



Identifying Inter-Sectoral Exposures in Ireland using Network Analysis

Mary Cussen¹

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Abstract

To identify potential sources of contagion, this Letter examines the financial connections between the economic sectors of the Irish economy using *network analysis* tools. This has not been done before for the Irish economy and the analysis benefits from the availability of unpublished whom-to-whom data. The findings reveal that, at a high level of aggregation, the broad sectors of the Irish economy are very connected. Non-resident entities have had very significant network links with the domestic economy. This largely reflects the activities of multinational corporations. Domestic investment funds and money market funds have very strong links with non-resident entities but their connections with the Irish economy are quite limited. Irish households have a high net exposure to non-resident entities through their holdings in insurance and pension fund products. This underlines the importance of continued surveillance of this channel. Finally, domestic credit institutions² are highly connected to all parts of the economy but, towards the end of the sample studied, these links have been in secular decline due to the deleveraging process.

1 Introduction

This Letter examines the financial linkages between the economic sectors of the Irish economy using *network analysis*. Identifying the size and significance of connections between sectors can reveal vulnerabilities that are not obvious using sector aggregates alone. The Global Financial Crisis and its aftermath provides us with a unique opportunity to identify and understand the effects of inter-sectoral linkages since it is a period in which significant inter-sectoral spillovers have occurred.

In recent years, international institutions have also emphasised the importance of identifying interconnectedness between sectors. Extending inter-sectoral data formed one of the recommendations outlined in the FSB/IMF report on addressing data gaps highlighted by the financial crisis (FSB and IMF, 2009). In addition, tools for identifying possible contagion risks such as, *centrality analysis*, *cluster analysis*, and *balance sheet simulation methods*, have increasingly formed part of the IMF's Article IV reports and Financial Sector Assessment Programmes (IMF, 2014). The balance sheet approach (BSA) to identifying financial sta-

¹The views expressed in this paper are those of the author only and do not necessarily reflect the views of the Central Bank of Ireland. The author would like to acknowledge, with thanks, comments provided by Gabriel Fagan, Joe McNeill, Rory McElligott, Peter Dunne, Reamonn Lydon and Niamh Hallissey.

²CI-doms are those institutions whose ultimate parent is resident in Ireland, or which have a significant (greater than 20 per cent) level of business with Irish households and non-financial corporations in terms of their overall resident business activity.

bility risks is outlined in Allen et al. (2002) and was further extended by Mathisen and Pellechio (2006).

The choice of the sectoral breakdown that will be subjected to contagion assessment in this Letter is partly dictated by the availability of disaggregated sectoral information, and by prior knowledge of the potential linkages. Mathisen and Pellechio, for example, argue that assessing inter-sectoral linkages involving credit institutions is particularly important, as these entities are central to the distribution and transmission of risk in any economy. When the global financial crisis began, the dependence of some credit institutions on financing from the interbank market was a source of considerable vulnerability. Furthermore, the bursting of property bubbles in a number of countries left credit institutions with significant property-related lending exposed to substantial credit risk. State interventions to support the banking sector during the financial crisis led to some transfer of risk from the banking sector to the government sector, adversely impacting sovereign bond yields. This Letter further disaggregates Irish credit institutions into domestic credit institutions (CI-doms) and non-domestic credit institutions (CI-non-doms) so as to clearly identify the linkages of both to the Irish economy.

Non-bank financial institutions are also potential sources of systemic risk to other sectors of the economy. This is especially the case when they are involved in liquidity or maturity transformation, credit provision, or invest in risky assets on behalf of their clients. The non-bank financial institutions in this Letter are: other financial intermediaries (OFIs), investment funds (IFs), pension funds (PFs), money market funds (MMFs), and insurance corporations (ICs).

This Letter uses unpublished whom-to-whom data for total assets/liabilities obtained from Quarterly Financial Accounts compilation systems. Whom-to-whom matrices quantify each sectors financial positions and transactions vis-a-vis those of all the other sectors of the economy. The data used for the analysis in this Letter are described in Appendix 2.

³This letter refers to both institutional sectors, and subsectors of the economy as 'sectors'.

This letter examines the inter-sectoral linkages of the Irish economy using a number of *network analysis* tools. The remainder of this Letter is arranged as follows: Section 2 describes the network analysis tools used to measure interconnectedness. Section 3 discusses the results. Conclusions are presented in Section 4. Results tables and the data used are described in Appendix 1 and Appendix 2, respectively.

2 Measuring Interconnectedness

Network analysis tools have been increasingly used to map the financial relationships between the institutional sectors³ of the economy and, where data are available, between individual financial institutions. This Letter uses *network analysis* to examine the former only. It takes a top-down approach towards identifying potential contagion risks in the economy at a high level.

This could be complimented by employing a bottom-up approach using more granular data and balance sheet simulations of financial shocks. The Letter uses *network analysis* charts to depict the gross connections between sectors, the summed transactions between sectors over time, and connections between sectors on a net basis i.e. liabilities minus assets. Each sector of the economy (known as a 'node' in network theory) is connected to the other sectors if a financial claim greater than 1 per cent of GDP exists between them. Coloured lines represent connections greater than 5 per cent of GDP. Directed lines are used to indicate which sector is a debtor and which is a creditor. The relative size of the claims can be depicted through the thickness and colour of the lines. The magnitude of connections between entities within the same sector is represented by the size of the sector's node.

While *network analysis charts* can give a valuable overview of connections, *network analysis* statistics provide very useful summary information which can make it easier to compare networks over time. The degree of centrality statistics measures how many connections each sector has with the other sectors. *In-degree* counts all incoming links. *Out-*

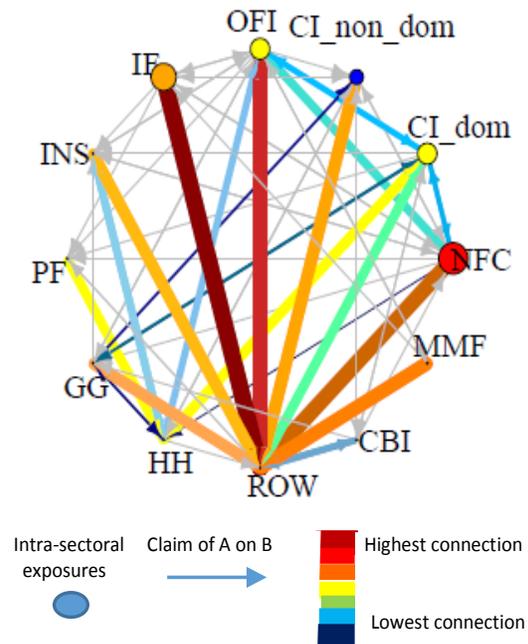
degree counts all outgoing links. *Degree counts* both incoming and outgoing links. The *clustering coefficient (CC)* divides the number of links a sector has with other sectors by total number of possible links. The CC is a useful statistic for ascertaining if a network is becoming more or less connected over time, or comparing interconnectiveness between countries.

3 Discussion of Results

The connectedness of the Irish economy at a very high level over time is summarised in Tables 1-3. The data are firstly presented on an European System of Accounts (ESA)⁴ 1995 basis, so as to facilitate a consistent comparison over time and also with other countries. *Degrees* and *CC* are compared for the first available time period (Q1 2002), just before the crisis intensified in Ireland (Q2 2008) and for the latest period for which ESA 1995 data is available (Q1 2014). The tables show that all sectors had links with most other sectors, indicating an extremely high degree of centrality. In addition, the *CC* is extremely high for all three periods shown in the tables. At Q1 2014, the *CC* was 0.92. In contrast, Castren and Rancan (2013) found that the average *CC* for 11 euro area countries on an ESA 1995 basis was 0.68 at Q1 2012. Consequently, it would appear as though, on an aggregate basis, the Irish economy is much more connected than the average euro area economy, reflecting, in part, that the Irish economy is generally smaller and more open than average.

It is instructive to disaggregate the connectedness of the sectors of the economy further, where possible. This is because financial sectors may have very different connections and risks depending on their main activities. As discussed in Appendix 2, further disaggregation of the financial sector is possible using ESA 2010, QFA and supplementary data sources. Unfortunately, these data are currently only available from Q1 2012. Using these data, the *CC* for Q2 2015 is much lower, at 0.57. Money market funds (MMFs) and pension funds (PFs) had the lowest *Degrees* and *CC*.

Figure 1: Heatmap Signifying the Gross Exposures of the Sectors of the Economy, Q2 2015



NFC = Non-financial corporations, CBI=Central Bank, CI-doms= Domestic credit institutions, CI-non-doms = Non-domestic credit institutions MMF = Money market funds, IF= Investment funds, OFI = Other financial intermediaries, INS = Insurance corporations, PF= Pension funds, GG = General government, HH = Households and NPISH, ROW = Non-resident entities.

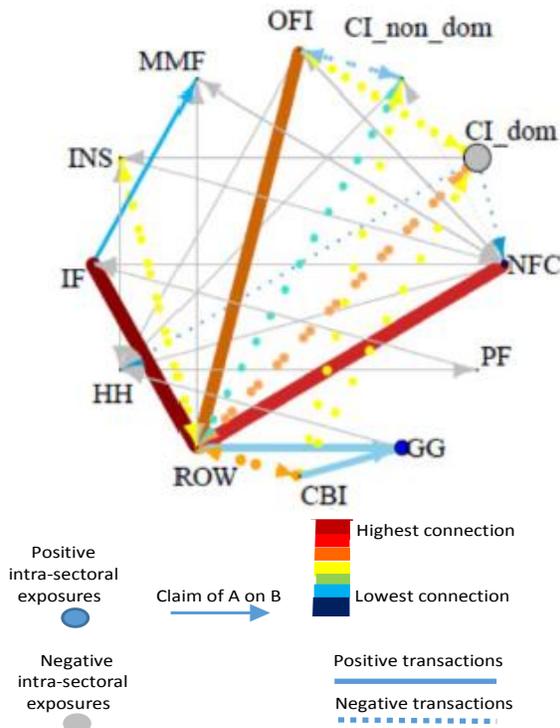
Source: Internal Estimates.

The connections between the sectors of the economy on a gross basis using the disaggregated data are mapped in Figure 1 for Q2 2015. The central role played by the rest of the world, both in terms of providing and receiving funding from the domestic sectors of the economy, is highlighted in the Figure. The rest of the world has the highest degree of centrality. It is the only sector that has connections with all the other sectors of the economy. In addition, the seven highest connections identified are between the rest of the world and other sectors. The sectors with the strongest connections with the rest of the world are investment funds (IFs), non-financial corporations (NFCs), other financial intermediaries (OFIs), money market funds (MMFs), credit institutions non-domestic (CI-nondoms) and insurance corporations (ICs). It is im-

⁴ESA are the statistical manuals which are used to compile all national accounts, including financial accounts. In 2015, ESA 1995 was replaced with ESA 2010. Appendix 2 describes the differences between the 1995 and 2010 manuals relating to financial accounts.

portant to note that these connections reflect in part the activities of some very large financial and non-financial multi-national corporations (MNCs) connections with non-residents. Many of these MNCs do not have very strong connections with the domestic economy. The seventh strongest connection is between the rest of the world and the Government. This is due to the substantial holdings of Irish Government bonds by non-residents, as well as loans received from the EU and the IMF.

Figure 2: Heatmap Signifying the Transactions between the Sectors of the Economy- Q1 2012 to Q2 2015



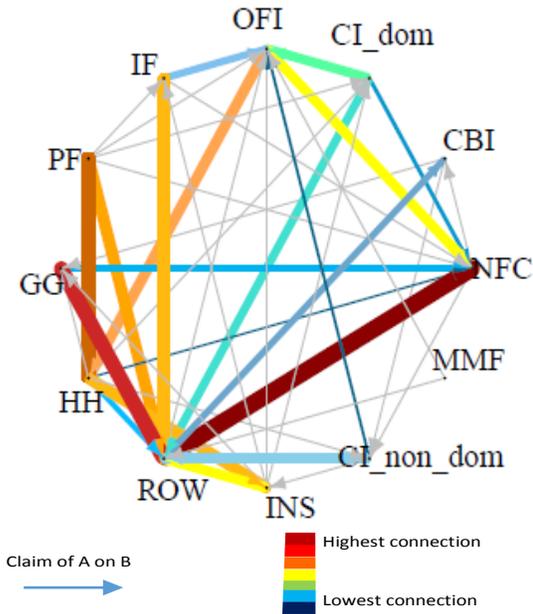
NFC = Non-Financial Corporations, CBI=Central Bank, CI-doms= Domestic Credit Institutions, CI-non-doms = Non-domestic Credit Institutions MMF = Money Market funds, IF= Investment Funds, OFI = Other financial Intermediaries, INS = Insurance corporations, PF= Pension funds, GG = General Government, HH = Households and NPISH, ROW = Non-resident entities.

Source: Internal Estimates.

Given the central role played by credit institutions, identifying and monitoring the interconnectiveness of this sector is important. Five sectors had connections with CI-doms greater than 5 per cent of GDP. In addition, the nodes (i.e. circles)

in Figure 1 illustrate that credit institutions also had quite high intra-sectoral financing. The figure shows however that CI-doms did not have material connections with MMFs and that their connections with insurance corporations and pension funds were less than 5 per cent of GDP. Figure 2, shows however, the deleveraging by CI-doms in the last part of the sample. The figure illustrates the summed transactions between the sectors of the economy from Q1 2012 to Q2 2015. Full lines represent positive transactions on aggregate, whereas dashes represent negative transactions. OFIs, households and NFCs have all, on net, decreased their loan liabilities with these institutions reflecting deleveraging in Ireland since the financial crisis. For households and NFCs this trend reflects the significant deleveraging since the crisis began.

Figure 3: Heatmap Signifying the Net Exposures of the Sectors of the Economy- Q2 2015



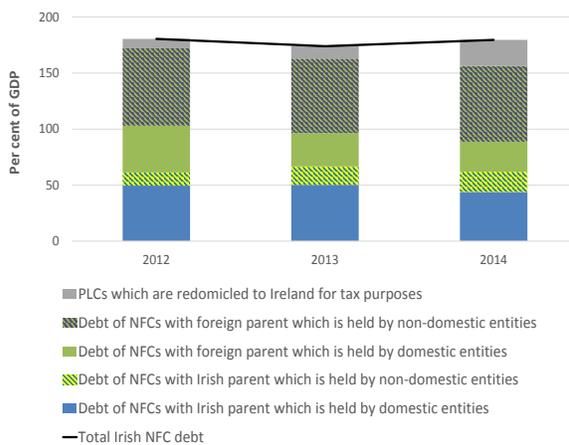
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Source: Internal Estimates.

It is also informative to monitor each sector's net exposures to each other. Net exposures are calcu-

lated as liabilities minus assets. The analysis shows that households, on a net basis, hold significant assets with insurance corporations (ICs) and pension funds (PFs), relating to their insurance technical reserves assets (Figure 3). The results show that ICs' and PFs' claims are, in turn, mostly on the rest of the world. Therefore Irish households could be quite exposed to the rest of the world through their investment in insurance and pension fund products. This is a possible channel through which risk originating outside of Ireland could be transferred to Irish households.

Figure 4: NFC debt with Irish and foreign parents held by domestic and non-domestic entities



Source: Central Statistics Office.

NFCs were the second most connected sector in the Irish economy, having connections with most sectors (Figure 1). However, many of the connections were less than 5 per cent of GDP. On a net basis, the connection between NFCs and the rest of the world was the strongest of the NFC aggregate

connections (Figure 3). It is mostly foreign-owned firms, however, which obtain debt funding from the rest of the world (Figure 4). Irish-owned companies predominately obtain their debt financing from Irish entities.

4 Conclusion

This Letter identifies interlinkages in the Irish economy at a very high level. It finds that the Irish economy is highly interconnected at a sectoral level. This could pose risks to the Irish economy, as a shock to one sector could be transmitted to other sectors. A number of papers find, however, that a high level of interconnectedness may also have benefits for financial stability. Allen and Gale (2000) and Muoz and Scuzzarella (2011) find, using more granular data than in this letter, that high levels of interconnectedness can mean that a shock is absorbed by a number of different sectors, thereby lessening its impact.

The letter finds that the rest of the world is the most connected sector. This reflects in part the role of MNCs, as well as the openness of the Irish economy. CI-doms was the second most connected sector. As part of the deleveraging process however, it has been reducing its links with other sectors. It is noteworthy that Irish households are quite exposed to the rest of the world through their holdings of insurance and pension fund products. Therefore, continued surveillance of this channel through which risk could be transmitted to households is extremely important. The analysis in this Letter could be complimented by employing a bottom-up approach using more granular data and balance sheet simulations of financial shocks.

Appendices

Appendix 1 - Tables 1 - 4

Table 1: Network Analysis Statistics at ESA 1995 sectoral level, Q1 2002⁵

Measure	NFC	MFI	OFI	ICPF	HH	GG	ROW	Average
In-degree	5	6	5	5	5	5	6	
Out-degree	6	6	4	4	5	5	6	
Degrees	11	12	9	9	10	11	12	
CC	0.92	1	0.75	0.75	0.83	0.92	1	0.88

Table 2: Network Analysis Statistics at ESA 1995 sectoral level, Q2 2008

Measure	NFC	MFI	OFI	ICPF	HH	GG	ROW	Average
In-degree	6	6	5	6	5	6	6	
Out-degree	6	6	5	5	5	6	6	
Degrees	12	12	10	11	10	11	12	
CC	1	1	0.83	0.92	0.83	1	1	0.94

Table 3: Network Analysis Statistics at ESA 1995 sectoral level, Q1 2014

Measure	NFC	MFI	OFI	ICPF	HH	GG	ROW	Average
In-degree	6	6	5	6	5	5	6	
Out-degree	6	6	5	4	5	6	6	
Degrees	12	12	10	10	10	11	12	
CC	1	1	0.83	0.83	0.83	0.92	1	0.92

⁵In-degree counts all incoming links. Out-degree counts all outgoing links. Degree counts both incoming and outgoing links. The clustering coefficient (CC) divides the number of links a sector has with other sectors by total number of possible links.

Table 4: Network Analysis Statistics with additional financial sector breakdowns, Q2 2015

Measure	NFC	CBI	CI -dom	CI-non -dom	MMF	OFI	IF	INS	PF	GG	HH	ROW	Average
In-degree	9	5	9	5	3	9	6	4	1	7	7	11	
Out-degree	9	4	5	5	2	8	5	7	5	6	7	10	
Degrees	18	9	15	11	5	17	11	11	6	13	14	21	
CC	0.82	0.41	0.68	0.50	0.23	0.77	0.50	0.50	0.27	0.59	0.64	0.95	0.57

Appendix 2 - Intersectoral Exposures Data

A number of papers (Castren and Kavonius (2009), Silva (2010) and Hyun (2010)) have used Financial Accounts data to identify inter-sectoral linkages between institutional sectors. Financial Accounts present complete balance sheet and transactions data for all the institutional sectors of the economy on a quarterly basis. As most countries do not publish the inter-sectoral positions or whom-to-whom breakdowns of Financial Accounts, these papers estimate the whom-to-whom networks using maximum entropy techniques. However, Upper (2011) finds that when using estimation techniques, bias in results may potentially be introduced due to the assumptions used.

In Ireland, the Central Bank compile Quarterly Financial Accounts (QFA) using a range of data sources including: money and banking statistics, international investment positions (IIP) data, balance of payments (BOP) data, quarterly financial accounts of government, and securities issues statistics. From these data sources, QFA are compiled based on whom-to-whom matrices, where possible. Whom-to-whom matrices quantify each sectors financial positions and transactions vis-a-vis those of all the other sectors of the economy. Compiling data using the whom-to-whom matrices acts as an important quality check on the QFA data, as discrepancies in the raw data can be identified and investigated by QFA compilers. Since April 2015, whom-to-whom data has been published by the Central Bank for deposits, short-term loans and long-term loans. In early 2016, whom-to-whom data will also be published for debt securities, quoted shares. and mutual funds. This letter uses unpublished whom-to-whom data for total assets/liabilities obtained from QFA compilation systems. Using actual data to examine possible contagion risk eliminates biases which may have been introduced from the types of assumptions which are necessary under maximum entropy techniques.

QFA are currently published for each of the nine institutional sectors of the economy⁶ on an ESA 2010 basis for Q1 2012 to Q2 2015. QFA are available on an ESA 1995 basis for Q1 2002 to Q1 2014. The ESA 2010 QFA data differs from ESA 1995 data in that it reclassifies holdings companies from NFCs to OFIs. In addition, it provides a more detailed breakdown of the financial sector. It separates IFs from OFIs, and PFs from ICs.

In the case of Ireland, the financial and non-financial sectors of the economy contain MNCs which can be extremely large relative to the size of the economy. These MNCs can have substantial positions with the rest of the world. This makes it very difficult to distinguish how much of a sector's positions with the rest of the world are due to MNCs and how much due to the activities of domestically-owned entities. In addition, the contagion risks of these MNCs could be different to the risks associated with domestically-focused corporations. The QFA data in this letter is, therefore, supplemented with data on MMFs and domestic

⁶The institutional sectors are: non-financial corporations (NFCs), monetary financial corporations (MFIs), other financial intermediaries (OFIs), investment funds (IFs), insurance corporations (INS), pension funds (PF), general government (GG), households (HH) and non-resident entities (ROW).

credit institutions⁷ in order to strip out, in so far as possible, the impact of financial MNCs on sector results. The central bank balance sheet is also disaggregated from MFIs. It is unfortunately not currently possible to disaggregate NFC's connections with other sectors by Irish-owned corporations and foreign-MNCs.

⁷Domestic credit institutions (CI-doms) are those institutions whose ultimate parent entity is resident in Ireland, or which have a significant (greater than 20 per cent) level of business with Irish households and non-financial corporations in terms of their overall resident business activity.

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