2007) constructed aggregated variables for G5 economies with a starting date in the early 1980s and apply a SVAR approach to the data. They find that prices respond significantly and positively to global demand liquidity shocks. Their result is also robust according to a differentiated composition of the aggregate. Consequently, they argue that cross-country monetary flows – e.g. capital flows – may make it more difficult to disentangle the relation between money, inflation and output at the regional or national level. Rueffer and Stracca (2007) analyzed a similar group of countries over the sample 1980-2004 and used a similar set of variables. They found support for the conjecture that monetary aggregates may convey some useful information on variables which matter for inflation, concluding that liquidity is a useful indicator of inflationary pressures at the global level. They also studied the impact of global phenomena on domestic variables. In this case, they found that the channels through which liquidity can be transmitted cross-borders are more elusive and ambiguous. Additionally they also augmented the global model with property and equity prices and they did not find significant evidence of excess liquidity impacting on asset values at a global level.

Belke *et al.* (2010a) have expanded on the previous literature and constructed aggregate time series employing data for major OECD economies and, by the means of a cointegrated VAR, showed that the inclusion of commodity prices helps to identify a relevant transmission mechanism from global liquidity to other macro variables. In other words, global liquidity conveys appropriate information on commodity prices, which in turn are an important factor for aggregate demand and inflation. This supports the view that commodity movements are, to some extent, an outcome of a monetary phenomenon and the causality effect should move from monetary variables to commodity prices. Belke *et al.* (2010b) develop the analysis introducing house prices instead of commodity prices and they found a significant response of house prices to global liquidity as opposed to Ruffer and Stracca (2007). A less debated and more accepted result refers to the significant and positive relationship between global and regional liquidity (either credit or money) with country specific developments of asset values (see Alessi and Detken, 2009; Agnello and Schuknecht, 2009). Interestingly, Belke *et al.* (2010b) also find subsequent splillovers from asset prices to consumer prices on a global scale. Moreover, they also estimate a positive impact of house prices on global liquidity, which is interpreted as an effect of increased demand for credit. Accordingly they find that house prices are an important element for their model.

Lastly, and as regards monetary and fiscal policy interactions at a global level, the potential effects of public debt on inflation have not been studied from a global perspective yet. In general, the so-called fiscal theory of the price level is based on fiscal and monetary policy rules such that the price level is determined by government debt and fiscal policy alone. In a theoretical framework, Sims (1994) stresses that in a fiat-money economy, the value of fiat money depends on public beliefs about fiscal policy under circumstances that are never observed in equilibrium and inflation is a fiscal phenomenon. Little empirical evidence has looked into the usefulness of a fiscal rule in accounting for the evolution of prices. Empirical analysis conducted in Canzonieri *et al.* (2001) support the evidence of Ricardian regimes[1]. This in turn suggests that prices are determined in a conventional way, say by money supply and demand. Public debt could then have an inflation increasing effect indirectly via more aggregate demand.

3. Data

3.1 Time series construction

Our analysis covers a time period spanning from 1960 to 2010 and it employs eight quarterly frequency time series. Seven out eight variables are constructed from a country aggregation, namely: money (M), credit to the private sector (CRP), real GDP (Y), consumer price index (CPI), house prices (RPP), public debt (D) and short-term interest

[1] Following Woodford (2005) a Ricardian regime is identified when primary surpluses move automatically to assure fiscal solvency for any path the price level might take. Then prices are determined in a conventional way, say by money supply and demand.

rates (INT). Additionally, we also make use of a global commodity price index (COM) which has been constructed by The Economist. Two selection criteria have been applied to the aggregating algorithm. First, a country *i* is included at time *t* when the eight series jointly are available at time *t* for country *i*. This necessary condition facilitates the comparison across the aggregated variable since the same basket of countries is considered in each period *t*. Second, the country coverage in each period *t* represents at least 68 per cent of world GDP measured in terms of Purchasing Power Parity (PPPs) and an overall average coverage of at least 70 per cent up to period *t*. The PPPs and current GDP levels are taken from the Penn World Table Version 7.0[2]. This information is employed to construct the country weights applied in the aggregation procedure. To obtain global aggregated time series we follow a similar approach as in Belke *et al.* (2010) based on Beyer *et al.* (2001). The latter paper found the least problematic method of aggregation to be the variable weight method of growth rates. Moreover Beyer and Juselius (2011) show that this method is sensitive to the choice of the weights. They suggest the use of nominal GDP weights for aggregation purposes. The aggregation procedure of the series takes into account all these results. For a detailed description of the aggregation procedure and the weights employed refer to Annex A.

Table 1 reports the detailed country coverage and representativeness of the aggregated series. The initial coverage in 1960 included seven economies which accounted for more than 70 per cent of world GDP. The table lists countries depending on the year of entry into the time series. The full coverage incorporates twenty eight countries, namely: Australia, Austria, Belgium, Canada, Switzerland, People Republic of China, Denmark, Spain, Finland, France, United Kingdom, Germany, Greece, Honk Kong, Ireland, Italy, Japan, South Korea, Malaysia, Netherlands, Norway, New Zealand, Portugal, Singapore, Sweden, Thailand, United States and South Africa. Some countries enter in different years since the necessary condition previously described holds at that time only and, more generally, the main constraint in the aggregation is the availability of a house price index. The sources for the entire set of variables are primarily IMF, OECD, ECB, Haver Analytics, the Global Financial Database and the Economist – for more details on data sources see Annex B. The

[2] Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 7.0, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, May 2011. http://pwt.econ.upenn.edu/php_site/pwt_index.php

aggregated series have been seasonally adjusted with X12 methodology applying an additive seasonal adjustment[3].

3.2 Data inspection

We investigate the statistical properties of the newly constructed series. An initial inspection of the time series can help to gauge the main cycles and potential co-movements across the variables. Chart 1 reports inflation developments against the other seven variables entering our analysis. All variables are reported as a twelve window moving average of the quarter on quarter growth rates. This is done to smooth out the volatility and still capture the major trends for presentational purposes, whereas in our empirical analysis we employ higher (i.e. quarterly) frequency fluctuations.

Inflation cycles are captured by the CPI variable. The time series pictures the Arab OPEC oil embargo related to the Yom Kippur War of 1973 and the associated spike in oil prices, the oil price increase shocks of 1979-1980 and 1990-1991, and the major oil price decline in 1986. Additionally, it also captures the recent commodity prices surge in the late 2000s. It also represents the great moderation period in inflation dynamics witnessed globally in the last twenty-five years. Interestingly, the cyclicality in house price dynamics seems to have increased over time. After the mid-1980s house prices show a more exacerbated boom and bust cycle. In other words, a reduction in the volatility of inflation has been coupled with a higher volatility in house price dynamics with a tendency to have more pronounced busts. In the 1990s' cycle and during the current cycle house price growth decelerated sharply and even turned persistently negative. The moving average of the public debt variable is constructed from the growth rate of the public debt to GDP ratio. It fits the story of increasing deficits and, consequently, overall debt during the recession periods of the 1970s, early 1980s, early 1990s and the 2008-2009 recession. The last cycle stands out for its acceleration in public debt accumulation.

The money variable has been constructed using the broadest available monetary aggregate for every single country in each period. Money and quasi money comprise of the sum of currency outside of the banks, demand deposits other than those of the central government, savings, and foreign currency deposits of resident sectors other than the central government. M3 has been employed, when available; otherwise M2 or M1

[3] The estimation results reported in the next section have been cross checked with series non-seasonally adjusted and no significant differences have been detected.

aggregates have been used. It has to be mentioned that the "liquidity spectrum" of such an aggregate may vary across countries. A narrow definition of money, say M1, for country A can be a broad enough definition for country B. For example, short- and medium-term maturity products are more likely to be liquid in mature capital markets where the maturity structure of recipients and payments can be more easily matched. Overall, the employed variables show a lagged, low frequency correlation between inflation cycles and money cycles (Benati, 2009).

We have also included a short-term interest rate variable to have a complete coverage of potential monetary channels. Interest rates have been included following the arguments of e.g. - Laurent (1988) and Bernanke and Blinder (1992) who stressed that money growth can be influenced by economic conditions. The money growth represents a confluence of both supply factors (monetary policy actions) and demand factors (such as private-sector portfolio shifts). Consequently, the inclusion of short-term interest rates should allow us to capture a further hidden monetary propagation channel.

We have also constructed an aggregated credit to private sector variable, which is defined as claims on private sector (IFS line 32d). It includes gross credit from the financial system to individuals, enterprises, nonfinancial public entities not included under net domestic credit, and financial institutions not included elsewhere. The cyclicality of the credit aggregate is visually correlated with money and it shows more pronounced swings than the monetary aggregate. Additionally, the average growth rate of the private credit variable is higher than the money aggregate. This is also related to the interactions between the money multiplier and banking sector intermediation activity. Last but not least, commodity price dynamics recapitulate the most well known shocks including the latest commodity cycle as well as a high correlation with inflation cycles characterised by different amplitudes.

Table 2 reports the results of a Granger causality test across all variables. The significant relationships are highlighted in bold. Most, if not all, of the statistically significant results reflect fairly intuitive interactions. Inflation is the most affected variable since all variables Granger cause inflation whereas the reverse relationships do not hold. This is an interesting property which helps in modelling inflation cycles. As expected there is a bi-directional relationship between money and credit to the private sector. Interestingly, global money seems to "Granger cause" global commodity development. GDP "Granger causes" credit and public debt. House prices "Granger cause" GDP and credit, via most likely collateral and wealth effects, and public debt as a substitute asset. On the other hand, house prices seem to be primarily linked to interest rates and public debt. This initial inspection of the dataset suggests reasonable relationships among the variables. It advocates the use of a system of equations to empirically investigate further the interrelations across the global variables and to better gauge their impact on inflation.

4. Methodology and empirical analysis

The inspection of the time series in section 3 has highlighted several relations among the variables. A vector autoregressive (VAR) model is the proper econometric methodology to account for such relations and exploit propagation channels. All variables are endogenous in a VAR system of equations. Consequently, this methodology helps to track potential feedback effects and interrelations allowing for a quantification of the cross variables' impacts.

4.1 Empirical framework and practical approach

As a starting point we consider a traditional reduced-form VAR model formulated as a polynomial in the lag operator *L*:

$$\Pi(L)X_t = \gamma_0 + \varepsilon_t \quad (1)$$

$$t = 1,\ldots,T\ ,\ \varepsilon_t \sim \mathrm{N}(0,\Omega)$$

where X_t is the vector of endogenous variables , $\Pi(\cdot)$ is a matrix polynomial in the lag operator such that $\Pi(L) = I + \sum_{i=1}^{p} B_i L^i$ with *p* lags, γ_0 is the vector of unrestricted constants and ε_t is a normally distributed zero mean and Ω variance error term. Autocorrelations in the residuals is excluded. However, Ω is not a diagonal matrix and covariance across the variables is allowed. More formally, $E(\varepsilon_t \varepsilon_s^{'}) = \omega$ for each $t = s$ and and $E(\varepsilon_t \varepsilon_s^{'}) = 0$ for each $t \neq s$ .To proceed in the analysis we need to design a concrete approach to estimate the full model based on eight variables. The variables are taken in log-changes and a constant is added to the model. The full vector of endogenous variables is:

$$X_t = [\Delta Y_t, \Delta D_t, \Delta CPI_t, \Delta RPP_t, \Delta M_t, \Delta CRP_t, \Delta COM_t, INT_t]' \qquad (2)$$

Specifically it includes real output (ΔY_t), public debt growth (ΔD_t), consumer price inflation (ΔCPI_t), house price dynamics (ΔRPP_t), money growth (ΔM_t), private credit growth (ΔCRP_t), commodity inflation (ΔCOM_t) and short-term interest rate (INT_t). In practise, without the inclusion of some restrictions the parameters in the VAR are not identified and consequently some shocks to the system cannot be interpreted in a structural fashion. To a certain extent the set of variables included in X_t is similar to Sousa and Zaghini (2007) and Belke *et al.* (2010a). Consequently we refer to these two studies to define the identification scheme. To model the shocks we employ a decomposition similar to Sousa and Zaghini (2007) and for some variables to Belke *et al.* (2010b). Both papers are also employed as reference for the interpretation of some structural shocks. For details on the structural VAR (SVAR) representation see Annex C. The SVAR can be employed to conduct several simulation exercises. Among them we consider a structural impulse response function (IRFs) exercise and a forecast error variance decomposition exercise. The second exercise based on a variance decomposition is to determine the proportion of the variability of the errors in forecasting *X* vector of variables at time $t+s$ based on the information available at time *t* that is due to the variability in the structural shocks ε_t between times *t* and $t+s$. To do so, a structural decomposition is used to construct forecast errors and impute the proportion of variance for variable *i* due to shock *j* at time $t+s$. In general, the recursive causal structure involves restrictions about the contemporaneous relationships among the variables. Such ordering may influence the results. A sensitivity analysis is conducted in section 4.3 to disentangle the potential influence of the chosen ordering and check the robustness of the results.

The ordering of the system in the SVAR follows the idea that monetary variables react faster to innovations stemming from the real and nominal economy than vice versa (see Favero, 2011). Real activity, *Y*, is ordered at first as in Rueffer and Stracca (2006) and Sousa and Zaghini (2007). Government spending has been ordered among the first variables in studies focused on fiscal issues such as Blanchard and Perrotti (2002). Accordingly, government debt is ordered among the first group of variables. Consumer price reactions to shocks are not assumed to be contemporaneous to money and commodities since prices of goods and services tend to adjust with some degree of stickiness (Mankiw and Reis, Calvo, Taylor). This price stickiness tends to be attributed to frictions in labour and goods markets, which have a slowing down effect on price adjustment. By contrast, commodity markets, being auction-based, are able to respond rapidly to overall macroeconomic conditions (see Barsky and Kilian, 2002), and more generally to new information (Frankel, 1986). Moreover, they are characterised by fewer frictions in the price-adjustment process because market participants have more balanced information than the consumer goods and services counterparts (Browne and Cronin, 2007). Consequently commodity prices are assumed to respond contemporaneously to almost the entire set of innovations.

House prices are ordered similarly to Belke *et al.* (2010b) on the assumption that residential housing markets have a rather inelastic supply in the short-run. This can be related to several overlapping factors such as scarcity of land, restrictions on land utilisation/investments expansions[4] and transaction costs. Consequently additional demand related to higher income, and other real factors, is likely to have an immediate impact on house prices. Drawing from an extensive literature on money demand[5] modelling (e.g. see Boor-man and Havrilesky, 1972), global money[6] is modelled as in Sousa and Zaghini (2007), where the equation represents a stylised money demand function with money expected to respond (negatively) to hikes in financing costs, and to other forces due to transaction, portfolio allocation motives and opportunity costs (see Ericsson, 1998). To recall, consensus had grown around the idea of a stable[7] long-run money demand (see Poole, 1988 and Lucas, 1988). Looking at the short term developments, one of the primary concerns was the potentially short-run instability of the demand function for money – e.g. see Alvarez and Lippi (2011). Indeed, short-run demand has been detected to be unstable in several studies (*inter alia* see Goldfeld and Sichel, 1990). Little is known about how short term shifts in money demand, or changes in the quantity of money demanded, affect the relationship between money and other macro aggregate variables

[4] e.g. new construction requires several steps of approval and regulation defines the number of days to obtain building permits; additionally also to renew buildings/spaces authorities approval is usually necessary.

[5] For a review on the theoretical analysis on the demand for money see McCallum and Goodfriend (1988)

[6] Sousa and Zaghini (2007) refer to global liquidity and we refer to global money. Both aggregates refer to a global variable made up of country specific definitions of broad money. The difference stems in the representativeness of the global variable. Sousa and Zaghini (2007) employ G5 economies whereas this paper employs a much broader set of countries – see section 3.

[7] Among others, Ball (2001), Brand and Cassola (2004) and Holtemöller (2004) have identified stable long-run demand functions. Recently, and including data after 2001, Dreger and Wolters (2010) were able to identify a stable long-run money demand relationship for the euro area.

and thereby how they can possibly impact on monetary policy transmission. Hence, it is worth to look at demand shocks to improve our understanding of the effects – if any – of temporary money shifts on real and nominal variables. As described in section 3.2 the money variable has been constructed using the broadest available monetary aggregate for every single country in each period. Our model includes the quarterly changes of the variables and the short run variations in the broad money aggregate can be interpreted as demand driven components – i.e. an exogenous increase in agents' preferences for liquidity. Global credit is modelled as a function of global money, income, real assets and financing costs. Specifically, increases in wealth, as captured by house price developments, are expected to exert a positive impact on private credit via balance sheet effects. Short-term interest rates are ordered as in Belke *et al.* (2010b) assuming that respond immediately to the overall set of available information.

Last but not least, an outcome of the aggregation procedure (outlined in section 3.1) relates to the inherent treatment of the country specific idiosyncratic components. The existing literature on the potential "aggregation bias", implicit in using aggregated series – i.e. world data in our study, considers two main fundamental approaches. Gorman (1953) and Theil (1954) studied in a static framework the problem of aggregation in econometrics analysing the aggregation error resulting from aggregating equations based on microdata equations. Lippi and Forni (1990) propose a more general representation that emphasizes the dynamics as a possible source of aggregation bias. The latter approach is based on unobserved components while the former representation is based on observable series. To the contrary, Grunfeld and Griliches (1960) show that the aggregation error can actually become an aggregation gain under certain assumptions. Being aware of these aggregation issues and the underlying literature, we do not intend to investigate the aggregation bias at its roots. We follow Belke *et al.* (2010) in our analysis and, consequently, we focus on the common co-movement of the aggregate. The basic intuition is that an idiosyncratic component is, loosely speaking, something that disappears with aggregation. Factor models reflect this idea. To this end, we draw from that literature and we apply the underlying assumptions of standard factor models to our constructed series. Then, the set of aggregated variables is driven by a common component, if idiosyncratic components are mutually orthogonal, because the variance of an aggregated idiosyncratic component tends to zero as the number of cross sections tends to infinite. This permits the emergence of the common component as primary driver. Under this assumption the shocks in our model are taken as common global shocks

– see literature review in section 2 – and consequently responses to the shocks are interpreted as reactions to common global innovations applied to the system.

4.2 Empirical Results

Our model includes log-variables in first differences except the short-term interest rate. The first step of our analysis is to investigate the unit root properties of all the series proposed in section 3 over the full sample period. We use an extended set of statistics to test the order of integration of the level and first difference of each variable, namely: Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF), Elliot, Rothenberg and Stock (ERS) and Ng-Perron (NP). The number of lags for the DF and the ADF tests are selected using the Akaike Information Criterion (AIC), while we use the Bartlett spectral estimation method to choose the truncation point for the Newey-West adjustment required for calculating the ERS statistic and the Schwarz info criterion for the lag length selection in the NP statistic.

The test results in Table 3 show that most first differences of the series are integrated of order zero and most levels are integrated of order one at 95% confidence level. The only exceptions are CPI and INT series. For CPI some evidence suggests integration of order (1) for the first differenced variable at 90% confidence level and for INT integration of order (1) is partially detected in the level variable. Specifically, the null hypothesis of a unit root is not rejected for both variables by the ADF statistics. The hypothesis, however, is rejected by the non-parametric PP and NP tests. In general, the ADF test has very low power against I(0) alternatives that are close to being I(1). That is, unit root tests cannot distinguish highly persistent stationary processes from nonstationary processes very well. The tests proposed by Elliot, Rothenberg and Stock (1996) and Ng and Perron (1995; 2001) should be able to have more power against very persistent alternatives. Given these arguments and evidence, we proceed on the basis that the first difference of CPI and the level of INT are integrated of order zero as well as the first difference of the other series.

Concerning the properties of the VAR employed for the empirical examination, the usual selection criteria to detect the number of lags point to five lags (see table 4). More specifically, the lags are selected using the final prediction error and the Akaike information criterion. For completeness, a test on the autocorrelation of the residual is also proposed. It should be recalled that the testable assumption of no autocorrelation in the residuals has some important implications for the economic interpretation of the results and it is a relevant assumption for our model given the long time horizon perspective. As stressed in Hendry (1995) and Jusélius (2006), autocorrelated residuals would imply that agents do not use the information in the data as effectively as possible. A LM-test for autocorrelation in the residuals based on seven lags suggests no autocorrelation (see table 5). It implies that there are not omitted variables issues.

We will use the model to conduct two exercises. First, an IRFs exercise has been conducted to analyse the interlinked responses of the variables to one standard deviation innovations. Second, a variance decomposition exercise was also carried out. We recognise that an effective identification of all shocks in such a large system (as designed in section 4.1) can be difficult and that more work on the sensitivity of the results is needed to determine the exact form of the identifying restrictions. However we are interested in uncovering the relationships among the variables and we are careful to interpret all the orthogonalised shocks as structural. We take somewhat a risk in interpreting some shocks in a structural fashion. We do so because (i) the restrictions of our model are similar to other previous studies (see section 4.1) and (ii) responses to some shocks reflect ex-ante expectations and results from other studies.

An initial check of the overall impulse responses gives reasonable results and conforms to both expectations and other studies. Charts 2 to 6 show a collection of impulse responses to a one standard deviation innovation derived from the fully fledged model over a twenty period window. All shocks are calibrated to be one standard deviation of the log-change of the respective series. Overall, these results provide a good qualitative benchmark and reveal economically meaningful relationships among the variables employed. In line with the before mentioned literature (see section 2), consumer prices react significantly, but only with considerable lags, to global demand money shocks whereas they respond almost immediately to commodity price shocks. This is evidence of commodity prices inflating consumer good prices via a cost-push mechanism. Additionally, the CPI response to a commodity shock is short lived when compared to its reaction to a global money shock. Commodity prices react immediately to output and money. The former relationship can be interpreted as a reaction of commodity prices to higher demand, which in the very short-run push up commodity prices given inelastic supply. The relationship between commodity prices and global money suggests that commodity prices initially overshoot their new equilibrium values in response to a global money demand shock and possibly increase inflation via a global monetary expansion channel. Last but not least, the overall reaction to interest rates is in line with the literature, including the negative response of both GDP and money to a positive shock in interest rates. We find also the well-known and documented "price puzzle".

Chart 2 reports the responses to **a global demand money shock** as defined in Sousa and Zaghini (2007). Interestingly this shock affects the nominal and financial side of the system whereas insignificant responses are recorded for the real variables. The global money shock gives rise to a significant lagged response of ***inflation*** (ΔCPI). More in detail, inflation responds significantly (measured by the ± 2 S.E. bands) after eight periods (i.e. two years). This evidence stresses the relevance of the relation between money growth and inflation whereas no response of inflation to private credit expansion is detected. This suggests looking at money instead of credit as a measure of global liquidity when we are interested in an assessment of potential inflation developments and risks. ***Commodity prices*** (ΔCOM) respond positively and immediately to a global money shock. This finding helps to sustain further the idea that monetary aggregates may convey some useful information about the development in commodity prices. Browne and Cronin (2007) support this view. They used a cointegrating VAR estimated on US data and they found that commodity prices overshoot their new equilibrium value in response to a money shock and such a deviation has a significant explanatory power for consumer price inflation. This evidence becomes even more relevant for the understanding of the recent dynamics in commodity prices which can be explained as too much liquidity chasing too few assets (i.e. reflected in commodity prices) given the growing demand from emerging markets. The statistically significant effect of such a shock is short lived since it does not last for more than four periods. ***Private credit*** (ΔCRP) responds positively to global money shocks. An expansion in the monetary aggregate growth leads to a temporary expansion in credit growth. This channel exemplifies the financial stability competences and relevance of larger financial and monetary players able to influence global money growth and to affect global developments in the system including credit.

Chart 3 reports the responses of the system to a **financing cost shock**. ***Real GDP*** growth decreases at impact and then tends to recover to its initial level. This is a similar finding to Sousa and Zaghini (2007). However the response in our model lasts less and the response at the peak is less pronounced. ***Inflation*** (ΔCPI) responds positively to financing cost shocks. We detect the well-known and documented "price puzzle" (see Bernanke and

Blinder, 1992; Christiano, Eichenbaum, and Evans, 1994). One explanation of the "price puzzle" is that central banks respond to expectations of future inflation by raising rates. However the raise may not be enough to prevent a surge in inflation. As a result interest rates hikes are followed by a positive response of inflation.[8] An alternative explanation relates to central banks reactions to supply shocks by raising rates. Rates can be raised not enough to extinguish the inflationary consequences of the supply shock. Note that the supply shock explanation can explain both the "price puzzle" and the negative response of output to a positive financing shock innovation. ***Global house prices*** (ΔRPP) respond negatively to positive interest rate innovations. We anticipate that this variable does not respond to any other shock. This is another finding *per se.* However it does not contradict the traditional findings in the boom and bust literature (e.g. Alessi and Detken, 2009) where house price corrections are correlated to credit dynamics and other variables. To the contrary, it supports the idea of employing a regional or country specific perspective[9] to analyse house prices and housing market dynamics. Global house price developments seem to be primarily influenced by global developments in the cost of financing. This finding clears the way for another of inflation transmission channel moving from interest rates (financing costs) to inflation, via house price developments, which is discussed in more detail below. ***Global money*** responds immediately and negatively to a financing cost shock as expected. However the response is short-lived. This confirms the relevance of an asset motive to hold money. Shocks in financing costs change temporarily the portfolio allocation across assets, including money holdings. This finding is similar to those available for single country models, however the response is not long-lasting. ***Private credit*** has a short-lived and lagged negative response to a positive shift in financing costs. Such a response reflects the temporary reaction of agents whose budget constraint caps the ability to access an increasing amount of funds after an increase in borrowing costs.

Chart 4 reflects the responses to **a global commodity shock**. ***Inflation*** (ΔCPI) reacts almost without any lag to commodity shocks. This is due to the inclusion of consumer goods heavily exposed to commodity fluctuations in the basket of consumer price indexes. Similar evidence has been found in Sousa and Zaghini (2007). However, the impact is not

[8] This explanation may also imply that the positive correlation between an apparently contractionary monetary policy intervention and future prices stems from failing to properly identify exogenous changes in interest rates due to monetary policy decisions.

[9] Such a perspective can be applied to single countries and regions (e.g. US and the euro area) or to a set of countries pooling the country specific observations as it has been frequently done in the boom/bust literature.

long lasting. Our results confirm on the one hand a significant commodity price pass-through effect on inflation (see Ferrucci *et al.*, 2010) when consumer prices tend to respond to shocks originated in the upstream level of the production chain (e.g. commodity prices) with shorter gestation lags than to money. On the other hand, commodity price inflation *per se* has not generally spawned strong second-round effects on inflation (see Cecchetti and Moessner, 2008). All in all this evidence confirms the relevance of commodity price hikes for short-term inflation developments, and not vice versa. Such a channel can also be seen as an indirect response of inflation to a global money shock which set in motion immediate responses in commodities and, consequently, in inflation. ***Financing costs*** respond positively, and only after two/three quarters, to a shock in commodities reflecting a possible global reaction of monetary authorities to global commodity price surges.

Chart 5 shows the responses of the system to a **global house price shock**. Interestingly, ***inflation*** positively responds to a global house price shock with a short lag (see also Belke et al., 2010). Moreover, the reaction is long-lasting and persists for roughly 20 periods (i.e. five years). Such positive response confirms different transmission channels. It can be subject to a two-fold interpretation. First, increased house prices lead to an increase in households' net wealth. Higher net worth fosters consumption via a housing equity withdrawal channel (Aron et al., 2010), which allows transforming house price increases into actual transitory income and thereby higher consumption expenditure. Ultimately, this translates into stronger aggregate demand, which contributes to increased positive inflation dynamics. Second, the economic literature features a large number of in-depth studies concerning the relationship between asset returns and inflation (Fama and Schwert, 1977). Housing is an asset held by households. This interpretation, supported by our results, suggests that house price shocks have a positive impact on inflation since houses are a reserve value to hedge against inflation risk and, consequently, they generate a positive and statistically significant reaction in inflation dynamics (Kuan-Min et al., 2008).

Private credit growth responds significantly to house price innovations. Conversely we did not find a significant response of money to a house price shock as it was otherwise found in Belke *et al.* (2010b), the reason being that we include also credit. Indeed they interpreted their finding as an effect of increased demand for credit since private credit was not included in their model. However our model includes also private credit. This suggests the existence of a collateral effect, which favours credit expansions and contractions. This evidence sustains the interpretation that house price decreases have substantially contributed to trigger (negative) credit dynamics, including the sharp decline over the recent crisis. This evidence concurs with Goodhart and Hofmann (2007) and Ferreira and Gyourko (2011). The latter study stressed that key players in the lending market responded to the market conditions and asset value dynamics. All in all, our model based evidence supports further attempts to study private credit developments as a function of the collateralised asset values.

Real GDP growth is mildly responsive to house price innovations. This can be interpreted as a mild evidence of a positive wealth effect on aggregate consumption and ultimately total output. ***Financing costs*** are responsive to house price innovations. This could suggest that frictions in credit supply imply a rise in the price of credit with a booming demand for loans to finance an increasing demand for housing. Lastly, ***public debt*** responds negatively to positive house price dynamics. This can be interpreted in the light of a portfolio reallocation, which highlights a substitution effect between public debt and house prices.

The system shows also marginal and short-lived responses to a **global public debt shock** (see chart 6). ***Inflation*** responds negatively to positive public debt shocks. Specifically, a positive public debt shock has a negative impact on inflation after five periods and the statistically significant response lasts for roughly five periods ahead (i.e. slightly more than one year). This suggests the existence of a mechanism working through demand and global money. In other words, an ex-post Ricardian effect is determined where an expansion in public expenditure (or a tax cut) determines a contraction in demand due to expected higher taxation. In turn this has a dampening effect on consumer prices. This result is in line with the empirical analysis conducted in Canzonieri *et al.* (2001) which supports the evidence of Ricardian regimes. In other words, so far and loosely speaking, fiscal dominance concerns did not drive a positive correlation between public debt and inflation.

All in all, inflation responds to most of the proposed shocks either almost immediately or with some lags. To further substantiate the findings on the transmission channels to global inflation, we analyse the results stemming from the forecast error variance decomposition. Chart 7 reports the forecast error variance decomposition of inflation based on the structural decomposition employed in the impulse response function exercise. Chart 7.a shows the breakdown across all shocks whereas chart 7.b focuses only on those shocks described above and their relative contributions. *Prima facie* most of the results obtained from the IRFs exercise are confirmed.

An assessment of the variance decomposition suggests that commodity shocks do not contribute significantly to the forecast error variance of inflation in the medium term. After contributing to the variance of inflation by roughly 10 to 15 per cent in a one-year window, the commodity shock contribution steadily decreases over time. The house price shock contribution to the overall variance kicks in after some periods and it steadily increases over time to contribute almost thirty per cent after twenty periods. The money shock explains significantly more than 10 per cent of the inflation variance after ten periods and its contribution increases further to 20 per cent after twenty periods. Interestingly, the public debt component explains roughly an average 10 per cent of the variance decomposition all over a twenty periods window.

4.3 Robustness Checks

We have conducted several experiments to check the robustness of our model. First we have conducted a robustness analysis "at the surface" of the model changing the lag length and the ordering to some of the variables. To assess the effect of the changes on the model we have conducted an impulse response exercise after the implementation of each change. Given the results in section 4.2, we have ordered the house prices at first. As expected we do not detect any relevant difference. Additionally, we have swapped money and private credit. The results based on the impulse response exercise remain basically unchanged when compared to the results in section 4.2. Last but not least, the commodity variable has been ordered at first on the basis of no contemporaneous correlation with the other innovations in the system. Again, no significant change is detected. Moreover, the model has been estimated using a lag length of two which was selected by the Hannan-Quinn information criterion (see table 4). The results are fully confirmed, albeit a slightly muted persistence in the responses for some variables.

Second, the estimation period has been reduced and restricted between 1960 and 2000. By doing so, we have excluded the last ten years of our sample which have been characterised by several notable economic events, namely: the last pronounced cycle in house prices, the latest credit expansion and the related financial innovation process, the strong and increased volatility in commodity prices culminating in the 2008 spike and, last but not least, the 2007-2010 global recession/financial crisis. An impulse response does not provide significantly different results from those described in section 4.2.2. However, some differences are detected. These are documented in chart 8 as concerns the response of CPI to the innovations in the system[10]. Overall, the main difference lies in a muted response to global house prices innovations. Inflation seems to be less responsive to house price changes. Additionally, global money becomes the first factor explaining CPI forecast error variance after twenty periods. This stresses the relevant impact of the last housing cycle. However the overall results of our model estimated over the full period are confirmed.

Third, we have estimated our model based on a different construction of the variables. We have constructed aggregated variables using the countries available from 1965, which basically represent the G7 economies. By doing so, we have excluded a large amount of countries which have impacted on the global developments only over the last two decades. For example, the representativeness of the new aggregate, measured in GDP-PPP terms, shrinks significantly from 1990 onward. Charts 9 reports the response of the CPI to all innovations[11] considered in section 4.2. These results confirm and support the evidence provided in section 4.2 – i.e. a marginally lower response of inflation to money growth is detected. This suggests that inflation developments for the G7 economies are certainly influenced by money growth in these economies. Furthermore, it hints that money growth in economies other than those included in the series (e.g. Asian emerging markets) may also have contributed to inflation in advanced economies.

5. Concluding remarks

In this study, we examine from a global perspective and for the 1960-2010 period, the relationship between money, asset prices (real estate), commodity prices, public debt, private credit, GDP and inflation. The study finds that first, global money demand shocks affect inflation and also global commodity prices. Global commodity price shocks in turn affect inflation. These findings highlight an additional global transmission mechanism to inflation, which individual countries cannot control, via commodity prices. Second, asset/property price dynamics appear to be driven primarily by financing cost shocks at

[10] The full set of IRFs can be provided upon request.
[11] Detailed and additional results for these robustness checks can be provided upon request.

the global level (rather than being driven by shocks to global money). Moreover, an increase in house prices exerts a positive influence on inflation at the global level suggesting that an interest rate channel may work via asset values. Third, there appears to be a limited negative relationship between public debt and inflation. This relationship builds on the notion that increased public debt induces private demand to fall in a Ricardian manner, thus reducing inflation. However, this does not exclude a positive public debt-inflation link looking forward given much increased global public indebtedness.

From a policy perspective, two conclusions emerge. First, notably large monetary and financial players should recognise the implications of their policy and strategic decisions on global inflation dynamics directly via money growth and indirectly through the effect on commodity prices. Second, house prices seem to be influenced by financing cost shocks and lead inflation developments. In addition to financial stability considerations, this is another reason why global real estate price evolutions should be monitored closely.

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Annexes

A. Aggregation procedure and weights

PPP-adjusted GDP levels measure the size of economies in volume terms and provide a more meaningful measure of the relative size of countries rather than simple exchange-rate based comparisons[12]. For our purposes we are interested not only in a snapshot of relative volumes in a year, we aim at having the evolution of GDP volumes between countries and over time. To do so we combine spatial and temporal observations using a sequence of current PPPs at an annual frequency. The use of this method based on time varying PPPs helps to take into account potential catching up processes and price convergence dynamics across countries and over time. In other words, a new set of price level and exchange rate data is taken up every period since prices and price structure is allowed to vary over time (Bournot *et al.,* 2011). Comparisons over time need to incorporate and adjust for several effects such as relative price movements and relative volume changes. Such shifts can be negligible in a short-run perspective. Accordingly a constant PPPs approach can be appropriate to aggregate short time series. To the contrary, we are considering a fifty year horizon and ignoring the dynamic effects (e.g. relative price movements across countries) may generate a less precise representation of economic developments. This calls for the employment of a time varying-PPP approach. Last but not least, a time varying PPPs approach safeguards the sensitivity of the results from the choice of the base year.

In addition to the selection stage in the aggregation procedure, we follow a similar approach as in Belke *et al.* (2010) based on Beyer *et al.* (2001) to obtain aggregated global series. This aggregation procedure entails three steps. First, country weights are computed for each year. In detail, the weight of country *i* for period *t* is:

$$w_{i,t} = \frac{GDP_{i,t}^{Nom} e_{i,t}^{ppp}}{\sum_{i=1}^{N_t} GDP_{i,t}^{Nom} e_{i,t}^{ppp}} \qquad (1)$$

where $GDP_{i,t}^{Nom}$ is the nominal GDP adjusted by the PPPs exchange rates $e_{i,t}^{ppp}$ given a set of countries *N* in period *t*. The United States of America is the reference country for exchange rate and price level comparisons. Second, the quarter on quarter growth rate, $g_{i,t}^{j}$, in domestic currency is computed for each variable *j* in each country *i*. The aggregate quarter on quarter growth rate is obtained combining country weights determined in eq. 1 with country specific growth rates:

$$g_t^j = \sum_{i=1}^{N_t} g_{i,t}^j w_{i,t} \qquad (2)$$

The last step entails the construction of an index for each series *j* and an initial value of 100 has been chosen.

[12] We have measured the hypothetical size of our country sample using exchange rate adjusted GDP only and compared it to the same measured based on GDP-PPPs adjusted. The former measure accounts for a larger share of world GDP than the latter.

$$Index^{j} = 100 * \prod_{t=1}^{T} \left(1 + g_t^{j}\right) \qquad (3)$$

This procedure has been applied to all series but the commodity price index, which has been produced by the Economist, and it has country coverage comparable to our constructed series. The aggregation procedure has several advantages. On the one hand, it allows aggregating indexes such as the house price index and the consumer price index. On the other hand, it helps to reduce the potential bias, which may originate in aggregating levels of variables with potentially different national definitions of money and private credit. Indeed, an aggregation of different definitions may sum up to a total, which does not reflect the effective proportions across countries. Additionally, the GDP-PPPs weights take also into account the size of the economies and their relative movement over time including also relative price adjustments and not only exchange rate movements. Last but not least, the constructed time series capture also the contribution of the emerging markets, which becomes clearly crucial over the last 20 years or so. Indeed, the representativeness of the index would have fallen well below the 68 per cent threshold without the inclusion of emerging markets.

B. Data

Data was collected from various international and national sources. The series employed covers a long period spanning from 1960 to 2010 or shorter depending on the country - for the starting date of the series in each country see table 1. Series for some variables and specific countries may entail more than one source. A combination of sources has been employed only when it has not been possible to find the required missing data from a common national and/or international source. In order to guarantee a high degree of cross-country harmonisation, a common source principle has been applied as the preferred selection criteria. Moreover, when quarterly data was not available, a quadratic interpolation procedure was applied.

The following country abbreviations are used: AUS for Australia; AT for Austria; BE for Belgium; CAN for Canada; CHE for Switzerland; CHN for China; DNK for Denmark; ES for Spain; FI for Finland; FR for France; UK for United Kingdom; DE for Germany; GR for Greece; HKN for Hong Kong; IE for Ireland; IT for Italy; JPN for Japan; KOR for Korea; MYS for Malaysia; NL for the Netherlands; NOR for Norway; NZL for New Zealand; PT for Portugal; SGP for Singapore; SWE for Sweden; THA for Thailand; USA for United States of America; ZAW for South Africa.

The following abbreviations of sources are used: *OECD*: Organisation for Economic Co-operation and Development; *ESA95*: European System of National Accounts 95; *ECB/ESCB*: European Central Bank and European System of Central Banks (including individual National Central Bank); *STAT*: Eurostat and National Office of Statistics; *BIS*: Bank of International Settlements; *IFS*: International Financial Statistics – International Monetary Fund; *GFD*: Global Financial data; *ECO*: The Economist; *HA*: Haver Analytics; *CEIC*: CEIC Database

Consumer price index (CPI)

Consumer price indexes were collected from a single source.

Source: *IFS*

Money (M)

Monetary variables were collected from different sources and refer to the broader monetary aggregate available for each country. M3 is employed when available; otherwise M2 or M1 aggregates have been used. It is worth nothing that the "liquidity spectrum" of such aggregate may vary across countries. A narrow definition of money, say M1, for country X can be a broad enough definition for country Z.

Source: *IFS*, *ECB/ESCB*, *GFD*

Gross Domestic Product (Y)

Real GDP was collected from different sources.

Source: *IFS*, *ECB/ESCB*, *GFD, HA, ESA95*

The weightings employed for the aggregation procedure in section 3.1 are annual variables defined as GDP in purchasing power parity terms and obtained from the Penn World Table Version 7.0 - Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 7.0, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, May 2011. http://pwt.econ.upenn.edu/php_site/pwt_index.php

Private credit (CRP)

Private credit was primarily obtained from as the IMF's International Financial Statistics, lines 22d and 42d, which measure claims on the private sector by commercial banks and other financial institutions.

Source: *IFS, ECB/ESCB*

Public debt (D)

For a reference to the IMF database employed see S.M. A. Abbas, N. Belhocine, A.A. ElGanainy and M. A. Horton (2010), A Historical Public Debt Database, Working Paper No. 10/245

Source: *IMF*

House prices (RPP)

Country: AUS; AT; BE; CAN; CHE; CHN; DNK; ES; FI; FR; UK; DE; GR; HKN; IE; IT; JPN; KOR; MYS; NL; NOR; NZL; PT; SGP; SWE; THA; USA; ZAW

Source: *OECD, ECB/ESCB, STAT, HA, CEIC, BIS*

The series for FR, AUS and US were constructed employing additional sources not reported above. Moreover, FR was backdated with data from Conseil General de l'Environnement et du Developpement durable (CGEDD) - http://www.cgedd.developpement-durable.gouv.fr/home-prices-in-france-1200-2011-r137.html; US backdated with data from Robert J. Shiller, Irrational Exuberance, 2nd. Edition, Princeton University Press, 2009; AUS was backdated with Stapledon, N.

D. (2009) "Housing and the Global Financial Crisis: US versus Australia" *The Economic and Labour Relations Review*; NL backdated with The Herengracht Index.

Short-Term Interest rates (INT)

The preferred measure of short-term interest rates is defined as 3-months interest rates otherwise the shortest available maturity has been employed. Notably for AUS data has been backdated to before 1969 with the 3-year housing loan interest rates.

Source: *IFS, HA, STAT*

Commodity Prices (COM)

The Economist Price Index has been calculated since 1851. Among others the index contains prices for foods and industrials. Moreover it is representative for prices of metals, non-metals, farm and non-farm products.

Source: *ECO*

C. Methodology

We consider a traditional reduced-form VAR model formulated as a polynomial in the lag operator *L*:

$$\Pi(L)X_t = \gamma_0 + \varepsilon_t \qquad (1.C)$$
$$t = 1,\ldots,T\ ,\ \varepsilon_t \sim \mathrm{N}(0,\Omega)$$

where X_t is the vector of endogenous variables , $\Pi(\cdot)$ is a matrix polynomial in the lag operator such that $\Pi(L) = I + \sum_{i=1}^{p} B_i L^i$ with *p* lags, γ_0 is the vector of unrestricted constants and ε_t is a normally distributed zero mean and Ω variance error term. Autocorrelations in the residuals is excluded. However, Ω is not a diagonal matrix and covariance across the variables is allowed. More formally, $E(\varepsilon_t \varepsilon_s^{'}) = \omega$ for each $t = s$ and and $E(\varepsilon_t \varepsilon_s^{'}) = 0$ for each $t \neq s$. It should be recalled that the testable assumption of no autocorrelation in the residuals has some important implications for the economic interpretation of the results and it is a relevant assumption for our model given the long time horizon perspective. As stressed in Hendry (1995) and Jusélius (2006), autocorrelated residuals would imply that agents do not use the information in the data as effectively as possible.

Without the inclusion of some restrictions the parameters in the VAR are not identified and consequently the shocks to the system cannot be interpreted in a structural fashion. To model the shocks we employ a decomposition similar to Sousa and Zaghini (2007) and for some variables to Belke et al. (2010b). Both papers are also employed as reference for the interpretation of some structural shocks. The reduced form VAR in equation 1.C can be written in a structural VAR (SVAR) representation:

$$A(L)X_t = e_t \qquad (2.C)$$

where $A(L) = K + \sum_{i=1}^{p} K_i^* L^i$ and $E(e_t e_t^{'}) = K^{-1}E(\varepsilon_t \varepsilon_t^{'})K^{-1^{'}} = K^{-1}\Omega K^{-1^{'}} = \Sigma$. Moreover, $\Omega = CC^{'}$ is defined such as $E(\varepsilon_t \varepsilon_f^{'}) = 0$ when $t \neq f$. The inverse *C* is taken up to construct the matrix *K* such as $E(e_t e_t^{'}) = K^{-1}CC^{'}K^{-1^{'}} = DC^{-1}CC^{'}C^{-1^{'}}D^{'} = DD^{'}$.

The SVAR can be employed to conduct several simulation exercises. Among them we consider a structural impulse response function (IRFs) exercise and a forecast error variance decomposition exercise. The second exercise based on a variance decomposition is to determine the proportion of the variability of the errors in forecasting *X* vector of variables at time $t+s$ based on the information available at time *t* that is due to the variability in the structural shocks ε_t between times *t* and $t+s$. To do so, a structural decomposition is used to construct forecast errors and impute the proportion of variance for variable *i* due to shock *j* at time $t+s$. In general, the recursive causal structure involves restrictions about the contemporaneous relationships among the variables. Such ordering may considerably influence the results. A sensitivity analysis is required to disentangle the potential influence of the chosen ordering and check the robustness of the results.

To proceed in the analysis we need to design a concrete approach to estimate the full model based on eight variables. The variables are taken in log-changes and a constant is added to the model. The full vector of endogenous variables is:

$$X_t = [\Delta Y_t, \Delta D_t, \Delta CPI_t, \Delta RPP_t, \Delta M_t, \Delta CRP_t, \Delta COM_t, INT_t]^{'} \qquad (3.C)$$

Specifically it includes real output (ΔY_t), public debt growth (ΔD_t), consumer price inflation (ΔCPI_t), house price dynamics (ΔRPP_t), money growth (ΔM_t), private credit growth (ΔCRP_t), commodity inflation (ΔCOM_t) and short-term interest rate (INT_t).

To a certain extent the set of variables included in X_t is similar to Sousa and Zaghini (2007) and Belke *et al.* (2010a). Consequently we refer these two studies to define the identification scheme. Considering equations 4 and 5, the residuals ε_t are linked to the structural innovations e_t by the non-recursive structure $Ke_t = \varepsilon_t$:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ k_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ k_{31} & k_{32} & 1 & 0 & 0 & 0 & 0 & 0 \\ k_{41} & k_{42} & k_{43} & 1 & 0 & 0 & 0 & 0 \\ k_{71} & k_{72} & k_{73} & k_{74} & 1 & 0 & 0 & k_{58} \\ k_{61} & 0 & 0 & k_{64} & k_{65} & 1 & 0 & k_{68} \\ k_{71} & k_{72} & k_{73} & k_{74} & k_{75} & k_{76} & 1 & 0 \\ k_{81} & k_{82} & k_{83} & k_{84} & k_{85} & k_{86} & k_{87} & 1 \end{bmatrix} \begin{bmatrix} e_t^{GDP} \\ e_t^{D} \\ e_t^{CPI} \\ e_t^{RPP} \\ e_t^{M} \\ e_t^{CRP} \\ e_t^{COM} \\ e_t^{INT} \end{bmatrix} = \begin{bmatrix} \varepsilon_t^{GDP} \\ \varepsilon_t^{D} \\ \varepsilon_t^{CPI} \\ \varepsilon_t^{RPP} \\ \varepsilon_t^{M} \\ \varepsilon_t^{CRP} \\ \varepsilon_t^{COM} \\ \varepsilon_t^{INT} \end{bmatrix} \qquad (4.C)$$

Tables

Table 1. Country coverage and GDP-PPPs weight in the world economy

Year	**Country coverage**	**% of world GDP - PPPs**
1960	Australia, Canada, France, United Kingdom, Japan, Netherlands and United States	72.3%
1962	Germany	73.0%
1965	Italy	72.7%
1966	South Africa	72.9%
1970	Denmark, Finland, Ireland, New Zealand and Switzerland	71.4%
1971	Spain	73.5%
1976	Belgium and Singapore	71.3%
1979	Norway	70.9%
1980	Sweden	71.2%
1987	Austria	68.8%
1988	Portugal	69.6%
1990	Korea	68.4%
1993	Hong Kong	68.1%
1995	Thailand and Greece	70.9%
1998	China	73.0%
1999	Malaysia	72.3%

Table 2. Granger Causality test across the set of variables

	CPI	COMMODITY	MONEY	CREDIT	GDP	HOUSE PRICES	PUBLIC DEBT	INT
CPI	-	1.36	1.34	0.33	**6.37***	1.42	**3.62****	0.77
COMMODITY	**14.40***	-	1.17	2.16	**3.17****	1.19	**4.40****	**3.61****
MONEY	**4.34****	**5.31***	-	**3.36****	2.59	2.02	0.14	**3.22****
CREDIT	**8.85***	1.34	**9.87***	-	**9.50***	0.12	0.04	1.80
GDP	**8.06***	2.07	0.07	**3.41****	-	0.21	6.68*	**4.03***
HOUSE PRICES	**11.70***	2.20	2.13	**8.29***	**5.33***	-	7.23*	**4.20***
PUBLIC DEBT	**2.33*****	**2.53*****	0.08	**3.34****	**0.37219**	**2.82*****	-	**4.45***
INT	**5.44***	**2.48****	0.48	0.96	**7.21***	**3.47****	1.67	-

F-statistics and * *1 per cent, ** 5 per cent and *** 10 per cent significance levels*

Note : the Null Hypothesis is 'variable Y does not Granger cause variable X'. The test should be read across lines. Hence, any variable on the Y axis does not cause any variable on the X axis. The test is computed including two lags of the quarterly variables.

Table 3. Unit Root tests

First Differences							
	DF	**ADF**	**ERS**	**NP**			
				MZa	*MZt*	*MSB*	*MPT*
Y	**-2.586**	**-5.452**	**2.129**	**-13.108**	**-2.536**	**0.193**	**1.965**
M	**-3.543**	**-4.056**	**1.231**	**-19.154**	**-3.095**	**0.162**	**1.280**
CPI	**-1.884**	-2.040	**4.099**	**-5.611**	**-1.705**	**0.243**	**4.216**
RPP	**-3.758**	**-4.709**	**1.017**	**-28.078**	**-3.612**	**0.129**	**1.304**
CRP	**-3.451**	**-4.649**	**0.701**	**-24.684**	**-3.513**	**0.142**	**0.993**
COM	**-6.122**	**-10.174**	**0.893**	**-57.200**	**-4.998**	**0.087**	**1.255**
D	-1.323	**-4.215**	**1.567**	-5.216	-1.562	0.300	4.843

Levels							
	DF	**ADF**	**ERS**	**NP**			
				MZa	*MZt*	*MSB*	*MPT*
Y	1.694	-1.492	3625.039	1.439	2.331	1.620	188.104
M	1.131	-1.340	3034.268	1.216	1.428	1.174	97.825
CPI	-0.019	-1.772	372.044	-0.862	-0.423	0.492	15.903
RPP	0.780	**-2.986**	970.390	0.835	1.110	1.329	114.058
CRP	1.064	**-2.676**	3703.590	1.025	1.179	1.150	90.634
COM	1.280	-0.631	76.382	1.337	1.206	0.902	62.029
D	0.716	0.257	47.324	0.644	0.331	0.515	22.332
INT	**-2.016**	-2.474	**3.041**	**-8.671**	**-2.023**	**0.233**	**3.058**

Note : Bold numbers refer to at least 10% level

Test critical values:		*1% level*	*5% level*	*10% level*
Augmented Dickey-Fuller test statistic (ADF)		-3.463	-2.876	-2.574
Dickey-Fuller test statistic (DF)		-2.577	-1.942	-1.616
Elliott-Rothenberg-Stock test statistic (ERS)		1.911	3.171	4.332
Ng-Perron test statistics (NP)	*MZa*	-13.800	-8.100	-5.700
	MZt	-2.580	-1.980	-1.620
	MSB	0.174	0.233	0.275
	MPT	1.780	3.170	4.450

Table 4. Lag length criteria tests

VAR - eight variables - INT, Y, CPI, M, CRP, RPP, D, COMM						
Lags Number	LogL	LR	FPE	AIC	SC	HQ
0	4219.181	NA	4.08E-28	-43.20186	-43.08437	-43.15429
1	4864.398	1237.493	9.01E-31	-49.3169	-48.37696*	-48.93633
2	4949.876	157.8056	6.21E-31	-49.69104	-47.92865	-48.97747*
3	5007.451	102.1583	5.71E-31	-49.77898	-47.19415	-48.73241
4	5058.56	87.01705	5.64E-31	-49.80062	-46.39334	-48.42105
5	5118.317	97.44968	5.12e-31*	-49.91094*	-45.68122	-48.19838
6	5162.766	69.29542	5.49E-31	-49.86427	-44.8121	-47.81871
7	5210.295	70.68420*	5.74E-31	-49.84918	-43.97457	-47.47062

Note : * indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

Table 5. LM test - autocorrelation in the residuals

Number of Lags	VAR - variables - Y, CPI, M, INT, CRP, RPP, D, COMM LM-Statistics	Prob
1	60.14028	0.1322
2	54.20104	0.2512
3	50.07743	0.4304
4	55.4216	0.2454
5	34.53972	0.9414
6	60.73994	0.1213
7	58.38595	0.1685

Note : Null Hypothesis: no serial correlation at lag order h

Figures

Chart 1. Inflation against the other variables – *twelve periods moving average of quarter on quarter growth rates*

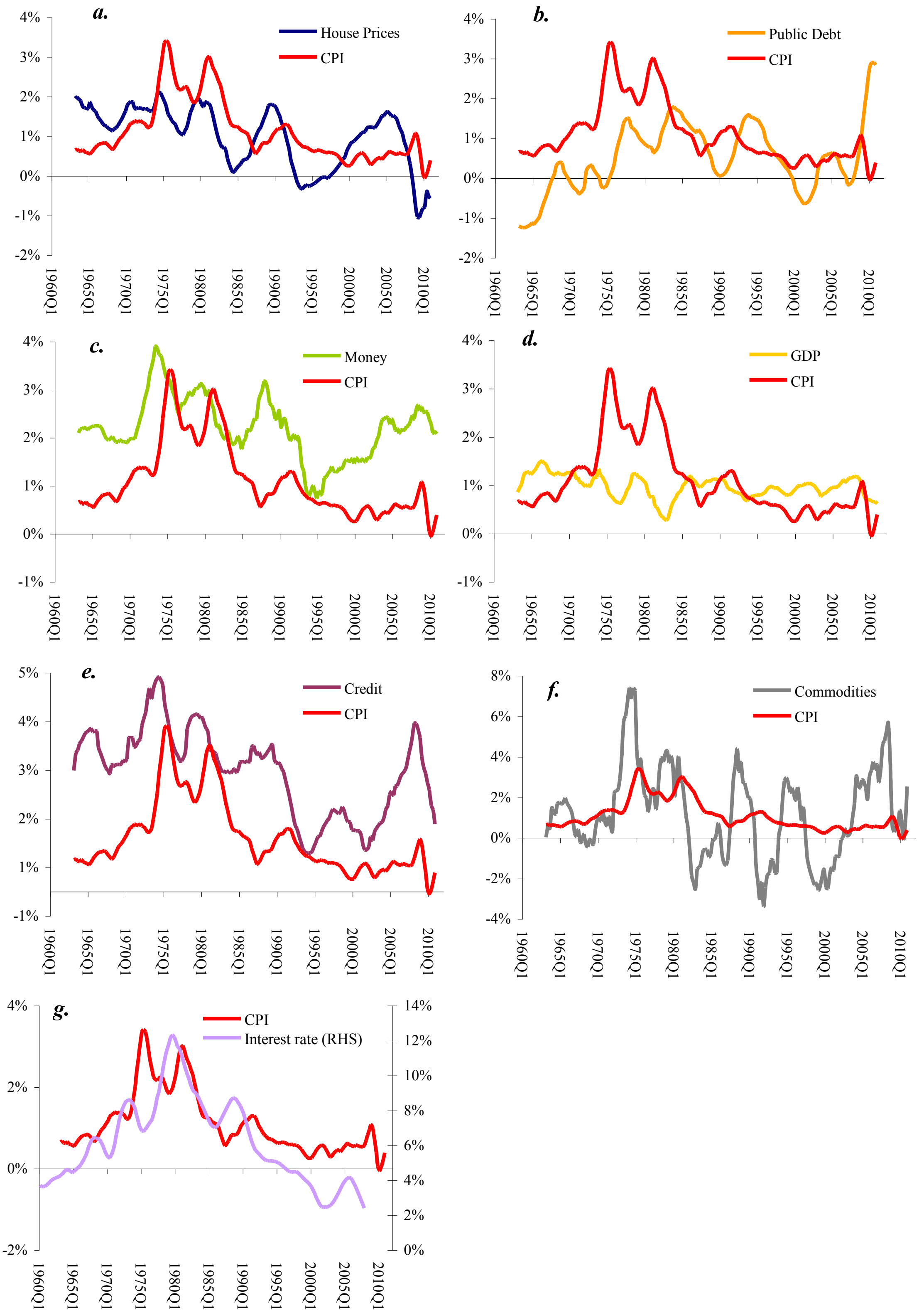
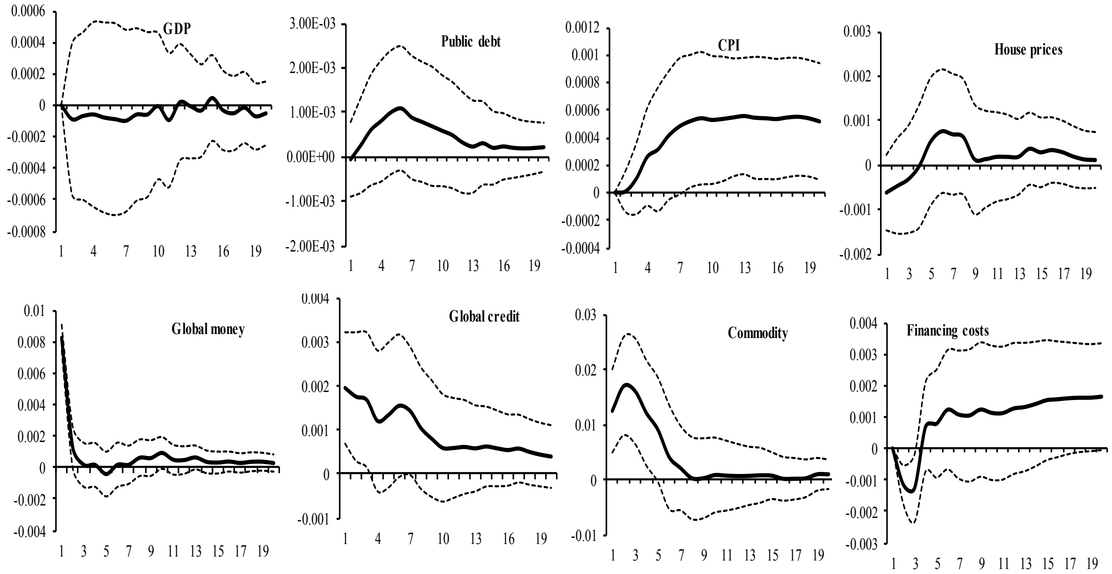


Chart 2. Impulse response function–Global demand money shock– *response to one S.D. innovations and ± 2 S.E. band*

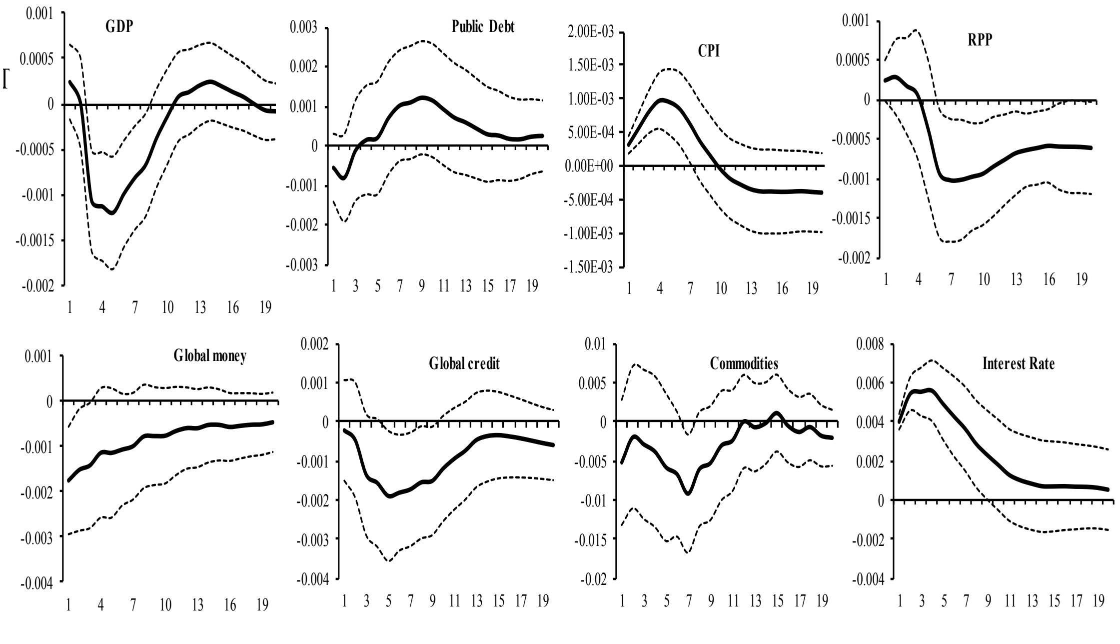
b. Global Money Shock



Note: the figures represent a deviation from the model based baseline. Confidence intervals display 2 standard deviations and are calculated via the studentized Hall bootstrap method. The shock is equal to 1 standard deviation of the variable.

Chart 3. Impulse response function– Financing cost shock–*response to a one S.D. innovations and ± 2 S.E. bands*

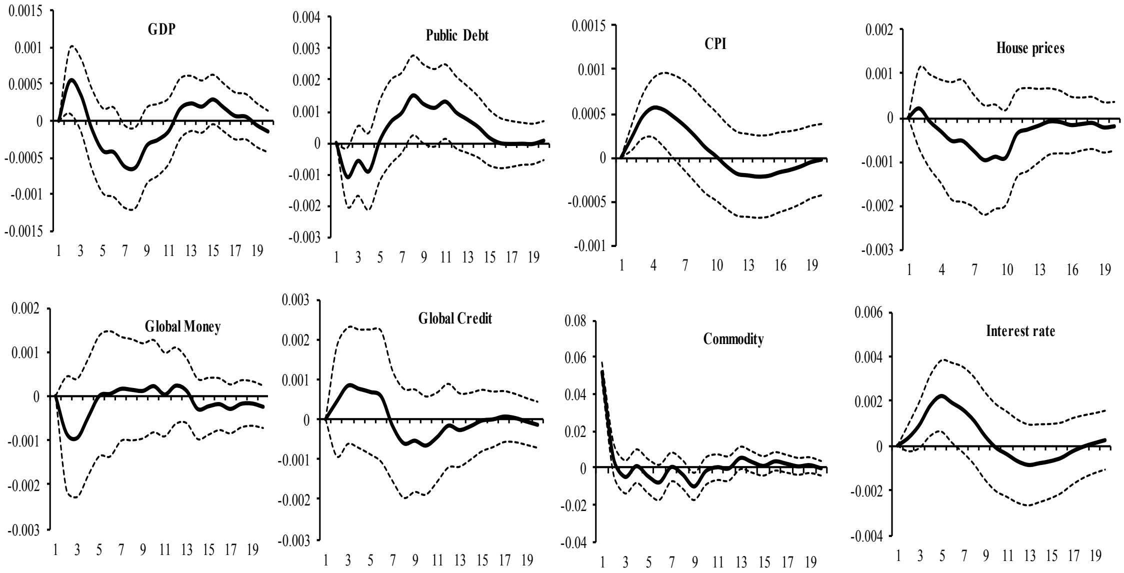
a. Financing Cost Shock



Note: the figures represent a deviation from the model based baseline. Confidence intervals display 2 standard deviations and are calculated via the studentized Hall bootstrap method. The shock is equal to 1 standard deviation of the variable.

Chart 4. Impulse response function– Commodity shock – *response to one S.D. innovations and ± 2 S.E. band*

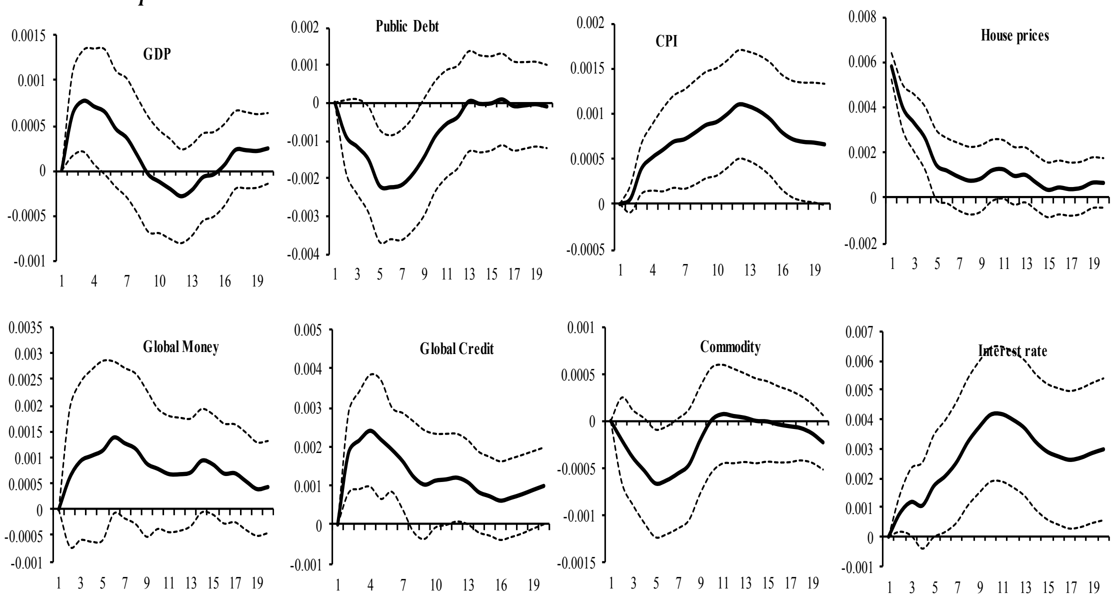
c. Commodity Shock



Note: the figures represent a deviation from the model based baseline. Confidence intervals display 2 standard deviations and are calculated via the studentized Hall bootstrap method. The shock is equal to 1 standard deviation of the variable.

Chart 5. Impulse response function– Global house price shock – *response to one S.D. innovations and ± 2 S.E. band*

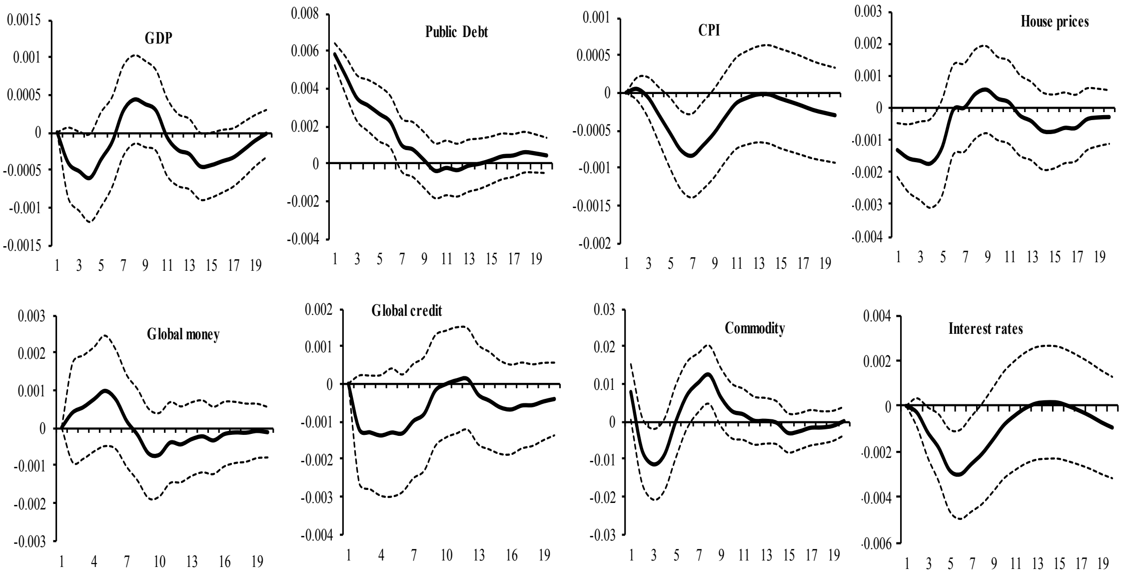
d. Global house price shock



Note: the figures represent a deviation from the model based baseline. Confidence intervals display 2 standard deviations and are calculated via the studentized Hall bootstrap method. The shock is equal to 1 standard deviation of the variable.

Chart 6. Impulse response function – Global public debt shock – *response to one S.D. innovations and ± 2 S.E. band*

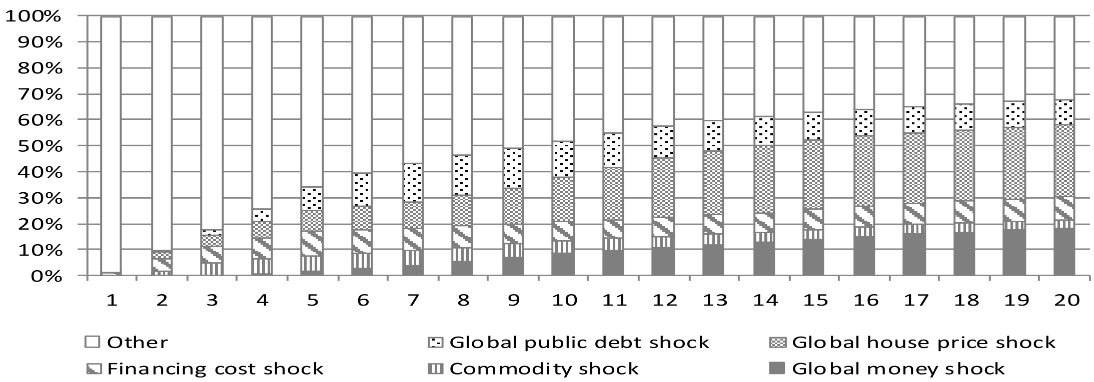
e. Global public debt shock



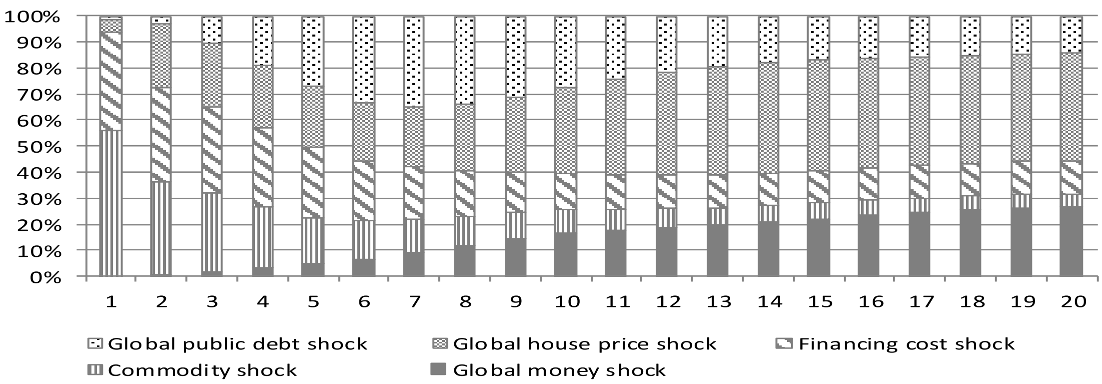
Note: the figures represent a deviation from the model based baseline. Confidence intervals display 2 standard deviations and are calculated via the studentized Hall bootstrap method. The shock is equal to 1 standard deviation of the variable.

Chart 7. Forecast error variance decomposition of inflation

a. Forecast error variance decomposition of inflation



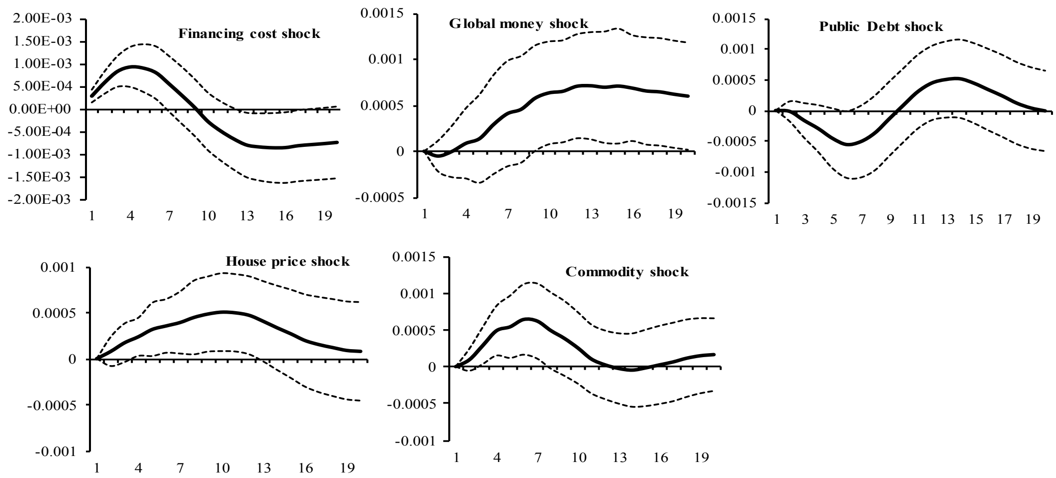
b. Variance decomposition - distribution across all shocks except "Other"



Note: the structural decomposition employed is the same of the IRFs exercise

Chart 8. Impulse response function model estimated over a restricted sample (1960-2000) – responses of CPI – *response to one S.D. innovations and ± 2 S.E. band*

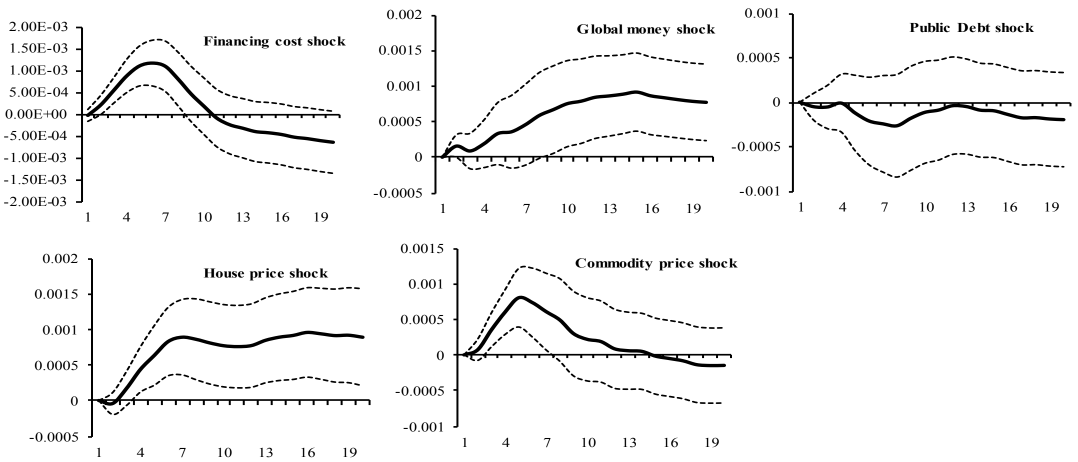
Responses of CPI



Note: the figures represent a deviation from the model based baseline. Confidence intervals display 2 standard deviations and are calculated via the studentized Hall bootstrap method. The shock is equal to 1 standard deviation of the variable.

Chart 9. Impulse response function model based on the variables constructed as described in section 4.3 – responses of CPI – *response to one S.D. innovations and ± 2 S.E. band*

Responses of CPI



Note: the figures represent a deviation from the model based baseline. Confidence intervals display 2 standard deviations and are calculated via the studentized Hall bootstrap method. The shock is equal to 1 standard deviation of the variable.