EUROPEAN CENTRAL BANK

EUROSYSTEM

WORKING PAPER SERIES

NO 1124 / DECEMBER 2009

BALANCE SHEET INTERLINKAGES AND MACRO-FINANCIAL RISK ANALYSIS IN THE EURO AREA

by Olli Castrén

and Ilja Kristian Kavonius

EUROPEAN CENTRAL BANK

EUROSYSTEM

WORKING PAPER SERIES

NO 1124 / DECEMBER 2009

BALANCE SHEET INTERLINKAGES AND MACRO-FINANCIAL RISK ANALYSIS IN THE EURO AREA [1]

by Olli Castrén and Ilja Kristian Kavonius [2]

In 2009 all ECB publications feature a motif taken from the €200 banknote.

1 The views expressed in this paper are those of the authors and they do not necessarily reflect the views or policies of the European Central Bank or the European System of Central Banks. The paper benefited from useful comments by Matthias Drehmann, Dale Gray, John Fell, Philipp Hartmann, Steven Keuning, Goetz von Peter, Hung Shin, Matthias Sydow, Tuomas Takalo, Christian Upper, the members of the ESCB Banking Supervision Committee, seminar participants and commentators at the ECB and the Bank of England, and participants of the ECB workshop "Recent Advances in Modelling Systemic Risk Using Network Analysis", without implicating them in any remaining errors.

2 European Central Bank, Kaiserstrasse 29, D-60311 Frankfurt am Main, Germany; e-mail: olli.castren@ecb.europa.eu and ilja_kristian.kavonius@ecb.europa.eu

Address
Kaiserstrasse 29
60311 Frankfurt am Main, Germany

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

Telephone
+49 69 1344 0

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

Fax
+49 69 1344 6000

ISSN 1725-2806 (online)

CONTENTS

Abstract

The financial crisis has highlighted the need for models that can identify counterparty risk exposures and shock transmission processes at the systemic level. We use the euro area financial accounts (flow of funds) data to construct a sector-level network of bilateral balance sheet exposures and show how local shocks can propagate throughout the network and affect the balance sheets in other, even seemingly remote, parts of the financial system. We then use the contingent claims approach to extend this accounting-based network of interlinked exposures to risk-based balance sheets which are sensitive to changes in leverage and asset volatility. We conclude that the bilateral cross-sector exposures in the euro area financial system constitute important channels through which local risk exposures and balance sheet dislocations can be transmitted, with the financial intermediaries playing a key role in the processes. High financial leverage and high asset volatility are found to increase a sector's vulnerability to shocks and contagion.

Keywords: Balance sheet contagion, financial accounts, network models, contingent claims analysis, systemic risk, macro-prudential analysis.

JEL Classification: C22, E01, E21, E44, F36, G01, G12, G14

Executive Summary

The process of financial stability assessment typically involves identification of risks and vulnerabilities in various parts of the financial system. It also calls for identification of potential triggering events which, if crystallised, could flip the state of the financial system from stability to instability. However, the events of the recent global financial turmoil have demonstrated that financial stability analysis should also aim at identifying *links* between sectors and *channels* through which local shocks may propagate wider in the financial system. Seeing the financial system as a network of interlinked exposures can help to detect such transmission mechanisms. Analysis of this network may then reveal that parts of the financial system that might not be considered particularly vulnerable to a given adverse scenario could still be affected due to their close interconnection with sectors that are directly confronted by the unforeseen events.

This paper proposes a new framework that captures several types of interlinkages within the financial system. The approach yields three main contributions to the existing work: first, by using the data from the euro area financial accounts and thus focusing on sector-level bilateral exposures, we aim at filling a gap in the literature that applies networks to financial stability analysis. The existing studies mainly look at bilateral exposures at the firm-level, such as in the inter-bank money markets, or at the country level, typically using cross-border banking flows data. Second, in the latter part of the paper, we apply the contingent claims analysis to extend the constructed accounting-based network of bilateral exposures to *a risk-based network* where we can trace the propagation of volatility shocks and changes in risk exposures. This extension provides particularly interesting results as regards the interactions between leverage and volatility in an environment where measures of credit risk are characterised by strong non-linearities. Third, we carry out simulation exercises which illustrate the extent of balance sheet contagion (defined as the propagation of mark-to-market losses along the bilateral exposures) and risk contagion (defined as an increase in correlation among sector-level risk exposures in times of financial stress) in the euro area financial system.

The data that is used to construct the sector-level balance sheets are from the euro area accounts (EAA), published jointly by the ECB and Eurostat. This type of data is also known as *flow of funds statistics* which are available in most developed economies – based on the common definitions listed in the world-wide manual of System of National Accounts (SNA) –

in varying instrument breakdowns, publication frequencies and lengths of time series. The EAA form a closed system which means that each financial asset item of a sector has a counterparty item on the liability side of some other sector. Due this internal consistency, the EAA are well suitable for analysis that aims at identifying counterparty risk exposures and shock propagation channels in various financial instrument categories at the sector level.

The main results can be summarised as follows. Over the first ten years of the EMU, the bilateral financial accounts network linkages have grown markedly, with the banking sector constituting a key part of the euro area financial system. In simulation exercises we analyse the propagation of shocks and contagion in the network of sector-level balance sheets in a multi-period context and find that under mark-to-market accounting, local cash-flow shocks can spread around quickly along the bilateral exposures even when there are no defaults in the process, with banks and non-financial firms playing key roles in the transmission. These results provide interesting empirical support to the conceptual models of shock transmission via balance sheet exposures as formalised, among others, by Kiyotaki and Moore (1997, 2002), Goodhart (2006) and Shin (2008). We then calculate the risk-based balance sheets for individual sectors following the recent conceptual work by Gray, Merton and Bodie (2007) and Gary and Malone (2008) and show how these evolved prior to and after the recent financial turmoil broke out. Simulation exercises on the risk-based network illustrate how correlations among sector-level risk indicators surged amid the outbreak of the financial turmoil in mid-2007. We also show how sector-level credit risk indicators are affected by shocks in other parts of the network and how the risk indicators of sectors with highest leverage are the most vulnerable ones to shocks to volatility. In that sense, higher leverage increases sensitivity to volatility shocks in the same way as in deeply out-of-the money options.

In a recent paper, Borio and Drehmann (2009) argue that the desirable features of an operational financial stability framework should include, *inter alia,* the following three characteristics. First, it should focus on the financial system as a whole as opposed to individual institutions. Second, the more interconnected areas of the system should deserve more attention than others. Third, the analysis should capture common exposures, arising either from claims to non-financial sectors or from exposures within the financial sector. Our proposed framework captures these features and it thus provides one contribution to the work towards such operational frameworks. It also opens up several avenues for further research in financial stability and macro-prudential analysis using network models and risk-based balance sheets.

1. Introduction

The process of financial stability assessment typically involves identification of risks and vulnerabilities in various parts of the financial system. It also calls for identification of potential triggering events which, if crystallised, could flip the state of the financial system from stability to instability. But the events of the recent global financial turmoil have demonstrated that financial stability analysis should, perhaps first and foremost, also aim at identifying *links* between sectors and *channels* through which local shocks may propagate wider in the financial system.[1] Seeing the financial system as a network of interlinked exposures can help to detect such transmission mechanisms. Analysis of this network may then reveal that parts of the financial system that might not be considered particularly vulnerable to a given adverse scenario could still be affected due to their close interconnection with sectors that are directly confronted by the unforeseen events.[2]

This paper proposes a new framework for analysing financial system stability that captures several types of interlinkages within the financial system. The approach yields three main contributions to the existing work: first, by using the flow of funds data from the euro area financial accounts and thus focusing on sector-level bilateral exposures, we aim at filling a gap in the literature that applies networks to financial stability analysis. The existing studies mainly look at bilateral exposures at the firm-level, such as in the interbank money markets, or at the country level, typically using cross-border banking flows data.[3] Second, in the latter part of the paper, we apply the contingent claims analysis to extend the constructed accounting-based network of bilateral exposures to a risk-based network where we can trace also the propagation of volatility shocks and changes in risk exposures. This extension provides particularly interesting results as regards the interactions between leverage and

---

[1] Indeed, the spreading of the financial turmoil from the external environment via the off-balance sheet vehicles to euro area banks and further to other financial and non-financial sectors as the financial crisis evolved in 2007-09 exposed unforeseen counterparty linkages and eroded confidence in the way which further amplified the effect of the initial shocks.

[2] Reflecting growing awareness of such network externalities for financial stability analysis, recommendations issued by several committees for reforming the European financial supervision advised that more comprehensive systemic risk indicators, such as “financial stability maps” should be developed (see for example de Larosiere, 2009). In a normative dimension, understanding the structure and characteristics of the financial networks could also lead to recommendations for structural changes that may enhance the robustness and resilience of the system as recently suggested by Haldane (2009).

[3] For European studies on interbank networks, see *e.g.* Becher, Millard and Soramaki (2008), van Lelyveld and Liedorp (2006), Upper and Worms (2004) and Wells (2004). On the country-level networks, see McGuire and Tarashev (2008) and Castrén, Fell and Valckx (2009). Important theoretical contributions to network analysis are Watts (2004) and Gallegati et al (2008) which also contain extensive surveys of related literature.

volatility in an environment where measures of credit risk are characterised by strong non-linearities. Third, we carry out simulation exercises which illustrate the extent of balance sheet contagion (defined as propagation of mark-to-market losses along the bilateral exposures) and risk contagion (defined as an increase in correlation among sector-level risk exposures in times of financial stress) in the euro area financial system.

The main results of our work can be summarised as follows. Over the first ten years of the EMU, the bilateral financial accounts network linkages have grown markedly, with the banking sector constituting a key part of the euro area financial system. In simulation exercises we analyse the propagation of shocks and contagion in the network of sector-level balance sheets in a multi-period context and find that under mark-to-market accounting, local cash-flow shocks can spread around quickly along the bilateral exposures even when there are no defaults in the process, with banks and non-financial firms playing key roles in the transmission. These results provide interesting empirical support to the conceptual models of shock transmission via balance sheet exposures as formalised, among others, by Kiyotaki and Moore (1997, 2002), Goodhart (2006) and Shin (2008). We then calculate the risk-based balance sheets for individual sectors following the recent conceptual work by Gray, Merton and Bodie (2007) and Gary and Malone (2008). Simulation exercises on the risk-based network illustrate how correlations among sector-level risk indicators surged amid the outbreak of the financial turmoil in mid-2007. We also show how sector-level credit risk indicators are affected by shocks in other parts of the network and how the risk indicators of sectors with highest leverage are the most vulnerable ones to shocks to volatility. In that sense, higher leverage increases sensitivity to volatility shocks in the same way as in deeply out-of-the money options.

In a recent paper, Borio and Drehmann (2009) argue that the desirable features of an operational financial stability framework should include, *inter alia,* the following three characteristics. First, it should focus on the financial system as a whole as opposed to individual institutions. Second, the more interconnected areas of the system should deserve more attention than others. Third, the analysis should capture common exposures, arising either from claims to non-financial sectors or from exposures within the financial sector. Our proposed framework captures these features and it thus provides one contribution to the work towards such operational frameworks. It also opens up several avenues for further research in financial stability and macro-prudential analysis using network models and risk-based balance sheets.

The rest of this paper proceeds as follows. Section 2 describes the balance sheet data and discusses the pros and cons of using financial accounts data in the context of financial stability analysis. In section 3 we calculate the network of bilateral balance sheet exposures.

Section 4 analyses the transmission of shocks in the accounting-based network. Section 5 contains the analysis of risk-based balance sheets. Section 6 concludes.

2. Description of the balance sheet data

In this paper the euro area financial system is considered as a closely intertwined group of seven distinct sectors: households including non-profit institutions serving households, non-financial corporations (NFCs), banks (MFIs), insurance and pension fund companies, other financial intermediaries (OFIs), general government, and the rest of the world (RoW).[4] These sectors cover the entire economy and including the RoW sector the system is closed, *i.e.* paid transactions in the system have to equal received transactions. This means that each financial asset item of a sector has a counterparty item on the liability side of some other sector.

The data that is used to construct the sector-level balance sheets are from the euro area accounts (EAA), published jointly by the ECB and Eurostat. In the EAA, the analytical grouping of economic agents into institutional sectors and transactions is based on the methodological framework established in the European System of Accounts 1995 (ESA95).[5] This type of data is often referred to as the flow of funds statistics which are available in most developed economies in varying instrument breakdowns, publication frequencies and lengths of time series. These data are broadly comparable between different countries as the overall framework is defined in the System of National Accounts (SNA), a worldwide manual for the compilation of national accounts. Importantly, the EAA data are non-consolidated which means that they include financial linkages not only between the sectors but also within the sectors in the system. This will have important implications to the analysis below.

Due to its internal consistency, the EAA are well suitable for analysis that aims at identifying counterparty risk exposures and shock propagation channels at the sector level. At the same time, this characteristic also gives raise to its main weakness as some economically important non-financial stocks and instruments do not have counterparty items on the liability sides. Therefore such items, most notably housing assets, have to be excluded from analyses which

---

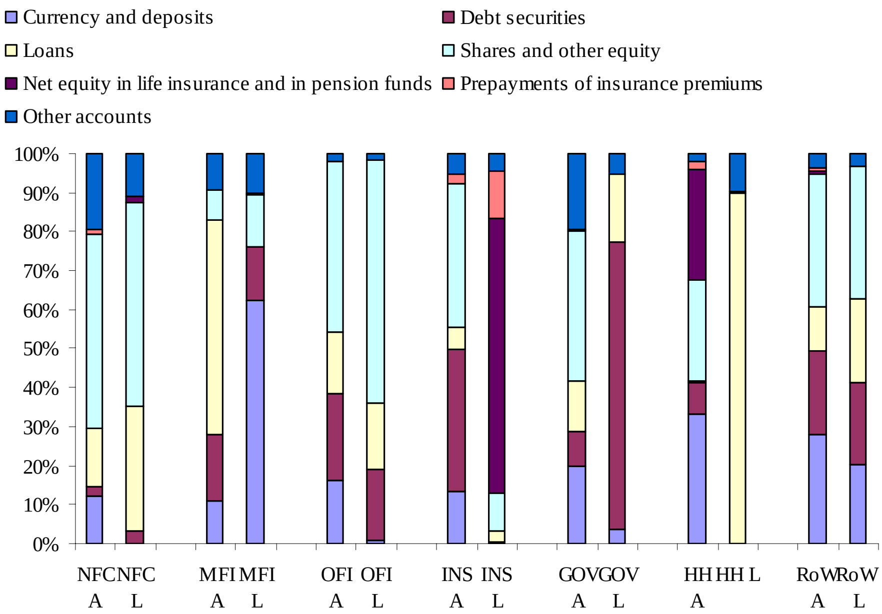
[4] Our definition of "financial system" is therefore relatively broad and based on accounting terms. Other definitions can be more nuanced. For example, in its Financial Stability Review the ECB defines the financial system as consisting of financial markets, institutions and infrastructures.

[5] The sectoral breakdown adopted in this paper is identical to the sectoral detail in the EAA. For more details, see http://forum.europa.eu.int/irc/dsis/nfaccount/info/data/esa95/en/titelen.htm. The ESA95 stands for the "European System of Accounts 1995" and it is an application of "System of National Accounts 1993" (SNA93). According to the ESA95 principle all data are valued at market prices. However, the practical application of market prices is not always straightforward since all financial instruments, such as loans, do not have proper secondary markets. In such cases the data is estimated as close to the market price as possible. The euro area figures are aggregated from the individual country data and the specific estimation methods can vary from country to country. Currently, only some countries publish parts of their financial accounts data at quarterly frequency and therefore European institutions do not publish country level figures. At annual frequency these data are published by most of the European Union member states.

use financial accounts data.[6] Annex 1 discusses the link between financial and non-financial wealth in more detail and illustrates how housing assets and housing wealth are recorded in the integrated *(i.e.* financial and real) accounts.

Chart 1 illustrates the composition of the EAA financial accounts balance sheets (assets and liabilities) of the seven sectors at the end of the second quarter of 2009; the relative shares of the various asset and liability stock items tend to remain rather constant over time. The categories of financial instruments included in the balance sheets are distinguished in the ESA95 national accounts which are classified according to liquidity factors and legal characteristics.

Chart 1: The composition of sector-level balance sheets in the euro area financial accounts (A=assets, L=liabilities)



For most sectors, the asset sides of the financial account balance sheets consist of holdings, in different proportions, of cash and money market instruments as well as debt and equity securities. Several sectors (notably MFI, but also non-financial firms and OFIs) also extend large amounts of loans to the other sectors. There are also smaller asset items, such as pre-

[6] The non-financial assets could be technically included in the financial balance sheets by securitising them in the accounting framework. In practice, a new imaginary counterparty sector, which would technically own the properties, would then have these non-financial assets in its balance sheet. The imaginary sector would have shares as liabilities, the value of which would be equal to the value of the non-financial assets. These balance sheet items would in turn be counter-parted to the actual owner sector of the non-financial assets. However, this arrangement would not reflect the true state of the world since the imaginary counter-party sector would not have any analytical interpretation. Similar kinds of constructions have been applied in some of the national applications where housing corporations have been recognised as an independent sector in the national accounts.

payments of insurance premia and net equity in life insurance and pension funds. Owing to the inclusion of the rest of the world sector these asset holdings include instruments that are originated by both domestic and foreign counterparties.

In contrast to the asset holdings, the sector-specific liability positions show more distinct characteristics. The liabilities of the non-financial firm sector consist of loans, as well as equity and debt securities issued to other firms and other sectors in the financial system. For banks (MFI), the liabilities are deposits collected from other banks and from the private sector, as well as currency, stocks and bonds issued to the other sectors.[7] The bulk of the OFI sector liabilities are mutual fund shares while the largest share of the insurance and pension funds sector's liabilities consist of net equity of households in life insurance premia and in pension funds. For government, the largest share of liabilities is represented by government bonds which in developed economies are mostly denominated in domestic currency. Household sector liabilities consist almost entirely of MFI loans to finance housing and consumption expenditures. Finally, for the rest of the world sector, both sides of the balance sheet are rather evenly split between cash, loans and securities.

Despite that fact that in integrated financial accounts, like the EAA, the assets must equal liabilities at the system level, this is not necessarily the case at the sector level. Indeed, some sectors in the financial system may show systematic deficits in their financial accounts whilst other sectors may report systematic surpluses. The non-financial corporations and government sectors are typically (although not always) net debtors, while households form the main creditor sector. In so far as the deficits run by the domestic borrowing sectors exceed the surpluses recorded by the domestic lending sectors, the gap must be financed by borrowing from the rest of the world. In fact, the financial position of the rest of the world sector mirrors, by definition, the current account of the balance of payments of the domestic financial system.[8]

The difference between a sector's financial assets and its liabilities amounts to that sector's net financial wealth position which will become important in the later parts of this paper. Chart 2 illustrates the evolution over time of the net financial wealth positions in the sectors of the euro area financial system, with the positive net financial wealth of the surplus sectors (mainly households and the rest of the world) matching the negative net financial wealth of the deficit sectors (mainly government and non-financial firms). It is noteworthy that in financial accounts, the net financial wealth of the financial sectors (*i.e.* the MFI, insurance and OFI sectors) is close to zero. This reflects the fact that as financial intermediaries, the bulk of

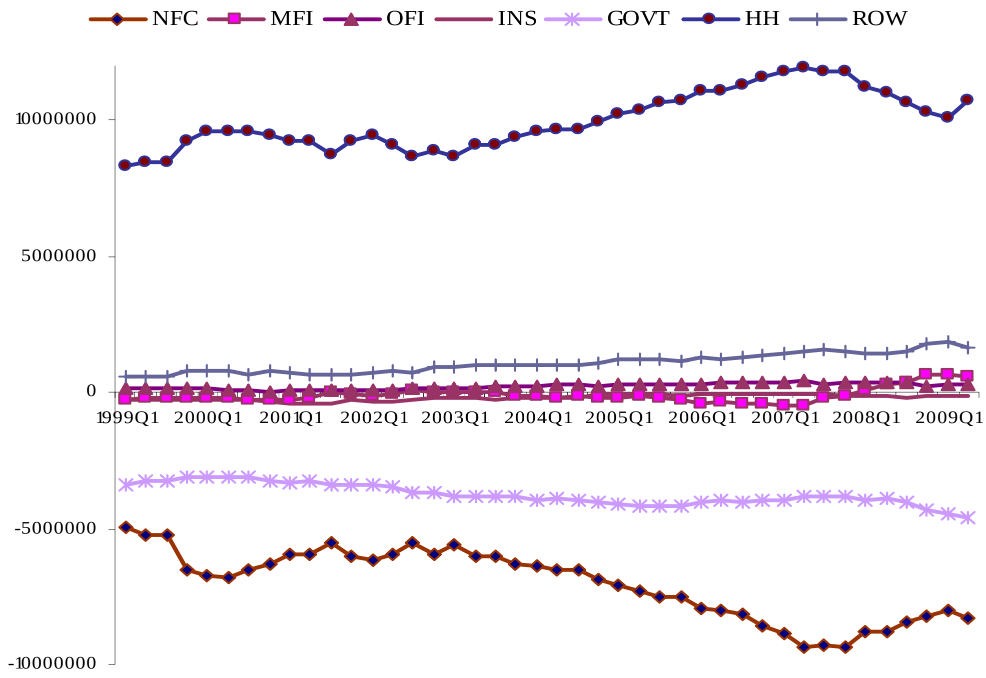
---

[7] Note that in EAA, the central bank is incorporated in the MFI sector.

[8] Note that despite the fact that the rest of world sector "closes" the system, it is actually an independent sector and its balance sheet is calculated on the basis of own data sources.

the assets and liabilities of these sectors consist of financial instruments while their holdings of real assets such as real estate and production assets are relatively minor.[9]

Chart 2: Evolution of the sector-level financial net wealth components in the euro area financial system



3. The network of balance sheet exposures for the euro area financial system

Although the EAA form a closed system in the sense that all financial assets must have a counterparty item in some other sector's liability side, the financial accounts do not currently provide detailed information about the specific counterparties of the instruments issued by a given sector (the so called "who-to-whom" accounts). In the absence of this information, we estimate the bilateral balance sheet linkages between sectors. When the aggregate asset (liability) holdings of each sector are known on an instrument-by-instrument basis, the allocation of these aggregate holdings across the liabilities (assets) of all other sectors can be

---

[9] Net wealth and its role in allocating the sectors to borrowers and lenders in the financial system provide a link between the financial and the real accounts. Net wealth (a stock measure) can be defined as accumulated lending or borrowing (flow measures), including changes in prices and other components. Net lending/borrowing of a sector can be further decomposed to investment (gross capital formation) and saving. Therefore, shocks to savings and investment are conveyed to the financial accounts via their impact on the flows of net lending and, therefore, on the net wealth position. Conversely, shocks from the financial part of the economy are transmitted via the net lending/borrowing positions to the non-financial parts of the economy. This linkage is illustrated in Annex 1.

approximated using maximum entropy techniques which exploit the relative shares of the sector-specific total assets and liabilities. The applications of such methods are common in statistical exercises, input-output analyses and in models of financial contagion and interbank networks (see *e.g.* Allen and Gale, 2000, Upper and Worms, 2004, Wells, 2004 and van Lelyveld and Liedorp, 2006).[10]

More specifically, the bilateral exposures among N sectors under each financial instrument category k can be collected in an NxN matrix X_k with entries x_{ij}, where x_{ij} denotes the exposure of sector i towards sector j in a instrument category k:

$$X_k = \begin{bmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1N} \\ \vdots & \ddots & \vdots & \therefore & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{iN} \\ \vdots & \therefore & \vdots & \ddots & \vdots \\ x_{N1} & \cdots & x_{Nj} & \cdots & x_{NN} \end{bmatrix} \quad \text{with} \quad \sum_{j=1}^{N} x_{ij} = a_{i,k} \quad \text{and} \quad \sum_{i=1}^{N} x_{ij} = l_{j,k}$$

The sum of all the elements x_{ij} in a given row corresponds to the total instrument k-specific assets $a_{i,k}$ held by a sector and issued by the other sectors. Accordingly, the sum of the elements in a given column equals the total instrument k-specific liabilities $l_{j,k}$ of a sector claimed by the other sectors. Under maximum entropy, the individual elements x_{ij} are estimated using information about the relative distribution of the sum elements $a_{i,k}$ and $l_{j,k}$, assuming that the a's and l's are realizations of the marginal distributions $f(a)$ and $f(l)$ and that X_k amounts to their joint distribution $f(a,l)$.

For analyses that use firm-level data or consolidated accounts, this procedure has the unappealing feature that the diagonals of the matrices X_k can be non-zeroes (implying that agents would have transactions with themselves). To fix this problem, additional constraints need to be included in the estimation process to guarantee that the elements on the diagonals equal zeroes.[11] Since the data in the parts of the EEA used in this paper are non-consolidated, however, they do include transactions within sectors so that there is no reason why the elements in the diagonals of the X_k matrices should amount to zeroes. For example, firms

[10] An exception is Mueller (2006) who uses data from the Swiss interbank market which provide complete who-to-whom accounts.

[11] In the case of input-output analysis the technique is referred to as RAS-procedure, named after the typical sequence of matrices. The RAS has the following properties: 1) the signs of individual elements are preserved; 2) zero elements remain zeroes; and 3) enforcement of consistency may cause implausible changes in some of the coefficients. See for instance: Eurostat Manual of Supply and Use and Input-Output Tables 2008.

within the NFC sector and banks within the MFI sector can lend to and borrow from each other and own each others' shares and debt instruments.[12]

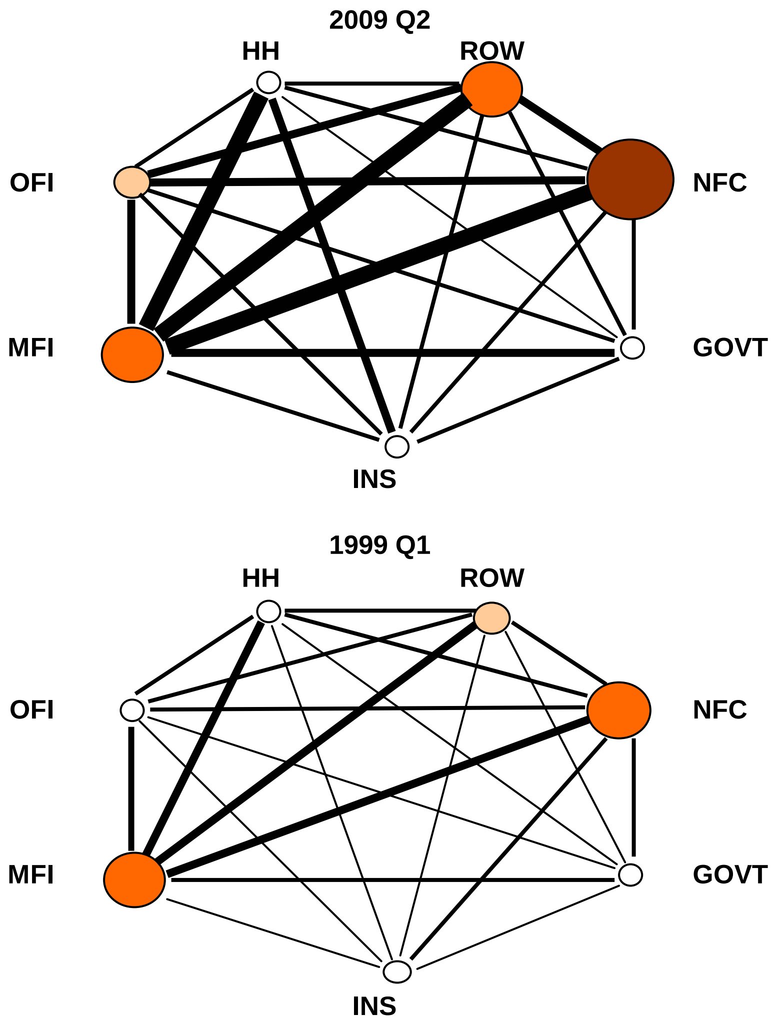
Annex 2 shows the estimated who-to-whom exposures for each sector, instrument-by-instrument, as of 2009 Q2. They suggest, among other things, that on the asset sides almost all of the currency and deposits held by different sectors are originated by the MFI sector while the bulk of the debt securities held by other sectors are issued by the government sector. Most of the loans extended by the MFI and the OFI sectors are to the NFC and the household sectors, while equity holdings of various sectors to a large extent consist of shares issued by the NFC and the RoW sectors. On the liability sides, the estimated bilateral linkages indicate that large parts of debt securities issued by various sectors are counter-partied by the MFI, insurance and RoW sectors while by far the largest share of loans are owed to the MFI sector. The NFC and the OFI sectors are the largest holders of the equity shares issued by most sectors. These results are all intuitive and in the absence of detailed who-to-whom accounts they provide useful approximations of the true bilateral exposures.

Once the bilateral exposures have been calculated for each instrument category, a network connecting all sectors in the financial system can be constructed using the gross exposures, *i.e.* assets plus liabilities connecting individual sectors in all instrument categories. Chart 3 illustrates this network of balance sheet gross exposures for the euro area financial system at two distinct points in time, in the first quarter of 1999 and the second quarter of 2009. In Chart 3, the sizes of the *nodes* describe the exposures within sectors. These include, among other items, cross-shareholdings of firms and financial institutions and intercompany loans. The *links* show the gross bilateral cross-sector exposures, summed up across all instrument categories; the thickness of the link connecting two sectors is commensurate with the magnitude of this gross exposure.

The degree of nodes (*i.e.* the number of links connecting each sector) is six in case of all sectors. This means that the degree distribution of the network is symmetric, resembling a "complete" structure of claims in the terminology by Allen and Gale (2000). This could be expected in the case of a network of gross exposures which consists of a relatively small number of nodes: at an aggregated level each sector has at least some asset or liability link to all other sectors in the euro area financial system. Looking at the bilateral exposures at the instrument level the picture changes as there are sectors which are not connected to some of the other sectors in some instrument categories, while there are sectors that can be highly interconnected in most instrument categories (see also Annex 2).

[12] For the intra-rest of the world sector, the who-to-whom statistics are zeroes by definition also in non-consolidated data. This causes a discrepancy which we have corrected using RAS. Additionally, in the current version of the data the intra-MFI sector currency and deposits flows are consolidated.

Chart 3: Cross-sector balance sheet gross exposures in the euro area financial system in 1999Q1 and in 2009Q2



Note: The size of the node illustrates the amount of gross exposures (assets plus liabilities) within sectors. The thickness of the links shows the size of the gross exposures between two sectors.

Three main observations can be drawn from Chart 3. The first is the overall increase in the size of balance sheet exposures over the first decade of Economic and Monetary Union, suggesting that interconnectiveness in the euro area financial system has expanded over this time period. While this in "normal" times would indicate enhanced risk sharing in the financial system, one can also imagine unanticipated events which may tip the network to a state where it works as a shock amplifier rather than a shock absorber. We will return to this point in detail in section 5 below.

The second is the crucial role played by the banking (MFI) sector in the euro area financial system. As a financial intermediary, it holds liabilities in the form of deposits collected mainly from the household, NFC and RoW sectors, while it holds assets in the form of loans mostly extended to these same sectors. In addition, the MFI sector also plays an important role in securities markets, as it issues equity and debt securities mainly to the household, insurance, OFI and RoW sectors and holds securities issued mainly by the NFC, OFI, government and RoW sectors. Although the degree of nodes in the matrix of gross exposures is the same for all sectors, the large volume of the links connecting the MFI sector to the rest of the system provides it a role as a "hub" in the network. For that reason, it is evident that stresses in the MFI sector would have substantial negative spill-over effects into practically all other sectors in the network of euro area financial system while the MFI sector is directly exposed to balance sheet shocks especially from the household, NFC, RoW and OFI sectors.

The third observation is the increasing role played by the OFI sector over the past ten years. While in the euro area this sector mostly consists of investment funds (mostly bond funds), its growth over time also reflects the expansion of lending to firms and households by non-bank financial intermediaries as well as the growth of the special purpose vehicles for securitisation purposes and other off-balance sheet structures which are included in the OFI sector.

Overall, the estimated network of bilateral exposures provides an important tool for systemic risk analysis. Indeed, assessing financial claims in a network concept captures several features that are missing in partial analyses that consider the individual sectors as separate and disconnect from the rest of the system. Among the useful features are the possibilities to model disruptions in credit chains, transmission of securities losses as well as liquidity spillovers that result from local balance sheet expansions or contractions. In addition, the framework captures counterparty risks that in normal times may be unknown or otherwise of little concern for the various agents in the financial system but could give rise to adverse surprises when an unanticipated shock hits a sector several steps away in the chain of mutual exposures.

4. Transmission of shocks in the network of balance sheet exposures

We can now take advantage of the network of financial exposures sketched out in Chart 3 to analyse how shocks to some sectors may cause chain reactions in which the balance sheets of other sectors are also adversely affected. The theoretical underpinnings for such shock transmission processes are provided in the literature on credit chains and balance sheet contagion that are illustrated in the papers by Shin (2008) and Kiyotaki and Moore (1997 and 2002).[13] The basic intuition behind these models is that the mutual extension of credit or debt by agents in the financial system creates balance sheet interlinkages which can act as channels

[13] In addition, Haldane (2009) provides a recent review of analysis of network contagion in financial systems in relation to the models developed in other sciences.

of contagion if some of the debtors become unable to service their obligations to their creditors. In the network model introduced above, we include the entire balance sheets of sectors. Therefore, we are not constrained to credit relationships but can analyse also counterparty exposures that arise through all types of financial instrument cross-holdings, including debt and equity securities and deposit instruments.[14]

Before proceeding, it is useful to clarify the definitions of "transmission", "propagation" and "contagion" in the current context. The literature has yet to reach a consensus on the precise definitions, but Gallegati et al (2008) provide a detailed discussion of the differences between these concepts and their relationships to risk sharing and diffusion processes. While these terms are used somewhat interchangeably below, in our context they relate to the broad case where a cash-flow shock is initially assigned on one sector which is linked to the other sectors via the network of bilateral balance sheet exposures. As a result of these links, other sectors' balance sheets (or risk exposures as introduced below in section 5) are then also affected.

To illustrate the propagation of shocks in the network, imagine a simplified three-sector framework where a shock to sector *A's* cash flow affects the balance sheet items of counterparty sectors *B* and *C* and, on further rounds, the balance sheet of sector *A* itself. The shock can be modelled as a sudden decline in net income which causes a deficit in *A's* profit and loss (P&L) account. Importantly, we impose the simple behavioural rule that *A* and all the other sectors are subject to mark-to-market accounting, which implies that on every period they have to deduct losses on P&L accounts or on available-for-sale assets from shareholder equity (see also Shin, 2008). In such a set-up shocks are quickly transmitted from P&L accounts to shareholder equity and further to the balance sheets of other sectors via cross-holdings of shares, with no need to assume defaults in the process.[15]

In Chart 4 we show how the contagion from the shock to sector *A's* balance sheet to *B's* and *C's* balance sheets takes place through the loss of net financial wealth that occurs via the

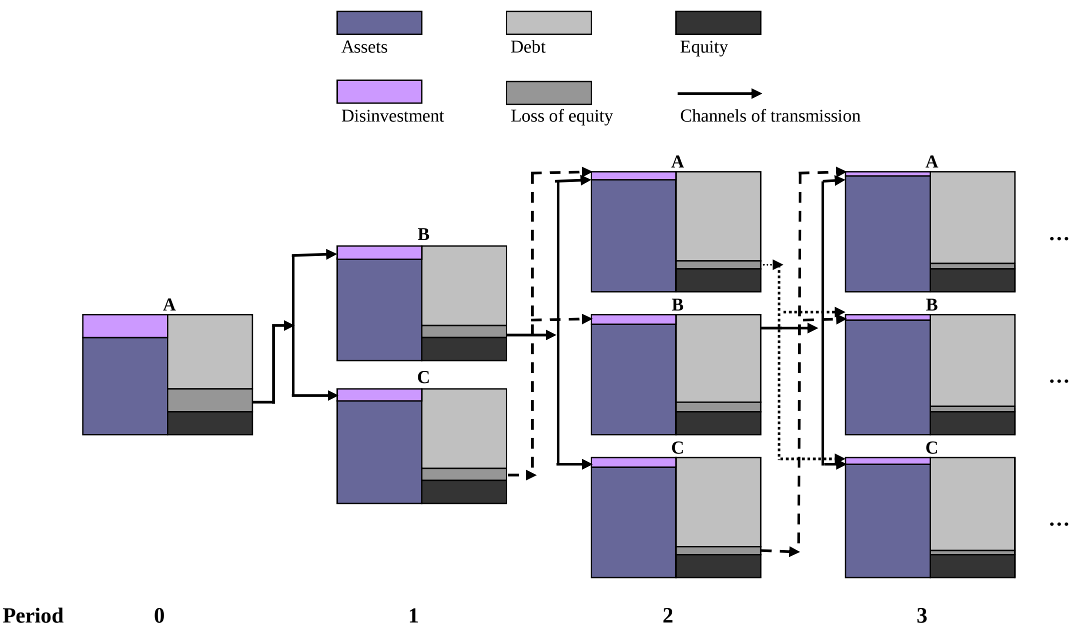
---

[14] Empirical applications of balance sheet contagion typically focus on cascades of bank failures which may propagate along the network of interbank credit exposures (see Cihak, 2007, for a recent review). Recently, Adrian and Shin (2008) have criticised models which use accounting-based valuations to study transmission of balance sheet shocks. Specifically, they argue that such "domino" models may provide an overly simplistic picture of the contagion mechanisms as they depend on shocks that have to be large enough to generate defaults in the system. In practice, as witnessed by the recent crisis that was triggered by losses in the US sub-prime mortgage exposures, even shocks which are relatively modest relative to the sizes of the balance sheets of the affected sectors may have severe consequences to the financial system via valuation losses in counterparty exposures. Below we will address this critique by adopting the rule of mark-to-market accounting which allows us to consider propagation of valuation losses without defaults.

[15] Indeed, in the context of the recent financial sector crisis, mark-to-market accounting has been quoted as a factor that accelerated the valuation losses and their spill-over from one sector to another after the financial turmoil first broke out in the asset-backed commercial paper markets and paralysed the financing of banks' off-balance sheet vehicles in August 2007. Similarly, of course, the large valuation gains over the years prior to the crisis in several asset categories, including housing, corporate stocks and commodities, had inflated the balance sheets of all sectors holding such assets or derivatives products written on these assets. These valuation gains increased borrowing capacity and allowed for higher balance sheet leverage which in turn exposed the investors to vulnerabilities when prices reversed and assets had to be marked to lower market values.

asset-side holdings of sectors *B* and *C* which own *A's* equity (which contracted due to the unanticipated P&L shock). Since *A's* counterparties are also assumed to be marked-to-market they in turn have to deduct the losses on their asset holdings from their own shareholder's equity.[16] But the drop in the value of *B's* and *C's* shareholder equity will again be reflected in a decline in value on the asset side holdings of those sectors which own the equity issued by *B* and *C*, triggering a further adjustment in net financial wealth and shareholder equity positions, and so forth. The process continues as long as some of the sectors report positive earnings that offset the initial P&L loss, or, alternatively, the shock reaches a sector that either is not connected to any other sector or is not subject to marking-to-market so that it does not need to deduct temporary asset losses from its equity.[17] Assuming that the share prices quickly react to disturbances and that markets have complete information about the various counterparty exposures, the process should take place rather instantaneously.

Chart 4: Transmission of a P&L shock under mark-to-market accounting



To quantify the importance of counterparty losses in our empirical network of sector-level exposures, we consider two alternative shocks that were assumed to crystallise at the end of 2009 Q2. Several shocks could also be assumed to be triggered simultaneously in a full-blown

---

[16] In this stage also the asset side of the initially affected sector will be impacted in so far as there are cross-shareholdings among agents within this sector.

[17] The assumption that there are no positive earnings surprises in any of the sectors in any of the following periods may not be particularly realistic but it is nonetheless useful in that it helps to isolate the effect of the shock and to identify the channels of propagation.

scenario, but for the purpose of the exercise which is to identify the main channels of propagation such simplified sensitivity tests provide the most transparent exposition. To measure the impact of the shock over discrete periods of time, we apply a round-by-round algorithm which calculates the distribution of the instrument-specific losses in each sector and on each round according to the sizes of the balance sheet linkages to the sectors that were affected in the previous round.

The first shock assumes a negative post-tax, post-dividend earnings growth in the non-financial corporate sector that is large enough to cause a 20% mark-to-market drop in the value of shareholder equity. The shock is transmitted to the rest of the system via the mark-to-market losses in counterparty positions through equity holdings. The second case assumes a permanent impairment of 15% of the loans extended to the household sector. This latter shock shows first on the asset sides of the sectors that are the creditors of the household sector and which have to deduct the loan impairments from their shareholder equity. In the subsequent rounds the shock propagates via the mark-to-market losses on equity holdings like in the first case.

Table 2: Simulated transmission of balance sheet shocks in the euro area financial system

20% NFC cash flow shock

	Round							
	1		2		3		Average	
	EUR bn	% of financial assets	EUR bn	% of financial assets	EUR bn	% of financial assets	EUR bn	% of financial assets
NFC	783	5.54	632	4.47	541	3.83	652.00	4.61
HH	318	3.00	256	2.42	220	2.07	264.67	2.50
MFI	189	0.81	152	0.65	130	0.56	157.00	0.67
INS	122	1.98	98	1.60	84	1.37	101.33	1.65
OFI	405	4.13	327	3.33	280	2.85	337.33	3.44
GOVT	114	3.97	92	3.20	77	2.74	94.33	3.30
ROW	278	3.34	224	2.99	192	2.78	231.33	3.04
Average	315.57	3.25	254.43	2.67	217.71	2.31		

15% HH loan impairment shock

	Round							
	1		2		3		Average	
	EUR bn	% of financial assets	EUR bn	% of financial assets	EUR bn	% of financial assets	EUR bn	% of financial assets
NFC	70	0.50	272	1.93	225	1.59	189.00	1.34
HH	1.3	0.01	110	1.04	91	0.86	67.43	0.64
MFI	545	2.32	66	0.28	54	0.23	221.67	0.94
INS	16	0.27	43	0.69	35	0.57	31.33	0.51
OFI	80	0.82	141	1.44	117	1.19	112.67	1.15
GOVT	19	0.65	40	1.38	33	1.14	30.67	1.06
ROW	52	0.34	97	0.63	80	0.52	76.33	0.50
Average	111.90	0.70	109.86	1.06	90.71	0.87		

The top panel of Table 2 shows the extent of balance-sheet contagion from the NFC sector cash-flow shock, measured both in billions of euros and in terms of percentages of financial assets. The sectors that are initially most affected by the contraction of the NFC sector equity are the NFC sector itself, plus OFI and government sectors, reflecting the large holdings of NFC sector's equity shares by these sectors.[18] Following this first-round impact which results from a direct transmission from the NFC sector, in the subsequent rounds the sectors which are large holders of equity of those sectors that were adversely affected in the first round will suffer the largest losses. The sectors relatively more affected in these rounds are thus those which hold large equity portfolios that are diversified across financial and non-financial corporate sectors. For example, the fact that the losses suffered by the RoW sector decline quite markedly on the subsequent rounds reflects the fact that its holdings of corporate equity assets are mainly concentrated on the NFC sector and it is therefore relatively less affected by the second and third round effects that originate from losses also on holdings of equity issued by the financial firms in the MFI, OFI and insurance sectors.

Despite the fact that our network represents a "closed" system the size of the average loss in relation to financial assets appears to diminish gradually over time. This is because the household and government sectors do not issue equity and therefore within the financial accounts they do not transmit the shock further (although they themselves keep suffering additional losses every period due to their exposure to other sectors' equity on their asset sides). Instead, the mark-to-market loss of these sectors' net financial wealth would be reflected in the real accounts as a decline in their net lending positions. In other words, in the *integrated accounts* the size of the shock remains constant over the different points in time (see also Annex 1).

Regarding the propagation of the household loan shock, the initial impact that occurs on the asset sides of the creditor sectors is by far the largest in the MFI sector which extends the bulk of long-term loans to households (in the euro area, the role of the OFI sector is relatively more prominent in short-term lending). Once the creditor sectors have deducted the impairments from their shareholder equity the shock propagates to those sectors which have large holdings of equity, particularly issued by the MFI sector, on their asset side. These further round impacts are therefore primarily felt by the NFC, OFI and government sectors so that their overall loss in relation to financial assets could exceed the loss that was faced by the MFI sector as a result of the initial loan impairment.

Importantly, the analysis above abstracts from the fact that in a multi-period setting, endogenous re-balancing of accounts might become necessary after asset or P&L shocks

[18] Recall that the EEA data applied in this paper are non-consolidated and that in the euro area there are large scale cross-shareholdings among non-financial firms.

caused a contraction of a sector's equity. In terms of Chart 4, the loss of sector *A's* shareholder equity results in a drop of value in its liabilities which implies that *A* may choose to de-leverage its balance sheet either by raising additional equity or debt or by dis-investing a part of its asset holdings (as shown in the far left part of Chart 4). This dis-investment process may follow different "rules". For example, agents can sell their most liquid or riskiest assets first, or they can reduce their asset holdings instrument-by-instrument in proportion to the initial composition of their asset holdings. The dis-investment rules can also be state-dependent in that assets shed in volatile market conditions are different than assets shed in more tranquil circumstances. In addition, as illustrated by Adrian and Shin (2008), the required asset shedding can be dis-proportionate to the initial equity loss if the sector targets a constant leverage ratio. Independent of the rule, by dis-investing a share of its financial assets in an effort to restore its balance sheet, *A* generates price and valuation losses on the debt side of the balance sheets of *B* and *C* which issued the dis-invested assets. This means that *B* and *C* in turn may have to dis-invest assets, which could set into motion a process which mirrors the one described above. The overall impact of the initial P&L shocks is then likely to be multiplied by these endogenous responses as argued by Adrian and Shin (2008).

In practice, asset dis-investment is complicated to model and at the sector level the algorithms guiding such processes are still in their infancy. While the spillover of mark-to-market equity losses provides a relatively clear channel of transmission to the relevant counterparties which own the affected sector's equity, in the case of asset shedding not only the instrument but also the purchasing counterparty needs to be defined. In addition, it is not straightforward to determine the price impact of such "distressed sales" in closed financial systems (see Duffie, Garleanu and Pedersen, 2007, for a proposed conceptual framework). The latter is an important factor as it will not only determine the net impact of asset sales on the balance sheet of the asset-shedding sector but also the extent of spillover to other sectors which issued these assets or hold related assets. Nevertheless, once the relevant rules are specified, our model can be used to simulate the propagation of losses from asset shedding to other sectors' balance sheets.

5. Measuring systemic risk using risk-based balance sheets

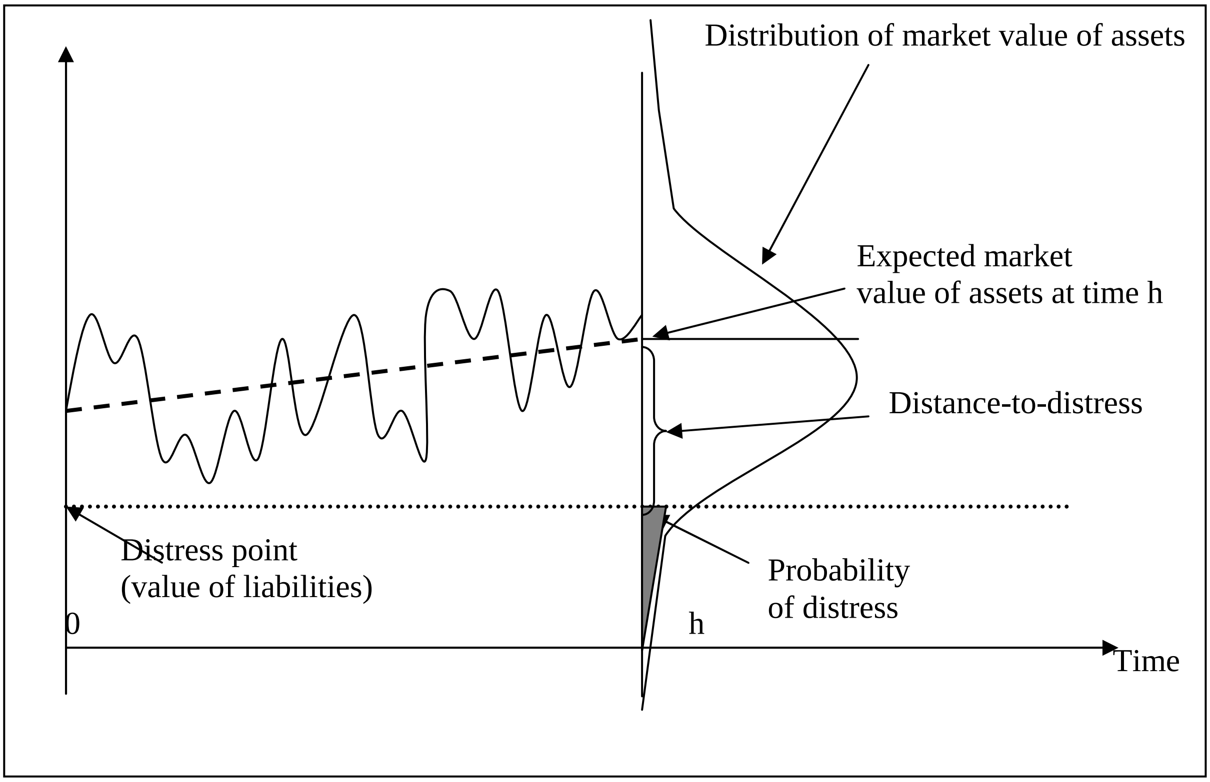
A key limitation of the presentation above is that it builds on a purely deterministic, accounting-based framework and therefore it is not possible to say anything about the accumulation and transmission of *risk exposures* in the financial system. To incorporate such characteristics, we need to move from accounting-based to risk-based balance sheets. This can be done using models that capture also the volatility of the key balance sheet items, such as shareholder equity and assets. To this end, we draw on recent work by Gray, Merton and Bodie (2007, henceforth GMB) and Gray and Malone (2008) who provide insights to the measurement of sector-level risk exposures by applying contingent claims analysis (CCA), originally developed for assessing firm-level default risk. A particular advantage of the CCA approach is that the accounting value-based and internally consistent network model developed in the earlier parts of this paper is fully nested in the risk-based framework that is the result of the CCA. Indeed, as discussed in detail by GMB (2007), by assuming that volatilities equal to zero in the CCA balance sheets, the stochastic elements cancel out and the risk-based models collapse to the deterministic accounting framework. The inclusion of the risk element opens up many additional insights and avenues for analysis. Most prominently, the risk-based "CCA network" implies an additional contagion channel in that also risk exposures can propagate across sectors. There are also important interactions between the various elements of the model owing to the strong non-linearities that are present in the CCA balance sheets.

5.1 The sector-level contingent claims model

Originating from the seminal papers by Black and Scholes (1973) and Merton (1974) and further developed by Moody's KMV (2002), the CCA approach is based on structural finance models which use options pricing theory and include as inputs data on balance sheet liabilities, interest rates, market value of assets, asset return and asset volatility. The output consists of the optimal debt-equity structure of the firm, plus a number of risk indicators such as distance-to-distress, expected loss, probability of distress, expected recovery rate and credit spread over the risk-free interest rate. While some of these indicators are available for selected financial and non-financial firms and corporate sectors from various private data sources, for other sectors such as households, government and OFIs the availability is much more limited, at least from a single, consistent data source.

The intuition behind the CCA is illustrated in Chart 5, where a firm's assets and liabilities are plotted on the vertical axis against time on the horizontal axis. The value of the firm's liabilities (the thin dotted line) is assumed to be fixed over the time horizon, *i.e.* all interest and amortisation payments on debt are made at the maturity date *h* of the debt. In contrast, the market value of the firm's assets fluctuate stochastically over time, with the asset drift (the bold dotted line) determined by the expected rate of return of the asset. At the end of the period, the assets are expected to take a value that corresponds to the mean of the distribution of all possible values. Should the value of the assets fall sufficiently far off the mean of the distribution to end up below the book value of the firm's liabilities (the distress point), the firm will default on its debt.[19] It should be noted that "distress" and "default" are clearly different concepts, as the former state is likely to be reached earlier than the latter (which in many ways can be considered a terminal event). The distress point could be understood as a covenant breach or a rating downgrade which typically takes place before default but may already have severe implications for the debtor's ability to continue in business. In the context of a sector-level analysis reference to distress is particularly appealing as default of an entire sector would, of course, be an almost un-conceivable event. The grey triangular area under the lower tail of the distribution measures the firm's probability of distress, while the difference between the expected value of assets and the distress point captures the distance-to-distress, a popular indicator for corporate credit risk.

Chart 5: The principles of the contingent claims model



It is clear from Chart 5 that the likelihood that the market value of assets will end below the distress point is essentially driven by three factors. First, the ratio of the debt to financial assets (the leverage ratio), which determines the vertical position of the distress point relative to the initial value of the assets; second, the slope of the asset drift; and third, the amplitude of

[19] Another way of seeing this is that when the market value of assets reaches the distress point, all equity has been depleted.

fluctuation of the market value of assets around the drift, which is measured by the expected volatility of the asset.[20]

GMB (2007) take the firm-level CCA models to the financial system level by considering interlinked market value balance sheets for the main sectors of the economy. Analytically, the total market value of assets A of a sector equals the sum of the market values of its junior claims J (mostly equity and net financial wealth) and debt D (other liability items):

$$A = J + D = J + B - P\,. \qquad (1)$$

In (1) the term P captures the expected loss that debt investors incorporate in the market value of the sector's debt and which draws a wedge between the book value (or accounting value) of debt B and the market value of debt D. In CCA, the value of the junior claims J and the expected loss on debt P are formulated in terms of implicit options whereby the value of a sector's junior claims resembles the value of a call option while the value of the expected loss on its debt resembles the value of a put option. The market value of debt can then be written to equal the default-free value, or book value, of debt minus the value of the put option.

The values of the implicit options can be solved under the assumptions that are required for the Black and Scholes (1973) options pricing model, where the value of a sector's assets over time is modelled as a geometric Brownian motion process:

$$dA_t = \mu A_t dt + \sigma A_t dZ_t \qquad (3)$$

The solution yields an expression for the implicit put option:

$$\begin{aligned} P &= Be^{-rt}(N(-d_2)) - A_0(N(-d_1)) \\ \Rightarrow P &= \left[-\frac{N(-d_1)}{N(-d_2)} A + Be^{-rt} \right] N(-d_2) \end{aligned} \qquad (4)$$

where

[20] See e.g Crouhy, Galai and Mark (2001) who provide a generalised presentation of the original Merton (1974) analysis.

$$d_2 = \frac{\ln\left(\frac{A_0}{B}\right) + \left(\mu - \frac{\sigma_A^2}{2}\right)t}{\sigma_A \sqrt{t}} \text{ and } d_1 = d_2 + \sigma_A \sqrt{t}\,. \qquad (5)$$

In (5), the term A_0/B is the inverse of a sector's leverage ratio; σ_A denotes the volatility of the sector's assets; μ denotes the "real world" (as opposed to risk-neutral) asset drift; r is the risk free interest rate and t is the time to maturity; and the terms $N(d)$ denote the probability that a random draw from a standard normal distribution will be less than d. The real world asset drift is related to the risk-neutral (or risk-adjusted) asset drift according to the following condition.

$$\mu = r + \lambda \sigma_A\,,$$

where λ denotes the market price of risk. The latter reflects investors' risk aversion and can be measured using the CAPM model where λ is expressed as a product of the market Sharpe ratio and the correlation of the asset return with the market.[21]

From equation 3 we can also derive the value of the junior claims J which is equal to the value of an implicit call option, expressed in the form of risk-based net wealth:

$$J = A_0 N(d_1) - Be^{rt} N(d_2)\,. \qquad (6)$$

For the analysis below, the expression for d_2 in equation 5 is a key output of the model. It measures the distance to distress (DD), also shown in Chart 5 and it (or its distribution) enters into all other output measures of the CCA framework. While we will be studying the properties of the DD more closely in the next section, it is nevertheless useful to analyse the comparative statics of this measure vis-à-vis the key input variables of the model, leverage and asset volatility. In particular, it turns out that

$$\frac{\partial d_2}{\partial \frac{A}{B}} > 0 \qquad \frac{\partial d_2}{\partial \sigma_A} < 0$$

[21] See Crouhy, Galai and Mark (2001) and GMB (2007) for a thorough discussion of the conditions that are required for relaxing the assumption of risk neutrality which is inherent in models that are based on the Black and Scholes pricing formula.

$$\frac{\partial^2 d_2}{\partial^2 \frac{A}{B}} > 0 \qquad \frac{\partial^2 d_2}{\partial^2 \sigma_A} > 0 \tag{7}$$

$$\frac{\partial^2 d_2}{\partial \frac{A}{B} \partial \sigma_A} > 0 \qquad \frac{\partial^2 d_2}{\partial \sigma_A \partial \frac{A}{B}} > 0$$

The two expressions on the top row state that DD is decreasing in market leverage (defined as *B/A*) and in asset volatility, meaning that higher readings of these variables imply higher credit risk. The expressions on the second row confirm, crucially, that these relationships are non-linear: in particular, credit risk increases exponentially as balance sheets deteriorate or when uncertainty about future asset returns increases. Finally, the expressions on the bottom row provide information about the interactions between the two input variables in relation to the DD. They suggest that a sector's vulnerability to a decline in DD as a result of an increase in volatility (leverage) is the higher the higher is leverage (volatility). Like a deep out-of-the-money option, credit risk is very sensitive to volatility shocks when leverage is high.[22] These characteristics of the CCA balance sheets are the sources of important features in terms of risk exposures and risk transmission that remain absent in the accounting-based balance sheets.

Finally, the empirical solution to equations 4 and 6 is complicated by the fact that we have two unknown variables, market value of assets A and asset volatility σ_A. The standard solution technique uses a third equation which exploits the fact that the volatility of assets σ_A can be expressed as a proportion of the volatility of junior claims σ_J according to the following relationship:

$$\sigma_J = \frac{N(d_1)A}{J}\sigma_A . \tag{8}$$

Armed with these results, we can solve for A and σ_A with data on interest rates, junior and senior claims and volatility of junior claims, and using iterative simulation techniques.[23]

[22] A high reading of *B/A* corresponds to a situation where the strike price of the option is far away from the current price of the underlying asset.

[23] The iteration process uses an initial guess of the volatility to determine the market value of assets and asset returns. The volatility of the resulting asset returns is used as the input to the next iteration of the procedure that in turn determines a new set of asset values and a new series of asset returns. The procedure continues in this manner until it converges. We use the Newton-Raphson iteration technique with 100 iterations and 5% tolerance interval.

5.2. Estimation of sector-level risk indicators

When calculating the empirical sector-level indicators for risk exposures, two practical issues needs to be considered. First, some sectors, notably households and government, do not issue equity that would directly qualify as junior claims. For this reason we define the junior claims as equity plus net financial wealth, both of which can be obtained from the EAA data and which are illustrated in section 2 above. This means that for those sectors where net financial wealth is negative, notably non-financial corporations, the junior claims are less than their shareholder equity while for the household sector which issues no equity the junior claims are solely represented by their net financial wealth. For the government sector, we follow GMB (2007) who measure junior claims by government debt securities issued plus the (negative) government net financial wealth position.[24]

Second, the value of the distress point B is not straightforward to define because debtors typically re-organise the maturity structure of their debt when encountering credit problems. The common solution in empirical CCA applications is to adopt the assumption that the distress point amounts to short-term liabilities plus one half of long-term liabilities, which is supported by empirical research based on large-scale statistical studies on historical defaults. These issues are discussed in detail in Moody's KMV (2002). In the current analysis, the financial instruments that were classified as short-term liabilities are currency and deposits, short-term loans and debt securities, derivatives instruments and other accounts and receivables. Long-term liabilities include long-term debt securities and loans, mutual fund shares, net equity of households in life insurance and pension fund reserves and pre-payments of insurance premia.

Apart from the EEA balance sheet measures that are used to calculate the values of the junior and senior claims, the data for volatility of junior claims, or σ_J , for the different corporate sectors (financial and non-financial) consists of 12-month implied volatilities of stock indices obtained from Bloomberg. For the MFI and the insurance and pension funds sectors, the implied volatilities of the relevant sector level stock indices were used while for the OFI sector the implied volatility of the financial services sub-sector stock index was applied. For the NFC sector, we calculated the average implied volatility using data from all individual non-financial corporate sectors. For the government and the household sectors which issue no equity we used the implied volatility of the German 10-year government bond yield and for the RoW sector the implied volatility of the VIX stock index was adopted. Finally, following GMB (2007) and Moody's KMV (2002) we adopt the convention that λ, *i.e.* the market price

[24] GMB (2007) argue that for emerging economies which often issue debt denominated both in domestic and in foreign currencies the foreign currency denominated part could be considered as the junior debt.

of risk, is fixed at 0.45, which represents the global long-term average value as calculated by Moody's KMV.

The "intermediate" results from the CCA include the estimated market value of assets and asset volatility. Chart 6 plots the sector-level market leverage for the euro area financial system for the period 1999 Q1-2009 Q2, defined as book value of debt (the distress point) divided by the estimated market value of assets. It can be seen that the market leverage of the financial sectors (MFI, insurance and pension funds, and OFI sectors) is generally higher than that of the other sectors which reflects the function of the former as financial intermediaries and justifies the fact that they are supervised by government authorities. The leverage ratio of the MFI sector is very stable over time. This is in line with the findings by Adrian and Shin (2008) who show that banks tend to target constant levels of leverage.[25] This implies that banks are prone to expand their balance sheets by taking on more debt when the market value of their assets goes up and quick to de-leverage when market value of their assets falls. For the insurance and pension funds and the non-financial corporate sectors the leverage ratios are clearly counter-cyclical as leverage increases "passively" with falls in market value of assets; this was particularly pronounced in 2002-03 when the leverage of these sectors increased sharply in the aftermath of the burst of the "new economy" stock market boom which had a negative effect on the market value of their financial assets. The leverage of the household sector is low as its financial liabilities are relatively minor compared to its financial assets (*i.e.* its net financial wealth is high). For most sectors, market leverage picked up towards the end of the period. The growth in leverage was first driven by increasing debt levels and later on by falling market value of assets after the financial turmoil erupted in 2007 Q3. The increase in leverage in the run-up to the crisis indicates that vulnerability to disturbances (*i.e.* future volatility shocks) generally increased.

[25] This can indeed be verified empirically for the euro area using our data and the results are available upon request.

Chart 6: Estimated sector-level market leverage for the euro area financial system

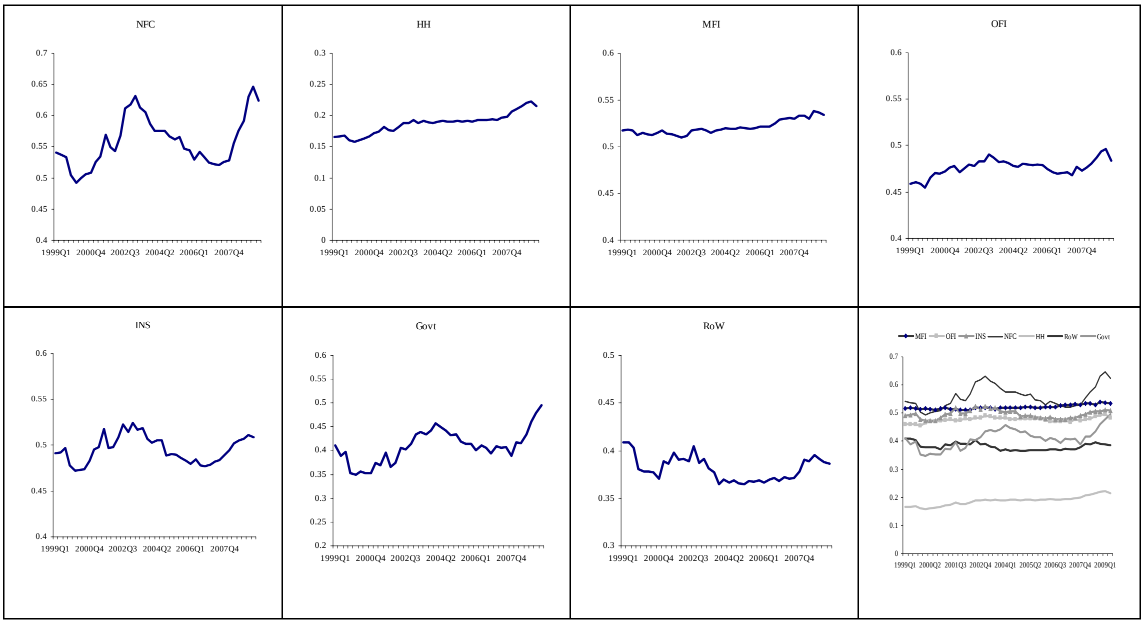
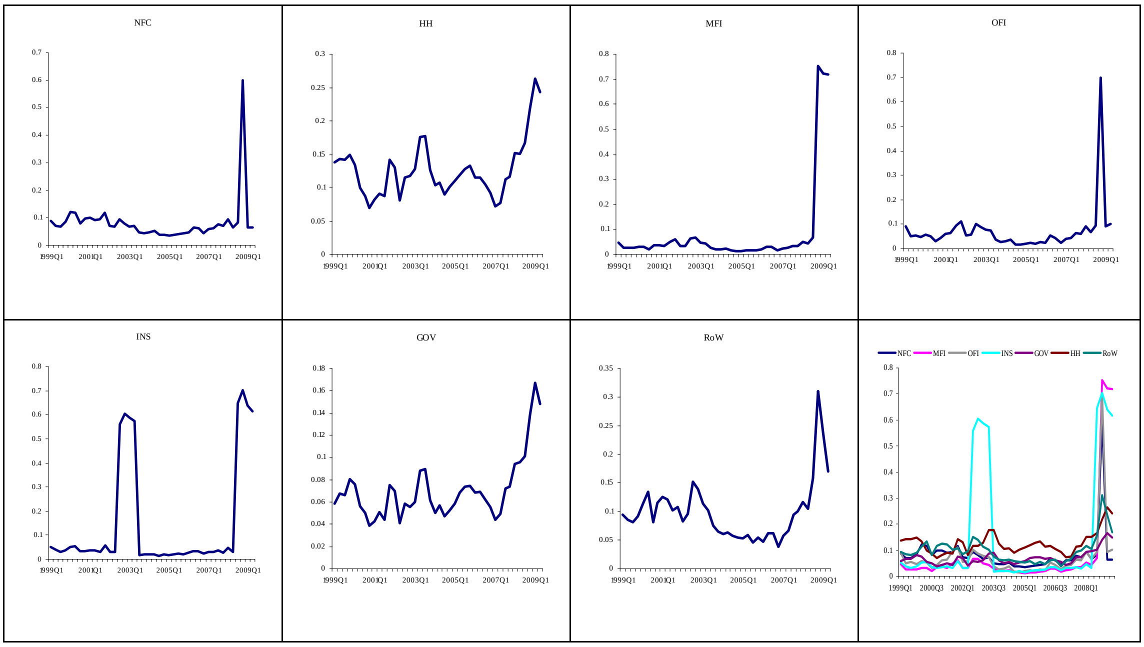


Chart 7 plots the estimated asset volatilities σ_A sector-by-sector. A key observation is that for practically all sectors, asset volatility reached historically low levels in 2005-06 as the financial markets were characterised by ample liquidity, high confidence and low perception of risk. This low volatility fed increased risk-taking and accumulation of leverage via popular risk management indicators, such as the value at risk (VaR), which by construction are increasing functions of volatility; in other words, a fall in volatility triggers a signal that an investor can increase his exposure on an asset class without breaching the limits of the risk metric. This interplay between volatility, risk measures and leverage was an important contributor to the general increase in financial vulnerabilities especially in the financial sectors during the years prior to the crisis. After the liquidity in the global money markets abruptly dried up in the third quarter of 2007, volatility increased sharply in those sectors that were most exposed to the incident, namely banks and other financial intermediaries (which include the off-balance sheet vehicles that were at the epicentre of the early stages of the turmoil). For the banking and other financial sectors, asset volatility reached extreme levels in 2008 Q4 after the collapse of Lehman Brothers eroded confidence towards the sector globally, while asset volatility also jumped in the non-financial sectors. The global nature of the turbulence is clearly illustrated by the surge in asset volatility in the euro area rest of the world sector, reflecting the strong impact of the crisis on the financial assets originated and held by many of the main financial counterparties of the euro area (notably the US, the UK and Switzerland).

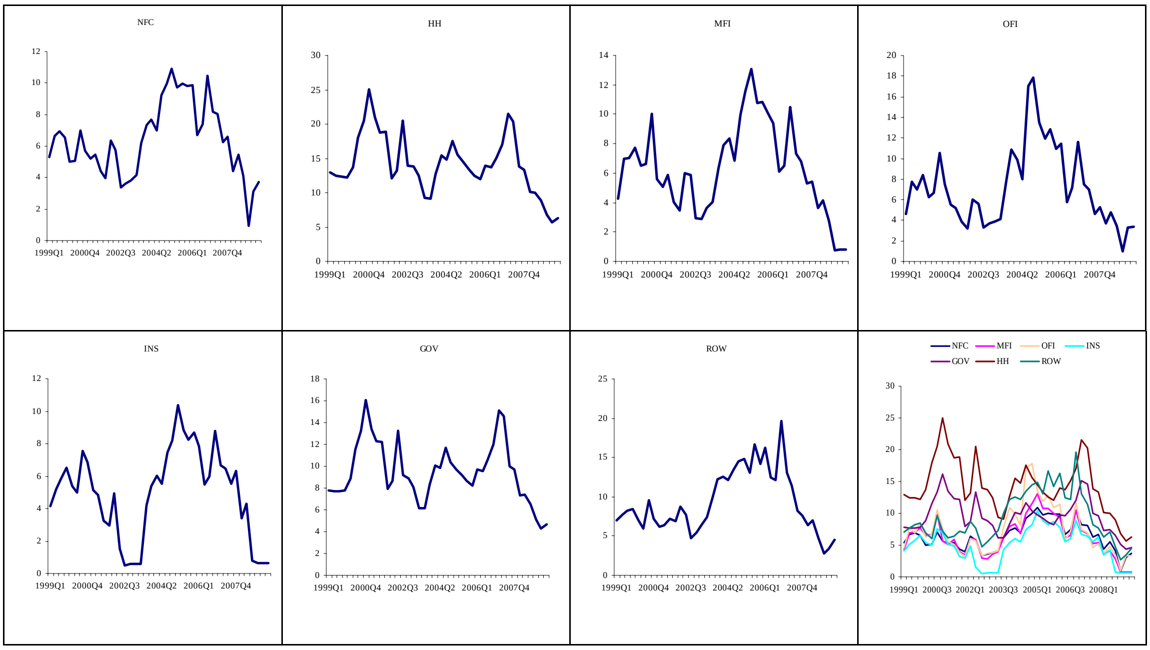
Chart 7: Estimated sector-level asset volatilities for the euro area financial system



After the market value of assets and asset volatilities have been calculated, the empirical sector-level risk metrics can be estimated. Chart 8 shows the distance to distress (DD, see the expression for d_2 in equation 5) for the different sectors in the euro area financial system from 1999 Q1 until 2009 Q2. Since the DD is expressed in terms of standard deviations, it provides a measure that is comparable across sectors. The main observations are that the sector-level DDs are rather high, reflecting the low distress probability of an entire sector. This notwithstanding, the impact of the financial sector turmoil that commenced in the second half of 2007 and intensified further in 2008 did cause a marked decline in the DDs (*i.e.* increase in credit risk) of all sectors, most prominently in the banking (MFI) and the rest of the world (RoW) sectors. Credit risk also increased in the household and government sectors, reflecting the increased volatility of these sectors' financial assets (which include, among other items, a fair amount of corporate ad MFI sector equity), although it remained at low levels relative to the other sectors.[26] The fact that DDs dropped sharply only after the crisis had started stresses the need to understand the behaviour of its main components. Indeed, by looking at the evolution of market leverage in Chart 6 it is clear that vulnerabilities were gradually accumulating in the form of rising indebtedness in most sectors. On the other hand, looking at the developments in asset volatility in Chart 7 reveals that the relatively "comfortable" readings of DDs in the years 2005-06 were mainly driven by historically low volatility which could have been expected to reverse at some point.

[26] However, the aggregate euro area figures for household sector distance to distress mask important differences in the country level owing to large discrepancies in household leverage across countries.

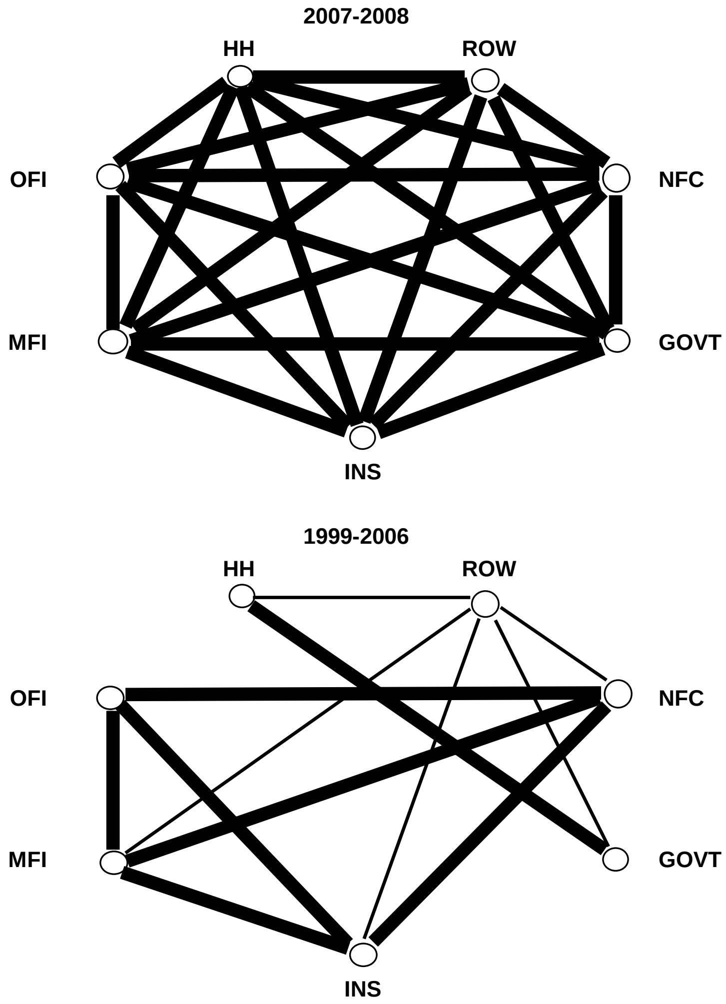
Chart 8: Sector level distances-to-distress for the euro area financial system



It is noteworthy that the DD of the insurance and pension funds and the NFC sectors also fell quite sharply in this time period, even if asset volatility remained at relatively lower levels. This reflects the presence of the non-linearities that are characteristic for CCA balance sheets as discussed in the previous sub-section: the relatively high leverage of the insurance and the NFC sectors makes their risk indicators vulnerable to even relatively small increases in asset volatility. However, the DDs of the insurance and pension funds sector remained above the low levels reached in the previous episode of financial stress in 2002-2003, reflecting the fact that until mid-2009 the epicentre of the turmoil in the euro area remained in the banking sector.

Finally, to analyse the interplay between sector-level DDs in the network context, Chart 9 shows the pair-wise correlations between sector-level DDs calculated as in Khadani and Lo (2007). Like in Chart 3 above, it is informative to illustrate these correlations in two distinct time periods. Given the likely impact of the recent financial crisis on the correlation structures, we show the networks for the periods 1999 Q1-2006 Q2 and 2007 Q3-2009 Q2.

Chart 9: Pair-wise correlations among sector-level distance-to-distress measures in the euro area financial system 1999-2006 and 2007-2008



Note: The thickest line shows pair-wise correlations in excess of 0.75, the second thickest between 0.50 and 0.75, the thinnest between 0.25 and 0.50 and no line correlations less than 0.25 or negative.

The main finding is that the correlations between sector-level DDs increased dramatically during the financial crisis, showing strong contagion of credit risk, where contagion is understood as an increase in cross-sector correlations in crisis times relative to correlations during tranquil times (see Gallegati et al, 2008). Prior to the crisis, the DDs were highly correlated between the financial sectors and the NFC sector whilst the government, household and the RoW sectors showed lower correlations. The fact that the pair-wise correlation between the household and government sectors nevertheless was high is interesting given the weak balance sheet linkage between the two sectors as shown in Chart 3. This confirms that correlation in risk exposures does not necessary require the existence of direct bilateral links, but exposures to similar types of assets (in this case mostly cash, corporate equity and debt instruments) would also be sufficient. During the crisis period, correlations in credit risk among all sectors surged. The fact that credit risk became highly correlated across sectors implies that additional shocks to any one sector would have had the potential to induce instantaneous increases in credit risk in all other sectors.[27]

An additional feature of the CCA balance sheets is that they include contingent liabilities in the form of implicit guarantees that may be extended by some sectors to others. GMB (2007) look at the particular case where the government sector provides an implicit guarantee for the financial sectors by underwriting a share of the expected losses (essentially, by taking a fraction of the put option on its balance sheet). Given the large-scale commitments by euro area governments to provide financial support for the banking sector that were announced in 2008 Q4, some of these implicit guarantees may in fact have become explicit. We leave the exercise to assess the implications of these measures on the sector-level risk indicators for future work once the data for the full year 2009 will have become available.

5.3. Shocks in the risk-based network of bilateral exposures

Once the sector-level risk measures have been derived, we bring back to the picture the network of bilateral balance sheet exposures. To this end, we exploit the fact that the CCA balance sheets fully encompass the accounting-based network. We will first use the propagation from the NFC cash flow shock scenario that was illustrated in section 4 and see how contagion across balance sheet items affects the *risk exposures* of sectors that were not directly hit by the initial shock. In the second stage we compare the risk-based network of bilateral exposures to the accounting-based network and see how the market values of the bilateral links might change when the risk exposures change as a response to volatility shocks.

As regards the first point, since the sector-level accounting items that enter the CCA calculations are exposed to disturbances which may originate from balance sheet counterparty exposures to other sectors, also the risk indicators in the CCA balance sheets should change as a result. In addition, when the financial system is confronted by a shock, it is typically the case that asset volatility increases. Table 3 shows the changes in the sector-level distances of distress – as derived above in Chart 8 – as a result of the non-financial corporate sector P&L shock that was considered above in section 4. In addition to the equity shocks from Table 2 which affect the value of the junior claims in the CCA balance sheets we also assume that the volatility of junior claims increases by 500 basis points across all sectors.

[27] Adrian and Brunnermeier (2009) study the co-movements of firm-level value at risk measures during episodes of distress using common factor analysis and extreme value theory (EVT). While EVT would provide an obvious improvement to the correlation analysis above, given the relatively short time series and the quarterly frequency of the balance sheet data, at the current stage our data set does not contain enough observations for such an analysis.

Table 3: Decline in distance-to-distress as a result of a combined balance sheet and volatility shock, 2009 Q2

	Decline in distance to distress	
	In standard deviations	In %
NFC	0.58	16
HH	1.7	20.11
MFI	0.39	5.62
OFI	0.19	3.4
INS	1.46	39
GOVT	4.04	12.99
ROW	0.51	12.13

A shock that was assumed to crystallise in 2009 Q2 would have caused the sector-level DDs to decrease between 3% and 40% in the financial sectors and between 12% and 20% in the non-financial sectors from the true levels at 2009 Q2. The very large percentage decline in the insurance and pension funds sector DD reflects the fact that its DD was among the lowest in the baseline (*i.e.* a relatively minor absolute decline in DD causes a large % drop when the decline takes place from a low level) and also the fact that, together with the NFC sector, its market leverage was the highest, *i.e.* it was particularly vulnerable to additional shocks. This again demonstrates the non-linear nature of the risk exposures in that the more vulnerable sectors in terms of balance-sheet leverage tend to show the largest jumps in risk measures.

In terms of stability of the network of bilateral exposures, these non-linearities in risk exposures provide an important link to a common feature in network models, the so called "knife edge" property. This property states that beyond a certain tipping point, the interconnections in the networks that in normal times work as shock absorbers may turn to shock amplifiers, spreading rather than sharing the risk. In the context of financial networks Allen and Gale (2000) and Gallegati et al (2008) argue that due to this characteristic, risk sharing that is achieved in networks might be beneficial only when the overall economic environment is favourable but can turn detrimental when the economic environment turns bad. Haldane (2009) argues that in certain states, events that *per se* may be of relatively modest economic importance – such as the US sub-prime mortgage crisis – may be sufficient to take the system beyond its tipping point. Analysis of risk-based networks provide an indication of how this might happen, as gradually accumulating leverage in some sectors pushes the implicit options further out-of-the-money and increases these sectors' vulnerability to shocks elsewhere in the system that manifest themselves in a general surge in volatility and may cause large jumps in risk measures.

As regards the second point, to analyse in detail the transmission of risk along the network of exposures would require calculation of indicators of bilateral risk exposures. However, this is not feasible using the CCA approach because there is no reason why a sector (say, NFC) would issue both equity and debt to another specific sector (say, MFI), which would be required to calculate the market value of the "bilateral assets" between the two sectors. However, we can approximate the risk-based bilateral exposures by using the "re-payment probabilities", or RPPs, defined as 1 minus probability of default (see Shin, 2008, who uses the concept of "realised re-payment" which in his model is a fraction of the book value of assets). Then, each accounting-based asset item held by sector *i* would be multiplied by the RPP of sector *j* that issued the instrument.[28] Since the RPPs are sensitive to changes in volatility, the approximated risk-based values of the gross exposures that form the bilateral links between the sectors can be subjected to scenarios that involve volatility shocks. As discussed above, it is a feature of CCA models that the sensitivity of the PDs and the RPPs to volatility changes is highly non-linear and large volatility shocks are thus likely to have potentially even larger impacts on the risk-based values of the bilateral exposures.

Using data on 2008 Q2, table 4 illustrates the "heat map" of changes in RPP-weighed gross bilateral exposures in a scenario where asset volatility of all sectors is assumed to jump to 30%. This volatility increase would cause an increase in PDs and a fall in RPPs, causing a drop in the risk-based value of the bilateral exposures (shown in euro terms in panel (i) and in terms of percentage losses relative to the sizes of the unconditional risk-based exposures in panel (ii) of Table 4). The rows in Table 4 show the decline in other sectors' risk-based assets as a result of a fall in a given sector's RPP while the columns illustrate the losses in value of the various bilateral gross exposures of a given sector, as a result of the fall in RPP of each of the counterparties to its financial assets. Note that even after the large jump in volatility, the RPPs of the household and government sectors remain close to one; hence there is no change (loss) in risk-based exposures in any other sector in the system from its exposure to these two sectors.

[28] Following Shin (2008), for simplicity, we assume that all debt is of equal seniority. In practice, the seniority structure should affect the RPPs on the various instruments on the liability side.

Table 4: Losses in risk-based bilateral gross exposures after a volatility shock, 2008 Q2

(i) In millions of EUR

	NFC	HH	MFI	INS	OFI	GOV	ROW
NFC	1,504,160	520,027	1,758,058	249,124	738,606	235,923	647,099
HH	2	0	11	0	2	0	1
MFI	598,816	1,084,040	735,112	304,805	441,841	167,498	1,003,149
INS	247,056	2,466,417	131,588	104,098	67,476	32,108	171,284
OFI	136,622	182,620	264,830	160,088	141,697	17,820	331,530
GOV	5	6	26	10	10	2	16
ROW	36,588	29,552	55,192	15,234	26,256	7,154	38,587
Total	2,523,250	4,282,664	2,944,818	833,358	1,415,887	460,506	2,191,666

(ii) In % from original exposures

	NFC	HH	MFI	INS	OFI	GOV	ROW
NFC	14	22	21	20	23	21	15
HH	0	0	0	0	0	0	0
MFI	6	12	10	19	11	5	12
INS	20	98	7	34	5	3	14
OFI	4	10	6	13	7	2	8
GOV	0	0	0	0	0	0	0
ROW	1	1	1	1	1	0	1
Average	6	20	6	13	7	4	7

Note: The rows show the impact on other sectors of a volatility shock assigned to the sector named on the left cell. The columns measure the impact on the sector named on the top cell of a volatility shock assigned on the other sectors. The darkest cells denote the highest impacts within the sample.

A key observation is that the results are rather asymmetric in the sense that the impact that a shock on sector *i* has on its exposure to sector *j* is different in size than the impact that a shock on sector *j* has on its exposure to sector *i*, reflecting the differences in sector-specific RPPs. In absolute (EUR) terms, the largest losses appear in the risk-based exposures vis-à-vis the NFC and MFI sectors (the first and third rows in panel (i)). The sectors that suffer the overall largest monetary losses from the reduced RPPs of other sectors are the HH and the MFI sectors, reflecting the large financial asset holdings by these sectors in the euro area financial system (the second and third columns of panel (i)). However, the largest proportional drop in risk-based values takes place in exposures vis-à-vis the insurance and pension funds and the NFC sectors, as reported on rows 1 and 4 of Table 4 (ii), respectively. This reflects the above observed fact that due to their high leverage and balance sheet vulnerability, the NFC and the insurance and pension funds sectors' RPPs are particularly sensitive to volatility shocks.

Mainly owing to the large fall in value of its bilateral exposure to the insurance and pension funds sector, the household sector suffers the largest average loss in risk-based exposures also in relative terms, as shown in the second column of Table 4 (ii). However, this result would almost certainly change if the exposures were weighted in terms of seniority, as a large share of the household sector's bilateral exposures to the insurance sector consists of senior debt instruments, such as net equity in insurance and pension funds reserves and pre-payments of insurance premia.

7. Concluding remarks

The financial crisis that erupted in August 2007 has highlighted the need for tools that can analyse risks and vulnerabilities in financial systems in a holistic way. While regular and detailed analysis of the main sectors of the financial system is necessary for identification of developments that may threaten financial stability, it is clearly not sufficient. Modelling the interlinkages between the sectors is equally important as this aims at revealing the channels through which local shocks can propagate wider in financial systems.

The network of bilateral sector-level financial exposures that is proposed in this paper takes a step to that direction. By acknowledging the suitability of the sector-level flow of funds accounts for the purposes of modelling financial networks, we highlighted the overall expansion in volume of bilateral exposures over the first ten years of the Economic and Monetary Union and the important role of the banking sector in the network of exposures. We also showed how the transmission of shocks takes place under mark-to-market accounting via the balance sheet cross-exposures that exist in the euro area financial system.

An important limitation of the analysis that uses such accounting-based data is that little can be said about the accumulation and transmission of risk in the system. To address this issue, we extended the model by applying the contingent claims approach to sector-level balance sheets. By so doing we were able to unearth important interactions between volatility and leverage, which form key ingredients of any financial stability analysis. In particular, in simulation exercises we illustrated how risk exposures of sectors which show high balance sheet leverage are particularly vulnerable to sudden increases in volatility. Moreover, the strong non-linearities which are characteristic for options-based contingent claims models turned out to play an important role in amplifying the interactions between the risks and vulnerabilities in the risk-based network of exposures.

There are numerous avenues for future research applying network models in the area of financial stability and macro-prudential analysis. Provided that more data on bilateral exposures at different levels of granularity will become available in the future, the interlinkages and channels of risk transmission between agents in the financial system can be better modelled and understood. In addition, further progress in modelling endogenous responses to shocks and resulting balance sheet adjustments at the sector level is necessary. Such work would also provide important inputs to modelling the feedback mechanisms between the real and the financial sectors of the economy, an area of growing interest in monetary policy and macroeconomic analysis. Above all, additional research efforts along the lines proposed in this paper would enhance the tools and models for financial stability analysis and improve the content and accuracy of macro-prudential policy recommendations.

References

Acharaya, V. and L. Pedersen (2005): "Asset Pricing with Liquidity Risk", *Journal of Financial Economics 77*

Adrian, T. and H. S. Shin (2008): "Liquidity and Financial Contagion", *Banque de France Financial Stability Review No 11*

Adrian and Brunnermeier (2009): "CoVaR", Mimeo, Federal Reserve Bank of New York and Princeton University

Allen, F. and D. Gale (2000): "Financial Contagion", *Journal of Political Economy* 108

Becher, C., S. Millard and K. Soramäki (2008): "The Network Topology of CHAPS Sterling", *Bank of England Working Paper* No 355

Black, S. and M. Scholes (1973): "The Pricing of Corporate Options and Liabilities", *Journal of Political Economy 81*

Borio, C. and M. Drehmann (2009): "Towards an Operational Framework for Financial Stability: "Fuzzy" Measurement and its Consequences", *BIS Working Papers* 284

Brunnermeier, M. and L. Pedersen (2009): "Market Liquidity and Funding Liquidity" *Review of Financial Studies 22*

Castrén, O., J. Fell and N. Valckx (2009): "Cross-Border Macro Stress-Testing: Progress and Future Challenges for the EU", In: Quadriagiello, M: (ed.): *"Stress-testing the Banking System",* Cabridge University Press

Castrén, O., T. Fitzpatrick and M. Sydow (2009): "Assessing Portfolio Credit Risks Changes in a Sample of EU Large and Complex Banking Groups in Reaction to Macroeconomic Shocks", *ECB Working Paper* 1002

Cihac, M. (2008): "Introduction to Applied Stress-Testing", *IMF Working Paper* 07/59

Crouhy, M., D. Galai and R. Mark (2001): "Risk Management", McGraw Hill, New York

De Larosiere, J. (2009): "Report", The High-level Group of Financial Supervision In the EU.

Duffie, D., N. Garlenau and L. Pedersen (2007): "Valuation in Over-the-Counter Markets", *Review of Financial Studies,* 20

ECB (2009): "Balance Sheet Contagion and Transmission of Risk in the Euro Area Financial System" Special Feature Article C in *Financial Stability Review,* June 2009

European System of Accounts 1995 (ESA95), Council (EC) Regulation No 2223/96 of 25 June 1996 on the European system of national and regional accounts in the Community, Official Journal of the European Union L 310/1-469

Eurostat Manual of Supply, Use and Input-Output Tables, Eurostat methodologies and working papers, European Communities 2008

Gallegati, M, B. Greenwald, M. Richiardi and J. Stiglitz (2008): The Asymmetric Effect of Diffusion Processes: Risk Sharing and Contagion, *Global Economy Journal* 8

Goodhart, C. (2006): “A Framework for Assessing Financial Stability?”, *Journal of Banking and Finance* 30

Guideline of the European Central Bank on the Statistical Reporting Requirements of the European Central Bank in the Field of Quarterly Financial Accounts, as amended (ECB/2002/7), of 21 November 2002

Gray, D., R. Merton and Z. Bodie (2007): “New Framework for Measuring and Managing Macrofinancial Risk and Financial Stability”, *NBER Working Paper N0 13607*

Gray, D. and S. Malone (2008): “Macrofinancial Risk Analysis”, Wiley Finance, UK

Haldane, A. (2009): “Rethinking the Financial Network”, Speech delivered at the Financial Student Association, Amsterdam

Khandani, A. and A. Lo (2007): “What Happened to the Quants in August 2007?”, *Journal of Investment Management* 5

Kiyotaki, N. and J. Moore, (1997): “Credit Cycles”, *Journal of Political Economy* 105

Kiyotaki, N. and J. Moore, (2002): “Balance Sheet Contagion”, *American Economic Review 92*

McGuire, P. and N. Tarashev (2008): “Global Monitoring with the BIS Banking Statistics”, *BIS Working Paper* 244

Merton, R. (1974): “On the Pricing of Corporate Debt: the Term Structure of Interest Rates” *Journal of Finance* 29

Moody’s KMV (2002): “Modelling Default Risk”, San Francisco, Ca. KMV LLC.

Mueller, J (2006): “Interbank Credit Lines as a Channel of Contagion”, *Journal of Financial Services Research* 29

Shin, H. S. (2008): Risk and Liquidity in a Systemic Context, *Journal of Financial Intermediation*

System of National Accounts 1993 (SNA93), Commission of the European Communities, International Monetary Fund, United Nations, World Bank, Brussels/Luxembourg, New York, Paris, Washington D.C., 1993.

Upper, C. and A. Worms (2004): “Estimating Bilateral Exposures in the German Interbank Market: is There a Danger of Contagion?” *European Economic Review*

van Lelyveld, I. and F. Liedorp (2005): “Interbank Contagion in the Dutch Banking Sector: a Sensitivity Analysis”, *International Journal of Central Banking*

Watts, D (2004): “The “New” Science of Networks”, *Annual Review of Sociology* 30.

Wells, S. (2004): “Financial Interlinkages in the UK Interbank Market and the Risk of Contagion,” *Bank of England Working Paper* 230.

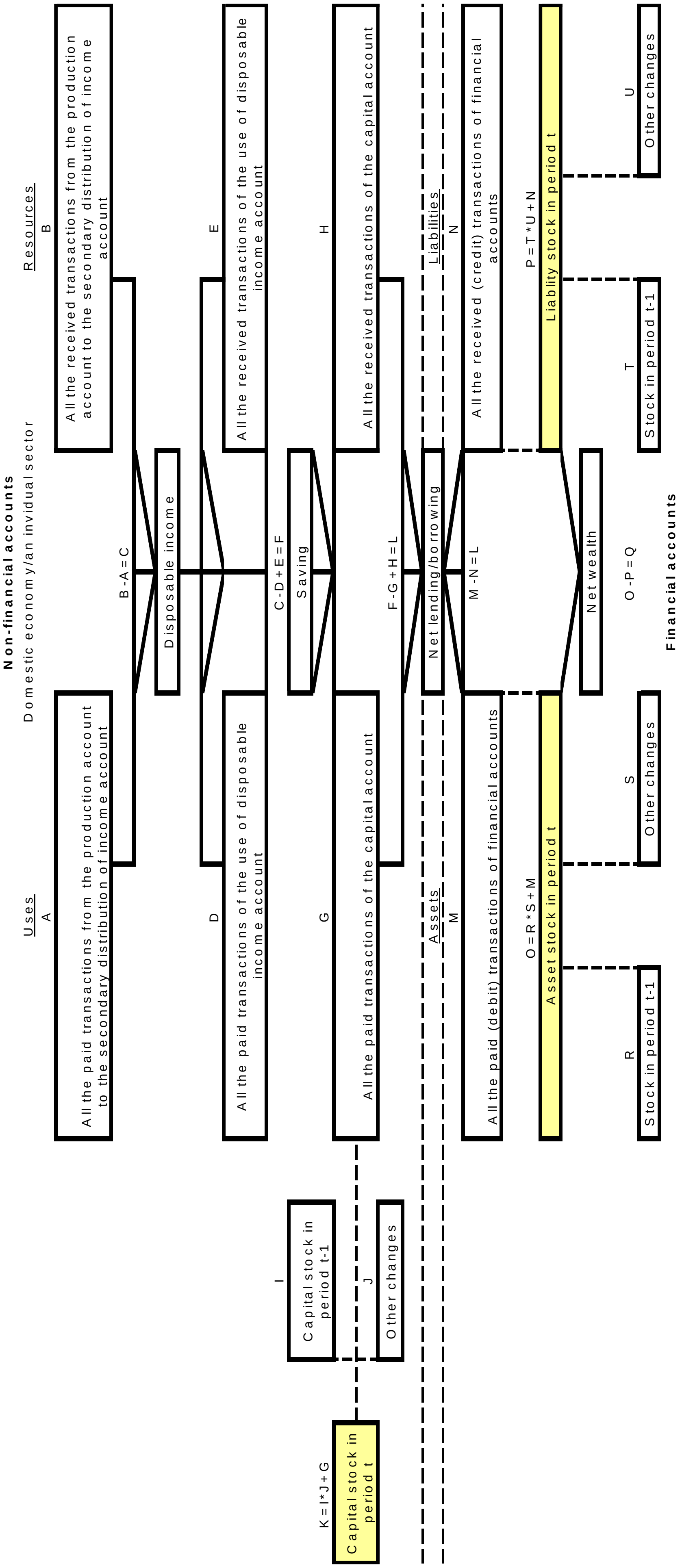
Annex 1: The table illustrates the linkages between financial (the financial markets) and non-financial accounts (the real economy). Thus, the table shows how different shocks to an economy are transmitted between and within the sectors in the sector accounts' framework. The table can be understood as illustrating either one sector or alternatively the whole domestic economy. It is, therefore, important to notice that the balances of individual transactions as well balancing items like saving, net lending/borrowing or as a stock net wealth are zero when the total domestic and external economy are added up. This rule also closes the system - to put it simply: every received transaction has to be paid by somebody, i.e. there has to be a counter-part for each transaction.

The dashed line in the middle of the table divides financial and non-financial economy. The linking transaction between these two is net lending/borrowing. As mentioned above, at the system level net lending/borrowing is by definition zero but individual sectors can have either positive or negative net lending/borrowing positions. There are two perspectives to interpret this balancing item: either it indicates how much a sector has money left after investing in production from saving to finance the activities of other sectors or, alternatively, what the sector's net financial flows are. Both interpretations are correct and lead to the same result.

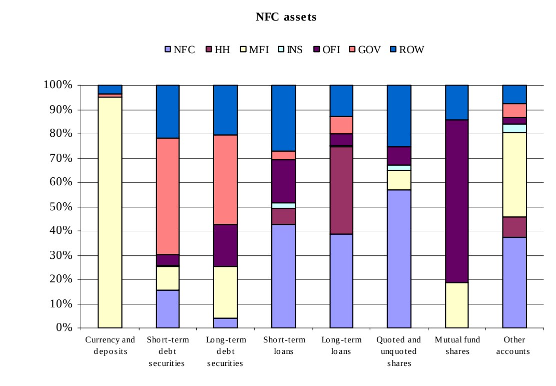
The yellow boxes in the table are stocks. As indicated already in the article, this analysis includes only financial stocks. The net wealth is the difference between the asset and liability stock, i.e. it can also be seen as an accumulated net lending/borrowing, which has been affected by the relative price changes of stocks. This is also the linkage to the real economy - via net lending/borrowing sectors either get financing for their own real economy activities or finance other sectors. The net wealth is also at the system level zero.

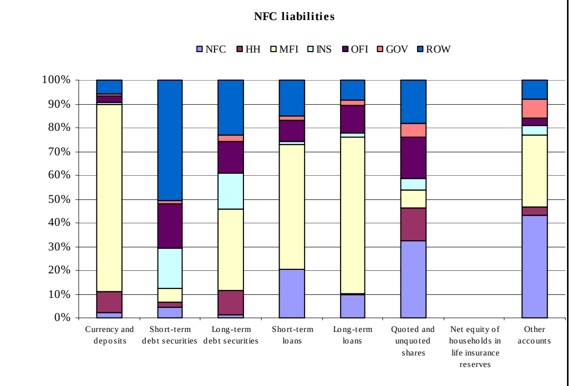
As can be seen from the table there are also non-financial stocks, i.e. fixed capital stocks. These include different kind of buildings like dwellings and industrial buildings but also for instance machines, which are used in a production process. Non-financial stocks are not included in this analysis as these are currently not available at quarterly basis. This naturally makes a considerable difference especially for sectors like households, which have a large part of their property in dwellings. However, it should also be noted that the nature of non-financial property is considerably different to the financial property. In the case of financial property a sector either borrows money from other sector or lends money to other sector and thus, the transaction always has a counter-party. For the borrower, financial property is also often a pure financial investment and he/she does not expect this to create any additional service flow.

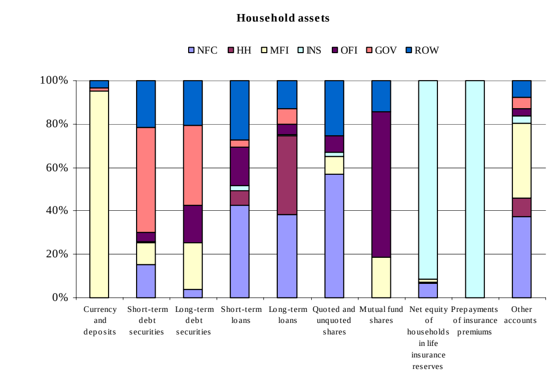
Non-financial wealth is not by definition counter-partied and therefore, it also does not have any direct linkage to other sectors. Additionally, non-financial wealth is expected to provide some kind of service flow - either as a component of a production process or by providing housing services for households (which is actually also understood as a production process in the national accounts). Therefore, non-financial wealth can be assumed to work as a certain kind buffer of the wealth, and since it is actually needed for production purposes its value does not necessarily change as frequently as the value of financial instruments.

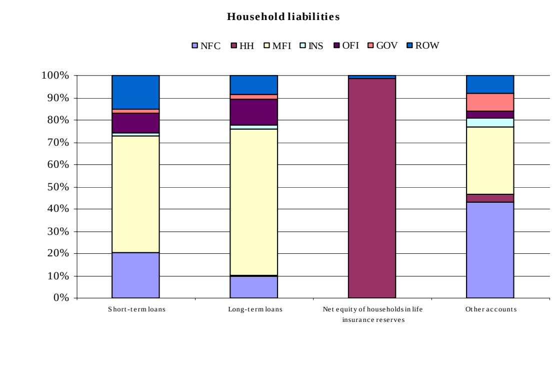

Non-financial accounts
Domestic economy/an invidual sector
Uses
A
All the paid transactions from the production account to the secondary distribution of income account
Resources
B
All the received transactions from the production account to the secondary distribution of income account
B-A=C
Disposable income
D
All the paid transactions of the use of disposable income account
E
All the received transactions of the use of disposable income account
C-D+E=F
Saving
G
All the paid transactions of the capital account
H
All the received transactions of the capital account
F-G+H=L
Net lending/borrowing
I
Capital stock in period t-1
J
Other changes
K=I*J+G
Capital stock in period t
Assets
M
All the paid (debit) transactions of financial accounts
Liabilities
N
All the received (credit) transactions of financial accounts
M-N=L
O=R*S+M
Asset stock in period t
P=T*U+N
Liablity stock in period t
O-P=Q
Net wealth
R
Stock in period t-1
S
Other changes
T
Stock in period t-1
U
Other changes
Financial accounts

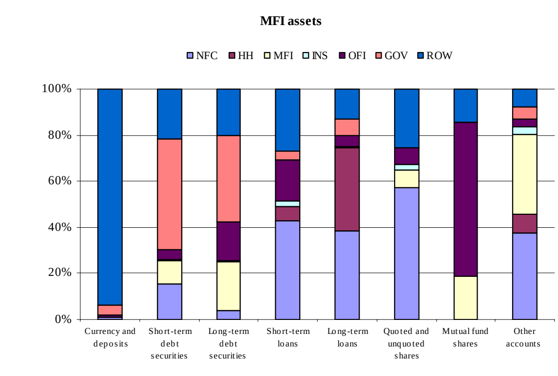
Annex 2: Estimated instrument-specific bilateral exposures, 2009 Q2

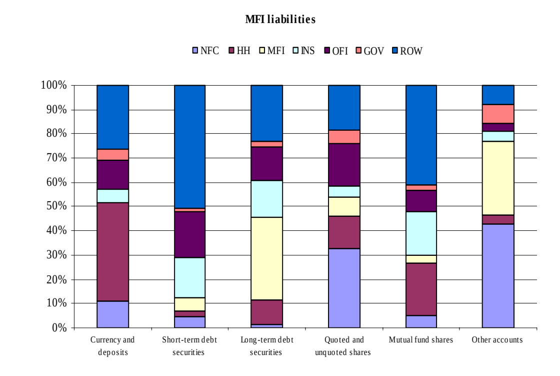


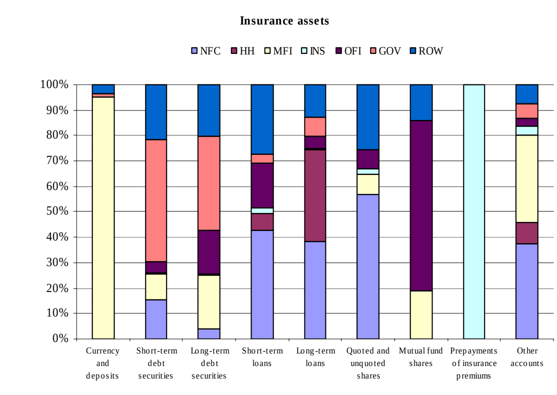


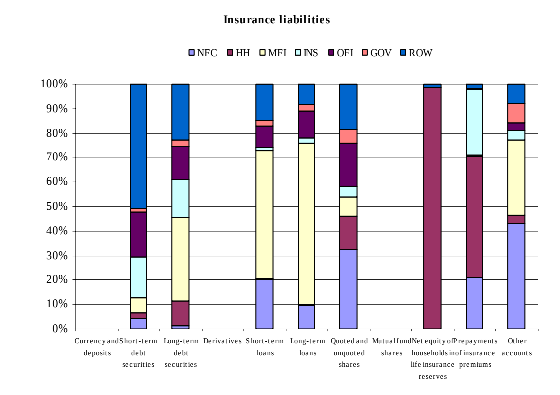


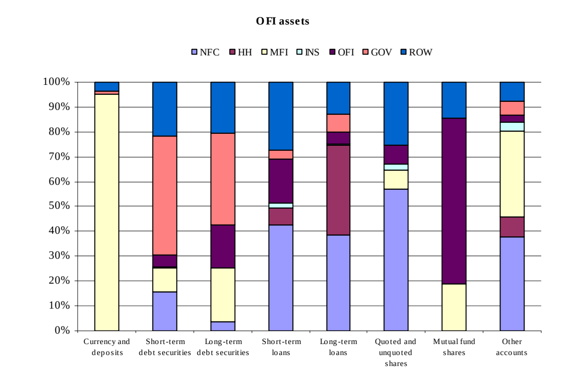


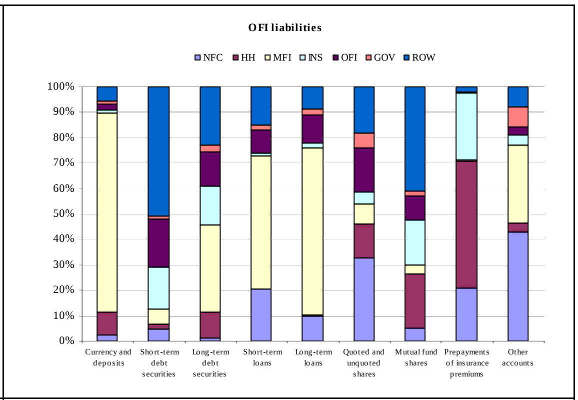


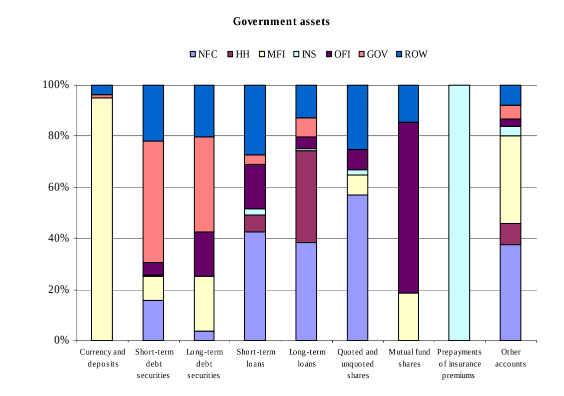


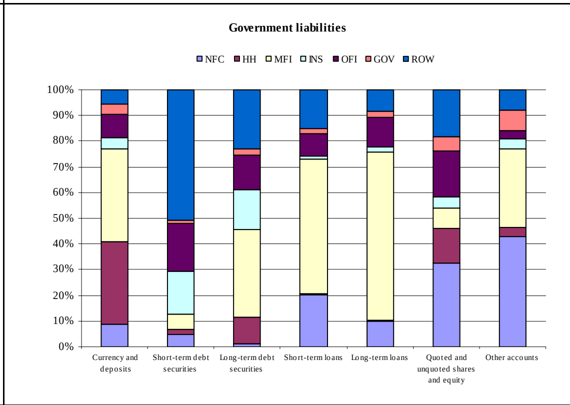


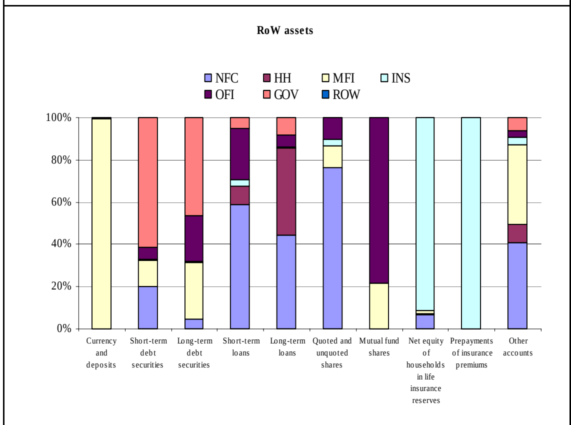


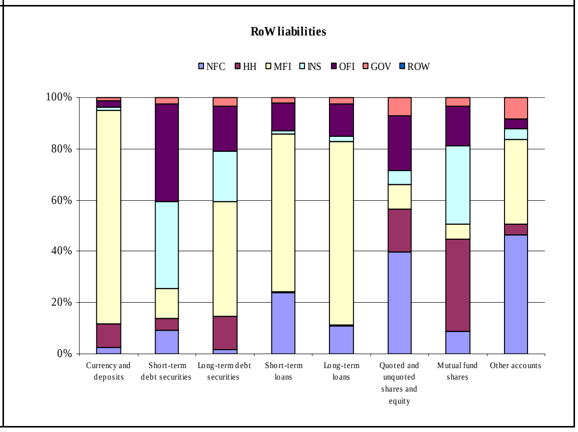

OFI assets
NFC HH MFI INS OFI GOV ROW
100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%
Currency and deposits
Short-term debt securities
Long-term debt securities
Short-term loans
Long-term loans
Quoted and unquoted shares
Mutual fund shares
Other accounts


OFI liabilities
NFC HH MFI INS OFI GOV ROW
100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%
Currency and deposits
Short-term debt securities
Long-term debt securities
Short-term loans
Long-term loans
Quoted and unquoted shares
Mutual fund shares
Prepayments of insurance premiums
Other accounts


Government assets
NFC HH MFI INS OFI GOV ROW
100% 80% 60% 40% 20% 0%
Currency and deposits
Short-term debt securities
Long-term debt securities
Short-term loans
Long-term loans
Quoted and unquoted shares
Mutual fund shares
Prepayments of insurance premiums
Other accounts


Government liabilities
NFC HH MFI INS OFI GOV ROW
100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%
Currency and deposits
Short-term debt securities
Long-term debt securities
Short-term loans
Long-term loans
Quoted and unquoted shares and equity
Other accounts


RoW assets
NFC HH MFI INS
OFI GOV ROW
100% 80% 60% 40% 20% 0%
Currency and deposits
Short-term debt securities
Long-term debt securities
Short-term loans
Long-term loans
Quoted and unquoted shares
Mutual fund shares
Net equity of households in life insurance reserves
Prepayments of insurance premiums
Other accounts


RoW liabilities
NFC HH MFI INS OFI GOV ROW
100% 80% 60% 40% 20% 0%
Currency and deposits
Short-term debt securities
Long-term debt securities
Short-term loans
Long-term loans
Quoted and unquoted shares and equity
Mutual fund shares
Other accounts

European Central Bank Working Paper Series

For a complete list of Working Papers published by the ECB, please visit the ECB's website (http://www.ecb.europa.eu).

1086 "Euro area money demand: empirical evidence on the role of equity and labour markets" by G. J. de Bondt, September 2009.

1087 "Modelling global trade flows: results from a GVAR model" by M. Bussière, A. Chudik and G. Sestieri, September 2009.

1088 "Inflation perceptions and expectations in the euro area: the role of news" by C. Badarinza and M. Buchmann, September 2009.

1089 "The effects of monetary policy on unemployment dynamics under model uncertainty: evidence from the US and the euro area" by C. Altavilla and M. Ciccarelli, September 2009.

1090 "New Keynesian versus old Keynesian government spending multipliers" by J. F. Cogan, T. Cwik, J. B. Taylor and V. Wieland, September 2009.

1091 "Money talks" by M. Hoerova, C. Monnet and T. Temzelides, September 2009.

1092 "Inflation and output volatility under asymmetric incomplete information" by G. Carboni and M. Ellison, September 2009.

1093 "Determinants of government bond spreads in new EU countries" by I. Alexopoulou, I. Bunda and A. Ferrando, September 2009.

1094 "Signals from housing and lending booms" by I. Bunda and M. Ca'Zorzi, September 2009.

1095 "Memories of high inflation" by M. Ehrmann and P. Tzamourani, September 2009.

1096 "The determinants of bank capital structure" by R. Gropp and F. Heider, September 2009.

1097 "Monetary and fiscal policy aspects of indirect tax changes in a monetary union" by A. Lipińska and L. von Thadden, October 2009.

1098 "Gauging the effectiveness of quantitative forward guidance: evidence from three inflation targeters" by M. Andersson and B. Hofmann, October 2009.

1099 "Public and private sector wages interactions in a general equilibrium model" by G. Fernàndez de Córdoba, J.J. Pérez and J. L. Torres, October 2009.

1100 "Weak and strong cross section dependence and estimation of large panels" by A. Chudik, M. Hashem Pesaran and E. Tosetti, October 2009.

1101 "Fiscal variables and bond spreads – evidence from eastern European countries and Turkey" by C. Nickel, P. C. Rother and J. C. Rülke, October 2009.

1102 "Wage-setting behaviour in France: additional evidence from an ad-hoc survey" by J. Montornés and J.-B. Sauner-Leroy, October 2009.

1103 "Inter-industry wage differentials: how much does rent sharing matter?" by P. Du Caju, F. Rycx and I. Tojerow, October 2009.

1104 "Pass-through of external shocks along the pricing chain: a panel estimation approach for the euro area" by B. Landau and F. Skudelny, November 2009.

1105 "Downward nominal and real wage rigidity: survey evidence from European firms" by J. Babecký, P. Du Caju, T. Kosma, M. Lawless, J. Messina and T. Rõõm, November 2009.

1106 "The margins of labour cost adjustment: survey evidence from European firms" by J. Babecký, P. Du Caju, T. Kosma, M. Lawless, J. Messina and T. Rõõm, November 2009.

1107 "Interbank lending, credit risk premia and collateral" by F. Heider and M. Hoerova, November 2009.

1108 "The role of financial variables in predicting economic activity" by R. Espinoza, F. Fornari and M. J. Lombardi, November 2009.

1109 "What triggers prolonged inflation regimes? A historical analysis." by I. Vansteenkiste, November 2009.

1110 "Putting the New Keynesian DSGE model to the real-time forecasting test" by M. Kolasa, M. Rubaszek and P. Skrzypczyński, November 2009.

1111 "A stable model for euro area money demand: revisiting the role of wealth" by A. Beyer, November 2009.

1112 "Risk spillover among hedge funds: the role of redemptions and fund failures" by B. Klaus and B. Rzepkowski, November 2009.

1113 "Volatility spillovers and contagion from mature to emerging stock markets" by J. Beirne, G. M. Caporale, M. Schulze-Ghattas and N. Spagnolo, November 2009.

1114 "Explaining government revenue windfalls and shortfalls: an analysis for selected EU countries" by R. Morris, C. Rodrigues Braz, F. de Castro, S. Jonk, J. Kremer, S. Linehan, M. Rosaria Marino, C. Schalck and O. Tkacevs.

1115 "Estimation and forecasting in large datasets with conditionally heteroskedastic dynamic common factors" by L. Alessi, M. Barigozzi and M. Capasso, November 2009.

1116 "Sectorial border effects in the European single market: an explanation through industrial concentration" by G. Cafiso, November 2009.

1117 "What drives personal consumption? The role of housing and financial wealth" by J. Slacalek, November 2009.

1118 "Discretionary fiscal policies over the cycle: new evidence based on the ESCB disaggregated approach" by L. Agnello and J. Cimadomo, November 2009.

1119 "Nonparametric hybrid Phillips curves based on subjective expectations: estimates for the euro area" by M. Buchmann, December 2009.

1120 "Exchange rate pass-through in central and eastern European member states" by J. Beirne and M. Bijsterbosch, December 2009.

1121 "Does finance bolster superstar companies? Banks, venture capital and firm size in local U.S. markets" by A. Popov, December 2009.

1122 "Monetary policy shocks and portfolio choice" by M. Fratzscher, C. Saborowski and R. Straub, December 2009.

1123 "Monetary policy and the financing of firms" by F. De Fiore, P. Teles and O. Tristani, December 2009.

1124 "Balance sheet interlinkages and macro-financial risk analysis in the euro area" by O. Castrén and I. K. Kavonius, December 2009.