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Banks: selected investigations on the roles of liquidity, globalization and credit risk

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The undersigned *Carmela D'Avino*, in his quality of doctoral candidate for a Ph.D. degree in Economics granted by the Università Ca Foscari Venezia, attests that the research exposed in this dissertation is **original** and that it has not been and it will not be used to pursue or attain any other academic degree of any level at any other academic institution, be it foreign or Italian.

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Abstract

This thesis presents three bank-related research studies inspired by some relevant events brought about by the recent *subprime* banking crisis. The first part of this work links banking-sector liquidity creation to both liquidity supply from central banks worldwide and international interbank liabilities, within a global macro-econometric framework. In the second part it is carried out a micro-econometric analysis on all global US banks with the intent to explain pre- and post-crisis dynamics in Net Inter-Office Accounts (NIOA). The last part of the thesis proposes a framework capable to model, among other things, inefficient policy interventions by a central banker during a crisis when an accurate assessment of the true solvency of a bank is unattainable.

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Dedicated to my father,
Vincenzo

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Preface

The depth and complexity of the recent banking crisis has highlighted the need to revise and further develop several research topics, in particular, those which might shed some light on the risks, operating models, responsibilities and incentives (just to cite a few) of banks. Banks are the focus of the whole thesis: the three chapters herein look at them from different perspectives. Special attention is paid to how globalization of interbank markets has affected some banks' behaviors: two chapters out of three of the thesis deal with this topic.

The issues investigated within the thesis have been selected with the intent to either fill some gaps in the existing literature or to shift the attention to different research questions. For instance, the *originate-to-distribute* banking business model is often referred to as the key factor which has stimulated the unprecedented leverage of the banking sector before the crisis. Less attention has been paid to other factors which might have driven banks' indiscipline. For instance, the excessive maturity mismatch by banks has not been investigated in relation to the massive increases in gross external interbank transactions, as pre-crisis stylized facts were clearly pointing out to.

The first part of the thesis investigates the pertinence of this relation. It links banking-sector liquidity creation to both liquidity supply from central banks worldwide and international interbank liabilities, in an attempt to better understand the driving forces behind the recent crisis. The main objective is to investigate whether international M0 liquidity shock spillovers had significant effects on banking liquidity creation, either directly or indirectly, in the two decades preceding the crisis. This is accomplished by carefully specifying a partial equilibrium system for the financial sector. We (*me*, E. Girardin and V. Smith) employ a 24-country Global Vector Autoregressive (GVAR) model, which allows to account for interbank cross-country dependencies in a framework centered on a composite measure for liquidity creation by deposit-taking banks. A central contribution of this work is that it bridges the gap between the micro and macro-founded strands of the related literature dealing respectively with banks' liquidity creation and international liquidity spillovers. The results both highlight the dangers of abundant global M0 liquidity creation for banking fragility in the US and help understanding the cross-country varying rationales underlying external interbank debt. In particular, we find that an M0 expansion in the US was followed by the adoption of the same stance by a number of other foreign countries. This increase in global M0 has fed back to the US by stimulating banks' liquidity creation even further. Evidence also suggests that for key countries such as the UK and the Euro Area, external interbank debt has been used in different ways. In the latter case, it has been used to augment banking sector's liquidity transformation; in the former, to take leverage positions in foreign interbank markets, such as in the US ones.

The second part of the thesis yields interesting predictions on why banks with a given nationality might borrow from foreign banks. This work partly complements the research carried out in the first part. The external interbank liabilities considered in the first part are, indeed, consolidated balance sheet figures, which prevent us to draw any conclusion on the the drivers of inter-office liabilities and on the role of foreign-related offices in international liquidity transmission. A deeper understanding of this topic is of particular relevance for some countries, such as the US, where 17 out of the 20 top banks have foreign-related offices. In the second chapter of the thesis, therefore, I carry out a micro-econometric bank-level study on all global US banks with the intent to understand which changes in balance sheet items can better explain Net Inter-Office Accounts (NIOA). This work differentiates from the empirical investigation in the previous chapter in several ways. The modelling approach and specification differ, as well as the focus, which here is more country-specific. Moreover, in this paper I also carry out an analysis which goes beyond the crisis explosion (i.e. up to 2010 2nd quarter): this allows making a comparative pre/post 2007q3 analysis by means of a dynamic GMM panel estimation. I find that banks' financial soundness, as proxied by a wide range of quantity-based balance sheet variables, has an important role in explaining changes in Net Inter-office Accounts. Over the entire sample it is not only a decrease in domestic interbank loans to affect positively NIOA-to-total assets but also an increase in deposits in foreign offices. In the two-and-half years preceding the crisis, there is evidence that a well-functioning domestic interbank market results in lower NIOA. Moreover, over this period, deterioration in bank's balance sheets results in more liquidity imported from foreign offices. This last evidence is even stronger in the crisis-period estimation (2007q3-2010q2) and partly in a further sub-period considered which spans from the failure of Lehman Brothers to sample-end. This paper contributes to the very limited literature on this subject by showing formally that banks' idiosyncratic and/or aggregate credit risk is an important driver for NIOA. Existing papers, indeed, argue that global banks import liquidity from their foreign offices either to cushion against adverse liquidity shocks in domestic inter-bank markets or to engage in carry trade activities.

The topic of the third part of the thesis differs to some extents from the two preceding ones as it proposes a theoretical and closed-economy banking model. In particular, it deals with one of the greatest concerns for policymakers, regulators and investors after the crisis' outburst: that is, the inability to assess accurately the true solvency of a bank. Opacity in banks' balance sheet is primarily due to discretionary accounting rules employed to value assets with missing markets and/or unknown fundamentals. The main implication of this opacity to investors has been that they were uncertain on whether to rollover their loans to the bank; the main implication for monetary authorities, on the other side, has been the risk of intervening inefficiently. We (*me* and M. Lucchetta), therefore, propose a framework capable to model: (1) runs on a bank whose solvency status is not accurately known (2) the pricing of assets whose fundamental value is imperfectly assessed and (3) over/under borrowing to banks by a central banker during a crisis. This is achieved with the introduction of opacity in a simple bank-run type model in which it is assumed that the contract offered to depositors solves the optimal risk-sharing problem (Allen and Gale, 1998). We adopt a novel characterization of 'opacity' which does not imply moral hazard or asymmetric information, as found in the existing theoretical models. Opacity is here defined as the inability of depositors, speculators and central banker to disentangle default risk and asset's return from the asset's expected return. We are able to draw interesting implications of opacity for bank-runs and fire-sale pricing when speculators are either risk-neutral or risk-averse. We show the conditions for which with opacity there might be a no-run equilibrium on an insolvent bank. Moreover, we illustrate how opacity leads to uncertainty on the fundamental value of the risky asset when speculators in the asset market are risk-averse. Lastly, we find that the intervention by a central banker might be desirable for depositors since it ensures a fixed level of consumption. However, the intervention will be inefficient with opacity given that the central bank lends either more or less than the bank should be entitled to, given the quality of its assets.

Part I

Commercial banks' liquidity creation: the effect of global high-powered money and cross-border interbank debt

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Abstract

This paper links banking-sector liquidity creation to both liquidity supply from central banks worldwide and international interbank liabilities, with the aim of uncovering the driving forces that led to (behind) the recent crisis. A 24 country Global Vector Autoregressive (GVAR) model grouped into 13 regions allows us to account for interbank cross-country dependencies in a framework centered on a composite measure for liquidity creation by deposit-taking banks. Focusing on the two decades preceding the crisis, our findings suggest that an *external interbank liability channel* may have been active for the US and that global interbank liabilities have helped the massive expansion in banks' liquidity creation in several countries.

Key Words: *Banking liquidity creation, International liquidity transmission, High-powered money.*

1 Introduction

The recent decision by the Federal Reserve to engage in bond purchases of at least \$600Bn (i.e. Quantitative Easing 2, QE2) is raising several questions, alongside concerns, in several parts of the world.[1] The main question is: how much will bank credit increase following such a stimulus? On the international front, the major concern is that this increase in high-powered liquidity will flow to emerging economies, appreciating their currency and stimulating inflationary pressure in their goods and asset markets. On the research front, interest in the relation between base money and banks' liquidity creation and the potential international consequences seems to arise only when an explicit quantitative easing policy is pursued by a central bank (e.g. Klyuev et al., 2009). This happens during economic recessions, such as the current one, when the underlying dynamics of the economic and financial system are distorted and, thus, most difficult to understand. The relationship between these variables during normal times appears to be underexplored.

It is, however, well-recognised that the abundant and prolonged liquidity creation by the banking system in the pre-crisis period was an important driver of the subprime meltdown. In particular, the combined incidence of excessive bank credit creation, most prominently in the US, UK and Euro Area,[2] within a marked-to-market pricing system stimulated the formation of price bubbles in several asset markets (Eichengreen, 2008, Taylor, 2009). The joint occurrence of several factors enabled banks in these countries to expand their activities at a rapid pace. A great burden of responsibility has been attributed to the laxity of monetary policy in the years preceding the financial meltdown. Low interest rates, far below those suggested by the Taylor rule (see Taylor, 2007, Dominguez, 2006, and Kuttner and Posen, 2004), stimulated excessive risk-taking by banks. Liquidity and credit creation by the banking sector were further stimulated by high growth rates, stable inflation, low volatility of exchange rates and the emergence of a set of speculative opportunities brought about by structured credit, as implied by the *originate-to-distribute* business model (Purnanandam, 2010). It is now evident that the combined dynamics of these factors within domestic boundaries allowed banks to expand their balance sheets excessively

[1] The news of the launch of the QE2 was disclosed by the Federal Reserve in the first week of November 2010.

[2] According to ECB, Federal Reserve and IMF sources, bank credit to the private sector in these countries increased by 100%, 105% and 66% respectively over the period 2000-2007. US figures relate to the sum of consumer and mortgage credit.

(Bean, 2009). It is, however, less clear whether shocks to equivalent foreign factors affected domestic banks' liquidity creation through spillover effects. In fact, related empirical literature depicts a dichotomy between bank-level microeconometric and closed-economy studies of liquidity creation (e.g. Berger and Bauman, 2009), and macroeconometric approaches to international liquidity transmission where banks play no role (e.g. Kim, 2001 and Canova, 2005).

The objective of this work is twofold. Firstly, to investigate whether international M0 liquidity shock spillovers had significant effects on banking liquidity creation either directly or indirectly, in the two decades preceding the crisis, thus attempting to bridge the gap between the micro and macro-founded strands of the related literature. Secondly, to explore the role of interbank debt on international markets for domestic banking liquidity creation.

Direct spillovers of M0 liquidity shocks on banking liquidity creation could be primarily attributed to the globalisation of the banking sector and the high integration of interbank markets (see Cetorelli and Goldberg, 2009, and Hattori and Shin, 2007). Banks may have, indeed, channeled foreign high-powered money from liquidity-rich interbank markets through either affiliated or unaffiliated financial intermediaries. Based on this idea, we explore whether external interbank transactions constituted a direct transmission channel and we define this liquidity-channeling mechanism as the 'External Interbank Lending Channel' (EILC). Indirect spillover effects of M0 liquidity shocks could, for example, eventuate when foreign central banks respond to an increase in liquidity abroad by creating additional liquidity in order to gain competitiveness, as implied by Dornbusch (1980). Such a response by the foreign monetary authority can have feedback effects on domestic and global banking liquidity creation. Our investigation concerning interbank liabilities aims to help us understand how this imported liquidity is employed by banks in different countries.

Our analysis is based on a partial equilibrium model of the financial sector, within a Global VAR (GVAR) multi-country framework (Pesaran, Schuermann and Weiner, 2004). The use of a partial equilibrium model is justified by several arguments supporting the view that in monetary regimes with low and stable inflation relevant information for banking crisis is contained in finance-based variables. For instance, Borio and Disyatat (2010) and Borio and Lowe (2002, 2003) show that the excessive elasticity of the financial sector, which accounts for disproportionate credit creation by banks, is a better indicator for banking crisis than real-economy-based variables. The global framework allows us to account for bilateral interbank relations and for the possibility of spillovers through interbank international debts for a sample of 24 countries grouped into 13 regions, accounting for about 74% of world GDP. Banking liquidity creation is investigated through the construction of a sectoral proxy, namely the Aggregate Liquidity Transformation Measure (ALTM), based on a measure proposed by Berger and Bouwman (2009).

This work reveals several interesting findings. Most notably, we find that an US M0 expansion is followed by the adoption of the same stance by a number of other foreign countries. This increase in global M0, in turn, stimulates US banks' liquidity creation through the EILC, suggesting that US banks were able to increase their leverage and liquidity creation with M0 liquidity created elsewhere.[3] Evidence also suggests that for key countries such as the UK and the Euro Area, an increase in external interbank liabilities stimulates banking sector's liquidity transformation.

Our results have important policy implications. In particular, they point to the need for limiting liquidity inflows through international interbank markets as a way to mitigate banking fragility. This would also help central banks to manage domestic interbank liquidity in a more effective manner, and thus better achieve their policy objectives.

The paper is organised as follows. Section 2 provides a critical overview on the state of the literature related to international-liquidity transmission and banking-liquidity creation, highlighting the existing *micro-macro dichotomy*. Section 3 describes the details of our sample and the variables included in the Global Vector Autoregressive model (GVAR), including the construction and performance of the liquidity creation proxy. In section 4 we summarise the results of the estimated individual country models and related tests. Section 5 presents the impulse response analysis. Section 6 briefly discusses the related policy implications and concludes.

2 Banking liquidity creation, international monetary transmission spillovers and M0

In this section we review and discuss the existing literature relating to banking-sector liquidity creation and cross-border liquidity transmission channels, as well as the role of bank credit. This provides the motivation for our proposed

[3]Stylised facts actually show that over the period 2001-2007, US banking liabilities of reporting banks vis-à-vis foreign central banks and foreign banking institutions more than doubled in volume.

approach of bringing together base money and banking liquidity creation in a global empirical analysis, as a way of better understanding the driving forces behind the recent crisis. Our proposed approach could help bridge the gap between the two main research streams: the micro-founded, dealing with banking-sector liquidity creation and the macro-founded focused on cross-border liquidity transmission channels.

2.1 Micro-based contributions to banking liquidity creation

While investigating the degree of liquidity creation can help assess the extent of liquidity risk facing banks, measuring the extent of banking-sector liquidity creation has only been a recent topic of attention in the literature. It involves tracking the dynamics of a chosen proxy, constructed from bank-level balance-sheet items, measured in stocks.[4] The construction of the related proxy is based on a conception of banking-sector fragility arising from liquidity creation, as initially advocated by Diamond and Dybvig (1983). Two main empirical contributions on the construction of liquidity creation measures can be found in the literature. The first and less refined proxy is the 'liquidity transformation gap' or *LT gap*, given by the ratio of the difference between liquid (i.e. with maturity of one year or less) liabilities/assets and total assets, as proposed by Deep and Schaefer (2004). More recently, Berger and Bouwman (2009) have introduced four different measures of liquidity creation, based on different balance-sheet classifications[5], which they compute for a sample of US banks. According to the *LT gap,* US banks have depicted an astonishingly low liquidity creation over the years 1997-2001. In contrast, Berger and Bouwman report that their best performing measure[6] reveals that bank liquidity creation escalated massively, exceeding $2.8 trillion in 2003, and nearly doubled in real terms between 1993 and 2003. These balance-sheet based notable contributions are, however, silent on the drivers, both domestic and foreign, of banking liquidity creation.

This weakness is also encountered in micro-founded theoretical models centered on banking liquidity creation where the central bank plays a limited role.[7]

[4] Models dealing with bank-risk measurements typically recur to figures in flows.

[5] According to the ease or time of disposal and by including/excluding off-balance sheet items. These items are then further classified as liquid, semi-liquid and illiquid.

[6] That is, the one which classifies all the items by category and that includes also off-balance sheet items.

[7] Ever since the renowned seminal contribution of Diamond and Dybvig (1983), several

In particular, in these closed-economy models, the central bank mainly plays the role of the lender-of-last-resort in the case where an illiquidity crisis materialises and the bank's liquidity transformation activity is exogenous. Multi-bank open-economy models, on the other hand, focus on system-wide propagation of liquidity shocks in the interbank market. For example, Allen and Gale (2000) and Freixas, Parigi and Rochet (2000) argue that illiquidity contagion can be attributed to either international interbank market relations or the degree of connections in the payments system, respectively. In both these studies, however, interbank regional claims/credit lines avoid costly liquidation by re-allocating liquidity and thus do not stimulate domestic banks' liquidity creation, which remains unaffected by the global availability of macroeconomic liquidity. In contrast, Chang and Velasco (1998) drawing on the implications of the East-Asian crisis, show that domestic liquidity creation can be stimulated by certain foreign factors (excessive foreign borrowing, financial liberalisation and an exchange rate peg). However, these factors are not directly attributable to the magnitude of money supplied by monetary authorities or to excessive debts of banks in international interbank markets.

2.2 Macro-based contributions to the international liquidity transmission mechanism

Various macro-based approaches deal with cross-border spillovers arising from shocks to global M0 liquidity. Motivated by the findings by Baks and Kramer (1999), a number of studies on international monetary transmission mechanisms pay particular attention to the effects of a global monetary shock on domestic asset prices. Their analysis typically involves exploring the implications of shocks to global monetary aggregates on domestic activity, inflation and asset prices by means of VAR modelling techniques, as pioneered by Sims (1980). The variable accounting for global (or US) liquidity is typically constructed as a sum (either simple or PPP-GDP weighted) of the monetary aggregates for a set of countries.[8] For example, Kim (2001) and Canova (2005) find evidence of significant effects of a US monetary policy shock on real demand of non-US G-7 and Latin American countries. The transmission materialises through a global

theoretical models have established the link between banks' liquidity creation arising from maturity transformation and banking-sector fragility/crises. See Gorton (1985), Jacklin and Bhattacharya (1988), Chari and Jagannathan (1988), Calomoris and Kahn (1991), Diamong and Rajan (2001).

[8] There are, however, some variations to this approach. For instance Canova (2005) includes (exogenously) estimated US structural shocks.

wealth channel which stimulates global demand.[9] In these studies, the US is the leading economy from which liquidity originates, affecting other small-open economies. An exception is the work by Sousa and Zaghini (2007), who estimate the effect of their measure of global liquidity (aggregating G5 broad monetary aggregates) on domestic excess liquidity (constructed as a ratio between broad /narrow money and nominal GDP) in the US, the Euro area and Japan. They find significant responses only for the latter two economies. In particular, positive shocks to foreign liquidity lead to a permanent increase in the euro area M3 aggregate and the price level. The US, in contrast, appears to be relatively more insulated from global excess liquidity shocks. A similar result is also found by Ruffer and Stracca (2006).

On the theoretical front, the Mundell-Fleming-Dornbusch framework (Dornbusch, 1980) constitutes a key theoretical contribution in the area of international liquidity transmission. Although no liquidity spillovers occur directly in their model, an increase in money supply in a country can induce a central bank abroad to increase its monetary base in order to boost the economy following trade-balance deterioration (beggar-thy-neighbor). New open economy models (e.g. Svensson and Van Wijnbergen, 1989 and Obstfeld and Rogoff, 1995), instead, predict that monetary expansion in a country might contemporaneously raise output in foreign countries, in which price rigidities render current prices of foreign goods cheaper than future ones (prosper-thy-neighbor). Other channels of transmission reported in the theoretical literature are inspired by the events regarding the East-Asian crisis, namely the push and pull channels. The former channel refers to the event in which a domestic monetary expansion stimulates capital outflows and inflates asset prices abroad. The latter, instead, implies that a domestic monetary expansion inflates domestic asset prices, which, in turn, might attract foreign capital, depressing asset prices abroad.

Although several relevant transmission channels for cross-border liquidity spillovers (i.e. wealth, interest rate, push and pull) have been highlighted in several theoretical and empirical contributions, it is surprising to see that banks have not been regarded as active players in the liquidity transmission process.

[9] That is, increased money balances lower US interest rates, which, in turn, under the assumption of perfect capital markets, lower world interest rates.

2.3 Bank credit in the monetary transmission mechanism

Whereas banks are not directly responsible for the transmission of liquidity shocks through the channels proposed in the literature, they do appear to play a role, together with their credit creation, in the more general monetary transmission mechanism. In fact, the role of liquidity transformation by banks in the monetary transmission mechanism started to gain importance in the 1990s with the recognition of the existence of a financial accelerator, see Bernanke, Gertler and Gilchrist (1999). In the theoretical model proposed by these authors, financial market frictions set-off an accelerator, which amplifies domestic monetary policy shocks mainly through changes in the external finance premium faced by bank borrowers.[10] In turn, changes in banks' supply of credit have a direct effect on goods and asset prices and ultimately real activity. This model, however, by focusing on the ultimate effects of the accelerator on the real economy, is unable to account for the possibility of the occurrence of banking liquidity crises which might, for instance, arise from banks' excessive liquidity transformation.

More recent work argues that excessive credit/liquidity creation can lead to banking crises in a monetary regime that successfully manages its inflation-target. For example, Borio and White (2004) and Borio and Disyatat (2010) have pointed out that macro-prudential regulators and monetary authorities should monitor the excess elasticity of the financial system[11], that is, the disproportionate credit creation (coupled with asset-price inflation) by financial intermediaries (see also Borio and Lowe, 2002, 2003). According to Borio and Disyatat, monetary regimes were accommodating the excessive growth of this elasticity prior to the crisis, though they overlooked the potential threats from its overly excessive expansion.[12] This is possibly because excessive liquidity creation by banks was not considered as a major threat, given the success of the central banks' inflation targeting.

[10] Here we disregard the bank-lending channel, given its proven empirical weakness (see Kashyap and Stein, 2000, Van den Heuvel, 2002, Adams and Amel, 2005, Loutskina and Strahan, 2006, Cetorelli and Goldberg, 2008).

[11] The two variables which contain relevant information on the evolution of excess elasticity are the ratio of private sector credit to GDP and inflation-adjusted equity prices.

[12] The concept of the 'elasticity of the financial system' is by no-means new. It can be traced back to the work of Wicksell (1936) in which banks are held responsible for changes in the price level caused by the way their activities affect the velocity circulation of money. Lindahl (1970[1939]) stresses the importance of banks and the elasticity of the credit system for the general theory of price movements.

2.4 A global partial equilibrium model for the banking sector

The global partial-equilibrium model of the banking sector presented in this paper encompasses several features from the related literature discussed above. Supporting motivation for the partial equilibrium nature of the model derives from the findings by Borio and White (2004), among others. In particular, we abstract from the variables typically included in models aimed at analysing the monetary transmission mechanism (production, asset and goods prices for instance) in order to single out the dynamics between base money and banking liquidity transformation. We do, however, account indirectly for the trade balance by including an exchange rate variable. This variable may also explain the occurrence of carry-trade activities between banks located in different countries. Moreover, we account indirectly for asset-price dynamics through the inclusion of a long-term interest rate variable. Indeed, illiquid domestic credit (i.e. banks' holdings) is closely and inversely linked to longer yields. Also, long term rates influence the price of several assets used as borrowing collateral, having an effect on funding opportunities (i.e. the liabilities side of the balance-sheet) for the intermediaries.[13] Furthermore, we choose to construct a proxy for banking-liquidity creation, rather than use a variable accounting for the volume of specific credit. This choice is driven by the fact that a proxy for the former is more informative on the leveraging activity and liquidity risk faced by banks, and, thus, on the possibility of precipitating a banking crisis. Lastly, in order to assess whether banks have been responsible for cross-border liquidity transmission through international interbank markets, in each country we include a variable which describes the gross international interbank liabilities of banks. The next section takes a closer look at the variables included in our empirical model.

3 The Global VAR Model

Empirical macroeconometric studies on international liquidity transmission typically use a small-scale Vector Auto Regressive (VAR) modelling framework, as seen in Section 2.2, which fails to capture important interactions that exist

[13] Through the use of the long-term interest rate we can further account indirectly for the surplus saving/ massive purchase of US dollar-denominated international reserves by countries with less developed capital markets, as argued by some observers (see Bernanke, 2005).

between countries, i.e. through trade or financial connections. Single-country VAR-type models do not explicitly allow for the fact that a country can be more susceptible to experiencing important spillovers from shocks occurring in another country, to which it is strongly connected. The Global VAR (GVAR) framework, pioneered by Pesaran, Schuermann and Weiner (2004), is most suitable for our analysis as it allows for interdependence at a variety of levels (national and international) in a transparent way, while providing a theory-consistent solution to the curse of dimensionality in global modelling. In particular, it allows us to account for inter-country bilateral interbank linkages through the use of a weight matrix constructed from bilateral banking data on the volume of foreign claims, as will be seen in what follows. This weight matrix as discussed earlier is used to compute the foreign variables and combine the country-specific models in a global model, which in turn allows us to simulate the effect of shocks in any country-specific variable within the global system.

The GVAR approach has been used in a number of different applications ranging from business cycle co-movement analysis (Dees *et al.*, 2007, Galesi and Lombardi, 2009), to intra-industry (Hiebert and Vansteenkiste, 2007) and trade spillovers (Bussière *et al.* 2009) and default risk transmission (Chen *et al.*, 2010). More recently it has been used to assess the international spillovers arising from global liquidity shocks to asset prices (i.e. Giese and Tuxen, 2007 and Dreger and Wolters, 2009). To our knowledge, there are no empirical investigations which have looked at the international transmission of liquidity shocks in relation to banking liquidity creation.

3.1 Country Composition and Sample

The model we use comprises 24 countries, where 12 of the included European countries (EMU-12) are grouped together to form the euro area region, and the remaining 12 are modeled individually (see Table 1). The model thus contains 13 countries/regions. Regional aggregation of the euro area is carried out using PPP-GDP weights for the EMU-12 countries, averaged over $2000-2005$. Given our interest in the euro area as a whole, we chose to aggregate these countries. Our dataset is quartely and the sample period considered covers $1987q1-2007q3$. The choice of the sample end date is motivated by our focus on the driving factors leading up to the crisis, rather than on the post-crisis dynamics.

Table 1: Countries included in the GVAR

Europe		Asia
Euro area	Austria	China
	Belgium	Japan
	Finland	Saudi Arabia
	France	
	Germany	Americas
	Greece	US
	Ireland	Canada
	Italy	Mexico
	Luxemburg	
	Netherlands	Oceania
	Portugal	Australia
	Spain	New Zealand
Rest of Europe	Denmark	
	Sweden	
	Switzerland	
	UK	

3.2 ALTM Construction

We propose a measure of banking liquidity transformation that resembles, albeit on an aggregate basis, one of the four measures proposed by Berger and Bouwman (2009): namely that which classifies balance-sheet items by category and excludes off-balance-sheet commitments.[14]. In a first step, we classify all the items (assets, liabilities, equity) from the aggregate balance-sheet according to their liquidity (i.e. liquid, semi-liquid or illiquid) as shown in Table A1 in Appendix A. The data is obtained from the International Financial Statistics (IFS) of the IMF which reports the balance-sheet of *deposit money* banks for a large set of countries. The stylised balance-sheet has the format as reported in Table 2 (see Table $A1$ in the Appendix for further details).

Table 2: Balance Sheet Composition by Banks (IFS)

Assets	Liabilities
Reserves	Capital
Foreign Assets	Foreign Liabilities
Loans to Public Sector	Government Deposits
Loans to Private Sector	Time/Saving/Restricted Deposits
Loans to Financial Sector	Securities
	Liabilities to Central Bank
	Liabilities to Government
	Liabilities to Financial Sector
	Other Items (Net)

Source: IFS Economic Concept View.

A weight is attached to each class of activities according to the traditional definition of liquidity creation à la Diamond and Dybvig: banks create liquidity

[14]This is the so-called *cat non-fat* measure, and our focus on this is primarily due to inter-country data limitations.

when they invest in illiquid assets from liquid sources of funding. Thus, a positive weight of one-half is attributed to those balance-sheet items which fall into the category of both illiquid assets and liquid liabilities. A weight of the same magnitude but of opposite sign is given to liquid assets and illiquid liabilities (i.e. they are netted out), since such items do not contribute to balance-sheet vulnerability and annihilate liquidity creation (this applies to liquid assets). Semi-liquid items are given a weight of zero.[15]

The Aggregate Liquidity Transformation Measure (ALTM) is, thus, constructed according to the following formula:

$$\begin{aligned} ALTM_{it} = {} & \frac{1}{2}(Assets_{illiquid})_{it} + 0(Assets_{semi-liquid})_{it} + \\ & -\frac{1}{2}(Assets_{liquid})_{it} + \frac{1}{2}(Liabilities_{liquid})_{it} + \\ & +0(Liabilities_{semi-liquid})_{it} - \frac{1}{2}(Liabilities_{illiquid})_{it} \end{aligned} \tag{1}$$

where t, $t = 1, ..., T$ is the time subscript and i, $i = 1, ..., N$ is the country index. The ALTM is, in a nutshell, an aggregate composite measure for banks' liquidity creation which attributes positive weights to those balance-sheet items which are typically considered as being responsible for banking-sector fragility. A detailed description of the altm construction is available from the authors upon request.

3.3 Domestic Variables

The global model presented in this paper comprises the following *domestic* endogenous variables for each country in the sample[16]:

- ALTM, measured in domestic currency ($ALTM$)
- Long-term interest rate (R)
- Base Money, measured in domestic currency, ($M0$)

[15] For this asset class, these are the loan items other than credit supply to domestic private sectors or financial institutions, such as foreign assets and loans to the public sector. Semi-liquid liabilities are, instead, those items which do not greatly affect banking liquidity risk since they require some time and/or cost to be claimed back.

[16] The data appendix and detailed altm construction is available from the authors upon request.

- External Banking Liabilities vis-à-vis Foreign Banks, measured in domestic currency, (EIL)
- Nominal Exchange Rate (E), foreign currency for 1 $US\$$

The following log transformations have been carried out on the above variables, where CPI_{it} refers to the Consumer Price Index of country i at time t, equal to 1 in the base year (2005):

$$\begin{aligned} altm_{it} &= \ln(ALTM_{it}/CPI_{it}),\ r_{it} = 0.25 \times \ln(1 + R_{it}/100) \\ mb_{it} &= \ln(M0_{it}/CPI_{it}),\ eil_{it} = \ln(EIL_{it}/CPI_{it}),\ er_{it} = \ln(E_{it}) \end{aligned}$$

where ALTM, base money and banks' foreign borrowings are in real terms. Real external banking liabilities vis-à-vis foreign banks allow us to assess the degree of dependence of certain countries[17] on foreign inter-bank borrowings, as argued by Cetorelli and Goldberg (2008), and Hattori and Shin (2007) for the US. Real base money is our measure for the magnitude of the liquidity directly created by the central bank and the long-term interest rate variable is our reference-return measure.

The domestic endogenous variables chosen for each country/region are, thus, summarised by the following $k_i \times 1$ vector:

$$\mathbf{x}_{it} = (altm_{it}, r_{it}, m0_{it}, eil_{it}, e_{it})',\ i = 0, 1, ..., N.$$

The *Case-Shiller index* shows that US national home prices started picking up in the years $2001 - 2002$, when most likely the housing bubble started to inflate. Interestingly enough, over these two years our proxy of liquidity creation, base money and external interbank liabilities (all in real terms), depict an upward trend in three key economies: the US, Euro Area and the UK, see Figure $B1$. Indeed, base-money creation by central banks started increasing at a steady pace from early 2002, while external interbank liabilities increased massively thereafter. The chart suggests that banking liquidity creation is driven by base money creation in most of the sample. However, in the last 5 years (i.e. $2002-2007$) the liquidity proxy appears to be driven also by external interbank liabilities. This is particularly evident in the US and the UK. A close look at the *altm* proxy, however, shows that over the whole period $1995q1-2007q3$ real

[17] Most expectedly the developed ones, which have a less limited access to world capital markets.

ALTM tripled in the UK and more than doubled in the Euro Area. In the US, instead, *altm* was more or less stable for eight years ($1995 - 2003$) thereafter increasing by almost 40% in less than 4 years.

3.3.1 Foreign Variables

International interdependencies in the GVAR approach are modeled through the inclusion of foreign variables in the individual country models. These variables essentially proxy for global unobserved common factors (see Dees *et al.*, 2007) and are treated as long-run forcing[18],which allows consistent estimation of the country models. For each country model the vector of foreign variables, $\mathbf{x}_{it}^*$ typically contains the foreign equivalent of the corresponding domestic variables, and is constructed as a weighted average as follows. Let x_{it}^* be a specific foreign variable to be included in country i, then

$$x_{it}^* = \sum_{j=0}^{N} w_{ij} x_{jt}$$

where x_{jt} is the corresponding domestic variable for country j and w_{ij} is a set of weights such that $w_{ii} = 0$ and $\sum_{j=0}^{N} w_{ij} = 1$.

The weights w_{ij} are constructed using bilateral data on foreign claims by nationality of reporting banks (immediate borrower basis) from the Bank of International Settlement (BIS) Consolidated Banking Statistics.[19] These weights allow us to account for the linkages between banking systems through the volume of their bilateral claims. In particular, these figures refer to consolidated banks' foreign claims; therefore, we account both for the bilateral interbank claims and unconsolidated interoffice liabilities. The weights are fixed and are given by the average of the series over the period 2000-2007.[20] Table $A2$ reports the matrix of the constructed weights. As it can be noticed, most countries in the sample have the largest share of their banking claims against US banks, followed by UK banks.

[18] Long-run forcing or weak exogenous implies no long run feedback from the domestic variables to the foreign variables in the long-run, without necessarily ruling out lagged short run feedback between the two sets of variables. This is a testable assumption, which we carry out in the empirical analysis.

[19] For China, New Zealand and Saudi Arabia where bilateral consolidated banking data was not available, we used IMF Direction of Trade data to construct the weights.

[20] We disregard the possibility to use time-varying weights given the volatility and different availability of these series for all the countries in the model.

3.4 GVAR Modelling

The GVAR framework consists of two steps. In the first step the $N+1$ individual country-specific vector error-correcting models are estimated, in which the domestic variables are related to corresponding foreign variables constructed to match the international, in our case, the financial pattern of the country under consideration. The individual country models are then linked and solved simultaneously for all the endogenous variables in the system. In what follows we briefly outline the mechanics behind the GVAR framework, before turning to the country-specific empirical results and the dynamic analysis of the estimated GVAR.

3.4.1 Country-Specific $VARX^*(p_i, q_i)$ models

Consider a typical country-specific $VARX^*(p_i, q_i)$ model, where p_i and q_i are the number of lags of domestic and foreign variables respectively. For example in the case of a $VARX^*(2,1)$, abstracting from any common (global) observed factors for ease of exposition, the model is given as

$$\mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{\Phi}_{i1}\mathbf{x}_{i,t-1} + \mathbf{\Phi}_{i2}\mathbf{x}_{i,t-2} + \mathbf{\Lambda}_{i0}\mathbf{x}^*_{it} + \mathbf{\Lambda}_{i1}\mathbf{x}^*_{i,t-1} + \mathbf{u}_{it}. \quad (2)$$

where $i = 0, 1, ..., N$ and $i = 0$ is taken to be the reference country.

The error correction form of the (2) specification can be written as

$$\Delta\mathbf{x}_{it} = \mathbf{c}_{i0} - \boldsymbol{\alpha}_i\boldsymbol{\beta}'_i[\mathbf{z}_{i,t-1} - \boldsymbol{\gamma}_i(t-1)] + \mathbf{\Lambda}_{i0}\Delta\mathbf{x}^*_{it} + \mathbf{\Gamma}_i\Delta\mathbf{x}_{i,t-1} + \mathbf{u}_{it}, \quad (3)$$

where $\mathbf{z}_{it} = (\mathbf{x}'_{it}, \mathbf{x}^{*\prime}_{it})'$, $\boldsymbol{\alpha}_i$ is a $k_i \times r_i$ matrix of rank r_i and $\boldsymbol{\beta}_i$ is a $(k_i + k^*_i) \times r_i$ matrix of rank r_i.

For estimation purposed, $\mathbf{x}^*_{it}$ are treated as 'long-run forcing' or $I(1)$ weakly exogenous with respect to the parameters of the VARX model. The VARX models are estimated separately for each country conditional on $\mathbf{x}^*_{it}$, using reduced rank regression, taking into account the possibility of cointegration both within $\mathbf{x}_{it}$ and across $\mathbf{x}_{it}$ and $\mathbf{x}^*_{it}$. This way, the number of cointegrating relations, r_i, the speed of adjustment coeffifients, α_i, and the cointegrating vectors $\boldsymbol{\beta}_i$ for each country model are obtained. Conditional on a given estimate of $\boldsymbol{\beta}_i$, the remaining parameters of the VARX model are consistently estimated by OLS regressions.

3.4.2 Solving the GVAR model

Having estimated the individual country models, the GVAR model is solved for the world as a whole (in terms of a $k \times 1$ global variable vector, $k = \sum_{i=0}^{N} k_i$), taking account of the fact that all the variables are endogenous to the system as a whole.

Starting from the following country-specific VARX(2,1) specification

$$\mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{\Phi}_{i1}\mathbf{x}_{i,t-1} + \mathbf{\Phi}_{i2}\mathbf{x}_{i,t-2} + \mathbf{\Lambda}_{i0}\mathbf{x}^*_{it} + \mathbf{\Lambda}_{i1}\mathbf{x}^*_{i,t-1} + \mathbf{u}_{it}, \quad (4)$$

define $\mathbf{z}_{it} = (\mathbf{x}'_{it}, \mathbf{x}^{*\prime}_{it})'$ and write (4) for each economy as

$$\mathbf{A}_{i0}\mathbf{z}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{A}_{i1}\mathbf{z}_{it-1} + \mathbf{A}_{i2}\mathbf{z}_{it-2} + \mathbf{u}_{it},$$

where

$$\mathbf{A}_{i0} = (\mathbf{I}_{k_i}, -\mathbf{\Lambda}_{i0}), \quad \mathbf{A}_{i1} = (\mathbf{\Phi}_{i1}, \mathbf{\Lambda}_{i1}), \quad \mathbf{A}_{i2} = (\mathbf{\Phi}_{i2}, \mathbf{0}).$$

We can then use the link matrices $\mathbf{W}_i$, defined by the financial weights w_{ij}, to obtain the identity

$$\mathbf{z}_{it} = \mathbf{W}_i\mathbf{x}_t, \quad (5)$$

where $\mathbf{x}_t = (\mathbf{x}'_{0t}, \mathbf{x}'_{1t}, ..., \mathbf{x}'_{Nt})'$ is the $k \times 1$ vector which collects all the endogenous variables of the system, and $\mathbf{W}_i$ is a $(k_i + k_i^*) \times k$ matrix.

Using the identity given by (5) it follows that

$$\mathbf{A}_{i0}\mathbf{W}_i\mathbf{x}_t = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \mathbf{A}_{i1}\mathbf{W}_i\mathbf{x}_{t-1} + \mathbf{A}_{i2}\mathbf{W}_i\mathbf{x}_{t-2} + \mathbf{u}_{it}, \text{ for } i = 0, 1, 2, ..., N,$$

and these individual models are then stacked to yield the model for $\mathbf{x_t}$ of the form

$$\mathbf{G}_0\mathbf{x}_t = \mathbf{a}_0 + \mathbf{a}_1\mathbf{t} + \mathbf{G}_1\mathbf{x}_{t-1} + \mathbf{G}_2\mathbf{x}_{t-2} + \mathbf{u}_t. \quad (6)$$

The coefficients $\mathbf{G}_0, \mathbf{G}_1$ and $\mathbf{G}_2$ depend on the financial weights and individual country parameter estimates. Premultiplying (6) by the inverse of the non-singular $\mathbf{G}_0$ matrix, the GVAR(2) model is obtained as

$$\mathbf{x}_t = \mathbf{b}_0 + \mathbf{b}_1\mathbf{t} + \mathbf{F}_1\mathbf{x}_{t-1} + \mathbf{F}_2\mathbf{x}_{t-2} + \boldsymbol{\varepsilon}_t, \quad (7)$$

where

$$\mathbf{F}_1 = \mathbf{G}_0^{-1}\mathbf{G}_1, \quad \mathbf{F}_2 = \mathbf{G}_0^{-1}\mathbf{G}_2$$
$$\mathbf{b}_0 = \mathbf{G}_0^{-1}\mathbf{a}_0, \ \mathbf{b}_1 = \mathbf{G}_0^{-1}\mathbf{a}_1, \quad \boldsymbol{\varepsilon}_t = \mathbf{G}_0^{-1}\mathbf{u}_t.$$

No restrictions are placed on the covariance matrix $\mathbf{\Sigma}_\varepsilon = \mathbf{E}(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t')$. Each country has a $k_i \times 1$ vector of estimated residuals, $\hat{\mathbf{u}}_{it}$, from which $\hat{\boldsymbol{\varepsilon}}_t$ and $\hat{\mathbf{\Sigma}}_\varepsilon$ can be computed.

4 Empirics I: Specification and Estimation of the country-specific models

For all countries excluding the US, the set of domestic variables included in the specification of the individual models (depending on data availability) is given by

$$\mathbf{x}_{it} = (altm_{it}, r_{it}, m0_{it}, eil_{it}, e_{it})', \ i = 1, 2, ..., N.$$

The set of domestic variables for our reference/numeraire country, the US, is

$$\mathbf{x}_{0t} = (altm_{0t}, r_{0t}, m0_{0t}, eil_{0t})'.$$

The corresponding set of foreign-specific variables entering the individual country models is given by

$$\mathbf{x}_{it}^* = (altm_{it}^*, r_{it}^*, m0_{it}^*, eil_{it}^*)', \ i = 1, 2, ..., N$$

while for the US model

$$\mathbf{x}_{US,t}^* = (e_{it}^*)'.$$

Note that the US is linked to the rest of the countries through the *nominal exchange rate.* Due to the key role of the US in the global interbank markets no other foreign variables are included in this model.[21]

Unit root tests, including standard Dickey-Fuller tests and Weighted Symmetric ADF type tests, and the 5% critical values suggest that majority of our variables are integrated are $I(1)$, as we are unable to reject the null of non-

[21] For a discussion of the exclusion of the foreign exchange rate in the rest of the country models see PSW.

stationarity.[22]

Given the size of our sample, we consider a maximum of two lags for the domestic variables ($p_i = 1$ or $p_i = 2$) and we set one lag for the foreign variables ($q_i = 1$). The lag order of the domestic variables in the $VARX(p_i, 1)$ models for each country is selected according to the Akaike Information Criterion, as reported in Table $A3$. We also test for the serial correlation in the estimated country-specific residuals. Table $A4$ reports the associated F-test statistics for the individual country equations. Results suggest that serial correlation at the 5% significance level is rejected for the majority of equations.

The country-specific models are estimated based on reduced-rank regression. Table $A5$ reports the statistics of the Johansen trace test carried out to assess the number of cointegrating relationships in the individual country models. All the models include a trend restricted to lie in the cointegrating space and an unrestricted intercept. At the 95% significance level we find that small economies, which feature very open banking systems, such as Denmark, Switzerland and New Zealand have 3 cointegrating relationships. For the euro area and Japan we find 2 cointegrating relationships, while for the US and UK only 1.

Table $A6$ gives the results of the test for weak exogeneity for each of the foreign variables in the system.[23] The tests yield satisfactory results, as only in two auxiliary regressions for our non-key countries, i.e. for *altm* for Canada and Sweden, we can reject the null hypothesis of the error correction terms being jointly equal to zero.

Table $A7$ reports the estimated impact elasticities of a foreign-specific variable in the equation of its domestic counterpart in the country-specific VECMX models. Significant and large impact coefficients between domestic and foreign variables imply strong co-movement, and thus international interlinkages.

Given the evidence of changes in error variances suggested by the structural stability tests given further below, we report the t-values corrected for heteroskedasticity (White, 1980). We also include the t-values corrected for heteroskedasticity and serial-correlation (Newey and West, 1987). The estimates point to strong interlinkages among all the economies' bond markets as all the impact elasticities of the variable ir_{it} are large, positive and highly significant.

[22] Real monetary base, long-term rates and exchange rates are unambiguously I(1). We found marginal evidence that the altm series is I(2) for Japan, the UK and the US. Similarly for the corresponding foreign series, for Australia and Canada. This could be due to the composite nature of the series. Given that first-differencing implies a large loss of information in the dynamics of the series, we decided to use it in levels.

[23] Details of the regressions carried out for this test are provided in Appendix C.

External interbank liabilities have significant, large and positive impact elasticities on the domestic counterpart variables in the models for the Euro Area, Canada, Denmark, Japan, Sweden, Switzerland and the UK. Most notably a 1% increase in el^*_{it} leads to a intra-quarter increase in el_{it} by 1.6% in Switzerland. The foreign correspondents of our proxy for liquidity creation do not have many significant impact elasticities. This can be due to the fact that these variables are affected by institutional features of the banking system and financial markets which result in more lengthy transmissions. By contrast, impact elasticities for foreign monetary base for Japan, Mexico, New Zealand, Canada, Sweden, Switzerland and the UK are positive and significant, and particularly large for the former three economies. This result can be interpreted as a prompt response of domestic monetary authorities aimed to adjust high-powered money supply in response to policy implementation followed abroad.

Having conditioned on the foreign variables at the estimation stage (to account for the presence of unobserved common factors), we would expect the idiosyncratic country-specific shocks to only be weakly cross-sectionally dependent. This is one of the key assumptions underlying the GVAR modelling framework. To examine whether this is indeed the case, for each variable Table $A8$ reports average pairwise cross-section correlations computed between countries, using the variables in levels and first differences, as well as the estimated individual country residuals. The long term interest rates show the highest cross-section correlation among the variables in level ranging between $81\%-93\%$; they are followed by base money for which cross-section correlation ranges between $50\% - 87\%$. First-differencing shows lower cross-correlations, most notably for our focus economies. Cross-correlations of the residuals are much smaller than those reported for the variables in levels and first differences, implying that the foreign country-specific variables have been effective in reducing the cross-section correlation of the variables in the GVAR model.

In Table $A9$ we report a summary of several test statistics to assess the structural stability of the estimated coefficients[24] and error variances of the country-specific VECMX models. The tests considered include the PK_{sup} and the PK_{mse} tests found in Ploberger and Krämer (1992), the parameter constancy test by Nyblom (1989), different Wald tests as found in Quandt (1960), QLR, Hansen (1992) , MW, and Andrews and Ploberger (1994), APW. The critical values are obtained by bootstrapping the GVAR model, along the lines

[24] We only consider the stability of the short-run coefficients. Given the limited number of observations, tests for structural stability of long-run parameters are not feasible.

described in Dees *et al.* (2007). Table $A11$ reports the number of times, i.e. across all countries, that the null hypothesis of parameter constancy is rejected for the various tests (the heteroskedasticity-robust version of the tests is also considered). The number of rejections differs across tests. It is generally quite small, though higher for the non-robust versions of the tests. This suggests that the instabilities in the model can be attributed to breaks in error variances (i.e. rather than parameter instability).

5 Empirics II: Dynamic Analysis of the GVAR

The GVAR model consists of 57 endogenous variables, including 22 cointegrating relationships and 35 stochastic trends. The eigenvalues of the model, suggest that it is dynamically stable. In particular, all eigenvalues are less or equal to one and the *moduli* of the three largest non-unity ones are equal to 0.90023, 0.865121 and 0.854643.

Figure $B2$ shows the time profiles of the effect of a system shock on the cointegrating relations in the GVAR model. Introduced by Pesaran and Shin (1996), persistence profiles allow us to assess the speed at which the cointegrating relationships return to their equilibrium states. They are an essential part of assessing the stability of the model. The persistence profiles of our exactly-identified cointegrating relations are well-behaved, tending to zero as the time horizon increases, as expected in the case of valid cointegrating vectors.

5.1 Generalised Impulse Response Functions

To assess the relative importance of different shocks and channels of transmission mechanisms in our global model, we use generalised impulse response functions (GIRFs), introduced in Koop, Pesaran and Potter (1996) and adapted to VAR models in Pesaran and Shin (1998). GIRFs are invariant to the ordering of the variables in the model. However, as they use the historically observed distribution of the errors to integrate out the effects of other shocks we cannot give the shocks a structural interpretation.

We consider the effects of both country specific and global shocks. The latter are shocks common to all countries defined in terms of PPP-GDP weights (see Appendix for further details). In particular, we first consider the effects of a global shock to base money as our interest is in investigating which countries augment their eil_{it} and/or $altm_{it}$ following a positive such shock. This way, we can investigate where an *EILC* might be active. We next report selected GIRFs corresponding to a shock to M0 in the US, in order to examine whether the increase in global M0 can be attributed to an initial M0 creation stimulus by the US. Finally we report the effect of a shock to eil_{it} on selected variables in the three largest economies: the US, the UK and the Euro Area.

5.1.1 A shock to M0

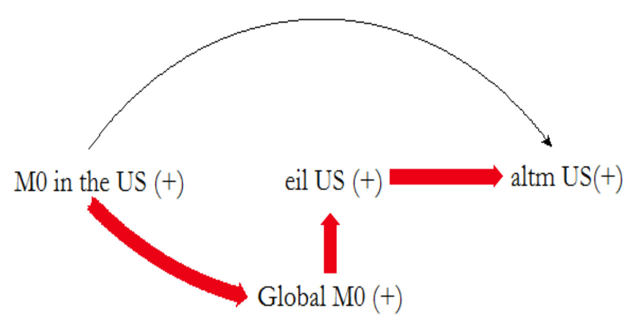
Global We consider a positive one standard error (1 s.e.) shock to **global M0**, which on impact is equivalent to a rise in M0 equal to 0.91%.and 0.8% on average in the medium/long-run. Figure $B3$ reports the response of the variable *altm* for selected countries together with 90% bootstrap confidence bounds. The most striking result is that *altm* increases in the US; this increase becomes significant after eight quarters, stabilising to around 1.4% on average. While *altm* in many countries does not respond significantly, in the Euro Area and Japan its response is negative and significant. The significant fall in *altm* in Japan can be the result of a decrease in Japanese banks' liquid assets stemming from the fact that foreign banks switch to liquidity coming from elsewhere (see Hattori and Shin, 2007). For Japan, this result is supported further by looking at the response of *eil* following a shock to global M0, as showed in Figure $B4$. Indeed, Japanese banks increase significantly their external interbank borrowings in order to make up for the shortfall in their liquid assets. For the Euro Area, instead, the negative and significant response corresponding to the *altm* variable could be due to the fact that Euro Area banks are typically creditors in global interbank markets. Therefore, higher global liquidity might result in lower demand for Euro Area loans in international interbank markets, which results in a slow-down in liquidity transformation by these banks. The response of *eil* for the US (figure $B4$), is positive and significant after four quarters. This response, together with the response of *altm*, suggest that for the US an *EIL Channel* might be actually at work. Indeed, a positive shock to global base money has a positive and significant effect on *eil* within the first four quarters and one year later this effect becomes significant for *altm* in the US.

US In figure $B5a$ we report the impulse responses following a positive 1 s.e. shock to M0 in the US. On impact central banks in many countries, apart from the Euro Area, expand their high-powered money supply, following the US. The effect is significant over the first year for the UK, Japan and New Zealand. In

Canada and Mexico, on the other hand, the effect is permanent and significant over the whole horizon. A closer look at the magnitude of the impacts shows that central banks in New Zealand and Mexico respond to the shock in M0 in the US by largely augmenting their M0 creation. Indeed, a 1% increase in M0 in the US on impact is followed by an increase in M0 by 3.7% and 1.9% in New Zealand and Mexico respectively. This evidence might be explained by the fact that these two countries rely largely on foreign investments in commodity markets; therefore, central banks expand their liquidity supply in order to avoid a damaging decrease in competitiveness.

Our impulse responses show that US banking liquidity creation is affected by M0 liquidity creation through two channels, as described in figure 1. A first direct channel works through the domestic money multiplier (see figure *B*5*b*). We also find that a further indirect channel is at work for the US. In a loop-effect, an increase in US M0 stimulates global M0 creation, which in turn is channeled through the US via the international interbank markets. This additional liquidity is then used by US-based banks to expand their liquidity creation.

Figure 1: Liquidity-Loop in the US



5.1.2 A shock to eil in various countries

US: Effect on Exchange Rates Figure *B*6 reports the impulse responses for the exchange rate variable for several countries following a positive 1 s.e. shock to *eil* in the US, equal to 3% on impact and 3.2% on average thereafter. These results are of interest as they reveal dynamics which are related to carry trade activities undertaken by US banks. In particular, a positive 1 s.e. shock to *eil* in the US shows a significant appreciation of the UK and New Zealand currency. The UK Pound appreciates significantly over the first year by about 0.7%; the New Zealand Dollar appreciates after seven quarters by about 2%. Currencies in the UK and New Zealand have often been labelled as *target* currencies. The high yields in these countries have stimulated the purchase of their currencies, financed possibly by borrowing funding, i.e. low-yielding, currencies. The appreciation in these countries' exchange rates is the result of the increased purchase of these higher-yielding currencies. A puzzling result, however, is the response of exchange rates in those countries, whose currencies are typically considered as *funding* ones, like Japan and Switzerland. Given the low borrowing costs in these countries we would expect their currencies to depreciate given the fact that they are sold short to buy *target* currencies. However, the responses of exchange rates in these countries show a significant appreciation in the short/medium run. One possible explanation for this is that funding *target* currencies over the sample considered have changed over time. For instance, the Japanese Yen has been a *funding* currency over some part though not the entire sample considered (especially since the post-2001 Quantitative Easing). Also, another possible explanation is that we do not consider exchange rate volatility in our model; this is an important variable in explaining carry trade activities (see Galati *et al.*, 2007).

UK: Effect on External Interbank Liabilities and other selected variables Figure *B*7*a* shows the responses of the *eil* variable for several countries following a positive 1 s.e. shock to *eil* in the UK, equal to 4.7% on impact and 5.1% on average thereafter. The responses highlight the relative importance of the UK banks in the international interbank markets, and especially in Europe. Indeed, *eil* responds positively and significantly in countries such as the Euro Area, Denmark, Sweden, Switzerland and Canada. The increase remains significant in all cases, apart from Switzerland in which it turns insignificant after five years. Figure *B*7*b*, shows additional responses to the same shock. In particular, *altm* increases significantly in Denmark. This is probably a second-round effect resulting from the domestic increase in *eil*, stimulated in turn by the increase in the external interbank debt by the UK banks. The *altm* variable in the US also shows a significant increase after the first two quarters. The increase in banks' liquidity creation in the US following a positive shock to *eil* in the UK might be due to several reasons, such as UK banks' leverage in international interbank markets to finance liquidity transformation in the US banking industry.

This effect is supported by the fact that after the subprime crisis banks in the UK have reported the largest losses on loans made to the US (see IMF, Global Financial Stability Report, 2009).

Euro Area: Effect on all variables Lastly, interesting patterns of response arise when shocking *eil* in the Euro Area. Figure $B8$ shows how the domestic endogenous variables respond to a positive shock to *eil* in the Euro Area, equal to 3.7% on impact and stabilising to 5.8% as the time-horizon increases. Bank liquidity creation increases significantly after three quarters, stabilising to about 1.13%. Therefore, even if the *EILC* is not active in the Euro Area, external interbank liabilities play a role in increasing banking liquidity creation domestically. The increase in the long term interest rate, which is significant after six quarters, might imply that the banks in the Euro Area borrow on international interbank markets to finance domestic long-term assets. The significant appreciation of the domestic currency vis-à-vis the US dollar further supports this finding.

6 Conclusions and Policy Implications

This paper explores the pre-crisis implications of the interaction between high-powered money and banks' liquidity creation in a global context. The analysis is complemented by an investigation of whether banks are directly responsible, through their excessive external borrowings in interbank markets, for the international transmission of liquidity shocks.

Our results point to some interesting findings. Firstly, global liquidity is found to be an important driver of banking liquidity creation, in particular, in the US, where an External Interbank Lending Channel was likely active in the two decades preceding the crisis. The US has played a leading role in both transmitting liquidity shocks across borders and affecting banking activities. We observe that a positive shock to M0 in the US has second-round effects on US banks' liquidity creation, due to several countries following the high-powered liquidity creation by the Fed. The resulting increase in global M0, in turn, stimulates US banks' liquidity creation. Our findings also suggest that the scope of borrowing from international interbank markets differs across countries. In the Euro Area, we find that external interbank liabilities affect domestic banking-sector liquidity creation, although they do not respond significantly to base-money shocks originating elsewhere. This borrowed liquidity is likely to be kept within domestic borders. UK-based banks, on the other hand, with a leading role particulary in European interbank markets, affect banking liquidity creation in the US. This is possibly due to the fact that banks based in the UK channel liquidity home before exporting it to the US. There is, indeed, evidence that much of the global liquidity reaches UK financial intermediaries before being channelled to the US (IFSL, 2008).

Important policy implications arise from our results. Clearly, understanding the interaction between high-powered money and banks' liquidity creation in a global context can enhance in the design and evaluation of policies to reduce the risks and manage the impact of liquidity crises. So far, at the domestic level, the need for policies aimed at reducing banking fragility has been emphasised. At the international level, our findings suggest that further prominence needs to be assigned to the monitoring and regulation of transactions in the international interbank markets during non-crisis times, as these can have important implications for domestic banking liquidity creation. Indeed, limiting liquidity channelling by banks through international interbank markets can be a valuable preventive tool for excessive bank-liquidity creation.

We also stress the dangers of increased global M0 creation. Given the evidence we find of a liquidity-loop in the US, a desirable outcome, particularly for the US, would be to limit the size of global M0 through central banks' cross-border coordination. However, this is most likely a practically infeasible outcome given that it may conflict with the policies implemented to achieve a given domestic inflation target. These issues clearly remain a challenge for policymakers in the years to come.

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Appendix A: Tables

TABLE A1: Balance Sheet Activities Classification (by category)

	Illiquid	Semi-Liquid	Liquid
		Assets	
Weight	$\frac{1}{2}$	0	$-\frac{1}{2}$
	Loans to Domestic Sector	Foreign Assets	Loans to Banking S.
		Loans to Public S.	Loans to Financial S.
			Reserves
		Liabilities	
Weight	$-\frac{1}{2}$	0	$\frac{1}{2}$
	Capital	Time/Saving/Restricted Deposits	Liabilities with C. B.
	Medium/Long Term Foreign	Foreign Liabilities	Demand Deposits
	Bonds	Liabilities to Non-resident	Liabilities to Financial S.
		Liabilities to Government	Liabilities to Banking S.
		Foreign Liabilities	MM Instruments
		Government Deposits	
		Shares	
		Securities Other Than Shares	

Table A2: Weight Matrix

	China	EuroArea	Japan	Mexico	Australia	Canada	N. Zealand	S. Arabia	Denmark	Sweden	Switzerland	UK	US
China	-	0,007	0,020	0,000	0,004	0,002	0,098	0,101	0,000	0,003	0,004	0,019	0,023
EuroArea	0,121	-	0,034	0,044	0,005	0,002	0,214	0,317	0,035	0,075	0,018	0,047	0,049
Japan	0,333	0,069	-	0,014	0,009	0,020	0,137	0,221	0,002	0,005	0,080	0,064	0,159
Mexico	0,013	0,032	0,004	-	0,001	0,012	0,011	0,004	0,000	0,002	0,003	0,006	0,135
Australia	0,046	0,027	0,030	0,000	-	0,022	0,268	0,020	0,000	0,011	0,013	0,072	0,068
Canada	0,034	0,018	0,030	0,056	0,003	-	0,021	0,013	0,002	0,006	0,010	0,015	0,091
NewZealand	0,005	0,003	0,003	0,000	0,533	0,001	-	0,004	0,000	0,000	0,001	0,010	0,005
SaudiArabia	0,009	0,002	0,002	0,000	0,001	0,000	0,014	-	0,000	0,000	0,001	0,004	0,004
Denmark	0,007	0,018	0,006	0,000	0,001	0,011	0,006	0,003	-	0,404	0,004	0,010	0,023
Sweden	0,010	0,019	0,011	0,000	0,001	0,005	0,008	0,008	0,362	-	0,006	0,013	0,018
Switzerland	0,011	0,033	0,011	0,000	0,006	0,004	0,006	0,010	0,030	0,013	-	0,017	0,033
UK	0,044	0,386	0,151	0,053	0,341	0,152	0,051	0,040	0,434	0,249	0,230	-	0,391
US	0,368	0,386	0,697	0,832	0,095	0,768	0,165	0,258	0,134	0,231	0,631	0,723	-

Notes: These figures were computed based on the Bank of International Settlement (BIS)'s Consolidated Banking Statistics bilateral data on foreign claims by nationality of reporting banks (immediate borrower basis). The weights are based on the variable 'real altm', averaged over 2000-2007.Trade weights are used for China, New Zealand and Saudi Arabia. Notes: Weights based on the variable 'real altm', averages over the years 2000-2007.

Table A3: VARX* Order of the Country-Specific Models

Akaike Information Criteria		
	p_i	q_i
China	2	1
Euro Area	2	1
Japan	1	1
Mexico	1	1
Australia	1	1
Canada	2	1
New Zeland	1	1
Saudi Arabia	2	1
Denmark	2	1
Sweden	1	1
Switzerland	1	1
UK	1	1
US	1	1

Notes: p_i and $q_i$are the lag orders of the domestic and foreign variables respectively selected based on the Akaike information criterion. For the UK the lag order of the domestic variables was set to one in order for the persistence profiles to converge to zero.

Table A4: F Statistics for the Test of Serial Correlation

	p_i	q_i		F c.v. 5%	altm	mb	eil	ir	er
CHINA	2	1	F(4,59)	2,528	2,364	**3,640**	0,441		1,296
EURO AREA	2	1	F(4,57)	2,534	1,672	**4,279**	2,291	1,603	0,707
JAPAN	1	1	F(4,62)	2,520	**3,871**	1,584	1,027	1,447	**2,968**
MEXICO	1	1	F(4,64)	2,515	1,222	1,219			1,824
AUSTRALIA	1	1	F(4,63)	2,518	1,231	1,029		0,211	1,146
CANADA	2	1	F(4,59)	2,528	1,304	1,271		**4,685**	0,571
NEW ZEALAND	1	1	F(4,62)	2,520	2,232	**3,795**	2,748	0,684	**2,956**
SAUDI ARABIA	2	1	F(4,57)	2,534	**3,054**	1,683	2,407	2,101	0,474
DENMARK	2	1	F(4,59)	2,528	1,858		1,227	1,483	0,447
SWEDEN	1	1	F(4,63)	2,518		1,394	**2,692**	**3,127**	1,899
SWITZERLAND	1	1	F(4,62)	2,520	2,355	**4,186**	0,518	1,750	1,616
UK	1	1	F(4,62)	2,520	**3,258**	2,416	0,333	0,304	1,092
US	1	1	F(4,69)	2,505	**3,867**	2,057	1,531	**5,758**	

Notes: The figures in bold denote rejection of the null hypothesis at the 5% significance levels.

Table A5: Number of cointegrating relations of the individual country models

	# Cointegrating Relationships
	Trace Test
China	2
EuroArea	2
Japan	2
Mexico	0
Australia	1
Canada	1
NewZealand	3
SaudiArabia	2
Denmark	3
Sweden	1
Switzerland	3
UK	1
US	1

Notes: The number of cointegrating relations is determined based on the 5% significance level.

Table A6: F Statistics for Testing the Weak Exogeneity of the Country-Specific Foreign Variables

	F-test	**F c.v. 5%**	**altm***	**mb***	**eil***	**ir***	**er***
China	F(2,65)	3,138	0,696	1,942	0,288	0,258	
Euro Area	F(2,63)	3,143	1,431	0,412	0,943	1,108	
Japan	F(2,68)	3,132	0,298	1,461	0,278	1,685	
Mexico	F(0,72)						
Australia	F(1,70)	3,978	0,123	0,060	1,549	0,946	
Canada	F(1,64)	3,991	**5,159**	0,200	2,170	0,162	
New Zealand	F(3,67)	2,742	0,391	0,122	2,664	1,808	
Saudi Arabia	F(2,69)	3,130	0,661	2,936	0,236	0,001	
Denmark	F(3,64)	2,748	1,732	0,176	1,260	0,933	
Sweden	F(1,70)	3,978	**4,247**	0,648	0,000	0,207	
Switzerland	F(3,67)	2,742	1,063	0,919	0,922	0,751	
UK	F(1,69)	3,980	1,869	0,041	0,019	1,596	
US	F(1,73)	3,972					0,177

Notes: The figures in bold denote rejection of the null hypothesis at the 5% significance levels.

Table A7: Contemporaneous Effects of the Foreign Variables on their Domestic Counterparts

		altm	mb	eil	ir
CHINA	Coefficient	**-0,852**	**0,254**	**-0,001**	
	t-Ratio	-3,299	1,107	-0,003	
	White's Adjusted t-Ratio	-3,065	1,221	-0,004	
	Newey-West's Adjusted t-Ratio	-3,028	1,393	-0,004	
EURO AREA	Coefficient	**-0,076**	**-0,248**	**0,745**	**0,878**
	t-Ratio	-1,024	-1,004	4,072	11,017
	White's Adjusted t-Ratio	-0,593	-1,099	4,310	13,630
	Newey-West's Adjusted t-Ratio	-0,587	-1,466	4,485	12,121
JAPAN	Coefficient	**-0,307**	**0,926**	**0,501**	**0,713**
	t-Ratio	-1,288	3,152	2,219	6,275
	White's Adjusted t-Ratio	-1,299	3,337	2,019	5,049
	Newey-West's Adjusted t-Ratio	-1,305	2,912	2,387	5,805
MEXICO	Coefficient	**-2,094**	**1,722**		
	t-Ratio	-1,704	3,419		
	White's Adjusted t-Ratio	-1,778	5,580		
	Newey-West's Adjusted t-Ratio	-2,341	5,794		
AUSTRALIA	Coefficient	**0,393**	**0,080**		**0,908**
	t-Ratio	1,339	0,986		7,959
	White's Adjusted t-Ratio	0,843	1,475		7,372
	Newey-West's Adjusted t-Ratio	0,848	1,364		7,281
CANADA	Coefficient	**0,775**	**0,880**	**0,732**	**0,871**
	t-Ratio	2,215	7,489	3,393	11,936
	White's Adjusted t-Ratio	1,521	4,593	3,088	9,080
	Newey-West's Adjusted t-Ratio	1,650	3,938	3,326	9,079
NEW ZELAND	Coefficient	**-0,058**	**1,458**	**-1,187**	**1,173**
	t-Ratio	-1,331	2,092	-2,269	10,466
	White's Adjusted t-Ratio	-1,783	1,540	-1,263	12,363
	Newey-West's Adjusted t-Ratio	-1,759	1,340	-1,208	12,262
SAUDI ARABIA	Coefficient	**-0,221**		**-0,454**	
	t-Ratio	-0,537		-1,942	
	White's Adjusted t-Ratio	-0,630		-1,661	
	Newey-West's Adjusted t-Ratio	-0,601		-1,978	
DENMARK	Coefficient	**-0,061**		**0,957**	**1,028**
	t-Ratio	-0,167		5,910	12,513
	White's Adjusted t-Ratio	-0,267		6,115	14,542
	Newey-West's Adjusted t-Ratio	-0,254		6,450	14,246
SWEDEN	Coefficient		**0,415**	**1,211**	**1,327**
	t-Ratio		2,853	8,682	13,804
	White's Adjusted t-Ratio		3,255	5,167	10,250
	Newey-West's Adjusted t-Ratio		3,274	4,964	10,223
SWITZERLAND	Coefficient	**0,044**	**0,509**	**1,553**	**0,556**
	t-Ratio	0,479	2,872	6,081	5,865
	White's Adjusted t-Ratio	0,564	2,188	7,077	7,110
	Newey-West's Adjusted t-Ratio	0,505	1,880	6,798	7,391
UK	Coefficient	**0,508**	**0,506**	**0,969**	**0,728**
	t-Ratio	2,850	3,395	4,869	9,687
	White's Adjusted t-Ratio	1,648	5,960	4,211	6,760
	Newey-West's Adjusted t-Ratio	1,619	5,187	3,872	6,478

Table A8: Average Pairwise Cross-Section Correlations of Variables and Residuals

	Levels	First Diff.	Res. Varx*		Levels	First Diff.	Res. Varx*
		atlm				e	
China	0,632	-0,209	-0,046	**China**	0,203	-0,017	0,000
EuroArea	0,662	-0,004	0,018	**EuroArea**	0,580	0,043	-0,128
Japan	-0,229	0,017	0,063	**Japan**	-0,094	0,215	0,138
Mexico	-0,087	-0,013	-0,005	**Mexico**	0,196	-0,112	0,005
Australia	0,662	0,060	0,032	**Australia**	0,608	0,302	0,192
Canada	0,625	0,011	0,009	**Canada**	0,529	0,224	0,138
NewZealand	0,651	-0,010	0,005	**NewZealand**	0,545	0,311	0,137
SaudiArabia	0,653	-0,011	0,002	**SaudiArabia**			
Denmark	0,436	0,066	0,005	**Denmark**	0,551	0,383	0,152
Sweden				**Sweden**	0,569	0,376	0,128
Switzerland	0,658	0,074	0,024	**Switzerland**	0,439	0,357	0,199
UK	0,660	0,082	-0,032	**UK**	0,456	0,355	0,153
US	0,015	0,059	0,025	**US**			
	Levels	**First Diff.**	**Res. Varx***		**Levels**	**First Diff.**	**Res. Varx***
		eil				mb	
China	0,448	-0,023	0,003	**China**	0,843	0,094	-0,013
EuroArea	0,710	0,334	0,032	**EuroArea**	0,701	-0,019	-0,087
Japan	-0,478	0,107	-0,018	**Japan**	0,838	0,092	-0,027
Mexico				**Mexico**	0,838	0,204	0,006
Australia				**Australia**	0,749	0,129	0,014
Canada	0,656	0,150	0,011	**Canada**	0,864	0,279	0,003
NewZealand	0,603	-0,091	0,029	**NewZealand**	0,774	0,226	0,047
SaudiArabia	0,486	-0,015	0,017	**SaudiArabia**			
Denmark	0,681	0,249	0,011	**Denmark**			
Sweden	0,513	0,277	-0,046	**Sweden**	0,802	0,177	0,037
Switzerland	0,687	0,242	0,013	**Switzerland**	0,498	0,230	0,034
UK	0,681	0,340	0,066	**UK**	0,866	0,184	0,004
US	0,707	0,119	-0,124	**US**	0,816	0,262	0,041
	Levels	**First Diff.**	**Res. Varx***				
		r					
China							
EuroArea	0,924	0,632	0,056				
Japan	0,875	0,417	-0,001				
Mexico							
Australia	0,920	0,449	-0,043				
Canada	0,932	0,578	0,089				
NewZealand	0,814	0,521	-0,091				
SaudiArabia							
Denmark	0,931	0,541	-0,038				
Sweden	0,928	0,588	0,068				
Switzerland	0,833	0,458	0,013				
UK	0,919	0,580	0,018				
US	0,896	0,544	-0,054				

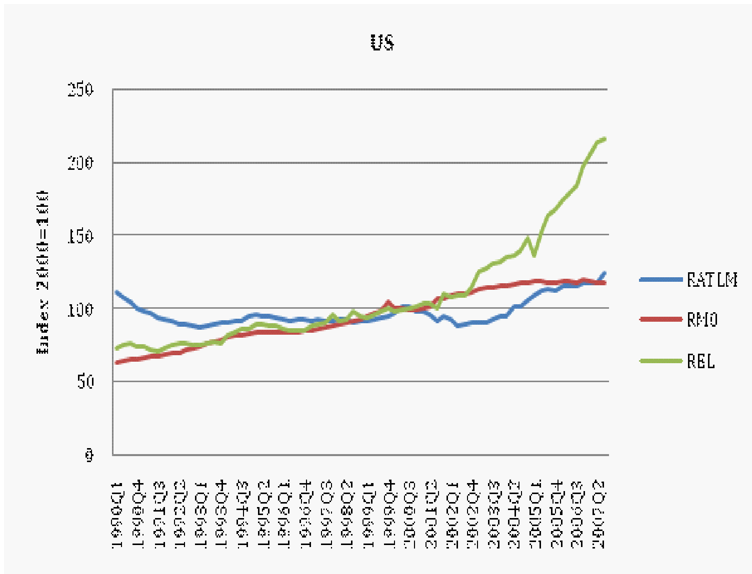
Table A9: Number of Rejections of the Null of Parameter Constancy Per Variable Across the Country-Specific Models

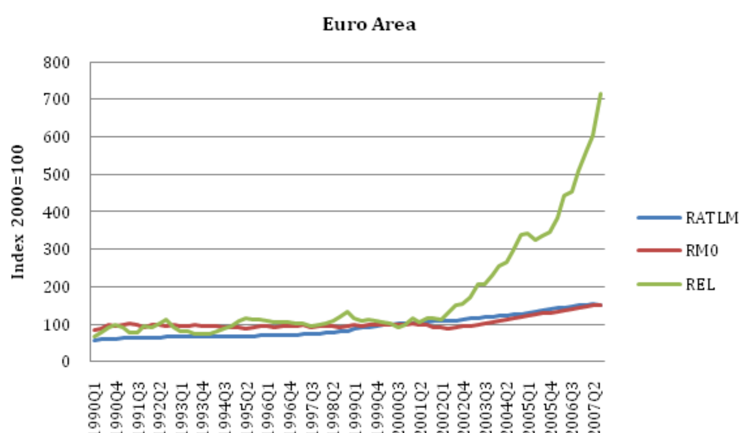
Alternative Test Statistics	altm	mb	eil	er	ir
PK sup	1	0	2	1	0
PK msq	1	1	1	1	0
Nyblom	1	1	1	1	0
Robust Nyblom	2	1	1	2	1
QLR	3	4	2	3	2
Robust QLR	1	0	2	1	0
MW	2	1	2	4	2
Robust MW	0	0	2	1	0
APW	3	3	2	4	2
Robust APW	0	0	1	1	0

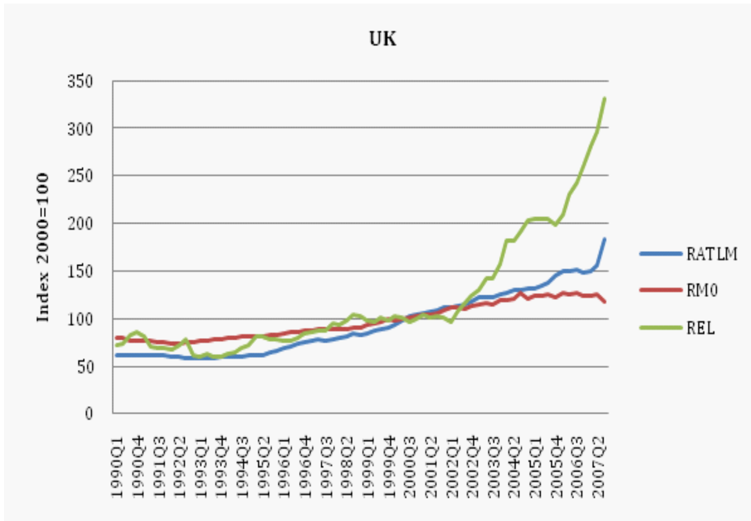
Notes: The figures are based on the 5% significance level. Critical values of the tests are obtained from bootstrapping the GVAR model using 2000 replications (see Dees et Al.)

Appendix B: Figures

Figure B1: Real $ALTM$, Real $M0$ and Real eil







Notes: The series in these graphs where calculated based on data from the IFS, BIS, ECB, Bank of Japan and Bank of England. The real ALTM variable is calculated as follows. In a first step, we classify all the items (assets, liabilities, equity) from the aggregate balance-sheet according to their liquidity (i.e. liquid, semi-liquid or illiquid). Then, a positive weight of one-half is attributed to those balance-sheet items which fall into the category of both illiquid assets and liquid liabilities. A weight of the same magnitude but of opposite sign is given to liquid assets and illiquid liabilities (i.e. they are netted out), semi-liquid items are given a weight of zero. Seasonally-adjusted series. Index 2000=100.

Figure B2: Persistence Profiles of The Long Run Cointegrating Relations of the GVAR Model (Horizon in quarters on the x-axis)

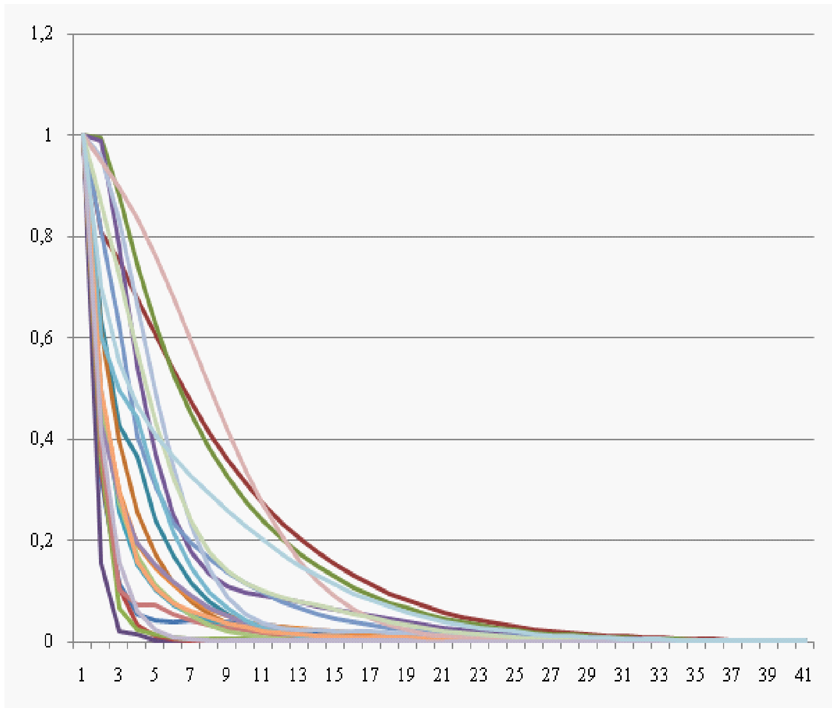


Figure B3: Effect on altm following a 1s.e. Positive Shock to Global M0

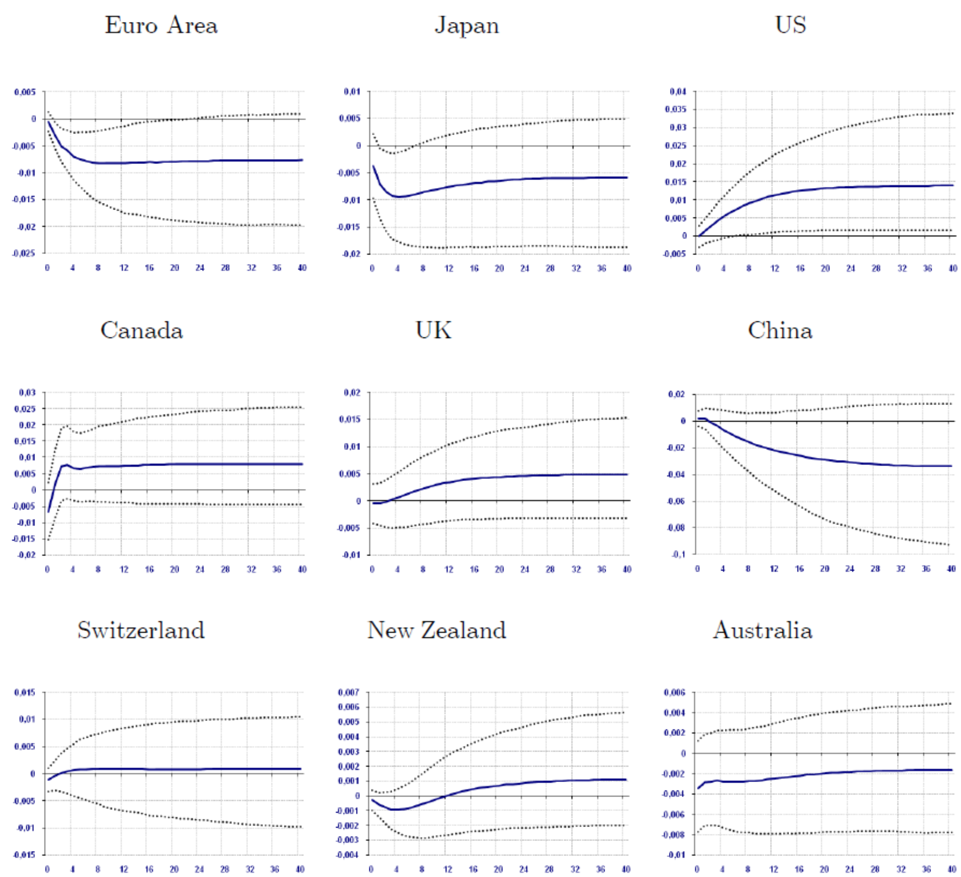


Figure B4: Effect on eil following a 1s.e. Positive Shock to Global M0

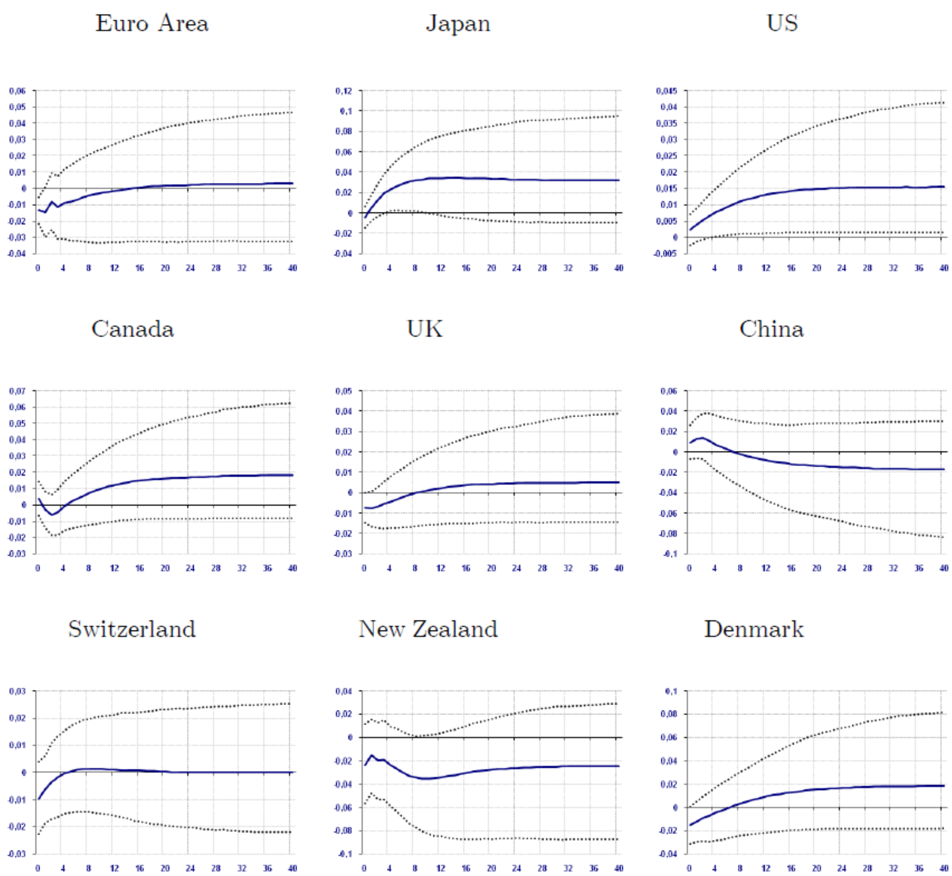


Figure B5a: Effect on M0 following a 1s.e. Positive Shock to US M0

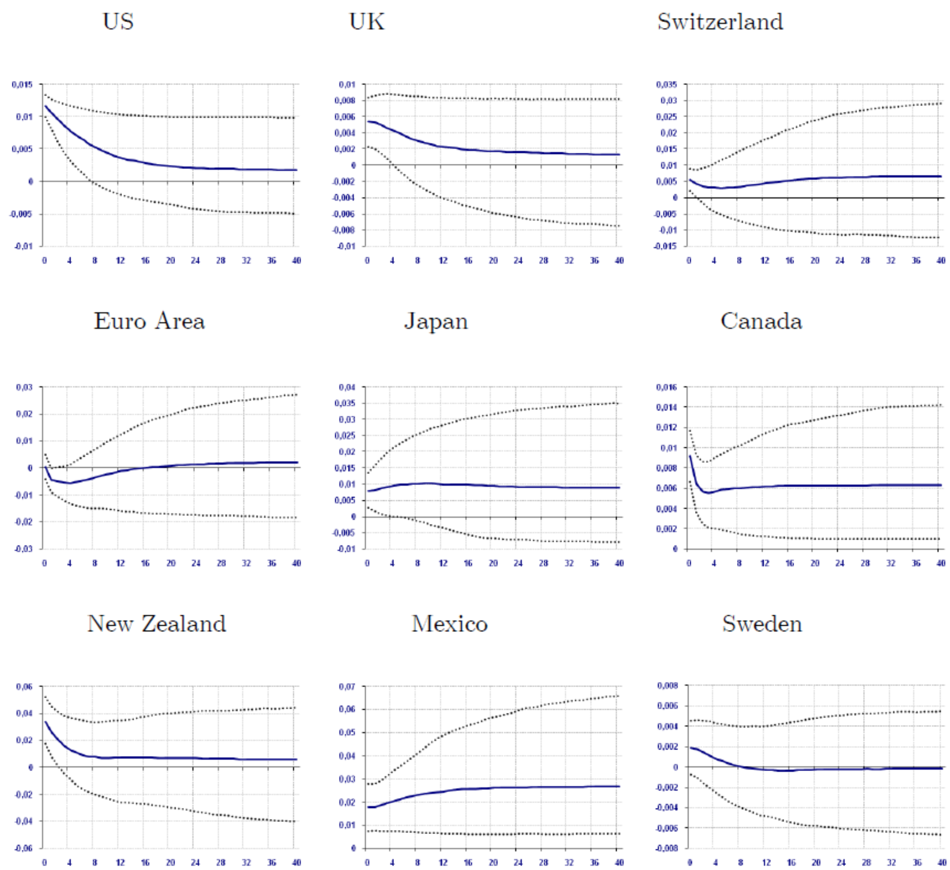


Figure B5b: Effect on US altm following a 1s.e. Positive Shock to US M0

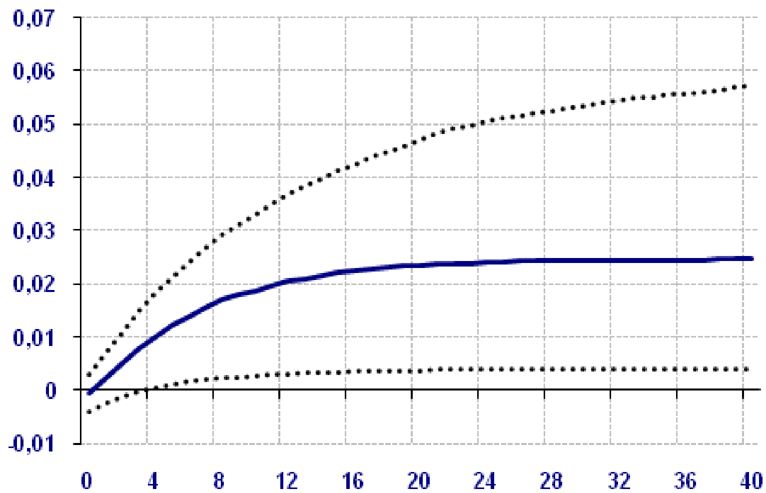


Figure B6: Effect on exchange rates following a 1s.e. Positive Shock to eil in the US

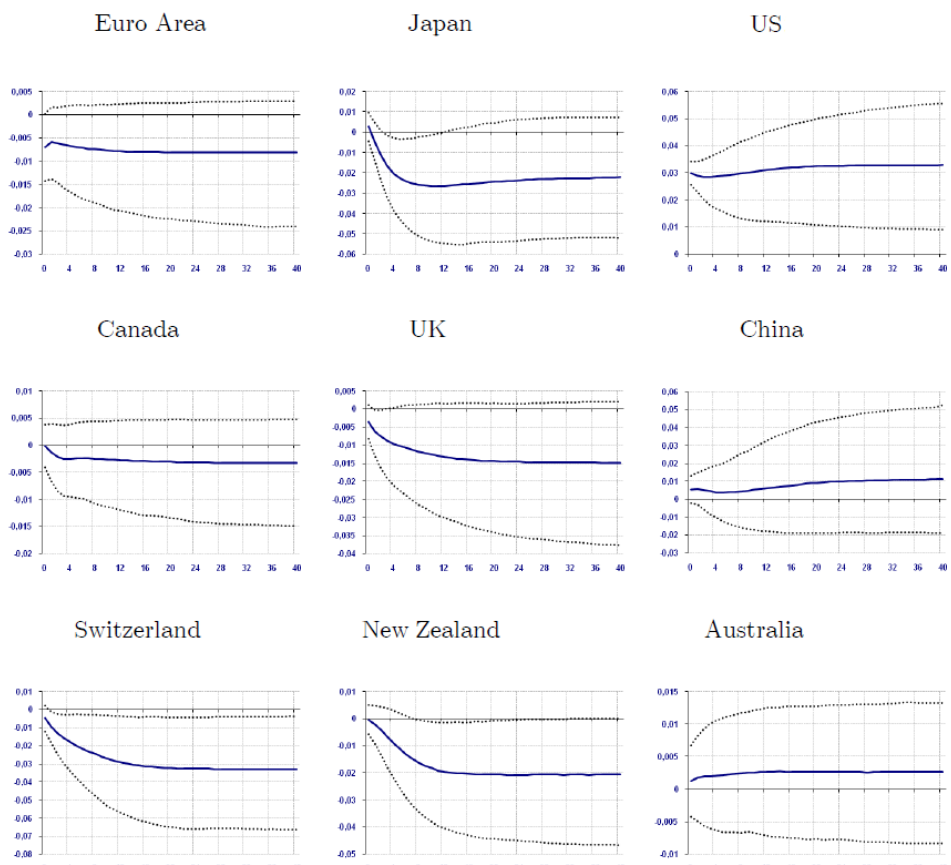


Figure B7a: Effects on eil following a 1s.e. Positive Shock to eil in the UK

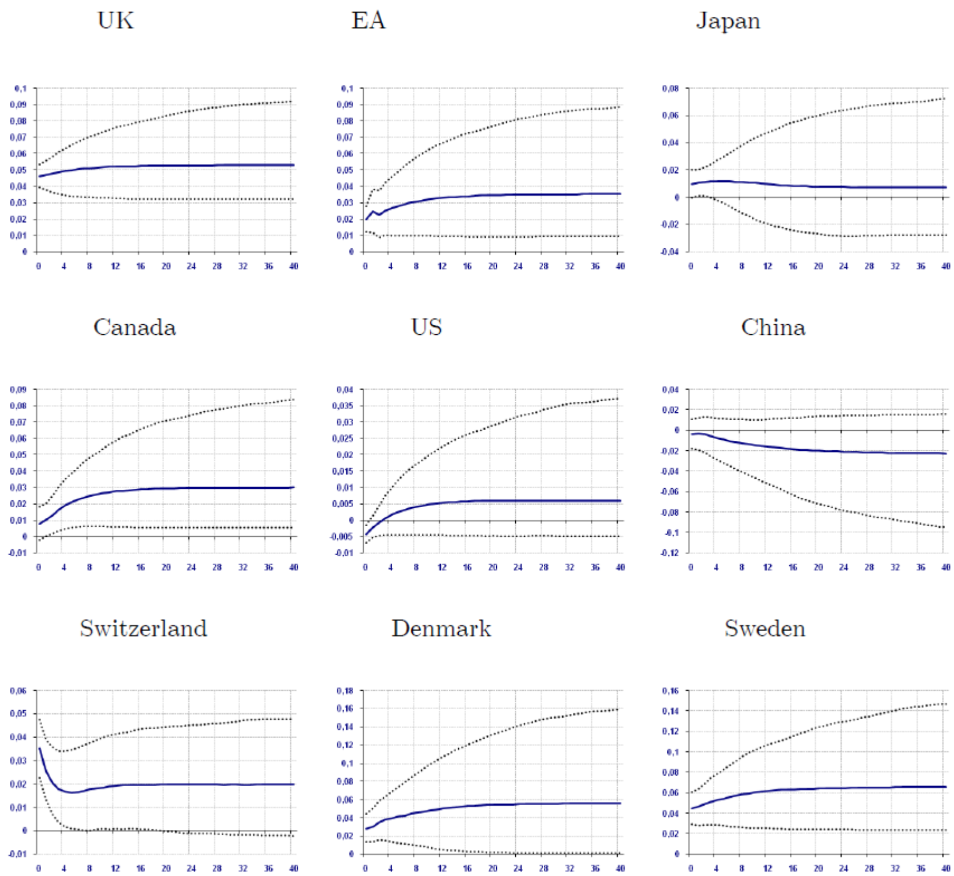


Figure B7b: Other Effects following a 1s.e. Positive Shock to eil in the UK

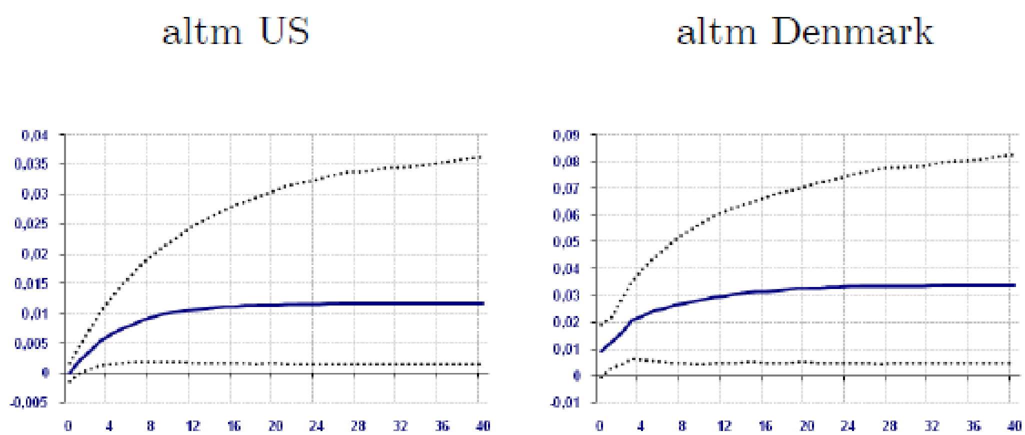
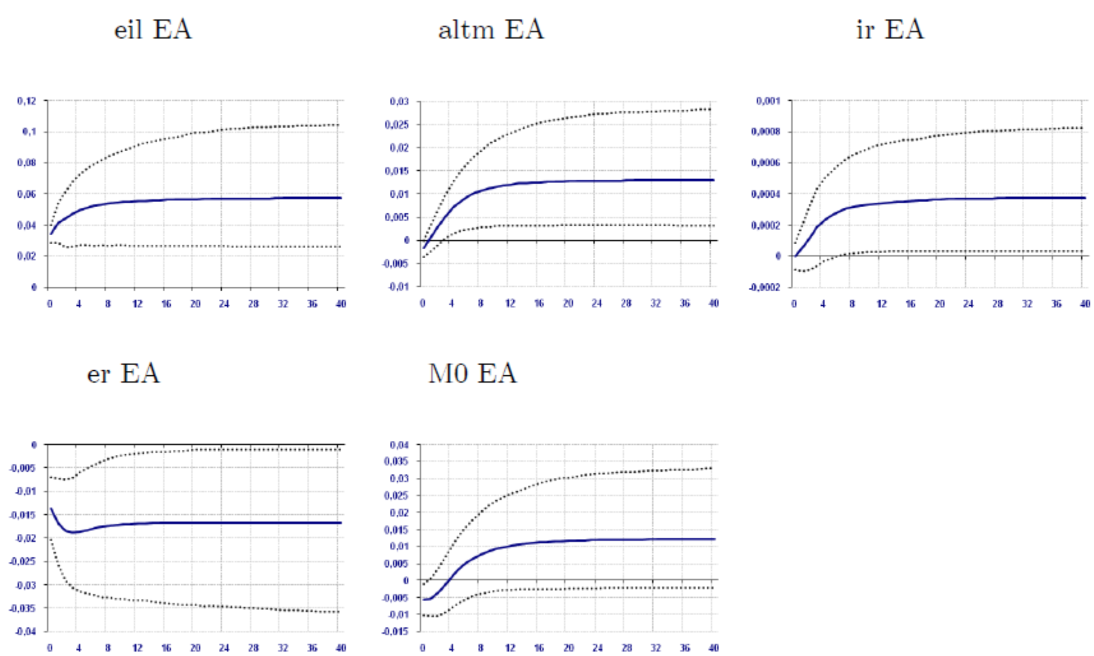


Figure B8: Selected Effects following a 1s.e. Positive Shock to eil in Euro Area



Appendix C

Test for Weak Exogeneity

Weak exogeneity is tested along the lines described in Johansen (1992). This involves a test of the joint significance of the estimated error correction terms in auxiliary equations for the country-specific foreign variables. In particular, for each ℓ^{th} element of $\mathbf{x}_{it}^*$ the following regression is carried out

$$\Delta x_{it,\ell}^* = a_{il} + \sum_{j=1}^{r_i} \zeta_{ij,\ell} ECM_{ij,t-1} + \sum_{k=1}^{s_i} \boldsymbol{\phi}_{ik,\ell}' \Delta \mathbf{x}_{i,t-k} + \sum_{m=1}^{n_i} \boldsymbol{\psi}_{im,\ell}' \Delta \widetilde{\mathbf{x}}_{i,t-m}^* + \eta_{it,\ell}$$

where $ECM_{ij,t-1}$, $j = 1, 2, ..., r_i$ are the estimated error correction terms corresponding to the r_i cointegrating relations found for the i^{th} country model, $\Delta \widetilde{\mathbf{x}}_{it}^* = (\Delta \mathbf{x}_{it}'^*, \Delta ep_{it}^*)'$ for $i = 1, ..., N$ (for the US the term Δep_{it}^* is implicitly included in $\Delta \mathbf{x}_{it}^*$), and s_i and n_i are the lag orders of the lagged changes for the domestic and foreign variables, respectively. The test for weak exogeneity is an F test of the joint null hypothesis that $\zeta_{ij,\ell} = 0$, $j = 1, 2, ..., r_i$ in the above regression. The lag orders s_i and n_i need not be the same as the orders p_i and q_i of the underlying country-specific VARX models. We set $s_i = n_i = 1$ for all i.

The Generalized Impulse Response Function (GIRF)

Consider the solution of the GVAR model expressed in terms of the country specific errors given by

$$\mathbf{G}_0 \mathbf{x}_t = \mathbf{a}_0 + \mathbf{a}_1 \mathbf{t} + \mathbf{G}_1 \mathbf{x}_{t-1} + \mathbf{G}_2 \mathbf{x}_{t-2} + \mathbf{u}_t.$$

The GIRFs are based on the definition

$$\mathcal{GIRF}(\mathbf{x}_t; u_{i\ell t}, n) = E(\mathbf{x}_{t+n} | u_{i\ell t} = \sqrt{\sigma_{ii,\ell\ell}}, \mathcal{I}_{t-1}) - E(\mathbf{x}_{t+n} | \mathcal{I}_{t-1})$$

where $\mathcal{I}_{t-1}$ is the information set at time $t-1$, $\sigma_{ii,\ell\ell}$ is the diagonal element of the variance-covariance matrix $\mathbf{\Sigma}_u$ corresponding to the ℓ^{th} equation in the i^{th} country, and n is the horizon.

On the assumption that $\mathbf{u}_t$ has a multivariate normal distribution[25], it follows that the GIRFs of a unit (one standard error) shock at time t to the ℓ^{th} equation in the above model on the j^{th} variable at time $t+n$ is given by the

[25] This result also holds in non-Gaussian but linear settings where the conditional expectation can be assumed to be linear.

j^{th} element of

$$\mathcal{GIRF}(\mathbf{x}_t; u_{\ell t}, n) = \frac{\mathfrak{e}_j' \mathbf{A}_n \mathbf{G}_0^{-1} \mathbf{\Sigma}_u \mathfrak{e}_\ell}{\sqrt{\mathfrak{e}_\ell' \mathbf{\Sigma}_u \mathfrak{e}_\ell}}, \ n = 0, 1, 2, ...; \ell, j = 1, 2, ..., k$$

where $\mathfrak{e}_\ell = (0, 0, ..., 0, 1, 0, ...0)'$ is a selection vector with unity as the ℓ^{th} element in the case of a country-specific shock. For a global M0 shock, $\mathfrak{e}_\ell$ has PPP-GDP weights that sum to one, corresponding to the M0 shocks of each of the $N + 1$ countries and zeros elsewhere.

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Part II

US Global Banks and their Scope for Inter-office Borrowings

Carmela D′Avino

Abstract

Cetorelli and Goldberg (2009) have recently showed that US global banks augment their net liabilities from foreign offices whenever domestic monetary policy restricts. Ever since the outset of the recent credit crunch, however, net borrowings from foreign offices have augmented substantially notwithstanding the extremely low inter-bank rates and abundant levels of liquidity injected by central banks in the inter-bank markets. Carry trade activities also cannot be the main driver of post-crisis dynamics in net interoffice liabilities, given high exchange rate volatilities and converging secured inter-bank rates. In this paper I argue that credit risk, arising from banks' balance sheets deteriorations, is an important driver of the dynamics of net interoffice accounts of US global banks during crisis periods.

Key Words: Global Banks, Net Inter-office Accounts, Subprime Crisis.

1 Introduction

Banks' infiltration through affiliates, branches and subsidiaries[26] in foreign banking systems has a multiple rationale. Traditionally, there are reasons linked to the exploitation of local knowledge, the increase in foreign market share, the ease of transactions with most relevant trade partners and the settlements of currency positions in the FX markets (see Mullineux and Murinde, 2003, for a survey). More recent finance-based research, however, has highlighted a few more complex facets of the operating model of global banks. Galati and Al. (2007), Hattori and Shin (2009) and McGuire and Peter (2009), for instance, have stressed the role of foreign offices for currency carry trades activities, when interest rate differential are high and exchange rate volatility is low. Cetorelli and Goldberg (2009), on the other hand, have shown that global US banks[27] exploit a further notable advantage. That is, they are better insulated from domestic adverse liquidity shocks since they can recur to an internal capital market with their affiliated offices, though which they channel liquidity. In this way, global banks stimulate the cross-border transmission of domestic liquidity shocks, other than limiting the effectiveness of the domestic monetary policy in regulating inter-bank liquidity.

The outbreak of the recent credit crisis, however, has revealed unexpected dynamics which point out that further investigation is needed for understanding the dynamics of Net Inter-Office Accounts (NIOA), that is, the difference between net liabilities and assets between parent and foreign offices. NIOA by US banks have, indeed, increased by almost 48% in less than 2 years from mid-2007 to end-2008, notwithstanding the abundant injection of liquidity in inter-bank markets by the Federal Reserve.

In this paper I argue that credit risk plays an important role in explaining NIOA during the Subprime crisis. Fears of counterparty risk arising from deteriorating balance sheets and difficulty to value certain illiquid assets have paralyzed US domestic unsecured inter-bank debt markets. During the recent credit crunch, banks holding highly safe assets could borrow at low rates on collateralized debt markets. Otherwise, banks with riskier collateral on their balance sheets had to recur to repo agreements with the monetary authorities, which were accepting a larger set of assets (i.e. including MBS) in their collateralized lending. I explore whether the limitation in borrowings against collateral, in conjuction with the increase in the costs of uncollateralized debt, has stimulated global banks to rely on foreign offices for unsecured borrowings.

[26] Throughout the paper I will refer to the general term *foreign offices* as to indicate foreign affiliates, branches and subsidiaries altogether.

[27] That is, US banks that have foreign offices.

A panel dataset containing relevant balance sheets variables for 277 US global banks over the period 1995-2010 is used for this intent. The results, as reported in section 3, point out to the fact that balance sheet deteriorations have indeed stimulated NIOA-to-total assets. This effect is evident both in the period preceding the crisis (i.e. from 2005q1) and after the crisis' outburst, even after the Lehman Borthers' failure (apart from loan losses due to securitization). Moreover, the empirical inferences show the crucial importance of the deposits available in foreign offices: NIOA-to-total assets are significantly affected also by liquidity conditions of the foreign offices, other than domestic liquidity conditions.

The paper is organized as follows: in the following section I propose a number of stylized facts in support the why credit risk is important for understanding NIOA during the recent crisis. In section 3.1 I present the data, the variables and the model to estimate. Sections 3.2, 3.3 and 3.4 discuss the empirical results obtained in four differend sample and variables specifications. Section 4 concludes.

2 Global banks and drivers of inter-offices transactions in the US

A bank is globally-oriented if it has direct access, via branches or subsidiaries, to foreign interbank markets. For banks headquartered in the US, globalization is a particularly relevant reality: in the second quarter of 2007, 17 out of the top 20 largest banks had related foreign funding facilities. Globalised banks depict a high degree of concentration: the 100 out of 8177 institutions showing positive/negative net liabilities due from/to foreign affiliates were holding the 57% of the industry's assets. Net liabilities largely outsize net assets which show positive values only for 24 banks. Over the period 1995-2009 NIOA of US banks reporting to the FDIC have increased by more than 6 times. As showed in table 1, the largest augment in this variable has been over the period 2002-2009, when the series has increased by 363%.

Existing finance-based literature advances two main explications for such a surge in NIOA. Global banks might import liquidity from their foreign offices either to cushion against adverse liquidity shocks in domestic inter-bank markets or to engage in carry trade activities. While these two rationales generally apply during normal times, a closer analysis of stylized facts regarding US global banks during the recent financial turmoil suggests that further investigation on this issue is needed.

Figure 1 shows the evolution of real NIOA over the period 2001-2009 in relation to effective federal funds rates. Over the period of the US's *great moderation* (2001-2004), characterized with low interest rates and steady growth in output and credit, NIOA growth was contained. Only towards 2005 NIOA have started increasing due to expectations of the increase in the fed-regulated interest rate. In general, over the period 2001-2007q2 an increase in fed rate is accompanied by a steady increase in net inter-office liabilities, with a correlation relationship of 0.72. This is in line with the predictions by Cetorelli and Goldberg: i.e. when domestic monetary policy is tighter liquidity flows from affiliates to parents are faster, while when it is expansionary these flows are either slower or moving in the opposite direction. However, from mid-2007 to 2009-end it can be noticed that aggregated NIOA have not slowed their increase notwithstanding the rapid and drastic cut in federal funds rate since late 2007. The correlation between the two series is, indeed, -0.33 over this period.

Carry trade activities, on the other hand, also could not justify this after-crisis behavior of NIOA. One could argue that although monetary policy in US was loosening over this period, carry trade opportunities were still profitable, given favorable interest rate differentials coupled with low exchange rate volatility. Hattori and Shin (2009), for instance, have showed that interest rate differentials between US and Japan have stimulated US offices located in Japan to engage in substantial carry trade activities before the subprime crisis. In turn, the massive growth in parent banks' Yen funding from foreign offices located in Japan (proxied by changes in net interoffice accounts) has led to a pre-crisis steady growth in the balance sheet of US securities brokers and dealers (including US investment banks). However, since late 2007, worldwide interbank interest rates have been converging; moreover, exchange rate volatilities have increased resulting in large position unwinds in the FX markets (see Melvin and Taylor, 2009). Figure 2 reports borrowings from foreign offices by location. As it can be noticed, the great majority of liquidity is imported from offices located in off-shore Caribbean centers. The exact location from which liquidity originates and, thus, the relevant interest rate differential to consider, are, therefore, impossible to be exactly understood (see Galati et al.). Graph 3, on the other hand, shows that interbank interest rate differentials were not favorable in key non-off shore countries as to justify carry-trade activities. Indeed, during 2007 central banks' interest rate differentials vis-à-vis UK and Euro Area were positive, implying that borrowing from domestic central bank was cheaper than what would have been abroad.

In this paper I explore which variables in the balance sheets of US global banks might have driven the sustained levels of net interoffice accounts. In particular, I focus on whether banks' idiosyncratic and/or aggregate credit risk (as opposite to liquidity risk), that has paralyzed the uncollateralized inter-bank debt markets in the US after the crisis, has been an important driver for explaining post-crisis dynamics in NIOA. The inability to obtain uncollateralized borrowings in the domestic interbank markets might have, indeed, stimulated global banks to import liquidity from foreign offices in order to sustain solvency. The signs of stress experienced in the unsecured credit markets since the outburst of the subprime crisis were, in fact, driven by the increase in counterparty risk in inter-bank markets arising from difficulties in pricing illiquid assets lying on the banks' balance sheets. As a result, margin requirements increased and the Libor-OIS spreads witnessed unprecedented high levels (see Hordhal and King, 2008) in US interbank markets. As showed in figure 4, since the very outset of the subprime crisis when credit risk has caused considerable departures of Libor rates from federal funds rate, changes in NIOA have been following changes in Libor rates (rather than the federal funds rate). This effect is particularly evident during the year 2008. The large drop in net interoffice liabilities towards the end 2008 and beginning 2009, instead, as could also be seen in figure 1, was probably due to the temporary credit relief due to the introduction of the Term Asset-Backed Securities Loan Facility program (TALF). In particular, in February 2009, the program was augmented by $1 Trillion and extended as to accept a much wider class of collateral (including mortgage-backed ABS).

3 An Empirical Investigations of NIOA for US Global Banks

3.1 The Panel and Variables

The empirical analysis of this paper is mainly based on bank-specific variables obtained in the quarterly Report of Condition and Income, or Call Report, collected by the Federal Financial Institutions Examination Council (FFIEC).

The quarterly unbalanced panel ranges from 1995q1 to 2010q2; the panel contains 277 cross-sections with 62 observations each. All the series considered in the different estimations are detailed in table 2. I consider all the cross-sections which have non-zero values of "Net due to/from own foreign offices, Edge and Agreement subsidiaries and IBFs" (Schedule RC-H)[28] at some point of the chosen sample[29]. In other words, a bank is considered as global whenever it has an active internal capital market with its foreign offices over the period considered.

[28] Similarly done in Cetorelli and Goldberg.
[29] In particular, banks with foreign offices compile the FFIEC 031 reporting form.

The bank-specific variables collected depict primarily both the liquidity and credit risks faced by the domestic offices of the bank as well as the liquidity conditions in the foreign offices. I particularly focus on the actual capability of each bank to borrow from domestic unsecured inter-bank debt markets (inter-bank deposits) as well as from secured borrowings (repurchase agreements). At the same time, I account for liquidity (deposits) available to the foreign offices from various sources: foreign banks, central banks and individuals in general. The health of the balance sheet of each bank is accounted for by a variety of variables, mainly describing the holdings of the bank. Among these, can be found cash and inter-bank lending (in particular, due from other banks), U.S. Treasury securities and securities in general (both held-to-maturity and available for sale), holdings of MBS, ABS and Credit Default Swaps. Nonaccrual loans of various types, including those secured by residential mortgages, are also considered in order to better account for the default risk of every single bank. Lastly, I also consider in turn some variables describing the existing capital (total equity, tier 1 and risk-based) of the bank as well as the outstanding amounts of assets which are given a high-risk weight (i.e. 50% and 100%) in the regulatory capital calculations.

Liquidity conditions in both secured and unsecured inter-bank debt markets are accounted for by the effective federal funds rate and the LIBOR (1 month) respectively. Lastly, I control for two key quantitative variables to proxy for liquidity and credit conditions in US inter-bank markets which might have been important drivers for the dynamics of the NIOA: the amounts of the Term Auction Credit supplied by the Federal Reserves and the total nonaccrual domestic inter-bank loans.

3.2 Full-sample Estimation

The inference is based on a **linear dynamic fixed-effect model** of the type:

$$y_{i,t} = \gamma_i y_{i,t-1} + \mathbf{x}_{i,t}^{'} \beta + \mu_i + v_{it} \tag{1}$$

where i is the index for each bank such as $i = 1, ..., N$ and t is the time index: $t = 1, ..., T$. Given K explanatory variables, β is a $K \times 1$ coefficient vector and $\mathbf{x}_{i,t}^{'}$ is the $K \times 1$ vector of explanatory exogenous variables; μ_i is the bank-specific unobserved individual effect and v_{it} is the white noise disturbance.

As a preliminary exercise, I consider the Least Squared Dummy Variable (LSDV)/ With-in group estimator of the coefficients of the dynamic fixed-effect model (1)[30] including exclusively those variables describing domestic and foreign

[30] See Baltagi (2005) for the details of the LSDV inference.

liquidity conditions and balance sheet health. The LSDV estimator wipes out the individual bank-specific effects by pre-multiplying (1) by a $T \times T$ idempotent matrix Q which allows to consider each variable in (1) in terms of deviations from cross-sectional means. It is well known that in a dynamic setting with a panel with a small T the LSDV estimator is biased (Anderson and Hsiao, 1982, Nickell, 1981, and Hsiao, 2003). However, in this case, all the variables considered span over a long period, i.e. 1995-2010, yielding a T as large as 60. Table 3 reports the estimates of the LSDV inference where the dependent variable is *NIOA-to-Total Assets*. A dummy variable accounting for the crisis period (i.e. equal to 1 for the period 2007q3-2010q2 and zero otherwise) and the product of the dummy with each of the variables are also included. The reported t-statistics refer to standard errors calculated under three different variance calculations. I compute ordinary estimates of the coefficient covariance (i.e. without serial and cross-section correlations and heteroskedasticity) as well as robust estimators allowing for either heteroskedasticity and serial correlation for each cross section (White period) or contemporaneous cross-section correlation (White cross section).

A few interesting features emerge from a close look at the estimates in table 3. Firstly, the coefficients of *total deposits in foreign offices* and *transaction deposits in domestic offices* are as expected: 0.648 and -0.0287. That is, an increase in *total deposits in foreign offices* has a large and positive impact on NIOA, while if domestic deposits increase, domestic offices borrow less from foreign offices. Secondly, a few coefficients of the contemporaneous variables accounting for the banks financial strength are positive and significant, implying that an improvement of the health of balance sheets stimulates inter-office borrowing by domestic offices. For instance, an increase in value of *securities assets*, both available-to-sale and held-to-maturity, and increase in *total equity* have a positive effect in NIOA-to-total assets. However, an increase in *cash holdings* leads to a significant fall in the dependent variable, suggesting that a scope for interoffice borrowing is to cope with liquidity shortage in domestic offices. Thirdly, the estimated coefficients of the lagged explanatory variables all have a negative sign. In particular, the estimates point out to the fact that a deterioration of the balance sheet in the previous period stimulates NIOA-to-total assets, although the coefficients are in absolute values lower than the contemporary counterparties, whenever available. The lagged value of the *effective federal funds rate* is, on the other hand, negative and significant, implying that a restrictive monetary policy in the previous period stimulates interoffice liabilities. The *Libor rate* is not significant neither in the contemporary and lagged parameters estimates. However, its interaction with the dummy for the crisis period is significant and positive, supporting the assertions advanced in the previous section (see figure 4). The positive and significant coefficient of the interaction variable between the crisis dummy and *treasury securities holdings* suggests that during the crisis a stronger balance sheet could allow to import more liquidity from foreign offices.

In order to have a clearer picture, in the next section I will consider inferences over shorter samples, in particular, differentiating among pre- and post- crisis period. However, for estimations involving fewer observations (i.e. less than 30) the LSDV estimator is not suitable since it leads to biased estimators (see for instance Judson and Owen, 1999). Moreover, a further potential shortcoming of the LSDV estimator is that, even if it allows eliminating bank-specific effects, it does not overcome the endogeneity problem of regressors that arises in panels. It is, in fact, very likely that the omitted unobserved fixed effects are correlated with the regressors treated as strictly exogenous, making the LSDV estimator not consistent. Therefore, an instrument-based approach is carried out in the following section to obtain asymptotically normal and consistent estimators (see Hsiao, 2003) in panels with smaller time-dimension.

3.3 Pre- and Post- Crisis Estimation

In this section I will particularly focus on two subsamples, pre- and post- crisis, in which the dynamics of NIOA are analyzed separately. In a dynamic setting with a unbalanced panel, a large cross-section dimension (N around $120 - 140$) and a small time sample ($T \leq 12$), the one-step GMM dynamic panel estimator yields to the smallest distortions (see Judson and Owen) compared to other dynamic panel estimators[31]. Pioneered by Arellano and Bond (1991), this approach removes the fixed effects by first-differencing and allows obtaining consistent and asymptotically normally distibuted estimator. Moreover, it requires including as additional instruments appropriate lags of the endogenous variable in order to take into account the orthogonality condition between the lags of NIOTA-to-total assets and the disturbance term v_{it}.

In a first instance, the sub-samples considered are 2: 2005Q1-2007Q2 and 2007Q3-2010Q2. The period 2005Q1-2007Q2 was characterized by a more restrictive monetary policy in the US. The sub-sample 2007Q3-2010Q2, instead, covers the whole crisis period, up to the latest available data. However, given different liquidity and credit conditions in the US interbank markets over this crisis period, I further consider the sub-sample 2008Q3-2010Q2. Indeed, this period was characterized by unprecedented injections of liquidity by the Fed in the interbank markets and highest credit risk (i.e. see Libor-OIS spread)

[31] For instance, 2-Steps GMM, AB 1 and 2 steps estimators.

following the failure of Lehman Brothers.

Three different estimations are therefore carried out according to each subsample of interest. The regressors, however, are not homogeneous across the three periods for data availability issues. Each specification considers up to two lags of the endogenous variable and one lag of the exogenous variables. The instument variables considered include, other than the suitable lags of the endogenous variable (in this case, 3 lags), bank's size, equity, liquidity and balance sheet strength as well as borrrowing costs in secured interbank markets (see tables 4-6). The adequacy of each set of instrument used in the three estimations is formally tested via a χ^2 Sargan test for over-identifying restrictions.

Tables 4-6 report the Arellano-Bond one-step estimators obtained through the GMM dynamic estimation. At the bottom of each table are reported the details of the instruments used and the p-value of the Sargan test. In all the considered estimations, the Sargan test supports the adequacy of the instruments used: i.e. the null hypothesis of uncorrelation between error terms and instruments is never rejected. The calculated standard errors of the GMM estimators are robust to the heteroskedasticity and serial correlation that might arise from cross-section disturbances.

Table 4 reports the estimates of a model for NIOA-to-total assets model over the pre-crisis period 2005q1-2007q2. Although there are several features in common with the results obtained with the LSDV estimator, here it can be seen a clearer pattern especially in relation to the health and the strength of the bank's balance sheet. As previously found in table 3, net interoffice accounts are significantly and positively affected by augmentations in deposits in foreign offices, with a large coefficient of 0.8504. Also, as expected, a contraction of total transaction deposits in domestic offices stimulates significantly net interoffice liabilities. Variables accounting for the relative ease to borrow and lend in the domestic interbank markets unambiguously show that a well-functioning market results in lower NIOA. Indeed, the estimated coefficients of series such as liquid (lagged) and interest bearing interbank assets and securities sold in repurchase agreements (lagged) all have a negative and significant coefficient. Most importantly, the results show that during out-of-crisis periods a deterioration of banks' balance sheets does not lead to credit rationing on foreign interbank markets, on the contrary, NIOA-to-total assets increases. This is evident if we look at the significant estimated coefficients of the variables *Nonaccrual C&I Loans*, *Tier 1 Capital* and *Total Assets Allocation by Risk Weight Category 50%* (regulatory capital). Indeed, increases in *Nonaccrual C&I Loans* and in *Total Assets Allocation by Risk Weight Category 50%*, as well as a decrease in *Tier 1 Capital* (i.e. a measure of a bank's financial soundness), all stimulate net borrowings from foreign offices.

In table 4*A* in the appendix are reported also the results over the sample 2006q1-2007q2 in order to account for a few variables which availability starts in 2006q1, such as non-accrual secured loans and credit default swaps. However, none of these variables result to be significant in driving changes in NIOA-to-total. Rather, over this period the *Nonaccrual C&I Loans,* both contemporaneous and lagged, have a great and significant role in stimulating positively the dependent variable.

Table 5 reports the Arellano-Bond estimates of the model during the whole crisis period 2007q3-2010q2. The results show that there is even stronger evidence in support of the fact that bank's financial soundness, in particular in the previous period, have a significant role in driving net interoffice account's dynamics. Indeed, deteriorations in the previous period's balance sheet, as witnessed by an increase in *CDs*, *MBSs, Total Risk-Based Capital* and a decrease in *Securities held-to-maturity* and *Tier 1 Capital*, stimulate NIOA. Also the estimated coefficient of the series *Treasury Securities held-to-maturity* (current value) supports this result: it is negative with a strongly significant coefficient of -0.0772. The coefficients of the *MBSs* and *Securities held-to-maturity* at time t suggest that, instead, there is a positive relationship between improvements in bank's financial soundness and NIOA. However, given the timing of the accounting procedure and reports it is reasonable to give prominent role to the effects of the lagged explanatory variables[32]. Interestingly enough, even during the crisis the coefficients of the series *Total Deposits in Foreign Offices* and *Domestic Interbank Transaction Deposit*s are strongly significant and have the same signs as in tables 3 and 4.

Lastly, table 6 reports the Arellano-Bond estimates of the model during the restricted crisis period 2008q3-2010q2. There are several interesting features that result from this inference. Firstly, the *Effective Federal Funds Rate* is significant at 5% significance level with a negative coefficient equal to -0.0048; this goes, clearly, in a different direction than what is expected to happen during normal times. The *Libor rate*, on the other side, is not significant. Secondly, among the series at time t, the coefficient of *Deposits in Foreign Offices (total)* is positive and strongly significant just as found in all the tables previously shown. However, the negative sign and the strong significance of the series *Deposits in Foreign Offices by Foreign Official Institutions* implies that the increase in NIOA is mainly due to increases in private deposits at the foreign offices. Thirdly, there is evidence that worsening in current aggregate credit conditions, as im-

[32] Reasonably, borrowing more from foreign offices depend also on some figures made available by the quarter-end accounts. This is especially true for securities.

plied by *Total Nonaccrual Loans*, stimulate NIOA-to-total assets. Although the coefficients of the variables *Liquid Interbank Balances* and *Securities held-to-maturity* are positive and significant, the estimated coefficients of the lagged values of some variables might be more relevant in explaining the dynamics of NIOA-to-total assets. There is evidence that previous period's deterioration of bank's balance sheet, indeed, increases current period's NIOA during the credit crisis. Most prominently, the coefficient of *Securities held-to-maturity* in the previous period is negative and highly significant. Moreover, there is a negative and significant relation between *Assets Allocation by Risk Weight Category 100% (Regulatory Capital)* and NIOA. However, over this crisis period considered there is a decrease in NIOA for those banks which have experienced in the previous period losses due to residential mortgage securitization. Indeed, the coefficient of the series *Nonaccrual Loans Secured by 1-4 family properties (Closed-end, first liens)* is positive and significant at 5% level. Lastly, it is interesting to note that the estimated coefficient of the Term Auction Credit is negative and significant, although its size is relatively small.

In conclusion, it can be asserted that while during the whole crisis period balance sheets deterioration and augmentations in credit risk have stimulated NIOA, the picture is more blurred over the period 2008q3-2010q2. During this period, in fact, the relxation of collateral requirements by the Federal Reserves coupled with massive has decreased the scope for inter-office liabilities.

4 Conclusion

This paper has contributed on understanding the rationales for which US banks borrow from their foreign offices. Shifting the attention away from the established finance-based argumentations (i.e. carry trades and domestic liquidity shocks insulation), this applied work has shown that banks' financial soundness, as proxied by a wide range of quantity-based balance sheet variables, has an important role in explaining changes in Net Interoffice Accounts. In particular, a dynamic GMM panel estimation focuses on two different periods: pre- and post- subprime crisis, other than the entire available sample 1995-2010. Firstly, I find that in all the three estimation samples it is not only a decrease in domestic interbank loans to affect positively NIOA-to-total assets but also an increase in deposits in foreign offices. In the two-and-half years preceding the crisis, there is evidence that a well-functioning domestic interbank market results in lower NIOA. Moreover, over this period deterioration in bank's balance sheets result in more liquidity imported from foreign offices. This last result is even stronger in the crisis-period estimation (2007q3-2010q2) and partly in a further sub-period considered which spans from the failure of Lehman Brothers to sample-end. However, it is only in this last period considered, i.e. after 2008q3 that securitization-linked losses have a negative effect on NIOA-to-total assets.

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A Tables

TABLE 1-Descriptive Statistics: Net Inter-Office Accounts, $ Thousands

	Sum	Mean	Median	Minimum	Maximum	Std. Dev.	Obs.
1995	63100710	313934	44421	-5970000	8925000	1184952	201
1996	22955781	122105	22345	-16464846	7074617	1566536	188
1997	43623519	286997	23074	-12539441	11512565	2278409	152
1998	62037313	462965	16253	-4150363	8106000	1465746	134
1999	81458401	621820	12526	-3018977	11852000	1815646	131
2000	110408193	862564	7647	-3439369	20715000	2701771	128
2001	96049505	787291	6523	-3674622	18824000	2759121	122
2002	99118951	854474	13889	-7377371	21189000	3027730	116
2003	140425050	1265091	10695	-7410910	16280000	3582743	111
2004	197873032	1849281	48801	-9032871	48404260	6403739	107
2005	255409292	2059752	30709	-30166000	65061261	8524926	124
2006	378400896	3290443	86475	-8166000	80999780	11652562	115
2007	513041937	4384974	87470	-12074304	87712235	14631722	117
2008	583011926	4983008	62812	-10780846	116535819	18538558	117
2009	459375368	3960132	66902	-13337379	103494242	14020016	116

Sorce: Call Report, Federal Reserves.

Notes: Net Interoffice Accounts constructed as the difference of net inter-office liabilities and interoffice assets. Figures refer to outstanding values in the last quarter of the year.

TABLE 2- Variables

Code	Name	Abbreviation
	Bank's Collateral and Balance Sheet Health	
RCFD0081	Noninterest-bearing balances and currency and coin due from depository institutions	nibb
RCFD0071	Interest-bearing balances due from depository institutions	ibb
RCON0020	Cash in process due from depository institutions	cpb
RCON0080	Currency and coin due from depository institutions	cb
RCFD1754	Securities: Held-to-maturity securities	shm
RCFD1773	Securities: Available-for-sale securities	sas
RCFD0211	U.S. Treasury securities: Held-to-maturity Amortized Cost	trhm
RCFD1287	U.S. Treasury securities: Available-for-sale Fair Value	tras
RCFD3548	Trading liabilities	trl
RCFDC027	Asset-backed securities (ABS): Available-for-sale Fair Value	ab
RCFDB559	Mortgage-backed securities, Quarterly Averages	mb
RCFDC969	Credit default swaps, Notional amounts	cds
RCFD3210	Total equity capital	te
RCFD8274	Tier 1 capital	t1
RCFD3792	Total risk-based capital	trc
RCFD5334	Regulatory Capital Total assets Allocation by Risk Weight Category 50%	rc50
RCFD5340	Regulatory Capital Total assets Allocation by Risk Weight Category 100%	rc100
RCFD8764	Regulatory Capital Current credit exposure across all derivative	ce
RIADB747	Charge-offs on assets sold and securitized on 1-4 Family Residential Loans	chof
	Nonaccrual Assets in Domestic Offices	
RCONC229	Loans Secured by 1-4 family residential properties (Closed-end, first liens)	narce
RCON5400	Nonaccrual Loans secured by 1-4 family residential properties (Revolving, open-end)	naroe
RCFD1253	Nonaccrual U.S. Commercial and industrial loans	naci
RCFDC410	Additions to nonaccrual assets during the quarter	naad
RCFDC411	Nonaccrual assets sold during the quarter	nas

Source: Call Report.

TABLE 2- Variables (continued)

Code	Name	Abbreviation
	Liquid Liabilities, Other and Aggregate Variables	
	Liquid Liabilities	
	Deposits in Domestic Offices, by	
RCONB551	US banks	dddb
RCON2213	Foreign banks	ddfb
RCON2215	Total	ddt
RCONB995	Securities sold under agreements to repurchase (domestic offices)	repo
	Deposits in Foreign Offices, by	
RCFN2625	Foreign Banks	dffb
RCFN2650	Foreign official institutions/central banks	dfo
RCFN2200	Total	dft
	Other Variables	
RCFD2170	Total assets	ta
RCON2163	Net due from own foreign offices, Edge and Agreement subsidiaries, and IBFs	nioa
RCON2941	Net due to own foreign offices, Edge and Agreement subsidiaries, and IBFs	niol
	Aggregate Variables	
FEDFUNDS	Effective Federal Funds rate	ffr
TERMAUC	Term Auction Credit	tac
-	Libor (1m)	libor
RCFD5379	Nonaccrual Loans To U.S. banks and other U.S. depository institutions	nalagg

Source: Call Report, Federal Reserves St. Louis. and Bloomberg.
Notes: The series RCFD5379 has been aggegated by the Author based on bank-level figures obtained by the Call Report.

Table 3: Estimates of the Fixed-Effect Model (LSDV Estimator) -to continue-

Dependent Variable: Net Interoffice Accounts (NIOA)-to- Total Assets

Variable	Coefficient
Constant	-0,010 (-3,808***; -2,645***; -2,027**)
NIOA-to-TA(-1)	0,735 (67,392***; 20,588***; 16,117***)
NIOA-to-TA(-2)	0,140 (13,754***; 4,775***; 3,833**)
Cash in process due from depository institutions	-0,132 (-2,256**; -1,519; -1,192)
Tr. Deposits in Domestic Offices-to-TA	-0,029 (-3,060***; 1,838*; -1,413**)
Deposits in Foreign Offices-to-TA	0,648 (56,257***; 15,590***; 6,643***)
Aggregate Nonaccrual Loans	0,000 (2,181**; 2,977***; 1,913*)
Non-interest balances due from banks-to-TA	0,204 (3,106***; 1,772*; 2,113**)
Securities Available for sale-to-TA	0,072 (3,875***; 1,202; 3,070***)
Securities held-to-TA	0,112 (3,404***; 1,184; 2,960***)
Total Equity-to-TA	0,095 (1,913*; 19,911***; 1,764*)
Tdummy*Deposits in Foreign Offices-to-TA	0,031 (1,836*; 1,225; 1,379)
Tdummy*Non-interest balances due from banks-to-TA	-0,101 (-2,462**; -1,023; -0,988)
Tdummy*Securities Available for sale-to-TA	-0,030 (-3,092***; -3,296***; -2,214**)
Tdummy*Treasury Securities-to-TA	0,217 (3,692***; 2, 171**; 2,182**)
Tdummy*Libor	0,001 (2,185**; 2,284**; 2,499**)
Periods	60
Cross-Sections	265
Total Panel Observations	6499
R-Squared	0,948
Adjusted R-Squared	0,946

Notes: T-Statistics in brackets refer to standard errors and covariance: ordinary, White cross-section and White period respectively. *,**,*** refer to statistical significance at 10%, 5% and 1% respectively.

Table 3: Estimates of the Fixed-Effect Model (LSDV Estimator) - continue-

Dependent Variable: Net Interoffice Accounts (NIOA)-to- Total Assets

Variable	Coefficient
Deposits in Foreign Offices-to-TA(-1)	-0,560 (-45,985***; -12,134***; -6,340***)
Aggregate Nonaccrual Loans(-1)	-0,531 (-3,300***; -2,064**; -2,353**)
Securities Available for sale-to-TA(-1)	-0,043 (-3,443***; -2,659***; -1,692*)
Securities held-to-TA(-1)	-0,102 (-5,215***; -3,149***; -2,639***)
Treasury Securities held-to-TA(-1)	-0,069 (-4,421***; -1,799*; -1,905*)
Total Equity-to-TA(-1)	-0,057 (-3,204***; -1,170; -1,237)
Federal Fund Rate(-1)	-0,001 (-2,984***; -2,432**; -2,231**)
Periods	60
Cross-Sections	265
Total Panel Observations	6499
R-Squared	0,948
Adjusted R-Squared	0,946

Notes: T-Statistics in brackets refer to standard errors and covariance: ordinary, White cross-section and White period respectively. *,**,*** refer to statistical significance at 10%, 5% and 1% respectively.

Table 4: GMM Estimation of the Fixed-Effect Model -Arellano and Bond 1-Step Estimator-

Dependent Variable: Net Interoffice Account-to-Total Assets

2005q1 2007q2

Variable	Coefficient
NIOA-to-TA(-1)	0,24854*** [3,6641]
Tr. Deposits in Dom. Offices-to-TA	-0,15377*** [-3,0357]
Deposits in Foreign Offices-to-TA	0,8504*** [18.7048]
Interest balances due from banks-to-TA	-0,5552*** [-3.3364]
Nonaccrual C&I Loans-to-TA	12,1736* [1.7915]
Tier 1 Capital-to-TA	-0,1701** [-2.2759]
Cash due from banks-to-TA(-1)	-0,4331** [-2.1059]
Deposits in foreign offices by inst.-to-TA(-1)	0,5899** [2.3698]
Deposits in Foreign Offices-to-TA(-1)	-0,20100*** [-3.4421]
Regulatory Capital Risk Weight Cat.50%-to-TA(-1)	0,0476* [1.8652]
Securities sold under repo (domestic offices)-to-TA(-1)	-0,1697*** [-2.6142]
Periods	10
Cross-Sections	102
Total Panel Observations	836
Instruments	ta(all lags) trhmta trhmta(-1) teta teta(-1) libor libor(-1) ffr ffr(-1) sasta sasta(-1) ceta ceta(-1) nalagg nalagg(-1) ibbta ibbta(-1) shmta shmta(-1) cpbta cpbta(-1) nioata(-3)
Sargan p-value	0.9989

Notes: T-Statistics in brackets refer to White period standard errors and covariance. *,**,*** refer to statistical significance at 10%, 5% and 1% respectively.

Table 4(A): GMM Estimation of the Fixed-Effect Model -Arellano and Bond 1-Step Estimator-

Dependent Variable: Net Interoffice Account-to-Total Assets	
2006q1 2007q2	
Variable	**Coefficient**
Deposits in Foreign Offices-to-TA	0,9093*** [19.5214]
Interest balances due from banks-to-TA	-0,7102*** [-5.2701]
Nonaccrual Loans	12,1736** [1.7915]
Total Equity-to-TA	-0,1278*** [-2.7209]
Non Accrual Loans(-1)	9,0733** [2.3286]
Trading Liabilities-to-TA(-1)	-1,0367*** [-2.6318]
Periods	6
Cross-Sections	102
Total Panel Observations	549
Instruments	ta(all lags) trhmta teta teta(-1) libor libor(-1) ceta nioata(-3)
Sargan p-value	0.9951

Notes: T-Statistics in brackets refer to White period standard errors and covariance. *,**,*** refer to statistical significance at 10%, 5% and 1% respectively.

Table 5: GMM Estimation of the Fixed-Effect Model -Arellano and Bond 1-Step Estimator-

Dependent Variable: Net Interoffice Account-to-Total Assets

2007q3 2010q2	
Variable	**Coefficient**
NIOA-to-TA(-1)	0,5726*** [6,8359]
Tr. Deposits in Dom. Offices-to-TA	-1,0179*** [-3,4418]
Deposits in Foreign Offices-to-TA	0,8598*** [10.5005]
MBS held-to-TA	-0,0972** [-2.4162]
Securities held to maturity-to-TA	0,3727*** [4.9392]
Treasury Sec. held to maturity-to-TA	-0,0772*** [-4.8143]
CDS-to-TA(-1)	0,0229** [2.1103]
Deposits in foreign offices by foreign banks-to-TA(-1)	-0,8537* [-1.8563]
Deposits in foreign offices by inst.-to-TA(-1)	-0,6836* [-1.7740]
Deposits in foreign offices-to-TA(-1)	-0,4506*** [-3.8092]
MBS held-to-TA(-1)	0,1410*** [3.3476]
Securities held to maturity-to-TA(-1)	-0,4602*** [-3.2666]
Tier 1 capital-to-TA(-1)	-0,4374*** [-2.7156]
Total risk-based capital-to-TA(-1)	0,3663*** [2.6151]
Periods	12
Cross-Sections	108
Total Panel Observations	1100
Instruments	ta(all lags) trhmta teta teta(-1) libor libor(-1) ceta nioata(-3)
Sargan p-value	0.1381

Notes: T-Statistics in brackets refer to White period standard errors and covariance. *,**,*** refer to statistical significance at 10%, 5% and 1% respectively.

Table 6: GMM Estimation of the Fixed-Effect Model -Arellano and Bond 1-Step Estimator- (to be continued)

Dependent Variable: Net Interoffice Account-to-Total Assets

2008q3 2010q2	
Variable	Coefficient
NIOA-to-TA(-1)	0,4736*** [4,1193]
R. Capital credit exposure across derivative to-TA	0,1576** [2.0957]
Tr. Deposits in Dom. Officesby foreign banks-to-TA	0,8066** [2.3053]
Tr. Deposits in Domestic Offices-to-TA	0,0796* [1.6819]
Deposits in foreign offices by foreign inst.-to-TA	-2,1340*** [-4.4558]
Deposits in foreign offices-to-TA	0,8590*** [10.4465]
Federal Funds Rate	-0,0048** [-2.0611]
Non Accrual Loans	0,0000** [1.9821]
Non-interest balances due from banks-to-TA	0,1909** [2.2338]
Regulatory Capital Risk Weight Cat.100%-to-TA	-0,0649* [-1.6770]
Securities held to maturity-to-TA	0,3041** [2.5396]
Term Auction Credit	0,0000*** [-2.7892]
Periods	8
Cross-Sections	103
Total Panel Observations	741
Instruments	ta(all lags) trhmta teta teta(-1) libor libor(-1) ceta nioata(-3)
Sargan p-value	0.1426

Notes: T-Statistics in brackets refer to White period standard errors and covariance. *,**,*** refer to statistical significance at 10%, 5% and 1% respectively.

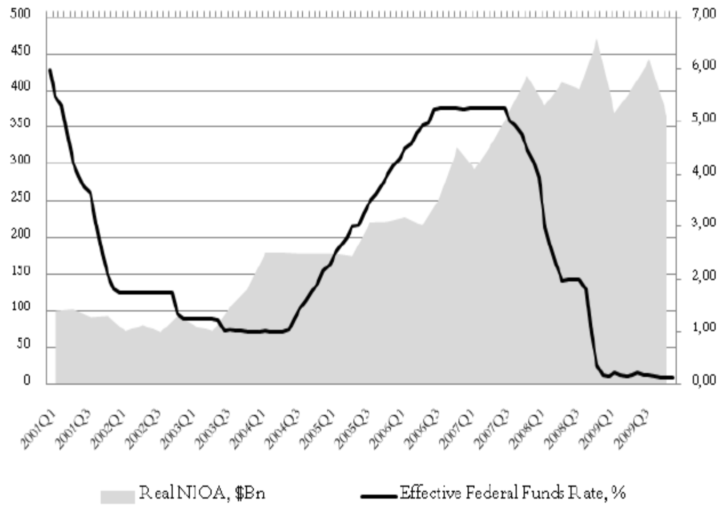
Table 6: GMM Estimation of the Fixed-Effect Model -Arellano and Bond 1-Step Estimator- (continued)

Dependent Variable: Net Interoffice Account-to-Total Assets	
2008q3 2010q2	
Variable	Coefficient
Deposits in foreign offices-to-TA(-1)	-0,3803*** [-2.7664]
Non Accrual Loans(-1)	0,0000* [-1.8700]
Nonaccrual Loans Secured by 1-4 family properties (Closed-end, first liens)-to-TA(-1)	-2,0272** [-2.3980]
Regulatory Capital Risk Weight Cat.100%-to-TA(-1)	0,0545** [2.2988]
Securities held to maturity-to-TA(-1)	-0,4914*** [-3.4529]
Periods	8
Cross-Sections	103
Total Panel Observations	741
Instruments	ta(all lags) trhmta teta teta(-1) libor libor(-1) ceta nioata(-3)
Sargan p-value	0.1426

Notes: T-Statistics in brackets refer to White period standard errors and covariance. *,**,*** refer to statistical significance at 10%, 5% and 1% respectively.

Figures

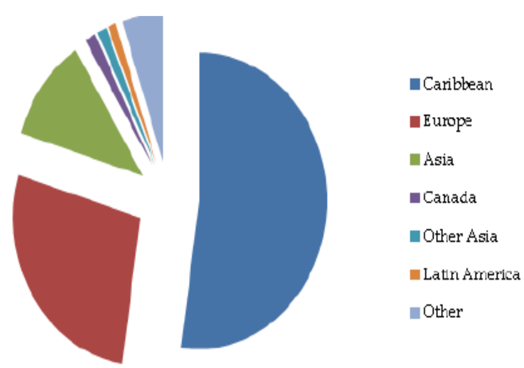
Figure 1: *Real NIOA of US global banks and Effective Federal Funds Rate.*



Source: Federal Reserve Board and Call Report

Notes: NIOA series is constructed by taking the difference between Net Interbank liabilities and Assets of global banks. The series is deflated by CPI Index Average 2000=1 (Fed St. Louis)

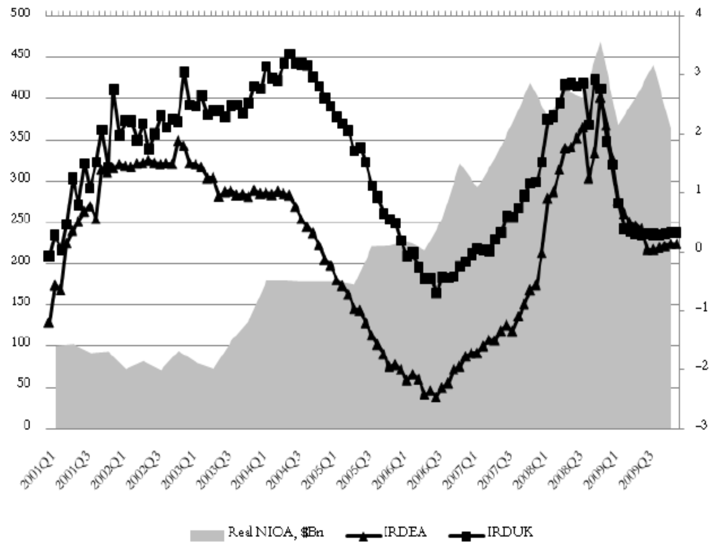
Figure 2: *Liabilities due to foreign offices by location.*



Source: Treasury International Capital Movements Data

Notes: Data refers to yearly average values of gross liabilities due to foreign affiliates over the period 1998-2003.

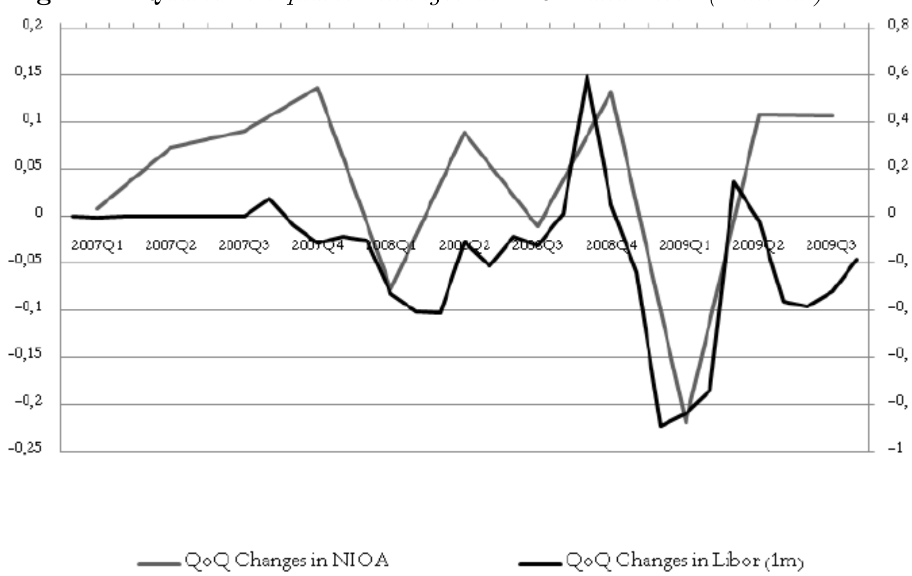
Figure 3: *Real Net Interoffice Accounts and Interest Rate differentials (IRDs) on Central banks'rates.*



Source: Federal Reserve of St. Louis, Bank of England, European Central Bank and Call Report.

Notes: IRDs refer to the interest rate differentials between foreign central bank's target rates and fed funds target rate.

Figure 4: *Quarter-on-quarter changes in NIOA and Libor (1 month).*



Source: Federal Reserve Board and Call Report

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Part III
Opacity of banks and inefficient runs

Carmela D′Avino and *Marcella Lucchetta* (University Cà Foscari in Venice and RSCAS at the European University Institute)

Abstract

In absence of bank risk-taking behavior, opacity is defined as the inability of depositors, speculators and central banker to disentangle default risk and asset return from a signal of the asset's expected value. We show the conditions under which opacity leads to a no-run equilibrium with an insolvent bank in equilibrium and uncertainty on fundamental values of the asset. The main repercussion of opacity is on the central bank's policy response which is inefficient during a banking crisis.

Key Words: Opacity, Bank Runs, Central Bank Intervention, Cash-in-Market Pricing.

1 Introduction

The opacity of banks is conventionally perceived as the inability of an agent to assess the effective riskiness embodied in a banks' assets portfolio. The difficulty in quantifying risk arises from either the bank's engagement in less-transparent and non-traditional activities (Myers and Rajan, 1995, Morgan, 2002, Wagner, 2007) or from limited accounting disclosures (Cordella and Yeyati, 1998, Estrella, 2004). Asymmetric information and/or moral hazard are typically the prerequisites for the existence of opacity in the current literature.

To many observers, opacity has had a key role during the recent banking crisis. Most prominently, opacity has been related to the uncertainty on the actual solvency status of banks, which was essentially due to the discretionary accounting standards used by banks in their assets' valuation. Specifically, before the crisis fair value standards[33] were only applied to trading books of banks and to brokerage firms' holdings valuation. Illiquid assets were, instead, valued at each bank's discretion using internal accounting models. Such internal models have made very hard for outsiders to value the risk embodied in some of the banks' assets at the credit crisis' outburst. Furthermore, the uncertainty on the actual solvency of many banks was further intensified (i.e. increase in opacity) by both the lack of markets and inability to assess the on fundamental values of the 'toxic' products after July 2007.

In such a climate, stress tests on banks undertaken by relevant authorities were primarily meant to reassure discouraged creditors. However, a series of controversial events have mined such a task. For instance, the Financial Accounting Standard Board (FASB) on April the 2^{nd} 2009 decided to relax US mark-to-market valuation rules, giving more discretion to banks when evaluating whether a permanent loss has occurred and how to measure it. Also, the announcement of the details of the results of the stress test carried out on the top 19 US banks has occurred after a long debate on how to disclose the details of the procedures of the test. Even more strongly so, the very recent stress tests carried out on 91 European banks (July 2010) has been preceded by diverging point of views among the 27 Union members on how much to disclose. Moreover, there have been serious doubts on the reliability of these tests, given their inability to anticipate the observed consequences on the banks' balance sheets following the current Irish banking crisis.

Existing theoretical models suggest that a certain degree of opacity might be desirable for certain agents. Cordella and Yeyati (1998), for instance, argue that portfolio risk disclosure increases the probability of bank failure when the

[33] In order to assess their 'fair' solvency status, banks should have recognized their marked-to-market losses which imply the unveiling of their opaque balance sheet.

bank manager does not have control over the volatility of the assets' return. In Myers and Rajan (1995) investors are better-off in an opaque banking system[34], as it allows them to restrain managers in their activities of assets trading and substitution. Wagner (2007) shows that it is optimal for banking managers to be less-transparent, especially during periods of increased financial development. Here, the leveraged capital structure imposed by the bank's owners induces managers to substitute assets, whose risk is better observed given the financial development, with more opaque (riskier) assets. It is, indeed, only with the investment in opaque assets that managers are able to extract some rent, since opacity causes owners to impose a less restrictive capital structure.

These existing models, thus, describe the various consequences for banks' owners or investors of alterations in managers' incentives and behavior arising from opacity. A possible drawback of these contributions is that they overlook the fact that investors are heterogeneous and a particular class of them, such as depositors, might react to opacity as well. In other words, they leave unexplored the effects of opacity on the run/no-run decision of depositors. As a consequence, it is cumbersome to understand how opacity influences, for instance, asset market pricing and the efficiency of the central banker's intervention.

Our paper can be considered as a first attempt to explain in a plain framework some observed facets of the current crisis. For instance, our model deals with: runs on a bank whose solvency status is not accurately known, the pricing assets whose fundamental value is imperfectly assessed and over/under borrowing to banks by the central banker during a crisis. The innovation of this work is twofold. Firstly, we introduce opacity in a simple bank-run type model. In this way, we are able to investigate the behavior of depositors when an opaque signal on the banks' asset portfolio is observed. Alongside, we model a market for the asset to which the opaque signal refer to and we analyze how opacity affects the pricing of this asset. Also, we investigate the conditions under which the intervention of a central banker which observes the opaque signal is inefficient. Secondly, we adopt a novel characterization of 'opacity' which does not imply moral hazard or asymmetric information, as found in the existing theoretical models. In this regard, we re-define opacity as the inability of depositors, speculators and central banker to disentangle default risk and asset's return from the asset's expected return. We abstract from asymmetric information since the bank faces the same uncertainty as the other agents when proposing to depositors a standard deposit contract. The signal on the asset's expected return, which is true and accurate, is determined by the nature and announced by the bank in an intermediate period, when all the agents have the same information

[34] Opacity in this paper implies "less liquid assets".

set. Moreover, we assume that the contract offered to depositors solves the optimal risk-sharing problem (Allen and Gale, 1998) in which the riskiness of the illiquid asset is irrelevant for the optimal portfolio allocation chosen by the bank. In this way, we are able to abstract from a situation in which the bank has incentives to undertake a moral hazard-type of behavior.

Our task is accomplished through the inclusion of default risk of the risky asset in a modified version the model by Allen and Gale (1998). We are able to draw interesting implications of opacity for bank-runs and fire-sale pricing when speculators are either risk-neutral or risk-averse. We show the conditions for which with opacity there might be a no-run equilibrium on an insolvent bank. Moreover, we show that opacity leads to uncertainty on the fundamental value of the risky asset when speculators in the asset market are risk-averse. Lastly, we find that the intervention by a central banker might be desirable for depositors since it ensures a fixed level of consumption. However, the intervention will be inefficient with opacity given that the central bank lends either more or less than the bank should be entitled to, given the quality of its assets.

The paper is organized as follows. In section 2 we propose the theoretical framework of the paper in which we define the standard deposit contract offered by the bank to consumers and the asset market in which the risky asset might be traded. Moreover, we specify the information set of the bank, consumers and speculators. Section 3 looks at the risky asset market pricing given the opaque signal sent by the nature in the interim period. We distinguish between two cases: one in which speculators are risk-neutral and another in which they are risk-averse. In section 4 we introduce the central banker and we analyze the welfare effects for the consumers following an intervention. We draw different welfare implication depending on whether the speculators are risk-neutral or risk-averse. Section 6 concludes.

2 The Model

2.1 Framework

The model comprises a four-periods economy, $t = 0, 1, \frac{3}{2}, 2$, with *one* consumption good (withdrawals). The agents in this framework are: *one* representative risk-neutral bank, a continuum of rational depositors/consumers and speculators. In section 4 we will introduce the central banker.

2.1.1 Depositors

Depositors are uninsured with initial endowment E normalized to 1, i.e. $E = 1$. They will deposit all their endowment in $t = 0$ at the bank, which offers them insurance against idiosyncratic liquidity shock[35]. Indeed, at period 0, depositors do not know when they will be hit by an idiosyncratic liquidity shock: with probability μ a given consumer will be withdrawing C_1 at $t = 1$, thus, being early consumer, and with probability $1-\mu$ he will withdraw C_2 in $t = 2$, being a late consumer. Ex-ante, the size of μ is publicly known, however, each consumer does not know which type (early/late) he will be at $t = 1$. The continuum of depositors is normalized to one such that μ is the proportion of early consumers. The utility arising from the consumption of each type in each period is described by a concave and continuous consumers' utility function $u(C_t)$.

2.1.2 The Bank

At $t = 0$ the bank issues demand deposit liabilities equal to one unit of consumption, collecting the whole consumers' endowment. The bank operates in a competitive market, maximizing the expected utility of consumers.

At date 0 the bank can invest the deposits in a safe and in a risky asset. The safe asset, y, is in variable supply and can be considered as a storage technology. Its price at $t = 0$ is normalized to one. y can be liquidated at no cost both at $t = 1$ and at $t = 2$ and has a risk-free gross return equal to 1. The amount of investment in risky asset is denoted as x and is such that $x + y = 1$. x is in fixed supply in $t = 0$ and yields a random return R only in $t = 2$. In $t = 2$ R yields R^h with probability p or zero with probability $1 - p$.

Information set of the Bank and Consumers At $t = 0$ and $t = 1$ both the bank and the consumers face the same uncertainty regarding the random

[35] The bank invests on behalf of consumers given its expertise in recognizing valuable risky assets. Deposits allow consumers that are hit in the last date by a liquidity shock to enjoy the return of the investment made by the bank. Depositors that are hit by the liquidity shock in the earlier period are assured a given level of consumption.

variable R. More specifically, they do not know both the probability density function of R and the exact value that R might take in the good state, that is, R^h.

Therefore, these agents in $t = 0$ and $t = 1$ know that in $t = 2$ R yields $\tilde{R}^h$ with probability p^i or zero with probability $1 - p^i$ where $i = l, h$. If $p = p^l$ then, the asset carries an high default risk; if $p = p^h$ then, the default risk is low. The probability p allows us to model the default risk of the risky asset, which is equal to $1 - p^i$. $p = p^h$ with probability α, while $p = p^l$ occurs with probability $1 - \alpha$. $\tilde{R}^h$ is also a random variable which is assumed to be distributed according to a normal distribution with mean $\bar{R}^h$ and finite variance σ_{R^h}. The distribution of R^h is ex-ante common knowledge.

We further assume that $E[R] > 1$; this implies that investment in risky asset dominates in terms of expected value the investment in storage technology.

The Deposit Contract The bank offers non-state contingent contracts that allow depositors to withdraw their funds on demand in either $t = 1$ or $t = 2$.

The bank promises a fixed level of consumptions $C_1 = \bar{c}$ to early consumers and $C_2 \geqslant \bar{c}$ to late consumers. If it is infeasible to give at least $\bar{c}$ to all consumers then there is risky asset liquidation and pro-rata distribution among all depositors. The size of $\bar{c}$ is computed from a state-contingent Optimal Risk-Sharing Problem (ORSP) where no asset liquidation takes place. The equilibrium allocations are fully state-contingent: i.e. the bank does not have to declare bankrupcy whenever the value of its assets falls below a certain threshold.

That is, $\bar{c}$ is equivalent to the equilibrium level of state-contingent early consumption $C_1(R)$ that solves the ORSP. $C_2(R)$ is, instead, the state-contingent consumption level of late consumers. Although consumption levels are dependent on R, the portfolio choices by the bank in $t = 0$ solving the ORSP are not a function of R. Indeed, since there is aggregate uncertainty in both the return and of its probability density function of the risky asset, the optimal risk sharing problem will yield an optimal portfolio choice (y^*, x^*) which is independent of R, R^h and of the probabilities attached to it.

The ORSP can be formalized as follows (see Allen and Gale (1998) for details):

$$\underset{x,y}{Max} E[\mu U(C_1) + (1 - \mu) U(C_2)] \tag{ORSP}$$

subject to:

$$y + x \leq 1 \tag{i}$$

$$\mu C_1(R) \leq y \tag{ii}$$

$$\mu C_1(R) + (1-\mu) C_2(R) \leq y + Rx \tag{iii}$$

The solution to the above problem (y^*, x^*) will determine the consumption levels of early and late consumers. In particular, the bank will promise $\bar{c}$ to early consumers such that:

$$C_1 = \bar{c} = \frac{y^*}{\mu} \tag{1}$$

Late consumers will receive:

$$C_2 = \frac{Rx^*}{1-\mu} \tag{2}$$

In the benchmark model aggregate uncertainty only concerns the return on the risky asset and is accurately revealed at $t = 1$; there, runs only happen on a truly insolvent banks[36] (i. e. when R is low enough so that $C_2 < \bar{c}$). However, as we will show in the section 4, our stochastic structure of p and R^h yields to different implications for the run decisions of consumers, as it causes uncertainty on the size of C_2 (i. e. (2) is not accurately observed).

2.1.3 Speculators and Asset Market

There exists an asset market in which the bank can liquidate the risky asset in the intermediate period $t = 1$ whenever the withdraw of early consumers exceeds y^*. In this market there are some identical speculators that will want to purchase the risky asset whenever speculative profits can be made, i.e. when its price falls below its fundamental value. Speculators hold some of the safe asset, y_s, which will be exchanged for the risky asset at a fire-sale price. This price will be determined by the size of y_s: the market price (cash-in-market pricing) will be:

$$P_x = \frac{y_s}{x^*} \tag{3}$$

[36] Throughout the paper, we refer to insolvent bank as a bank which is not able to guarantee at least $\bar{c}$ to all consumers.

It must be the case that $y_s < y^*$ for liquidation in the asset market to ever take place (see *proof 1* in the appendix).

Information set of Speculators. We assume that speculators have the same information set of banks and consumers. However, the size of y_s is speculator's private information in $t = 1$: it is publicly revealed only if cash in market pricing takes place after than a run has occurred. Before any asset merket liquidation takes place, the beliefs of the bank and the consumers on the size of $y_s$are the same and follow a uniform distributions on $[y^s_{\min}, y^*)$ with $y^s_{\min} \neq 0$:

$$y_s \char`~ U[y^s_{\min}, y^*) \tag{4}$$

2.2 Timing, Signal and Runs on a Solvent Bank

2.2.1 Timing and Signal

In the previous section we have outlined the uncertainty regarding p^i and R^h faced by all agents in the model in both $t = 0$ and $t = 1$. The main implication of the above framework is that *late* consumers before deciding whether to run, can only observe the expected value of their level of consumption in the final period, i.e. C_2. That is, they can work out the expected value of their consumption if no run takes place, which equal to:

$$E[C_2] = \frac{E[R]x^*}{1-\mu} = \frac{\bar{R}^h x^*}{1-\mu}(\alpha p^h + (1-\alpha)p^l) \tag{5}$$

However, we assume that in $t = 1$ the nature reveals a true and accurate signal on the expected value of the risky asset. That is,

$$\phi = E[R] = pR^h \tag{6}$$

The main implication of the above opaque signal is that depositors cannot assess with certainty how much of the observed ϕ is due to default risk and asset return.

Definition *An accurate signal on the asset's expected return is opaque because it does not enable agents to disentangle default risk and asset's return.*

The uncertainty regarding p^i and R^h is solved in $t = \frac{3}{2}$ while the uncertainty regarding whether R is R^h or *zero* is solved in the last period, $t = 2$. Therefore, the expected no-run consumption of late consumers in $t = 0$ and $t = 1$ becomes:

$$E[C_2] = \frac{\phi x^*}{1-\mu} \tag{7}$$

Late consumers, imposing $\mu = 1-\mu$[37], will run only if the following condition holds:

$$E[C_2] < \bar{c} \tag{8}$$

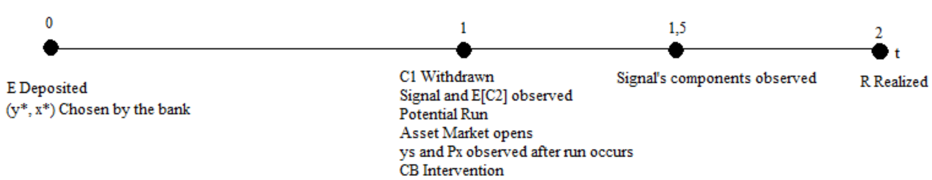
that is, if:

$$\phi < \frac{y^*}{x^*} \tag{9}$$

Since $\phi > 1$ then it must also be that a run can only occur when $y^* > x^*$. Clearly, values of ϕ sufficiently low can imply very opposite outcomes: very high returns associated with very high default risk or very low returns and low default risk.

If condition (8) holds, then, the run will cause costly liquidation on the asset market. As stated in the previous section, when consumers decide to run they do not know the exact size of y_s and so what the market price will be in case of liquidation. While formal asset pricing is derived in the following section, we summarize the timing of the framework in figure 1.

Figure 1: Timing of the model



2.2.2 Inefficient Runs

In this section we illustrate the main implications following an opaque signal in a simple framework which disregards how much depositors would obtain in the event of fire-sale (the market for asset liquidation is formally modelled in section 3).

The problem of runs dictated by the expected values of future consumptions is mainly that there can be equilibriums in which a run has occurred on what turns out to be a solvent bank and equilibriums in which a run did not happen

[37] This semplification is only for computational purposes. Setting $\mu \neq 1-\mu$ adds complexity to computation, leaving the intuitions behind the prepositions presented in this paper unchanged.

on what turns out to be an insolvent bank. In particular, for a given portfolio choice of the bank, (y^*, x^*), inefficient runs will depend on the sizes of $\tilde{R}^h$. For each observed signal ϕ (i.e. ex-post), $\tilde{R}^h$can be either R^{hl} or R^{hh}, such that $\phi = p^h R^{hl}$ with probability α and $\phi = p^l R^{hh}$ with probability $1 - \alpha$.

Let's firstly assume that $\phi < \frac{y^*}{x^*}$ so that a run occurs and the bank liquidates the risky asset . When default risk is low $(\alpha = 1)$[38] and the good state of the world unveils in $t = 2$ $(p^i = p^h = 1)$ the bank is solvent if:

$$R^{hl} > \frac{y^*}{x^*} \tag{10}$$

Or, if:

$$\phi < \frac{y^*}{x^*} < R^{hl} \tag{11}$$

Therefore, when the ratio $\frac{y^*}{x^*}$ satisfies (11), then the ϕ observed will induce late consumers to run on the bank, which would have been solvent in $t = 2$ if no costly liquidiation would have taken place in the interim period and if the good state of the world materialized with low default risk.

Now we consider the no-run case in which the observed ϕ satisfies $\phi > \frac{y^*}{x^*}$. In this case, there can be in equilibrium the event that a run does not happen on a bank that turns out to be insolvent in the good state of the world (e.i. $E[C_2] < \bar{c}$). In particular, this happens whenever ϕ is low enough, such that $\phi \longrightarrow 1$, but it is still greater than R^{hl}. Indeed, given that the bank is insolvent whenever $R^{hl} < \frac{y^*}{x^*}$ and the no-run condition implies $\phi > \frac{y^*}{x^*}$, then, whenever the following conditon applies:

$$R^{hl} < \frac{y^*}{x^*} < \phi \tag{12}$$

there can be a no-run equilibrium with an insolvent bank.

Therefore, the following proposition can be formalized:

Proposition 1 *In the presence of an opaque signal such that $\phi \longrightarrow 1$ and $\phi < \frac{y^*}{x^*}$, there might be in equilibrium a run on a bank which turns out to be solvent if the good state of the world materializes and low default risk unveals. This will occur whenever $R^{hl} > \frac{y^*}{x^*}$. In this state of the world, however, there might be a no-run equilibrium (i.e. for $\phi > \frac{y^*}{x^*}$) on a bank which is insolvent. This would happen whenever ϕ is low enough and $R^{hl} < \phi$.*

[38] We are implicitly assuming that $R^{hh} x^* > y^*$.

3 Risky Asset Market Pricing

3.1 Risk-Neutral Speculators

In this section we consider the pricing of the risky asset in the market when identical speculators are risk-neutral. If at date 1 the bank receives an higher level of withdraws than its available liquidity promised to early consumers, then, it is obliged by its contract terms to liquidate x and distribute all its assets on a pro-rate basis to all consumers.

The speculators in this market will observe the signal ϕ before carrying out any purchase of the risky asset. In particular, the signal $\phi = E[R]$ will perfectly reflect the fundamental value of the asset, given the risk neutrality of speculators. Indeed, the risk-neutrality of these agents implies that their spending decisions are not affected by the default risk or the relative return implied in the signal. Speculators, then, once observed ϕ will purchase the risky asset if its market price, P_x, is below its fundamental value, i.e. ϕ[39].

The pricing in the market happens through a cash-in-market mechanism (Allen and Gale 1998). That is, since speculators will want to exchange all their safe asset for the risky, given $\phi > 1$, then the price of the risky asset will simply be the ratio of the safe asset of the speculators, y_s, to the risky asset of the bank, x^*. In other words, it is the amount of safe asset, readily exchangeable to cash, to determine the market price of the risky asset. However, speculators will only buy if speculative profits can be made, that is, if y_s in their hands is such that prices are below fundamentals, that is:

$$P_x = \frac{y_s}{x^*} \leq E(R) = \phi \tag{13}$$

Given that (8) must hold, in order to a run to ever occur, then it must be that speculators will purchase the risky asset whenever the observed signal satisfies the following condition:

$$\frac{y_s}{x^*} \leq \phi \leq \frac{y^*}{x^*} \tag{14}$$

The associated consumption levels will be:

$$C_1 = C_2 = \frac{y^* + y_s}{2} \tag{15}$$

Figures 2 and 3 depict the asset market pricing of the risky asset and the (expected and actual) late consumption levels for all signal levels signal respectively.

[39] The safe asset is held by speculators in order to exchange it with profitable purchases of the risky asset.

In figure 2 it can be seen that for $\phi < \frac{y_s}{x^*}$ there does not exist a market for the risky asset as speculators are not willing to buy the risky asset. In this case, as shown in figure 3, early and late consumers share equally the available safe asset in the bank's portfolio, i.e. y^*. It is clearly seen from the pictures that when (14) is satisfied, then the late (realized) consumption level is as specified in (15). For high enough signals, i.e. $\phi > \frac{y^*}{x^*}$, then no run occurs and expected late consumption, as perceived in t=1, is equal to $E[C_2] = \phi x^*$.

3.2 Risk-Averse Speculators

In this section we relax the assumption of risk-neutrality of speculators, by assuming that they are risk-averse. The main implication of this modified setting is that the observed signal ϕ does not reveal anymore the fundamental value of the risky asset, which is perceived as the discounted expected return of the asset. Therefore, speculators now face uncertainty regarding the intrinsic value of the asset. Indeed, now the fundamental value has to reflect the default premia that speculators require to take on more risk. At date 1, if the risky asset has a higher default risk, i.e. $p^i = p^l$, then its fundamental value will be lower than the fundamental value of the asset with the lower default risk, i.e. $p^i = p^l$. The fundamental values of the asset in each state of the world can be written as:

$$F_v^h = \frac{E(R)}{1+\pi^l} \tag{16}$$

$$F_v^l = \frac{E(R)}{1+\pi^h} \tag{17}$$

where π^l and π^h are the discounts which reflect the default premia of the asset in each state with $\pi^h > \pi^l$. Given $F_v^h > F_v^l$, F_v^h is the fundamental value of the asset for which $\phi = p^h R^{hl}$ is true; while F_v^l is the fundamental value of the asset for which $\phi = p^l R^{hh}$ is true.

Speculators, will buy the risky asset only if (8) occurs and if the two conditions below are satisfied:

$$E(F_v) = \alpha F_v^h + (1-\alpha) F_v^l > 1 \tag{18}$$

$$P_x = \frac{y_s}{x} < E(F_v) \tag{19}$$

Condition (17) implies that the expected fundamental value corresponding to the observed ϕ has a gross return higher than that of the safe asset. (18), instead, states that the liquidity (safe asset, y_s) in the hands of speculators has to be such that the market price of the risky asset is less than the expected fundamental value. Indeed, buying only if $\frac{y_s}{x} < F_v^l$, would prevent speculators to make potential speculative profits if $F_v^l < \frac{y_s}{x} < E(F_v)$. Solving (18) with respect to ϕ, (after having done various substitutions) we find that:

$$\theta \frac{y_s}{x} < \phi \tag{20}$$

Where:

$$\theta = \frac{1}{\psi} = \frac{1}{\frac{\alpha}{1+\pi^l} + \frac{(1-\alpha)}{1+\pi^h}} > 1 \tag{21}$$

Combining (8) with (20), we find that the buy-condition for risk-averse speculators is:

$$\theta \frac{y_s}{x^*} < \phi \leq \frac{y^*}{x^*} \tag{22}$$

Or:

$$\frac{y'_s}{x^*} < \phi \leq \frac{y^*}{x^*} \tag{23}$$

with $\theta y_s = y'_s$.

The market price of the risky asset, if speculators buy, is always $\frac{y_s}{x}$.However, now, contrarily to what seen in the previous section, there is the chance that speculators might not make speculative profits. Figures 4 and 5 show how this might occur in $t = \frac{3}{2}$. Figure 4 shows what happens when speculators hold a larger amount of y_s. If speculators purchase the risky asset (as condition (23) holds for an observed ϕ), then, at a market price $P_x = \frac{y_s}{x}$ speculative profits will be made only if uncertainty unveils in $t = \frac{3}{2}$ that $\phi = p^h R^{hl}$ (i.e. so that $F_v = F_v^h$). If in $t = \frac{3}{2}$, however, turns out that $\phi = p^l R^{hh}$, then, the asset has been overpriced by the cash-in-market mechanism, i.e. speculators have paid too much for the risky asset. If, instead, y_s held by speculator is lower, as depicted in figure 5, then speculative profits can be made even if uncertainty unveils in $t = \frac{3}{2}$ that $\phi = p^l R^{hh}$ (i.e. $F_v = F_v^l$) given that the signal is at least s. If, instead, the signal is such that $\frac{y_s'}{x^*} < \phi \leq s$, then, again speculators have paid too much for the risky asset. It is worth noting that a buying strategy for speculators which implies buying if $s < \phi \leq \frac{y^*}{x^*}$ is not desirable since it would preclude speculators to make considerable profits if $F_v = F_v^h$.

A last case should also be considered; that is, the possibility that the safe asset in the hands of speculators could be so low that they would make speculative profits whatever the signal. In this case, the market prices would much smaller than the so-far considered cases and speculators will price the risky asset at a price lower than F_v^l for all signal included in $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$.

If there is no central banker's intervention, late consumers will be better-off the higher y_s in the speculators' portfolio, given that it is proportional to market price paid for the asset.

Given that, as stated in section 2.1.3.1, the beliefs of consumers on the size of y_s follow a uniform distribution on $[y^s_{\min}, y^*)$ with $y^s_{\min} \neq 0$, the expected late consumption in case of liquidation depends on y_s and in $t = 1$ is equal to:

$$E[C_2] = \int_{y^s_{\min}}^{y^*} \frac{y_s}{y^* - y^s_{\min}} dy^s = \frac{y^* + y^s_{\min}}{2} \tag{24}$$

In $t = \frac{3}{2}$ all the uncertainty on y_s is resolved.

Proposition 2 below formalizes the above findings.

Proposition 2 *With risk-averse speculators, an opaque signal causes uncertainty on the fundamental value of the risky asset in $t = 1$. When speculators hold enough safe asset they may overprice the risky asset if the nature unveils a state of the world with high default risk in $t = \frac{3}{2}$. In this instance, late consumers are better-off than if the safe asset in the hands of speculators was lower. Therefore, consumers benefit at the speculators' expenses from speculators' higher amounts of safe asset holdings with higher default risk.*

4 Central Banker's Intervention

In this section we consider the welfare effects of an intervention by the central banker. The central bank cannot restore consumption levels of a no-run equilibrium but can guarantee higher levels of late and early consumption than if cash-in-market pricing had taken place. We assume that the central bank has an exogenous initial endowment of cash equal to E_b, which might be lent to the bank if a net gain can be made.

The central banker in this model has the same information set of consumers. That is, he observes the signal ϕ at $t = 1$. Depending on the market price of the risky asset, whenever, a bank run occurs, the central banker might decide to intervene in order to sustain asset prices. If intervenes, he enters a repurchase agreement with the bank in which he purchase the risky asset. The price paid for the risky asset in the repo agreement is equal to its fundamental if investors are risk-neutral. If, instead, investors are risk-averse then the central bank faces uncertainty on the fundamental value of the risky asset and might over/under price the asset. The terms of the repurchase agreement oblige the bank to re-pay the central banker in $t = 2$ whatever it gets from the risky asset. The central banker will enter the repo agreement only if its expected net gain is greater than zero:

$$E[NG^{cb}] = \phi x^* - M[\alpha(1 - p^h) + (1 - \alpha)(1 - p^l)] > 0 \tag{25}$$

Where $M = P^s x^*$ is the price paid by the central banker to the bank for the purchase of the risky asset at the support price P^s. The social optimality of the central banker's intervetion, whenever (26) holds, depends on the risk-attitude of speculators and on the liquidity they hold, as we show in the following sections.

4.1 Risk-Neutral Speculators

If the asset market is populated by risk-neutral investors, then the fundamental price of the asset is equal to the observed signal ϕ. The central banker might decide to enter the repo agreement when the liquidity (safe asset) in the hands of speculators is low enough to drive market prices below fundamentals and when there is no market for the risky asset. Therefore, he will lend $M = \phi x^*$ to the bank with $P^s = \phi$, i.e. he will sustain prices to fundamentals. It can be easily noticed that in this setting the central bank will enter the repo agreement at every level of ϕ. Indeed, (25) becomes:

$$E[NG^{cb}] = \phi x^*\{1 - [\alpha(1 - p^h) + (1 - \alpha)(1 - p^l)]\} > 0 \ \ \forall\phi \tag{26}$$

The resulting consumption levels for early and late consumers will therefore, be:

$$C_1 = C_2 = \frac{y^* + \phi x^*}{2} \tag{27}$$

This is greater that what consumers would have received if fire-sale had occurred:

$$\frac{y^* + \phi x^*}{2} > \frac{y^* + P_x x^*}{2} \tag{28}$$

The main implication of the above intervention is that the central banker that engages in the rescue intervention is not certain about the solvency of the bank. Insolvency can be due to either the occurrence of the bad state of the world, i.e. $R^l = 0$, or to the fact that in the good state of the world late consumers get less than early consumers (this will depend on the size of R^{hl}).

The inability to distinguish a solvent from an insolvent bank renders the intervention by the central bank risky, in the sense that the central bank could bear the loss if either the bad state of the world materializes or R^{hl} is low enough so that the realized (i.e. in $t = 2$) NG^{cb} is less than zero. In the former case, then the bank in $t = 2$ will be unable to pay anything to the central banker, which will bear a loss equal to, the whole M. If instead, the good state of the world materializes and $R^{hl} < \frac{y^*}{x^*}$, then the loss faced by the central banker will be:

$$NG^{cb} = (R^{hl}x^*) - M < 0 \tag{29}$$

The intervention by the central banker, moreover, avoids late consumers to bear the losses incurred in the bad state of the world with $R^l = 0$. In fact, it guarantees a fixed level of consumption for late/early consumer equal to $\frac{y^*+\phi x^*}{2}$ which is in any case higher than what they would have received if the bank had gone to the asset market. This is shown in figure 7 in which are depicted the consumption levels (actual and expected) by late consumers following the central banker's intervention when $\phi < \frac{y^*}{x^*}$ (blue line). Figure 6, instead, shows the effect on the pricing of the risky asset of an intervention of this kind (blue line): the price is equal to its fundamental for every level of the signal.

Proposition 3 *With risk-neutral speculators the central bank will intervene to support prices to fundamentals at every $\phi < \frac{y^*}{x^*}$. The central bank will carry both the default risk and the risk that the bad state of the world materializes. Consumers are guaranteed a sure and fixed consumption level equal to $\frac{y^*+\phi x^*}{2}$.*

4.2 Risk-Averse Speculators

If the fundamental value of the risky asset is uncertain, then, it becomes more problematic for the central bank to pursue an intervention aimed to support fundamental prices. Reasonably, the central banker's intervention when there is opacity in fundamental values will be such that (1) consumers get more than they would do from the cash-in-market pricing and (2) the expected net gain of the central banker are maximized. The risky asset price that the central bank will support is, thus, dependent on these two conditions. However, it will on a first place depend on the cash-in-market price in the asset's market which is determined by y_s. Indeed, a *one-fits-all* policy that sustain prices at the expected fundamental level (i.e. $P^s = E(F_v)$ for $\forall\ \phi < \frac{y^*}{x^*}$) could decrease the expected net gains of the central bank. Let's see this in more details.

Let's assume, for simplicity, that the central bank has three possible intervention strategies. That is, it can lend to the bank either M_1, M_2 or M_3:

$$M_1 = E(F_v)x^* \tag{30}$$

$$M_2 = F_v^h x^* \tag{31}$$

$$M_3 = F_v^l x^* \tag{32}$$

The corresponding expected net gains are:

$$E[NG_1^{cb}] = x^*(\phi - E(F_v))[\alpha(1-p^h) + (1-\alpha)(1-p^l)]\} \tag{33}$$

$$E[NG_2^{cb}] = x^*(\phi - F_v^h)[\alpha(1-p^h) + (1-\alpha)(1-p^l)]\} \tag{34}$$

$$E[NG_3^{cb}] = x^*(\phi - F_v^l)[\alpha(1-p^h) + (1-\alpha)(1-p^l)]\} \tag{35}$$

Given that $\phi > E(F_v)$, $\phi > F_v^i$ and that $0 \leq \alpha(1-p^h) + (1-\alpha)(1-p^l) \leq 1$ then it must be that:

$$E[NG_3^{cb}] < E[NG_1^{cb}] < E[NG_2^{cb}] \tag{36}$$

Also note that (33), (34) and (35) are all greater than zero $\forall\phi$, therefore the central banker always wishes to intervene and lend to the bank.

4.2.1 Intervention with high levels of y_s

If speculators hold abundant levels of y_s in their portfolio, as described in figure 4, as we have already seen, they will make speculative profits only if he fundamental value turns out to be high (low default risk) when $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$. Sustaining asset price to low fundamental values, i.e. $P^s = F_v^l$ and $M_3 = F_v^l x^*$, although maximizes the expected net gain of the central banker, would not be a sustainable intervention. This is because early and late consumers would get less than if speculators were purchasing the asset, that is:

$$\frac{y^* + y_s}{2} > \frac{y^* + F_v^l x^*}{2} \tag{37}$$

Therefore, when $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$ the central bank will support prices to its expected fundamental values since $E[NG_3^{cb}] < E[NG_1^{cb}]$. The actual consumption level are, thus:

$$C_1 = C_2 = \frac{y^* + E[F_v]x^*}{2} \tag{38}$$

However, when the signal is low enough so that no market for the risky asset exists, that is, when $\phi < \frac{y_s'}{x^*}$, then the central banker can support prices to low fundamental values, that is $P^s = F_v^l$. In this case, early and late consumers will get more than if they were sharing equally the available y^*:

$$C_1 = C_2 = \frac{y^* + F_v^l x^*}{2} > \frac{y^*}{2} \tag{39}$$

The pricing of the risky asset with central bank's intervention and high levels of y_s is depicted in figure 8.

Proposition 4 *With risk-averse speculators and high enough market prices (and y_s) the central bank intervenes to support prices at every $\phi < \frac{y^*}{x^*}$. The central bank will carry both the default risk and the risk that the bad state of the world materializes. Consumers are guaranteed a fixed consumption level equal to $\frac{y^* + P_s x^*}{2}$.*

A central banker's intervention of this kind (i. e. with opacity) can cause inefficient asset pricing, that is, asset pricing different from fundamentals. Indeed, when the signal is very low such as $\phi < \frac{y_s'}{x^*}$ the central bank might under-price the asset, lending to the bank less than it should have received if in $t = \frac{3}{2}$ it occurs that $\phi = p^h R^{hl}$ (so that $F_v = F_v^h$). For higher levels of the signals such that $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$ the central bank is surely either over-pricing or under-pricing the asset. In other words, the central bank is lending either more or less than the bank should be entitled to, given the quality of its assets.

Proposition 5 *Opacity leads to inefficient policy responses. The central bank can lend either more or less than the bank should be entitled to, given the quality of its assets.*

Proposition 6 *Given high values of the signal (but always less than $\frac{y^*}{x^*}$), risk-averse speculators and high enough market prices (i.e. high y_s), the policy response is surely inefficient.*

4.2.2 Intervention with low levels of y_s

If speculators hold relatively low levels of safe asset as in figure 5, we have already shown that there exist a boundary signal s which determines two different outcomes for speculators. If the signal is such that $s < \phi \leq \frac{y^*}{x^*}$, then, speculative profits can be made whatever the fundamental value unveils (although clearly F_v^h is associated with higher profits). If, instead, the signal is such that $\frac{y_s'}{x^*} < \phi \leq s$ then again speculators make profits only if the default risk attached to the asset is low, that is, if $F_v = F_v^h$.

The central banker, thus, will adopt three different intervention strategies, depending on the observed signal. If there is no market for the risky asset as $\phi < \frac{y_s'}{x^*}$, as before, the central banker will support prices to F_v^l, lending to the bank M_3 and achieving the consumption levels as in (39). If the signal is such that $\frac{y_s'}{x^*} < \phi \leq s$ then, for the same reasoning as in the previous section, the central banker lends M_1 to the bank. If, instead, $s < \phi \leq \frac{y^*}{x^*}$ then the central bank will maximize its expected net gain by lending M_3 to the bank, which implies $P^s = F_v^l$ with the following consumption levels:

$$C_1 = C_2 = \frac{y^* + F_v^l x^*}{2} > \frac{y^* + y_s}{2} \tag{40}$$

The pricing of the risky asset with central bank's intervention and low levels of y_s is depicted in figure 9.

The safe asset in the hands of speculators, however, could be so low that they would make speculative profits whatever the signal (in this case the signal s would not exist). In this case, clearly the central bank would support the prices of the asset at its low fundamental value.

From these results we can formalize the following proposition:

Proposition 7 *When speculators hold low levels of safe asset, so that market prices are relatively lower, the central bank tends to support asset prices as if they carried a high default risk. For a small interval of signals, however, the central* *bank might over-price/under-price the asset.if the cash-in-market mechanism yields a higher pricing than F_v^l.*

4.3 The AG model

The inclusion of default risk embodied in a true but opaque signal in the benchmark AG model allows us to make a richer set of considerations on the role of the central bank's intervention during a banking crisis. In AG, indeed, a banking crisis occurs on a bank which is illiquid but always solvent. The central bank intervenes to avoid costly asset liquidation and to the collapse of the asset prices below fundamentals other than to guarantee the consumers the maximum attainable level of consumption given the occurred state of the world. The monetary authority lends the bank the liquidity needed by buying the risky asset at its fundamental level. Moreover, it will be paid back exactly the money lent, given that the fundamental value is contingent on the perfectly observed but future asset return.

In our framework we consider the case of insolvency crisis in which the central bank intervenes through repo agreements. Here the monetary authority intervenes only if it is convenient for him to do so; however, in the case in which intervention occurs he bears the risks attached to the investment in the risky asset. In other words, even if the expected value of entering the repo agreement is positive, the risk of the occurrence of default or a low-return state is to the central bank as if it was any other investor. Moreover, uncertainty on the fundamental value of the risky asset distorts the policy intervention: the central banker when there is opacity cannot assess exactly how much liquidity to lend given the quality of the risky asset is uncertain.

5 Conclusions

In this paper we have included opacity in a simple model in which a representative bank, solving an optimal risk-sharing problem, is subject to runs by depositors. Opacity is modeled through the inclusion of unobservable default risk on the bank's portfolio, as well as unobservable return on the risky asset. The unability of the agents to distinguish between the two, given a signal sent by the nature on their product, has many interesting implications. Firstly, we show that run decisions based on expected consumption levels can cause a run on a solvent bank or no-runs on an insolvent bank. Secondly, we model the asset market pricing that occurs through a cash-in-market mechanism. In this regard, we stress that opacity leads to uncertainty on the fundamental value of the risky asset when speculators in the asset market are risk-averse. Lastly, we analyze the welfare implications of a central banker's intervention which is unable to prevent the run but ensures a fixed level of consumption higher than if speculators were purchasing the asset during a run. The central banker, with the aim to minimize its loss function, will be very likely to enter a repo agreement with the bank by offering a price for the risky asset equal to the lowest fundamental level that it can take. Therefore, opacity can cause inefficient policy responses: this is because the central bank lends either more or less than the bank should be entitled to, given the quality of its assets.

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Proofs

Proof 1

Given the optimal allocations of the ORSP: $C_1 = \bar{c} = \frac{y^*}{\mu}$ and $C_2 = \frac{Rx^*}{1-\mu}$,for semplicity we assume that $\mu = 1 - \mu$ so that $C_1 = \bar{c}$ =y^* and $C_2 = Rx^*$. A run will occurr whenever $y^* > Rx^*$, that is, when $\frac{y^*}{x^*} > R$ where R is the asset's fundamental value. Let's now assume that $y_s > y^*$, which implies that in the case of asset liquidation the market price would be: $P_x = \frac{y_s}{x^*} > \frac{y^*}{x^*} = R$. However, for a market price higher than the fundamental value no purchase of the risky asset by speculators would take place.

Figures

Figure 2: Risky asset pricing and observed signal with risk-neutral speculators (without central banker's intervention)

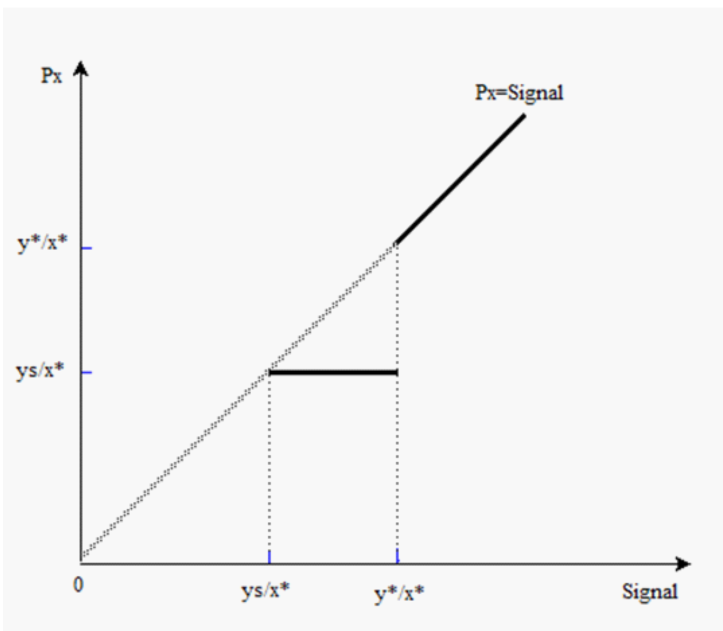


Figure 3: Expected late consumption and observed signal with risk-neutral speculators (without central banker's intervention). A bank run associated with speculators purchase of the risky asset occurs if the observed signal at date 1 is such that $\frac{y_s}{x^*} \leq \phi \leq \frac{y^*}{x^*}$. Realized late consumption in this case is equal to $C_2 = \frac{y^*+y_s}{2}$. It is easily seen that at this consumption level, late consumers receive more than they would have got if they did not run if $\frac{y_s}{x^*} \leq \phi \leq s = \frac{y^*+y_s}{2x^*}$. Otherwise (i.e. if $s \leq \phi \leq \frac{y^*}{x^*}$) late consumers would have received more if they did not run and cash-in-market pricing did not take place, even if $E[C_2] < y^*$. Indeed, recall that when a run takes place, consumers are unaware of the size of y_s. When the signal is so low that speculators are not willing to buy, i.e. $\phi \leq \frac{y_s}{x^*}$, the bank will share equally among early and late consumers the available y^*. Also in this case, late consumers might have received more if they did not run, in particular as $\phi \to \frac{y_s}{x^*}$.

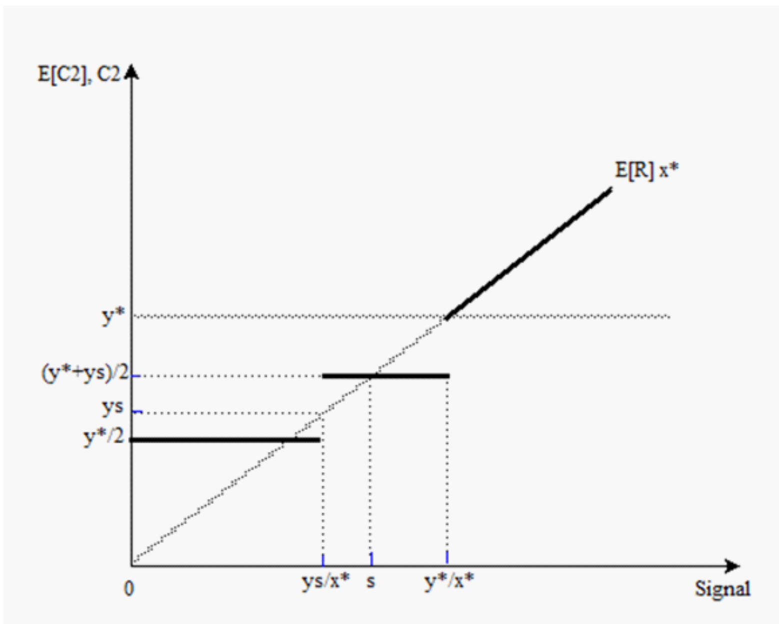


Figure 4: Buying decision and observed signal with risk-averse speculators- high levels of y_s. Note that $\frac{y\prime s}{x^*} = \theta \frac{y_s}{x^*}$.

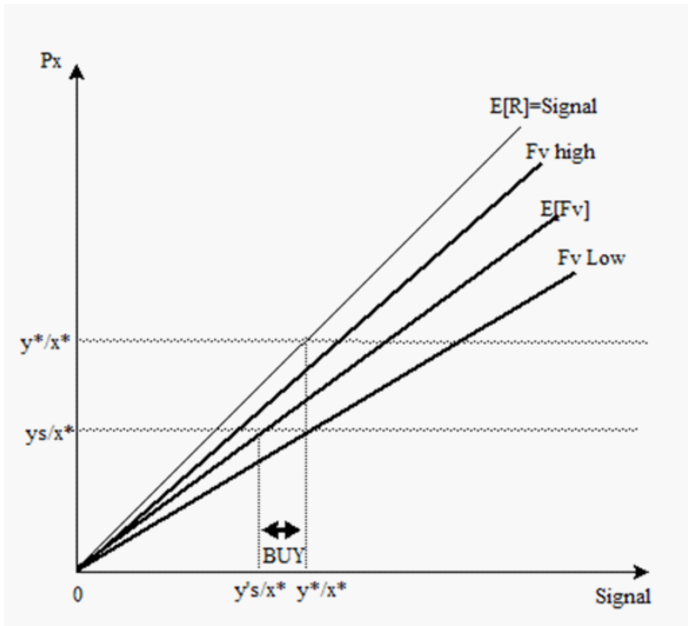


Figure 5: Buying decision and observed signal with risk-averse speculators- low levels of y_s

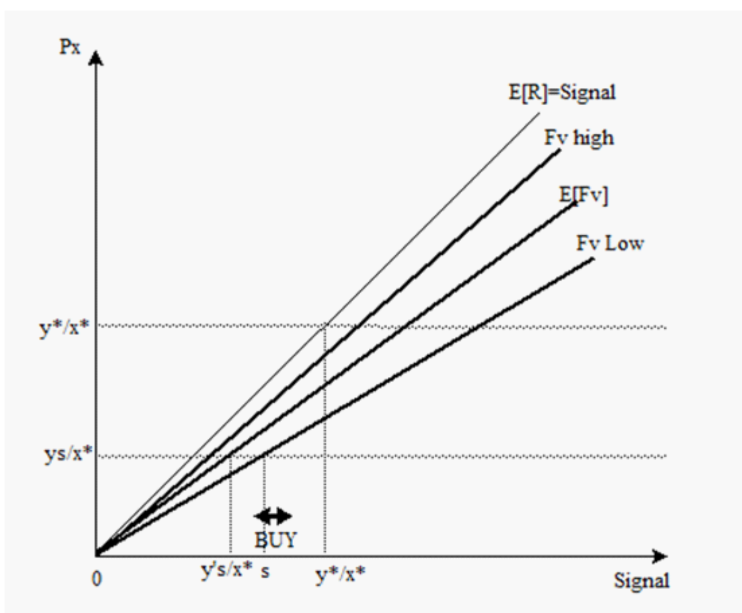


Figure 6: Risky asset pricing and observed signal with risk-neutral speculators (with central banker's intervention)

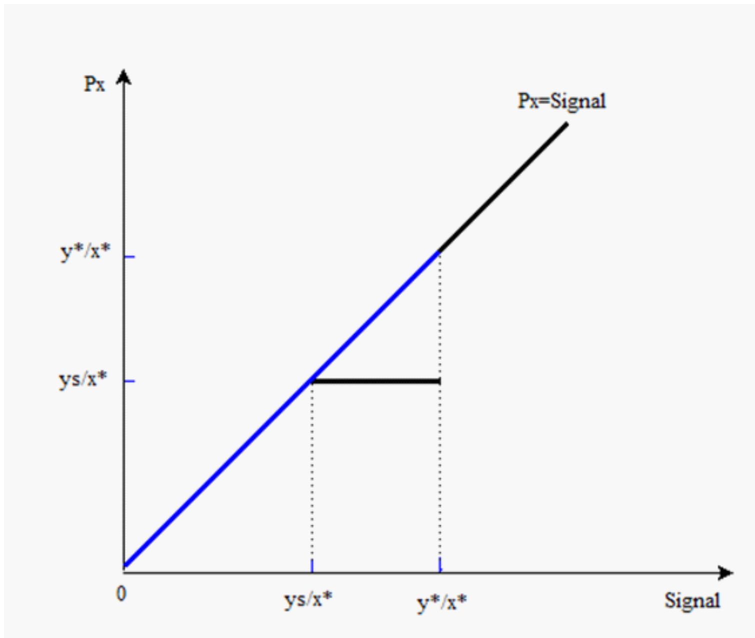


Figure 7: Expected late consumption and observed signal with risk-neutral speculators (with central banker's intervention)

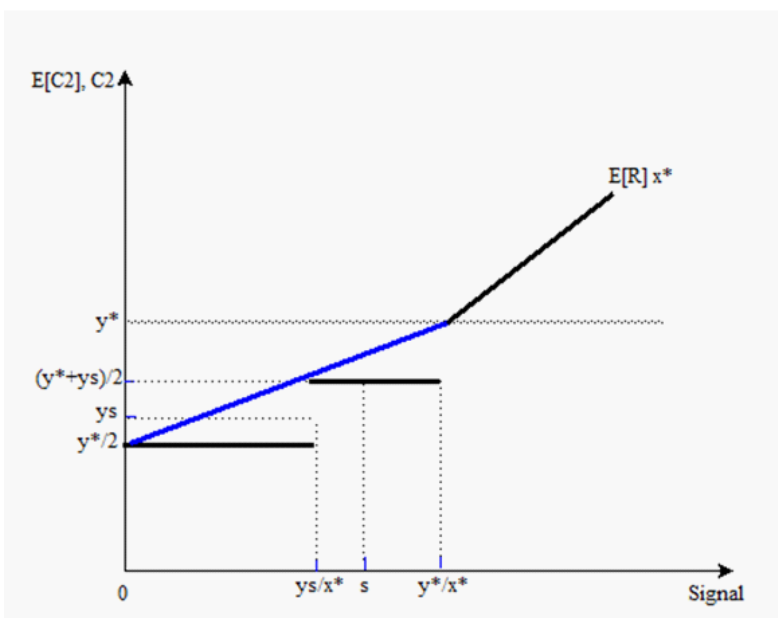


Figure 8: Risky asset pricing and observed signal with risk-averse speculators (with central banker's intervention)- high levels of y_s. The red lines refer to asset market pricing without intervention. That is, when $\phi < \frac{y_s'}{x*}$ there is no market for the risky asset; when $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$ there is cash-in-market asset pricing. In the former case, the central bank will support prices to low fundamentals (blue line). In the latter case, it will support prices to expected fundamental values (blue line).

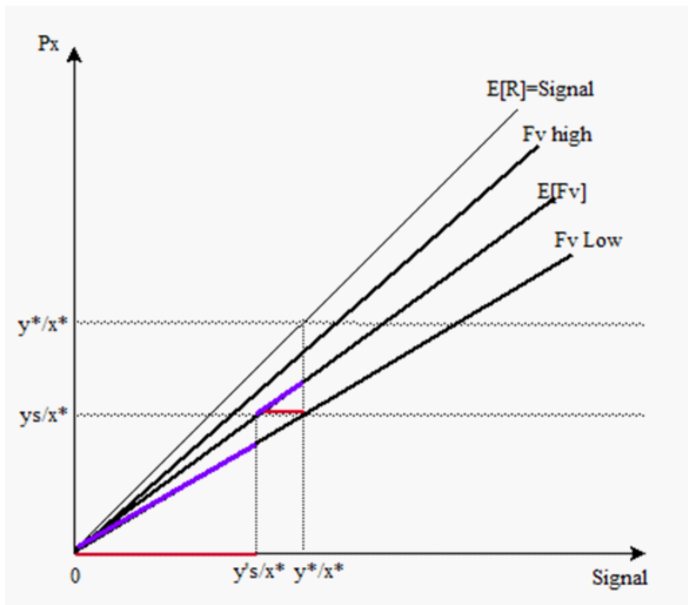
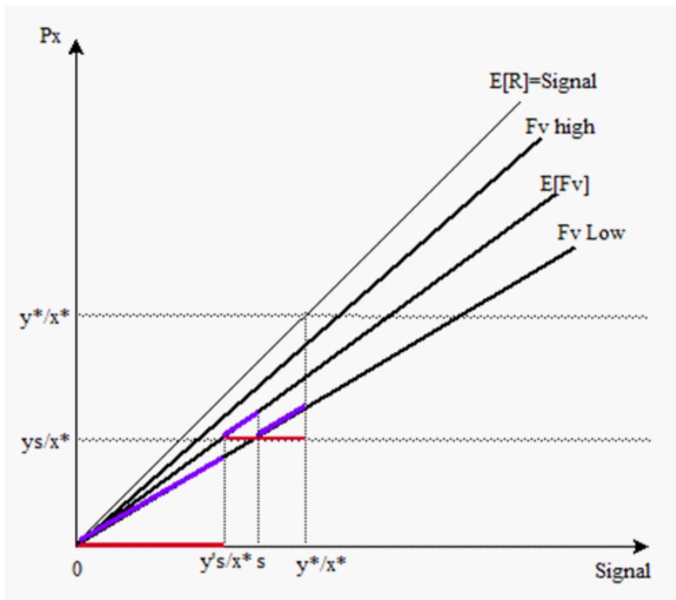


Figure 9: Risky asset pricing and observed signal with risk-averse speculators (with central banker's intervention)- low levels of y_s. The red lines refer to asset market pricing without intervention. That is, when $\phi < \frac{y_s'}{x*}$ there is no market for the risky asset; when $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$ there is cash-in-market asset pricing. In the former case, the central bank will support prices to low fundamentals (blue line). When $\frac{y_s'}{x^*} < \phi \leq s$ the central banker support prices at expected fundamental values (blue line). When $s < \phi \leq \frac{y^*}{x^*}$ the central bank will support prices to low fundamentals (blue line).



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Estratto per riassunto della tesi di dottorato

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Titolo della tesi: "Banks: selected investigations on the roles of liquidity, globalization and credit risk"

Abstract

This thesis presents three bank-related research studies inspired by some relevant events brought about by the recent *subprime* banking crisis. The first part of this work links banking-sector liquidity creation to both liquidity supply from central banks worldwide and international interbank liabilities, within a global macro-econometric framework. In the second part it is carried out a micro-econometric analysis on all global US banks with the intent to explain pre- and post-crisis dynamics in Net Inter-Office Accounts (NIOA). The last part of the thesis proposes a framework capable to model, among other things, inefficient policy interventions by a central banker during a crisis when an accurate assessment of the true solvency of a bank is unattainable.

La tesi presenta tre studi di ricerca su temi bancari connessi ad alcuni eventi osservati durante la recente crisi bancaria dei mutui *subprime*. Il primo capitolo della tesi collega la creazione di liquidità del settore bancario sia all'offerta di liquidità delle banche centrali di tutto il mondo e alle passività bel mercato interbancario internazionale, in un quadro macro-econometrico globale. Nel secondo capitolo è effettuato uno studio sulle banche globali degli Stati Uniti con l'intento di spiegare le dinamiche nei debiti netti tra uffici domestici e filiali straniere. L'ultima parte della tesi propone un modello teorico di corsa ai depositi bancari capace di spiegare, tra le altre cose, interventi inefficienti di un banchiere centrale durante una crisi, quando la valutazione della solvibilità di una banca è incorretta.

Firma

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