Banks Interconnectivity and Leverage*

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Abstract

In this paper we document that in the period that preceded the 2008 crisis, financial firms have become more interconnected (with each other) and more leveraged. To understand how cross-bank interconnectivity is related to bank leverage we first develop a dynamic model where banks make risky investments in the nonfinancial sector. To reduce the idiosyncratic risk, they sell some of the investments to other banks (interconnectivity). Thanks to diversification, the portfolio of each bank becomes less risky which increases the incentive to leverage. We explore this mechanism empirically using a large sample of over 14,000 financial institutions from 32 OECD countries along three dimensions: across banks, time and countries. Along each of these dimensions we find that there is a strong positive association between banks interconnectivity and leverage. In particular, banks that are more financially interconnected are also more leveraged; when an individual bank becomes more connected it raises its leverage; countries in which the banking sector is more interconnected tend to have more leveraged banks. Although bank interconnectivity reduces the idiosyncratic risk faced by each bank, it does not eliminate the aggregate financial risk which could increase with the leverage of whole financial sector.

JEL classification:
Keywords: Interconnectivity, Leverage

*The views expressed in this paper do not reflect the views of the Central Bank of Ireland or the European System of Central Banks. All errors are ours.

1 Introduction

During the last three decades we have witnessed a significant expansion of the financial sector. As shown in Figure 1, the assets of US financial businesses have more than doubled as a fraction of the country GDP. This trend has been associated to two other trends within the financial sector. First, in the period that preceded the 2008 crisis, financial intermediaries have become more interconnected, that is, they have increased the holding of liabilities issued by other financial intermediaries. Second, financial firms have become more leveraged.

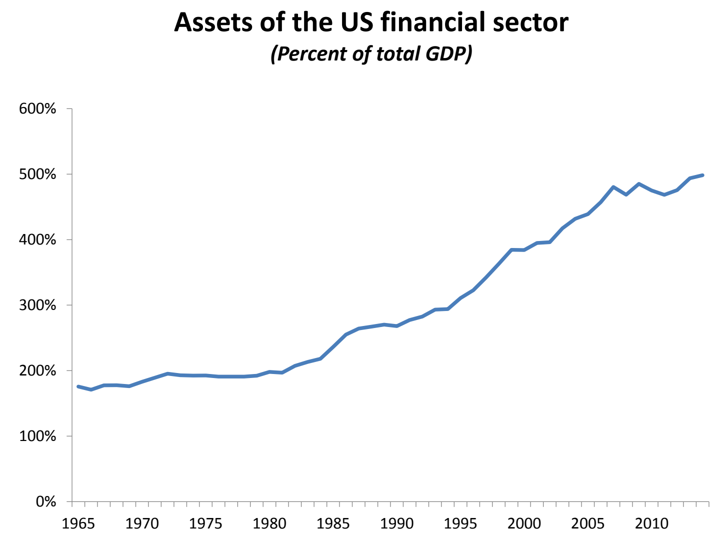

Figure 1: The growth of the financial sector.

To illustrate these two trends, the first panel of Figure 2 plots the ratio of non-core liabilities over total assets for the US banking sector using data from Bankscope, for the period 1999-2011. Non-core liabilities are those issued to other banks while core liabilities are issued to nonfinancial sectors (like the typical bank deposits of households and nonfinancial businesses). A more detailed description of the data will be provided later in the empirical section of the paper. We interpret the ratio as an index of financial inter-connectivity among banks. As can be seen from the figure, this ratio has increased significantly prior to the 2008 financial crisis.

The second panel of Figure 2 plots the ratio of assets over equity for the US banking

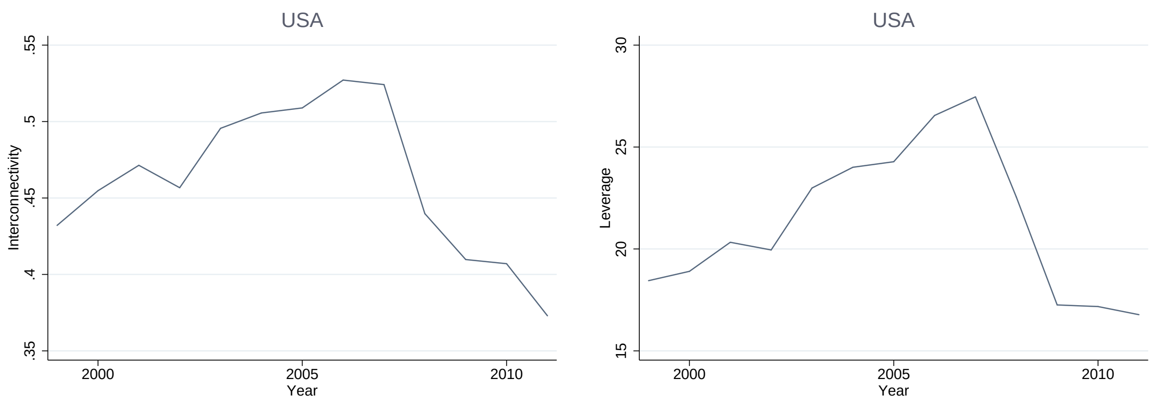

Figure 2: The expansion and decline of banks connectivity (first panel) and leverage (second panel) in the United States.

sector. This is our primary measure of leverage. As can be seen from the figure, the ratio of assets over equity has increased significantly during the same period in which banks interconnectivity has increased, that is, prior to the 2008 crisis. We can also see that the subsequent decline after the crisis tracks quite closely the decline in inter-connectivity. To further illustrate the co-movement between interconnectivity and leverage, Figure 3 plots these two variables for each year in which data is available. As can be seen, there is a very strong positive correlation between interconnectivity and leverage.

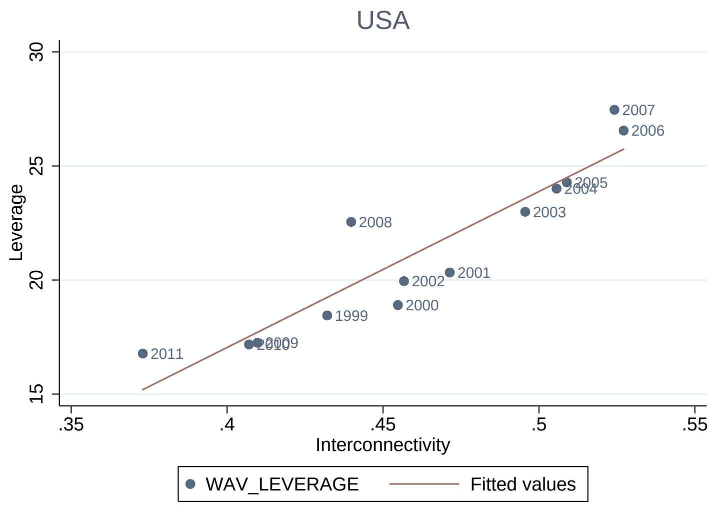

Figure 3: Interconnectivity and Leverage in the United States.

Motivated by these empirical patterns, this paper addresses two questions. First, are the simultaneous increases (and subsequent declines) in inter-connectivity and leverage related? Second, what are the forces that have induced banks to become more interconnected and leveraged?

To address these questions we first develop a dynamic model where banks make risky investments outside the financial sector. To reduce the idiosyncratic risk, banks sell some of the investments to other banks and become more diversified. Because of the diversification, they are willing to invest more and take more leverage.

To investigate this mechanism empirically, in the second part of the paper we use data from Bankscope and explore the prediction of the model along three dimensions: across banks, across time and across countries. The empirical analysis suggests that there is a strong association between banks interconnectivity and leverage. In particular, banks that are more financially interconnected are more leveraged; when an individual bank becomes more connected to other banks, it also raises its leverage; countries in which the banking sector is more connected tend to have more leveraged banks. Although this does not test the specific mechanism that in the model generates the positive association between connectivity and leverage, it is consistent with it.

A second prediction of the model is that bank connectivity and leverage increase when the cost of diversification declines and/or the difference between the investment return and the cost of funds (return spread) increases. This provides two possible candidates for explaining the pre-crisis increase in connectivity and leverage: (i) an increase in the operating margin of banks; and/or (ii) a decline in the cost of diversification (resulting, for example, from financial innovations).

The two potential changes have different implications for the return differential between the investments and the liabilities of banks. If the change in connectivity is driven by movements in the return spread, we would observe a positive correlation between connectivity and return differential. Instead, if the main driver is the change in the cost of diversification, we would observe a negative correlation between connectivity and return differential.

This is what we find in the data. Return differentials have declined over time before 2008. Furthermore, they are lower for banks that are more interconnected and leveraged. This suggests that the increase in connectivity and leverage is likely to derive from the reduction in the cost of diversification.

The paper is organized as follows. After a brief review of the related literature, Section 2 describes the model and characterizes its properties. Section 3 conducts the empirical analysis and Section 4 concludes.

1.1 Related literature

The paper is related to several strands of literature. The first is the literature on interconnectedness. There are many theoretical contribution starting with Allen and Gale (2000) and Freixas, Parigi, and Rochet (2000). They provided the first formal treatments of how the interconnectedness within the financial sector can be a source of propagation of shocks. These two papers led to the development of a vast literature. More recently, David and Lear (2011) present a model in which large interconnections facilitate mutual private sector bailouts to lower the need for government bailouts. Allen, Babus, and Carletti (2012) propose a model where asset commonalities between different banks affect the likelihood of systemic crises. Eiser and Eufinger (2014) show that banks could have an incentive to become interconnected to exploit their implicit government guarantee. Finally, Acemoglu at el. (2015) propose a model where a more densely connected financial network enhances financial stability for small realization of shocks. However, beyond a certain point, dense interconnection serves as a mechanism for the amplification of large shocks, leading to a more fragile financial system.

On the empirical side, Billio et al.(2012) propose econometric measures of systemic risk based on principal components analysis and Granger-causality tests. Cai, Saunders and Steffen (2014) present evidence that banks who are more interconnected are characterized by higher measures of systemic risk.[1] Moreover, Hale et al. (2014) study the transmission

[1] See also Drehmann and Tarashev(2013) for an empirical analysis of banks interconnectedness and systemic risk, as well as Cetorelli and Goldberg (2012) and Barattieri et. al (2014) for an application of financial

of financial crises via interbank exposures. They use deal-level data on interbank syndicated loans to construct a global banking network for the period 1997-2012. They distinguish between direct (first degree) and indirect (second degree) exposures and find that direct exposure reduces bank profitability.[2] Peltonen et al. (2015) analyze the role of the interconnectedness of the banking system into the macro network as a source of vulnerability to crises.

The second strand of literature related to this paper is on bank leverage. In a series of papers, Adrian and Shin (2010, 2011, 2014) document how leverage is pro-cyclical and there is a strong positive relationship between leverage and balance sheet size. They also show that, at the aggregate level, changes in the balance sheets have an impact on asset prices via changes in risk appetite.[3] Nuno and Thomas (2012) document the presence of a bank leverage cycle in the post-war US data. They show that leverage is more volatile than GDP, and it is pro-cyclical both with respect to total assets and GDP. Devereux and Yetman (2010) show that leverage constraints can also affect the nature of cross-countries business cycle co-movements.

These papers discussed above, however, do not consider explicitly the interlink between interconnectedness and leverage. Two important exceptions are Shin (2009) and Gennaioli et al (2013). As in our model, these papers highlight a theoretical link between bank interconnectedness and leverage but the underlying mechanisms are different. More importantly, we also conduct an empirical analysis using a large sample of banks from many OECD countries.[4]

interconnectedness to the monetary policy transmission.

[2]See also Liu et al., 2015 for a detailed analysis of different sources of interconnectedness in the banking sector.

[3]Potential explanations for the pro-ciclicality of leverage can be found in Geanakopulos (2010) and Simsek (2013).

[4]A positive correlation between inter-connectivity and leverage is also detected by Allahrakha et al (2015), but only for a sample of 33 U.S. bank holding companies.

2 The model

Consider a bank owned by an investor with utility

$$\mathbb{E}_t \sum_{t=0}^{\infty} \ln(c_t).$$

The concavity of the utility function (which for simplicity takes the log-form) is an important feature of the model. There are different ways of thinking about this function. One interpretation is that this function represents the preferences of the major shareholders of the bank. An alternative interpretation is that it represents the preferences of the top management who has to hold some of the shares of the bank to make sure that the incentives of managers are aligned with those of shareholders. It can also be interpreted as capturing, in reduced form, the possible costs associated with financial distress: even if shareholders and managers are risk-neutral, the convex nature of financial distress costs would make the objective of the bank concave.

The net worth of the bank at time t is denoted by a_t. Given the net worth, the bank could sell liabilities l_t to the nonfinancial sector at the market price $1/R_t^l$ and make risky investments k_t also in the nonfinancial sector at the market price $1/R_t^k$. The investments return $z_{t+1}k_t$ at the beginning of the next period, where z_{t+1} is a stochastic variable observed at time t+1. For the moment we assume that z_{t+1} is independently and identically distributed across banks (idiosyncratic) and over time with $\mathbb{E}_t z_{t+1} = 1$. Therefore, R_t^k is the expected return from the investment while $z_{t+1}R_t^k$ is the actual return realized at $t + 1$. There is no uncertainty on the liabilities side. Therefore, R_t^l is both the expected and actual return for the holder of the bank liabilities.

The riskiness of the investments creates a demand for insurance that can be obtained through interbank activities. The bank can sell a share α_t of its risky investments to other banks and buy a *diversified* portfolio f_t of risky investments from other banks. For an individual bank, the term $\alpha_t k_t$ represents interbank liabilities while f_t represents interbank assets. The market price for interbank liabilities and assets is denoted by $1/R^i$.

We should think of the sales of risky investments to other banks as investments that continue to be managed by the originating bank but other banks are entitled to a share α_t of the return. These sales are beneficial because they allow banks to diversify their investment risk. Agency problems, however, limit the degree of diversification. When a bank sells part of the risky investments to other banks, it may be prone to opportunistic behavior that could weaken the return for external holders of the investments. This is captured, parsimoniously, by the convex cost $\varphi(\alpha_t)k_t$.

To place some structure on the diversification cost we make the following assumption.

Assumption 1. *The diversification cost takes the form $\varphi(\alpha_t) = \chi\alpha_t^\gamma$, with $\gamma > 1$.*

The specific functional form will allow us to conduct a comparative static analysis with changes in the diversification cost captured by the single parameter χ.

The problem solved by the bank can be written recursively as

$$V_t(a_t) = \max_{c_t,l_t,k_t,\alpha_t,f_t} \ln(c_t) + \beta\mathbb{E}_t V_{t+1}(a_{t+1}) \tag{1}$$

subject to:

$$c_t = a_t + \frac{l_t}{R_t^l} - \frac{k_t}{R_t^k} + \frac{[\alpha_t - \varphi(\alpha_t)]k_t}{R_t^i} - \frac{f_t}{R_t^i}$$

$$a_{t+1} = z_{t+1}(1-\alpha_t)k_t + f_t - l_t.$$

The bank maximizes the discounted expected utility of the owner given the initial net worth $a_t = z_t(1-\alpha_{t-1})k_{t-1} + f_{t-1} - l_{t-1}$. The problem is subject to the budget constraint and the law of motion for the next period net worth.

The first order conditions for the above problem imply

$$\begin{aligned} R_t^i &= R_t^l, \\ R_t^i &= R_t^k \Big[1 - \varphi(\alpha_t) - \varphi'(\alpha_t) + \alpha_t\varphi'(\alpha_t)\Big]. \end{aligned}$$

Combining these two conditions we can express the return spread between risky investments and liabilities as

$$\frac{R_t^k}{R_t^l} = \frac{1}{1 - \varphi(\alpha_t) - \varphi'(\alpha_t) + \alpha_t \varphi'(\alpha_t)}. \tag{2}$$

This condition determines the share of risky investments sold to other banks α_t as a function of the return spread R_t^k/R_t^l. The following lemma establishes how the share α_t is affected by the return spread.

Lemma 2.1. *Bank diversification α_t is strictly increasing in $\frac{R_t^k}{R_t^l}$ and strictly decreasing in χ if $\alpha_t < 1$.*

Proof 2.1. *We can compute the derivative of α_t with respect to the return spread R_t^k/R_t^l by applying the implicit function theorem to condition (2). Denoting by $x_t = R_t^k/R_t^l$ the return spread we obtain $\partial\alpha_t/\partial x_t = 1/[(1-\alpha_t)\varphi''(\alpha_t)x_t^2]$. Given the functional form for the diversification cost (Assumption 1), $\varphi''(\alpha_t) > 0$. Next we compute the derivative of α_t with respect to χ. Again, applying the implicit function theorem to condition (2) we obtain $\partial\alpha_t/\partial\chi = -[\alpha_t^\gamma + \gamma(1-\alpha_t)\alpha_t^{\gamma-1}]x_t/[\gamma(\gamma-1)\chi(1-\alpha_t)\alpha_t^{\gamma-2}]$. This shows that the derivative is negative if $\alpha_t < 1$.* ■

The monotonicity of α_t with respect to the return spread and the diversification cost is conditional on having α_t being smaller than 1. Although α_t could be bigger than one for a single bank, this cannot be the case for the whole banking sector. In a general equilibrium with endogenous R_t^k and R_t^l, the return spread will adjust to make sure that $\alpha_t < 1$. But in our (partial equilibrium) analysis, prices are exogenous. Therefore, to make sure that $\alpha_t < 1$ we make the following assumption.

Assumption 2. *The parameter χ is sufficiently large so that $\alpha_t < 1$.*

2.1 Reformulation of the bank problem

We now take advantage of one special property of the model. Since in equilibrium $R_t^l = R_t^i$, only $l_t - f_t$ is determined for an individual bank. This is because a bank cannot make profits from funding diversified investment f_t with liabilities l_t. It will then be convenient to define the net liabilities $\bar{l}_t = l_t - f_t$ (net of the interbank financial assets). We also define $\bar{k}_t = (1-\alpha_t)k_t$ the retained risky investments. Using these new variables, the optimization problem of the bank can be rewritten as

$$V_t(a_t) \quad = \quad \max_{c_t,\bar{l}_t,\bar{k}_t} \ln(c_t) + \beta \mathbb{E}_t V_{t+1}(a_{t+1}) \tag{3}$$

$$\begin{aligned}
&\text{subject to:}\\
&c_t = a_t + \frac{\bar{l}_t}{R_t^l} - \frac{\bar{k}_t}{\bar{R}_t^k}\\
&a_{t+1} = z_{t+1}\bar{k}_t - \bar{l}_t,
\end{aligned}$$

where $\bar{R}_t^k$ is the *adjusted* investment return defined as

$$\bar{R}_t^k = \frac{1}{\frac{1}{(1-\alpha_t)R_t^k} - \frac{\alpha_t - \varphi(\alpha_t)}{(1-\alpha_t)R_t^l}}. \tag{4}$$

The adjusted return depends on the two exogenous returns R_t^l and R_t^k, and on the optimal diversification α_t. Since α_t depends only on R_t^k and R_t^l (see equation (2)), the adjusted return is only a function of these two exogenous returns.

The next lemma establishes that the adjusted return spread $\bar{R}_t^k/R_t^l$ increases in R_t^k/R_t^l. This property will be used later for the derivation of some key results.

Lemma 2.2. *The adjusted return spread $\bar{R}_t^k/R_t^l$ is strictly increasing in R_t^k/R_t^l.*

Proof 2.2. *Condition (4) can be rewritten as*

$$\frac{R_t^l}{\bar{R}_t^k} = \frac{1}{(1-\alpha_t)}\frac{R_t^l}{R_t^k} - \frac{\alpha_t - \varphi(\alpha_t)}{(1-\alpha_t)}.$$

Eliminating $\frac{R_t^l}{R_t^k}$ using (2) and re-arranging we obtain

$$\frac{\bar{R}_t^k}{R_t^l} = \frac{1}{1-\varphi'(\alpha_t)}.$$

Since α_t is strictly increasing in R_t^k/R_t^l (see Lemma 2.1) and $\varphi'(\alpha_t)$ is strictly increasing in α_t, the right-hand-side of the equation is strictly increasing in R_t^k/R_t^l. Therefore, $\bar{R}_t^k/R_t^l$ is strictly increasing in R_t^k/R_t^l. ■

Problem (3) is a standard portfolio choice problem with two assets: a risky asset $\bar{k}_t$ with return $z_{t+1}\bar{R}_t^k$ and a riskless asset $-\bar{l}_t$ with return R_t^l. The problem has a simple solution characterized by the following lemma.

Lemma 2.3. *The optimal policy of the bank takes the form*

$$
\begin{aligned}
c_t &= (1-\beta)a_t, && (5)\\
\frac{\bar{k}_t}{\bar{R}_t^k} &= \phi_t \beta a_t, && (6)\\
-\frac{\bar{l}_t}{R_t^l} &= (1-\phi_t)\beta a_t, && (7)
\end{aligned}
$$

where ϕ_t satisfies $\mathbb{E}_t\left\{\frac{1}{1+[z_{t+1}(\bar{R}_t^k/R_t^l)-1]\phi_t}\right\}=1$ and it is strictly increasing in the return spread R_t^k/R_t^l.

Proof 2.3. *See Appendix A.*

Conditions (6) and (7) determine $\bar{k}_t$ and $\bar{l}_t$ and the first order condition (2) determines the share of investments sold to other banks, α_t. Given $\bar{k}_t$ we can then determine $k_t = \bar{k}_t/(1-\alpha_t)$. What is left to determine are the variables f_t and l_t. Even if for an individual bank we cannot determine these two variables separately but only the net liabilities $\bar{l}_t = l_t - f_t$, in a banking equilibrium the aggregate variables must satisfy $f_t = \alpha_t k_t$. From this we can solve for $l_t = \bar{l}_t + f_t$. Therefore, given the interest rates R_t^l and R_t^k we can solve for l_t, k_t and f_t.

2.2 Leverage and interconnectivity

We now focus on the aggregate (non-consolidated) banking sector and denote with capital letters the aggregate variables. The aggregate leverage is defined as the ratio of (non-consolidated) total bank assets at the end of the period, $K_t/R_t^k + F_t/R_t^l$, and (unconsolidated) total bank equities, also at the end of the period, $K_t/R_t^k - L_t/R_t^l$,

$$LEVERAGE = \frac{K_t/R_t^k + F_t/R_t^l}{K_t/R_t^k - L_t/R_t^l}. \tag{8}$$

The aggregate leverage is obtained by summing the balance sheets of all firms but without consolidation. Therefore, total assets include not only the investments made in the nonfinancial sector, K_t/R_t^k, but also the assets purchased from other banks, F_t/R_t^l. Of course, if we were to consolidate the balance sheets of all banks, the resulting assets would include F_t/R_t^l. Similarly for the aggregate liabilities. The aggregate number can be interpret as the leverage of a representative bank.

Next we define bank interconnectivity as the ratio of aggregate non-core liabilities (assets purchased by other banks) over aggregate (non-consolidated) assets, that is,

$$INTERCONNECTIVITY = \frac{\alpha_t K_t/R_t^l}{K_t/R_t^k + F_t/R_t^l}. \tag{9}$$

The next step is to characterize the properties of these two financial indicators with special attention to the dependence from the return spread R_t^k/R_t^l and the diversification cost $\varphi(\alpha_t)$. The following proposition characterizes the dependence of leverage and interconnectivity from the return spread.

Proposition 2.1. *For empirically relevant parameters, leverage and interconnectivity are*

- *Strictly decreasing in the diversification cost, χ.*
- *Strictly increasing in the return spread, R_t^k/R_t^l.*

Proof 2.1. *See Appendix B*

The dependence of leverage and interconnectivity from the return spread and the diversification cost is one of the key theoretical results of this paper that will explore further in the empirical section.

2.3 Bank return differential

The return differential for the bank is defined as the difference between the return in total assets (revenue) and the return on total liabilities (cost), that is,

$$DIFFERENTIAL = \frac{K_t + F_t}{K_t/R_t^k + F_t/R_t^l} - \frac{L_t + \alpha_t K_t}{L_t/R_t^l + \alpha_t K_t/R_t^l} \tag{10}$$

The asset return is calculated by dividing the average value of all assets held by the bank at the beginning of $t+1$—$K_t + F_t$—by the cost incurred to buy these assets at time t—$K_t/R_t^k + F_t/R_t^l + \varphi(\alpha_t)K_t/R_t^l$. The return on liabilities is defined in a similar fashion: the value of all liabilities held by the bank at the beginning of $t+1$—$L_t + \alpha_t K_t$—by the revenue from issuing these liabilities at time t—$L_t/R_t^l + \alpha_t K_t/R_t^l$.

Proposition 2.2. *The bank return differential is*

- *Strictly increasing in the diversification cost, χ.*
- *Strictly increasing in the return spread, R_t^k/R_t^l, if χ is sufficiently large.*

Proof 2.2. *See Appendix C*

Proposition 2.2 is important because it has different implications for the observed correlation between the net return differential and inter-connectivity. If the the change in leverage and inter-connectivity is primarily driven by a change in the return spread, we would observe a positive correlation between inter-connectivity and net return differential. If instead the main driving force is a change in the cost of diversification, we would observe a negative relation between the net return differential and inter-connectivity, which is what we find in the data. As we will see in the empirical section of the paper, we compute different measures of net return differential for banks and we find that these measures are negatively correlated with our measure of interbank connectivity, suggesting that the second mechanism has played a more important role.

2.4 Numerical example

For the numerical exercise we specify the diversification cost as $\varphi(\alpha_t) = \chi\alpha_t^2$. The idiosyncratic shock z_t is assumed to be normal with mean 1 and standard deviation 0.05. For computational purposes, the distribution will be approximated on a finite interval.

The first panel of Figure 4 shows how bank interconnectivity changes with the return spread R^k/R^l and the diversification cost captured by the parameter χ. We consider five values of $R_t^k/R_t^l \in \{1.01, 1.015, 1.02, 1.025, 1.03\}$ and three values of $\chi \in \{0.05, 0.1.0.2\}$. As the graph shows, interconnectivity increases with the return spread and decreases with its cost.

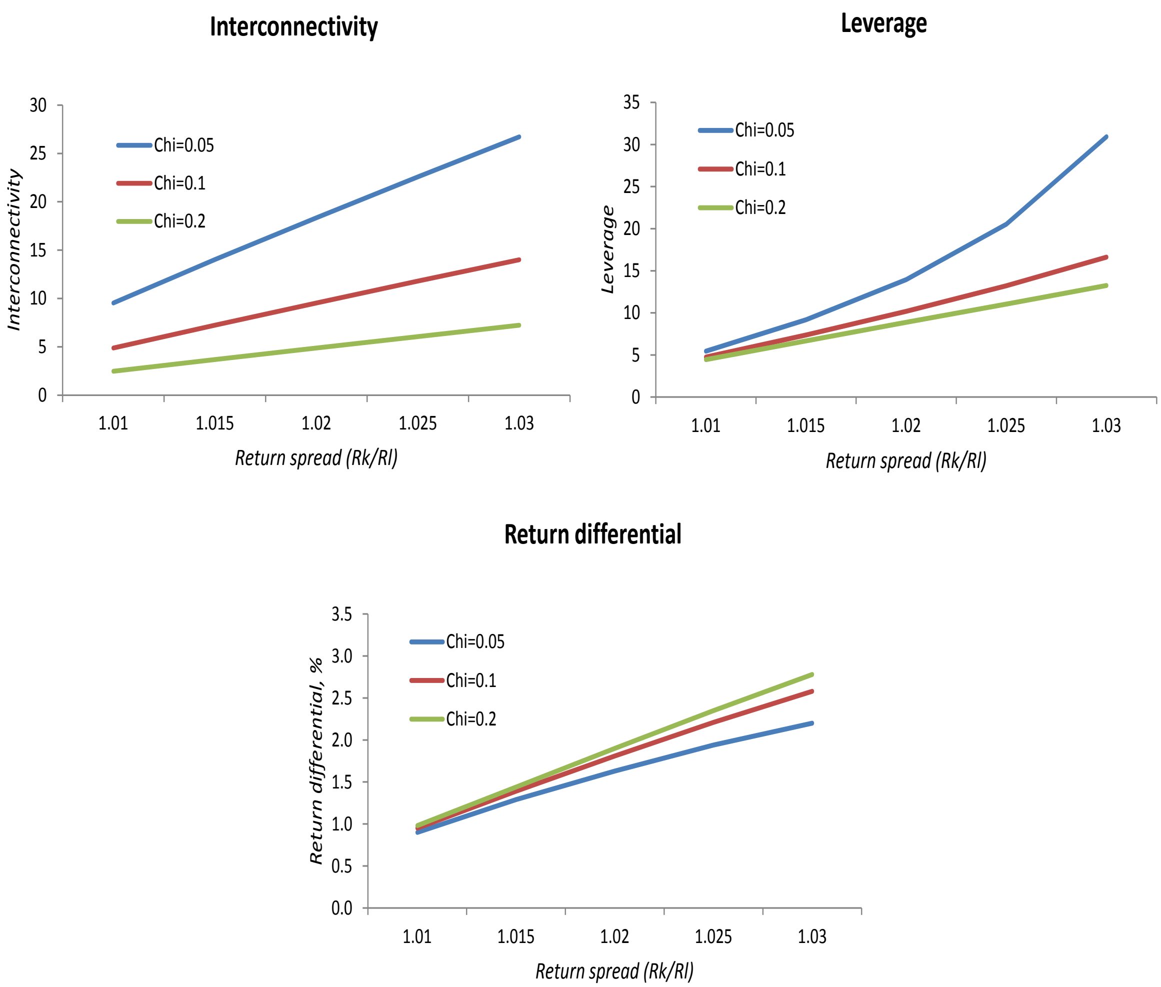

Figure 4: Interconnectivity, leverage and return differential as functions of the return spread and diversification cost.

The second panel of Figure 4 shows the sensitivity of leverage. Banks become more leveraged when the return spread increases and when the diversification cost becomes smaller. Finally the third panel plots the return differential which increases with the return spread and the diversification cost. In the next section we explore whether the theoretical properties of the model supported by the data.

3 Empirical analysis

In this section we present empirical evidence about the relation between interconnectivity and leverage and between interconnectivity and return differential between assets and liabilities. We proceed in three steps. First, we provide a brief description of the database. Second, we present the relation between inter-connectivity and leverage, starting with the country-level evidence and then moving to the firm-level evidence. Third, we provide some some evidence about the correlation between inter-connectivity and return differential.

3.1 Data

We use data from Bankscope, a proprietary database maintained by the Bureau van Dijk. Bankscope includes balance sheet information for a very large sample of financial institutions across several countries. The sample used in the analysis includes roughly 14,000 financial institutions from 32 OECD countries. We consider different types of institutions: commercial banks, investment banks, securities firms, cooperative banks and savings banks for the period 1999-2011. In order to minimize the influence of outliers on the aggregate dynamics, we winsorized the main variables by replacing the most extreme observations with the values of the first and last percentiles of the distribution. Appendix D provides further details about data preparation and cleaning.

Table 1 reports some descriptive statistics for the whole sample and for some sub-samples that will be used later: (i) Mega Banks (banks with total assets exceeding 100 billions dollars); (ii) Commercial Banks; and (iii) Investment Banks. The total number of observations is 211,291 with an average value of total assets of 7.8 billion dollars. Mega Banks are only 0.6% of the total sample (1,303 observations), but they have a very large value of assets (an average of 636 billions). Commercial banks are more than half of the sample (118,156 units representing 55.6% of the sample) with an average value of assets of 5.9 billion dollars. Investment banks represent 1.6% of the sample with an average value of assets of 28.9 billion dollars.

Table 2 shows the breakdown of the sample by countries. The last row of the table reports the total number of observations for the G7 countries (Canada, Germany, France, UK, Italy, Japan, and USA) representing almost 90% of the total sample.

We concentrate on two statistics: *interconnectivity* and *leverage*. We present the results for the G7 countries and for a world average calculated using weights based on assets.

Interconnectivity. Within the balance sheet of a financial institution we define the variable $DEPOSITS_{it}$ as the deposits received from non-financial institutions. These are the *core-liabilities* of the bank. Denoting by $LIABILITIES_{it}$ the total liabilities, the measure of interconnectivity for a financial institution, consistently with the definition (9) is measured as

$$INTERCONNECTIVITY_{it} = \frac{LIABILITIES_{it} - DEPOSITS_{it}}{ASSETS_{it}}, \tag{11}$$

that is, the share of not core-liabilities over total assets.[5]

As shown in Table 1, the aggregate average of interconnectivity is 0.16. Commercial banks are less interconnected that investment banks (0.10 versus 0.63).

Figures 5 and 6 report the evolution of the interconnectivity measure for selected countries. For each country, the aggregate measure is weighted by the asset shares of each institution in total asset. In Figure 5 we report also a world measure, calculated as the asset-weighted average of all countries in the sample. Interconnectivity increased in the period 2000-2007, and then decreased after the crisis. A similar trend is observed in the US,

[5] See Hahm et al (2013) for a use of the concept of non-core liabilities linked to the financial vulnerability of banks. While this measure is chosen to guarantee a full consistency between the theoretical model and the empirical investigation, all our results are robust to measuring interconnectivity as the share of non-core liabilities over total liabilities. Results are available upon requests.

the UK, France and Germany. In Japan, Canada and Italy, instead, bank interconnectivity does not show a clear trend.

Leverage. We measure leverage as the ratio of total assets over equity, that is,

$$LEVERAGE_{it} = \frac{ASSETS_{it}}{ASSETS_{it} - LIABILITIES_{it}}. \tag{12}$$

The second panel of Figure 2 presented in the introduction showed the dynamics of an asset-weighted average of leverage for the US economy. Interestingly, the aggregate dynamics presented in this figure hides very heterogeneous dynamics across different groups of banks. In Figure 7 we report, for instance, the dynamics of an asset weighted average of the leverage ratio for commercial and investment banks. While the trend for commercial banks is downward sloping, with a peak in 2007, the leverage of investment banks increased substantially in the period 2003-2007. Table 1 reports the aggregate averages of this measure. When calculated on the full sample, the average is 12.7. Commercial banks are characterized by lower leverages (10.8) than investment banks (17).

Figures 8 and 9 plot the evolution of the aggregate leverage for selected countries. As we can see, Germany, France, and particularly the UK, were characterized by a leverage cycle similar to the one observed for the US: an increase in leverage in the period 2003-2007, followed by de-leveraging after the crisis. In contrast, the leverages of Italy, Canada and Japan remain relatively stable over the whole sample period.

3.2 Interconnectivity and Leverage

We analyze the relation between interconnectivity and leverage along three dimensions: at the country level over time, at the firm level and across countries.

3.2.1 Country-level evidence

We start analyzing the correlation between interconnectivity and leverage at the country level. We first explore some simple unconditional correlation and then move to conditional correlations.

Unconditional correlations. Figures 10 and 11 show scatter plots of the aggregate leverage ratio against our measure of interconnectivity within countries across time. France, Germany and especially the UK present a strong positive correlation between leverage and interconnectivity. In the UK, as for the US, we see a contemporaneous rise in interconnectedness and leverage in the period 2003-2008 followed by a subsequent decline for both variables. The similarity in the dynamics of interconnectedness and leverage for the US and the UK might reflect the similarity of the financial sector in those two countries. On the other hand, in Japan, Canada and Italy there is not a clear relation between interconnectivity and leverage over time.

Figure 12 reports scatter plots for the leverage ratio and the interconnectedness measure for all sample countries and for different years. Also in this case we observe a positive correlation, which seems particularly strong in 2007 at the peak of the boom. On the one hand, we have low-interconnected and low-leveraged financial systems in countries like Poland, Turkey, and Mexico. On the other, we find highly interconnected and highly leveraged financial systems in countries like Switzerland, UK and France.

Conditional correlations. We move to explore some conditional correlations at the aggregate level with a simple two way fixed effect estimators. The results are reported in Table 3. In the first column we use interconnectivity as the only regressor. Thus, the coefficient estimate represents the average slope for all years in the scatter plots presented in Figure 12. Interestingly, variations in interconnectedness alone explain 38 percent of the variance in the aggregate leverage. In the second and third columns, we add country and time fixed effects. Apart from the fit of the regressions which increases substantially, the interconnectedness coefficient remains positive and highly statistically significant.

While this subsection provides strong evidence of the existence of a positive correlation between financial interconnectedness and leverage at the country level, the richness of micro data available allows us to go a step further and investigate the existence of such a correlation also at the micro level, that is, across banks.

3.2.2 Firm-level Evidence across all countries

We provide first some evidence for large banks, and then we move to the full sample.

Large Firms. We define large banks as financial institutions with a total value of assets that exceed 100 billion dollars. There are roughly 60 of these institutions in our sample. The average share of the value of their assets over the total assets of all financial institutions included in the sample is roughly constant at 50% over the sample period. Figure 13 shows the scatter plot of the leverage ratio against the share of non-core liabilities in these 60 institutions in various years. Also in this case we see a clear positive association between interconnectivity and leverage.

Table 4 reports some conditional correlations. In the first column we just run a simple regression using size (log of total assets) as the only control. The coefficient on the measure of interconnectedness is positive and highly statistically significant. In the second column we add country, year and specialization fixed effects. Again, the coefficient on interconnectivity is positive and strongly significant. The regression fit, unsurprisingly, increases significantly. Finally, in the third column, we include firm level and time fixed effects. We are hence now exploring whether there is a positive association between interconnectivity and leverage *within* firms. Again, we do find a positive and strongly significant coefficient attached to interconnectivity. In this case, also the size coefficient becomes positive and statistically significant.

We repeat the exact same exercise but focusing on different time periods: 1999-2007 and 2003-2007. The results are displayed in Figures 5 and 6. While the point estimates change slightly, the qualitative results remain the same.

Full sample. Having established the presence of a strong positive correlation between interconnectivity and leverage for large firms, we now explore whether the relation between interconnectivity and leverage also holds for the full sample. We concentrate here on within firms relation, thus considering a two-way fixed effects estimator.

Table 7 contains the results. The three columns correspond to the three different time periods used earlier. Again, we also condition on size which has a positive and highly significant effect. As for the measure of interconnectivity, we continue to find a positive and strongly significant coefficient. Therefore, we find a positive relation between leverage and interconnectivity even if we do not restrict the sample to contain only the very large financial institutions.

3.2.3 Firm-level evidence in selected countries

Finally, we explore whether the within firms results change across countries. In Table 8 we report the results obtained using a two-way fixed effects estimator in each of the G-7 countries, to explore the correlation between interconnectivity and leverage (conditioning on the size of banks). We find positive and statistically significant coefficients for all of the G-7 countries with the only exception of Canada.

We conclude that, consistently with the model presented in Section 2, we find empirical evidence of a strong association between interconnectivity and leverage: across firms, across countries and across time.

3.3 Interconnectivity and return differential

The model presented in Section 2 implies the existence of a relation between interconnectivity and the return differential on the assets and liabilities of banks. In this section we investigate this relation empirically.

We define the empirical return differential as the difference between (i) the interest income over the value of assets that earn interests, and (ii) the interest expenditures over the average liabilities. Specifically,

$$DIFFERENTIAL_{it} = \frac{INT\_INCOME_{it}}{AV\_ASSETS_{it}} - \frac{INT\_EXP_{it}}{AV\_LIABILITIES_{it}}.$$

While this measure does not reflect exactly the return differential as defined in the model—see equation (10)—it is our closest empirical counterpart.

Figure 14 reports the world asset-weighted average of the return differential. Interestingly, the figure shows a sharp decline in the boom phase of 2003-2007 and a mild increase since then. In the next subsections we investigate the relation between the return differential and interconnectivity at the country and firm level.

3.3.1 Country-level evidence

Figures 15 and 16 report the scatter plots of our measure of interconnectivity against the return differential for some selected countries and for the world average. In most of the cases, we can observe a strong negative relation between the two measures. The only notable exception is France where the relation appears to be weakly positive. A strong negative relation between interconnectivity and return differentials is also observed across countries as shown in Figure 17.

Next we regress the measure of interconnectivity against the return differential conditioning on country and time fixed effects. The results are shown in Table 9. Albeit the consideration of time and country fixed effects reduces the magnitude of the coefficient, we still find a negative and strongly statistically significant relation between interest rate differential and interconnectivity.

3.3.2 Firm-level Evidence

Moving to the firm-level evidence, Figure 18 shows the scatter plot of interconnectivity against the return differential for the sample of large banks in selected years. Again, we find a strong negative association between these two variables, irrespective of the year under consideration.

Tables 10 and 11 confirm the visual evidence through a regression analysis. The negative relation between interconnectivity and return differentials remains highly statistically significant after controlling for firm size, specialization, time and country fixed effects. By adding firm fixed effects we also find that the relation is negative within firms.

The finding that there is a negative relation between interconnectivity and return differentials suggests that the choices of interconnectivity and leverage are mostly driven by the diversification cost: banks choose to become more interconnected when it becomes easier to diversify. This also suggests that the upward trends in interconnectivity and leverage observed prior to the 2008-2009 crisis is more likely to have been driven by financial innovations that made diversification easier for banks. This pattern, however, seems to have reverted back after the crisis.

4 Conclusion

In this paper we have shown that there is a strong positive correlation between financial interconnectivity and leverage across countries, over time, and across financial institutions. The empirical evidence supports the theoretical results obtained in the first part of the paper. The theoretical results are derived from a model in which banks choose, simultaneously, the optimal diversification and the optimal leverage. Although cross-bank diversification (interconnectivity) reduces the idiosyncratic risk for each bank, it does not eliminate the aggregate or 'systemic' risk which is likely to increase when the leverage of the whole financial sector increases. Our model provides a micro structure that can be embedded in a general equilibrium framework to study the issue of interconnectivity and macroeconomic stability. We leave the study of this issue for future research.

A Proof of Lemma 2.3

The bank problem is a standard intertemporal portfolio choice between a safe and risky asset similar to the problem studied in Merton (1971). The solution takes the simple form thanks to the log-specification of the utility function together with constant return to scale investments.

We now show that ϕ_t is strictly increasing in the adjusted return spread. From Lemma 2.2 we know that the adjusted return differential $\bar{R}_t^k/R_t^l$ is strictly increasing in R_t^k/R_t^l. Therefore, we only need to prove that ϕ_t is strictly increasing in the adjusted differential $\bar{R}_t^k/R_t^l$. This can be proved by using the condition that determines ϕ_t from Lemma 2.3. For convenience we rewrite this condition here

$$\mathbb{E}_t\left\{\frac{1}{1+[z_{t+1}x_t-1]\phi_t}\right\}=1, \tag{13}$$

where we have used the variable $x_t = \bar{R}_t^k/R_t^l$ to denote the adjusted return differential.

Using the implicit function theorem we derive

$$\frac{\partial \phi_t}{\partial x_t} = -\frac{\mathbb{E}_t\left\{\frac{z_{t+1}\phi_t}{[1+\phi_t[z_{t+1}x_t-1]]^2}\right\}}{\mathbb{E}_t\left\{\frac{z_{t+1}x_t-1}{[1+\phi_t[z_{t+1}x_t-1]]^2}\right\}}$$

Since the numerator is positive, the sign of the derivative depends on the denominator which can be rewritten as

$$\begin{aligned}
\mathbb{E}_t\left\{\frac{z_{t+1}x_t-1}{[1+\phi_t[z_{t+1}x_t-1]]^2}\right\} &= \mathbb{E}_t\left\{\frac{z_{t+1}x_t-1}{1+\phi_t[z_{t+1}x_t-1]}\right\}\left\{\frac{1}{1+\phi_t[z_{t+1}x_t-1]}\right\} \\
&= \mathbb{E}_t\left\{\frac{z_{t+1}x_t-1}{1+\phi_t[z_{t+1}x_t-1]}\right\}\mathbb{E}_t\left\{\frac{1}{1+\phi_t[z_{t+1}x_t-1]}\right\}+ \\
&\quad COV\left\{\frac{z_{t+1}x_t-1}{1+\phi_t[z_{t+1}x_t-1]},\frac{1}{1+\phi_t[z_{t+1}x_t-1]}\right\}
\end{aligned}$$

The first expectation term on the right-hand side $\mathbb{E}_t\left\{\frac{[z_{t+1}x_t-1]\phi_t}{1+[z_{t+1}x_t-1]\phi_t}\right\}$ can be rewritten as $\mathbb{E}_t\left\{\frac{1}{1+[z_{t+1}x_t-1]\phi_t}\right\}-1$. By condition (13) this term is equal to zero. Therefore, we have

$$\mathbb{E}_t\left\{\frac{z_{t+1}x_t-1}{[1+\phi_t[z_{t+1}x_t-1]]^2}\right\} = COV\left\{\frac{z_{t+1}x_t-1}{1+\phi_t[z_{t+1}x_t-1]},\frac{1}{1+\phi_t[z_{t+1}x_t-1]}\right\}$$

The covariance is clearly negative because the first term is strictly increasing in z_{t+1} while the second term is strictly decreasing in z_{t+1}. Therefore, $\partial\phi_t/\partial x_t > 0$. ■

B Proof of Proposition 2.1

Using $F_t = \alpha_t K_t$, the leverage ratio defined in equation (9) can be written as $\frac{1+\alpha_t \frac{R_t^k}{R_t^l}}{1-\frac{L_t/R_t^l}{K_t/R_t^k}}$. Since α_t is decreasing in χ and increasing in R_t^k/R_t^l (see Lemma 2.1), to show that the leverage is decreasing in the diversification cost and increasing in the return spread, it is sufficient to show that the term $\frac{L_t/R_t^l}{K_t/R_t^k}$ is strictly decreasing in χ and strictly increasing in R_t^k/R_t^l.

By definition $K_t = \bar{K}_t/(1-\alpha_t)$, $F_t = [\alpha_t/(1-\alpha_t)]\bar{K}_t$ and $L_t = F_t + \bar{L}_t$. From equations (6)-(7) we can derive $\bar{L}_t = -[(1-\phi_t)/\phi_t](R_t^l/\bar{R}_t^k)\bar{K}_t$. Using these terms, we have

$$\frac{L_t/R_t^l}{K_t/R_t^k} = \left[\alpha_t - (1-\alpha_t)\left(\frac{1-\phi_t}{\phi_t}\right)\frac{R_t^l}{\bar{R}_t^k}\right]\frac{R_t^k}{R_t^l}.$$

We now use equation (4) to replace $\bar{R}_t^k$. After re-arranging we obtain

$$\frac{L_t/R_t^l}{K_t/R_t^k} = \alpha_t\frac{R_t^k}{R_t^l} + \left(\frac{\phi_t - 1}{\phi_t}\right)\left[1 - \alpha_t\frac{R_t^k}{R_t^l} + \varphi(\alpha_t)\frac{R_t^k}{R_t^l}\right].$$

This can be written more compactly as

$$\frac{L_t/R_t^l}{K_t/R_t^k} = \alpha_t x_t + y_t\Big[1 - \alpha_t x_t + \varphi(\alpha_t)x_t\Big], \tag{14}$$

where $x_t = \frac{R_t^k}{R_t^l}$ and $y_t = \left(\frac{\phi_t - 1}{\phi_t}\right)$.

Differentiating the right-hand-side with respect to χ we obtain

$$\frac{\partial\left(\frac{L_t/R_t^l}{K_t/R_t^k}\right)}{\partial\chi} = \alpha_t' x_t(1-y_t) + \Big[\chi\gamma\alpha_t^{\gamma-1}\alpha_t' + \alpha_t^\gamma\Big]x_t y_t,$$

where α_t' is now the derivative of α_t with respect to χ.

Since $1 - y_t = 1/\phi_t > 0$ and $\alpha_t' < 0$ (see Lemma 2.1), the first term of the derivative is negative. Therefore, a sufficient condition for the derivative to be negative is that also the second term is negative. For empirically relevant parameters $\phi_t > 1$ which implies $y_t = (\phi_t - 1)/\phi_t > 0$. In fact, if $\phi_t < 1$, then banks would choose $\bar{L}_t = L_t - F_t < 0$, that is, they would have less total liabilities than financial assets invested in other banks. Thus, the second term of the derivative is negative if

$$\chi\gamma\alpha_t^{\gamma-1}\alpha_t' + \alpha_t^\gamma < 0.$$

In Lemma 2.1 we have derived $\alpha_t' = -[\alpha_t^\gamma + \gamma(1-\alpha_t)\alpha_t^{\gamma-1}]x_t/[\chi(1-\alpha_t)\gamma(\gamma-1)\alpha_t^{\gamma-2}]$.

Substituting in the above expression and re-arranging we obtain

$$1 < \frac{\gamma x_t}{\gamma - 1} + \frac{x_t \alpha_t}{(1-\alpha_t)(\gamma - 1)}.$$

Both terms on the right-hand-side are positive. Furthermore, since $x_t > 1$ and $\gamma > 1$, the first term is bigger than 1. Therefore, the inequality is satisfied, proving that the derivative of the leverage decreases in the diversification cost.

To show that the leverage ratio is decreasing in $x_t = R_t^k / R_t^l$, we need to show that $\frac{L_t/R_t^l}{K_t/R_t^k}$ is decreasing in x_t. Differentiating the right-hand-side of (14) with respect to x_t we obtain

$$\frac{\partial \left(\frac{L_t/R_t^l}{K_t/R_t^k} \right)}{\partial x_t} = (1-y_t)(\alpha_t' x_t + \alpha_t) + y_t' \Big[1 - \alpha_t x_t + \varphi(\alpha_t) x_t \Big] + y_t \Big[\varphi_t'(\alpha_t) \alpha_t' x_t + \varphi(\alpha_t) \Big],$$

where α_t' is now the derivative of α_t with respect to x_t.

Lemma 2.1 established that α_t is increasing in $x_t = R_t^k / R_t^l$, that is, $\alpha_t' > 0$. Furthermore, Lemma 2.3 established that ϕ_t is strictly increasing in $x_t = R_t^k / R_t^l$, which implies that $y_t = \left(\frac{\phi_t - 1}{\phi_t} \right)$ is also increasing in $x_t = R_t^k / R_t^l$, that is, $y_t' > 0$. Therefore, sufficient conditions for the derivative to be positive are

$$\begin{gathered} \phi_t > 1 \\ 1 - \alpha_t x_t + \varphi(\alpha_t) x_t > 0 \quad . \end{gathered}$$

As argued above, the first condition ($\phi_t > 1$) is satisfied for empirically relevant parameterizations. For the second condition it is sufficient that $\alpha_t x_t \leq 1$, which is also satisfied for empirically relevant parameterizations. In fact, since in the data x_t is not very different from 1 (for example it is not bigger than 1.1), the condition allows α_t to be close to 1 (about 90 percent if x_t is 1.1). Since α_t represents the relative size of the interbank market compared to the size of the whole banking sector, α_t is significantly smaller than 1 in the data. Therefore, for empirically relevant parameterizations, leverage increases with the return spread $x_t = R_t^k / R_t^l$.

The next step is to prove that the interconnectivity index is decreasing in χ and increasing in $x_t = R_t^k / R_t^l$. The index can be simplified to

$$\frac{\alpha_t x_t}{1 + \alpha_t x_t}.$$

Differentiating with respect to χ we obtain

$$\frac{\partial INTERCONNECTIVITY}{\partial \chi} = \frac{\alpha_t' x_t}{(1 + \alpha_t x_t)^2},$$

where α_t' is the derivative of α_t with respect to χ. As shown in Lemma 2.1, this is negative. Therefore, bank connectivity decreases in the diversification cost.

We now compute the derivative of interconnectivity with respect to x_t and obtain

$$\frac{\partial INTERCONNECTIVITY}{\partial x_t} = \frac{\alpha_t' x_t + \alpha_t}{(1+\alpha_t x_t)^2},$$

where α_t' is the derivative of α_t with respect to x_t. As shown in Lemma 2.1, this is positive. Therefore, bank connectivity increases in the return spread. ∎

C Proof of Proposition 2.2

Taking into account that in aggregate $F_t = \alpha_t K_t$, the bank differential return defined in equation (10) can be rewritten as

$$DIFFERENTIAL = \left(\frac{x_t - 1}{1+\alpha_t x_t}\right) R_t^l.$$

For notational simplicity we have used the variable $x_t = R_t^k / R_t^l$.

Differentiating with respect to χ we obtain

$$\frac{\partial DIFFERENTIAL}{\partial \chi} = -\frac{\alpha_t' x_t (x_t - 1)}{(1+\alpha_t x_t)^2} R_t^l,$$

where α_t' is the derivative of α_t with respect to χ. We have shown in Lemma 2.1 that this derivative is negative. Therefore, the return differential increases in the differentiation cost.

Consider now the dependence of the bank return differential from the return spread. The derivative of the return differential with respect to $x_t = R_t^k / R_t^l$ is

$$\frac{\partial DIFFERENTIAL}{\partial x_t} = \frac{1+\alpha_t + x_t(1-x_t)\alpha_t'}{(1+\alpha_t x_t)^2} R_t^l,$$

where α_t' is the derivative of α_t with respect to return spread x_t. For the derivative to be positive we need that the following condition is satisfied

$$1 + \alpha_t + x_t(1-x_t)\alpha_t' > 0.$$

In Lemma 2.1 we have derived $\alpha_t' = 1/[(1-\alpha_t)\varphi''(\alpha_t)x_t^2]$. Substituting in the above expression and re-arranging we obtain

$$1 - (1-\alpha_t^2)\varphi''(\alpha_t) > \frac{1}{x_t}.$$

We now use equation (2) to eliminate $1/x_t$ and rewrite the condition as

$$\varphi(\alpha_t) + \varphi'(\alpha_t) - \alpha_t \varphi'(\alpha_t) > (1-\alpha_t^2)\varphi''(\alpha_t).$$

Using the functional form for the diversification cost specified in Assumption 1, the condition can be rewritten as

$$\left(\frac{1}{\gamma-1}\right)\alpha+\left[\frac{1+\gamma^2-2\gamma}{\gamma(\gamma-1)}\right]\alpha^2>1,$$

which is satisfied if α_t is sufficiently small. Since α_t is decreasing in χ, a sufficiently high value of χ guarantees that the bank return differential is increasing in the return spread $x_t = R_t^k/R_t^l$. For example, when the diversification cost takes the quadratic form ($\gamma = 2$), it is sufficient that $\alpha_t \leq 0.73$. This upper bound for α_t is significantly larger than the average value observed for the whole banking sector. (See Figure 2 for the US). ■

D Data Appendix

The data on bank balance sheets are taken from Bankscope, which is a comprehensive and global database containing information on 28,000 banks worldwide provided by Bureau van Djik. Each bank report contains detailed consolidated and/or unconsolidated balance sheet and income statement. Since the data are expressed in national currency, we converted the national figures in US dollars using the exchange rates provided by Bankscope.

An issue in the use of Bankscope data is the possibility of double counting of financial institutions. In fact, for a given Bureau van Djik id number (BVDIDNUM), which identifies uniquely a bank, in each given YEAR, it is possible to have several observations with various consolidation codes. There are eight different consolidation status in Bankscope: C1 (statement of a mother bank integrating the statements of its controlled subsidiaries or branches with no unconsolidated companion), C2 (statement of a mother bank integrating the statements of its controlled subsidiaries or branches with an unconsolidated companion), C* (additional consolidated statement), U1 (statement not integrating the statements of the possible controlled subsidiaries or branches of the concerned bank with no consolidated companion), U2 (statement not integrating the statements of the possible controlled subsidiaries or branches of the concerned bank with a consolidated companion), U* (additional unconsolidated statement) and A1 (aggregate statement with no companion).[6] We polished the data in order to avoid duplicate observations and to favor consolidated statements over unconsolidated ones.

[6] See Bankscope user guide and Duprey and Lé (2013) for additional details.

References

[1] Acemoglu, D., Ozdaglar, A. and A. Tahbaz-Salehi, 2015. "Systemic Risk and Stability in Financial Networks," *American Economic Review*, 105(2): 564608

[2] Adrian, T. and H.S. Shin, 2010. "Liquidity and Leverage", *Journal of Financial Intermediation*, Vol. 19(3): 418-437.

[3] Adrian, T. and H.S. Shin, 2011. "Financial Intermediary Balance Sheet Management," *Annual Review of Financial Economics*, 3, 289-307.

[4] Adrian, T. and H.S. Shin, 2014. "Pro-cyclical Leverage and Value at Risk," *Review of Financial Studies,* Vol. 27 (2), 373-403.

[5] Allahrakha, M., P. Glasserman, and H.P. Young, 2015. "Systemic Importance Indicators for 33 U.S. Bank Holding Companies: An Overview of Recent Data", Office of Financial Research, Brief Series.

[6] Allen, F. and D. Gale, 2000. "Financial Contagion," *Journal of Political Economy*, Vol. 108(1): 1-33.

[7] Billio, M., Getmansky, M., Lo, A.W. alnd L. Pelizzon, 2012. "Econometric measures of connectedness and systemic risk in the finance and insurance sectors," *Journal of Financial Economics*, vol. 104(3): 535-559.

[8] Barattieri, A. Eden, M and Stevanovic, D. 2014. "Financial Interconnectedness and Monetary Policy Transmission", mimeo.

[9] Cai, J., Saunders, A. and Steffen, S. 2014. "Syndication, Interconnectedness, and Systemic Risk". mimeo.

[10] Cetorelli, N. and L. Goldberg, 2012 "Banking Globalization and Monetary Transmission," *Journal of Finance*, vol. 67(5): 1811-1843.

[11] David, A., and Lehar, A. 2011. "Why are Banks Highly Interconnected?", mimeo.

[12] Devereux, M. and Yetman, J., 2010. "Leverage Constraints and the International Transmission of Shocks," *Journal of Monet, Credit and Banking*, vol. 42: 71-105.

[13] Eisert, T. and Eufinger, C. 2014. "Interbank Network and Bank Bailouts: Insurance Mechanism for Non-Insured Creditors?". SAFE Working Paper No. 10.

[14] Drehmann, M. and Tarashev, N. 2013. "Measuring the systemic importance of interconnected banks". *Journal of Financial Intermediation*. 22(4): 586-607.

[15] Freixas, X., Parigi, B.M. and J.C. Rochet, 2000. "Systemic Risk, Interbank Relations, and Liquidity Provision by the Central Bank ," *Journal of Money, Credit and Banking.* Vol. 32(3): 611-638.

[16] Geanakoplos, J. 2010. "The Leverage Cycle," In D. Acemoglu, K. Rogoff and M. Woodford, eds., NBER Macroeconomic Annual 2009, vol. 24: 1-65.

[17] Gennaioli, N., Schleifer, A. and R. W. Vishny, 2013. "A Model of Shadow Banking" *The Journal of Finance* Vol.68(4): 1331-1363.

[18] Hale, G., T. Kapan, and C. Minoiu, 2014. "Crisis Transmission in the Global Banking Network", mimeo.

[19] Hahm, J.H., Shin, H.S. and Shin, K. 2013. "Non-Core Bank Liabilities and Financial Vulnerability," *Journal of Money, Credit and Banking* Vol. 45(S1): 3-36.

[20] Liu, Z., S. Quiet, and B. Roth, 2015. "Banking sector interconnectedness: what is it, how can we measure it and why does it matter?", Bank of England Quarterly Bulletin, 2015 Q2.

[21] Merton, R.C., 1971. "Optimum Consumption and Portfolio Rules in a Continuous-Time Model," *Journal of Economic Theory* vol. 3(4): 373413.

[22] Nuno, G. and C. Thomas, 2012 "Bank Leverage Cycles", Banco de Espana Working Paper No. 1222.

[23] Peltonen, T. A. Rancal, M. and P. Sarlin, 2015. "Interconnectedness of the banking sector as a vulnerability to crises," mimeo

[24] Shin, H. S. 2008."Risk and Liquidity in a System Context," *Journal of Financial Intermediation* Vol. 17 (3): 31529.

[25] Shin, H. S. 2009. "Securitisation and Financial Stability," *Economic Journal* Vol. 119 (536): 30932.

[26] Simsek, A. 2013."Belief Disagreements and Collateral Constraints," *Econometrica*, Vol. 81(1): 1-53.

Table 1: **Summary Statistics**

	Number Obs		Total Assets		Leverage		Interconnectivity	
	Total	%	mean	s.d.	mean	s.d.	mean	s.d.
ALL	211291		7812.9	245	12.7	8.6	0.16	0.20
of which:								
MEGA BANKS	1303	0.6	635986.1	565491	25.7	13.8	0.54	0.22
Commercial Banks	118156	55.9	5964.5	65249.8	10.8	5.6	0.10	0.15
Investment Banks	3438	1.6	28948.2	95661.3	17	18.8	0.63	0.30

Notes: Millions of USD.

Table 2: **Composition of the sample by country**

Country	Obs.	Percent
AUT	3297	1.56
BEL	1045	0.49
CAN	967	0.46
CHE	5406	2.56
CHL	389	0.18
CZE	393	0.19
DEU	22688	10.74
DNK	1472	0.7
ESP	2260	1.07
EST	99	0.05
FIN	230	0.11
FRA	5100	2.41
GBR	5258	2.49
GRC	271	0.13
HUN	441	0.21
IRL	597	0.28
ISL	236	0.11
ISR	176	0.08
ITA	9174	4.34
JPN	9365	4.43
KOR	548	0.26
MEX	776	0.37
NLD	803	0.38
NOR	1483	0.7
NZL	185	0.09
POL	592	0.28
PRT	523	0.25
SVK	220	0.1
SVN	236	0.11
SWE	1304	0.62
TUR	647	0.31
USA	135110	63.94
G7	187662	88.82

Table 3: **Interconnectivity and Leverage: Cross-Country Evidence**

Dep Variable	A/E	A/E	A/E
INTERCONN	29.737***	25.700***	30.845***
	(1.860)	(2.729)	(2.990)
Country FE	No	Yes	Yes
Time FE	No	No	Yes
R-squared	0.382	0.841	0.858
N	416	416	416

Notes: Standard Errors in Parenthesis
*,**,*** Statistically Significant at 10%, 5% and 1%

Table 4: **Interconnectivity and Leverage, Very Large Financial Institutions (1999-2011)**

Dep Variable	A/E	A/E	A/E
INTERCONN	31.648***	29.363***	32.485***
	(1.978)	(2.968)	(8.090)
size	0.315	-0.231	3.421
	(0.398)	(0.422)	(2.118)
Specialisation FE	No	Yes	No
Country FE	No	Yes	No
Time FE	No	Yes	Yes
Banks FE	No	No	Yes
R-squared	0.263	0.505	0.200
N	1214	1214	1214

Notes: Standard Errors in Parenthesis
*,**,*** Statistically Significant at 10%, 5% and 1%

Table 5: **Interconnectivity and Leverage, Very Large Financial Institutions (1999-2007)**

Dep Variable	A/E	A/E	A/E
INTERCONN	32.758***	28.636***	33.013***
	(1.848)	(2.409)	(4.653)
size	0.471	-0.617	3.514***
	(0.543)	(0.562)	(1.198)
Specialisation FE	No	Yes	No
Country FE	No	Yes	No
Time FE	No	Yes	Yes
Banks FE	No	No	Yes
R-squared	0.278	0.525	0.173
N	820	820	820

Notes: Standard Errors in Parenthesis
*,**,*** Statistically Significant at 10%, 5% and 1%

Table 6: **Interconnectivity and Leverage, Very Large Financial Institutions (2003-2007)**

Dep Variable	A/E	A/E	A/E
INTERCONN	35.924***	34.494***	44.612***
	(2.607)	(3.392)	(6.223)
size	0.130	-0.337	8.441***
	(0.772)	(0.764)	(1.804)
Specialisation FE	No	Yes	No
Country FE	No	Yes	No
Time FE	No	Yes	Yes
Banks FE	No	No	Yes
R-squared	0.284	0.544	0.277
N	482	482	482

Notes: Standard Errors in Parenthesis
*,**,*** Statistically Significant at 10%, 5% and 1%

Table 7: **Interconnectivity and Leverage, All financial institutions**

Dep Variable	A/E	A/E	A/E
Time Period	1999-2011	1999-2007	2003-2007
INTERCONN	7.862***	6.928***	5.082***
	(0.142)	(0.149)	(0.196)
size	2.516***	2.606***	2.981***
	(0.024)	(0.026)	(0.038)
Banks FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
R-squared	0.106	0.134	0.137
N	176649	125787	69563

Notes: Standard Errors in Parenthesis
*,**,*** Statistically Significant at 10%, 5% and 1%

Table 8: **Interconnectivity and Leverage: By Country, 1999-2011, FE**

Dep Var: A/E	USA	CAN	GBR	JPN	DEU	FRA	ITA
INTERCONN	4.637***	-0.239	8.772***	17.852***	6.910***	9.593***	3.046***
	(0.180)	(1.279)	(1.053)	(2.019)	(0.378)	(1.035)	(0.371)
size	1.752***	3.463***	5.205***	4.645***	3.500***	7.696***	5.148***
	(0.025)	(0.303)	(0.206)	(0.379)	(0.094)	(0.244)	(0.109)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Banks FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.072	0.249	0.350	0.077	0.392	0.360	0.329
N	113369	777	2577	8723	20956	3479	8367

Notes: Standard Errors in Parenthesis
*,**,*** Statistically Significant at 10%, 5% and 1%

Table 9: **Interconnectivity and Return Differential: Cross-Country Evidence**

Dep Variable	INTERCONN	INTERCONN	INTERCONN
Differential	-0.069***	-0.042***	-0.029***
	(0.004)	(0.005)	(0.005)
Country FE	No	Yes	Yes
Time FE	No	No	Yes
R-squared	0.421	0.893	0.910
N	416	416	416

Notes: Standard Errors in Parenthesis
*,**,*** Statistically Significant at 10%, 5% and 1%

Table 10: **Interconnectivity and Return Differential, Very Large Financial Institutions (1999-2011)**

Dep Variable	INTERCONN	INTERCONN	INTERCONN
Differential	-0.098***	-0.110***	-0.025*
	(0.006)	(0.008)	(0.013)
size	-0.013*	-0.003	0.076**
	(0.007)	(0.007)	(0.031)
Specialisation FE	No	Yes	No
Country FE	No	Yes	No
Time FE	No	Yes	Yes
Banks FE	No	No	Yes
R-squared	0.226	0.680	0.229
N	963	963	963

Notes: Standard Errors in Parenthesis
*,**,*** Statistically Significant at 10%, 5% and 1%

Table 11: **Interconnectivity and Return Differential, All Financial Institutions (1999-2011)**

Dep Variable	INTERCONN	INTERCONN	INTERCONN
Differential	-0.039***	-0.019***	-0.006***
	(0.001)	(0.000)	(0.001)
size	0.043***	0.034***	0.038***
	(0.000)	(0.000)	(0.002)
Specialisation FE	No	Yes	No
Country FE	No	Yes	No
Time FE	No	Yes	Yes
Banks FE	No	No	Yes
R-squared	0.365	0.576	0.071
N	169372	169372	169362

Notes: Standard Errors in Parenthesis
*,**,*** Statistically Significant at 10%, 5% and 1%

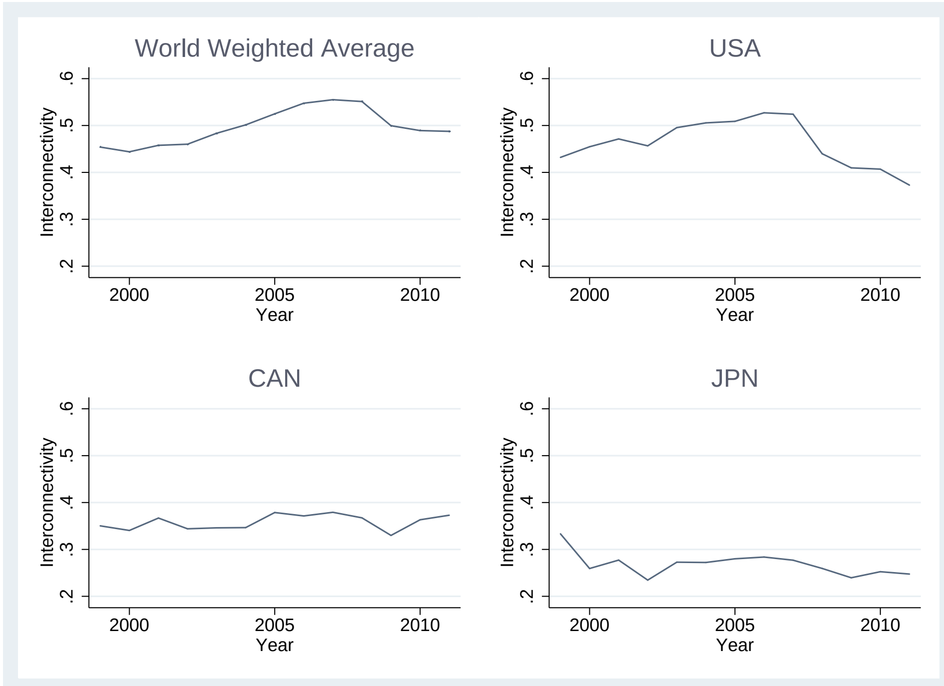

Figure 5: Interconnectivity over time, selected countries.

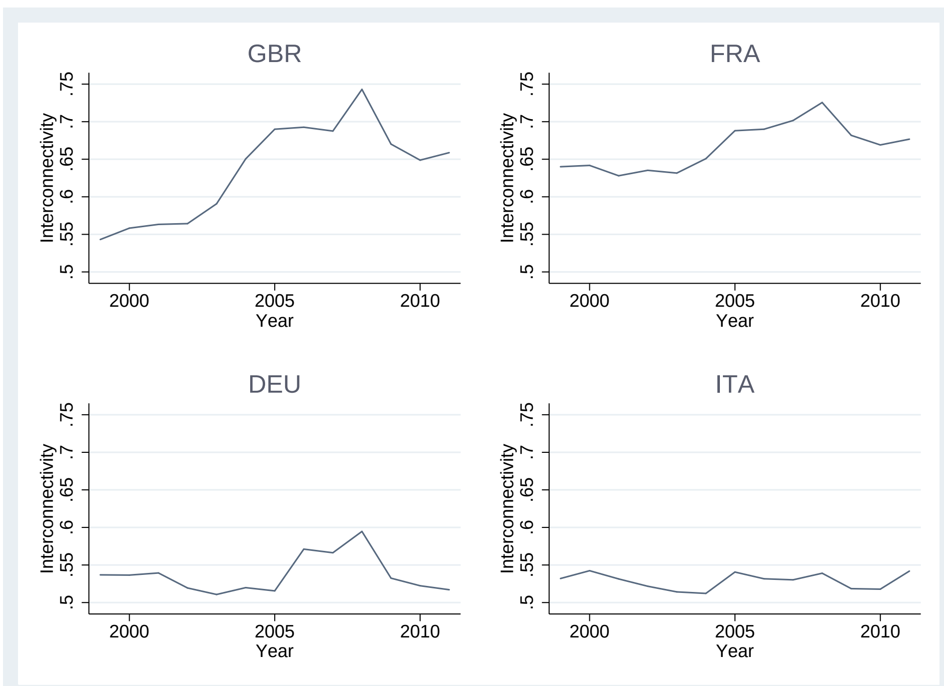

Figure 6: Interconnectivity over time, selected countries.

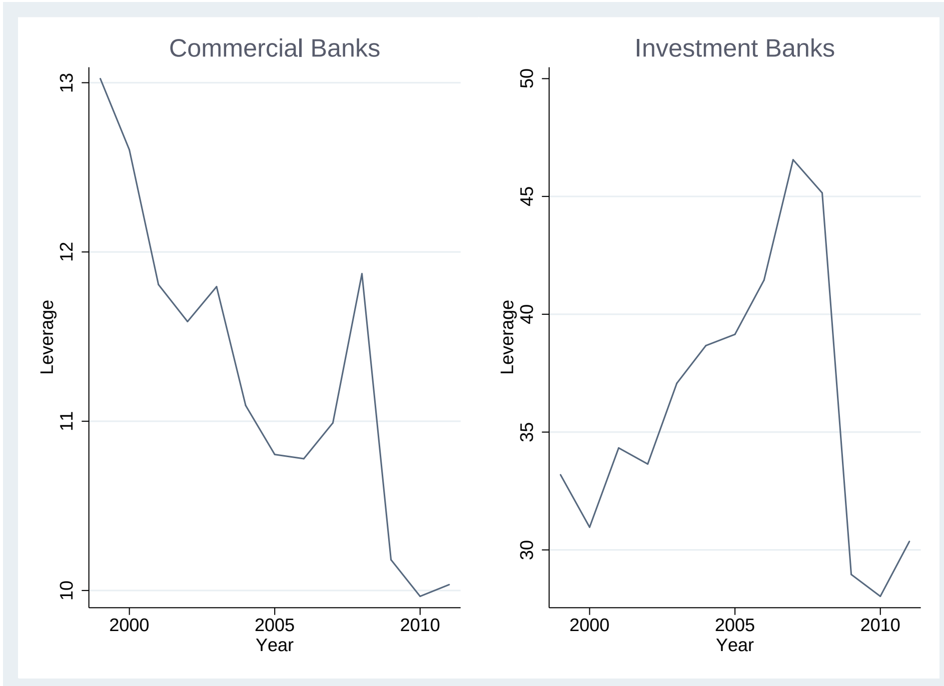

Figure 7: Leverage over time, USA, Commercial and Investment Banks

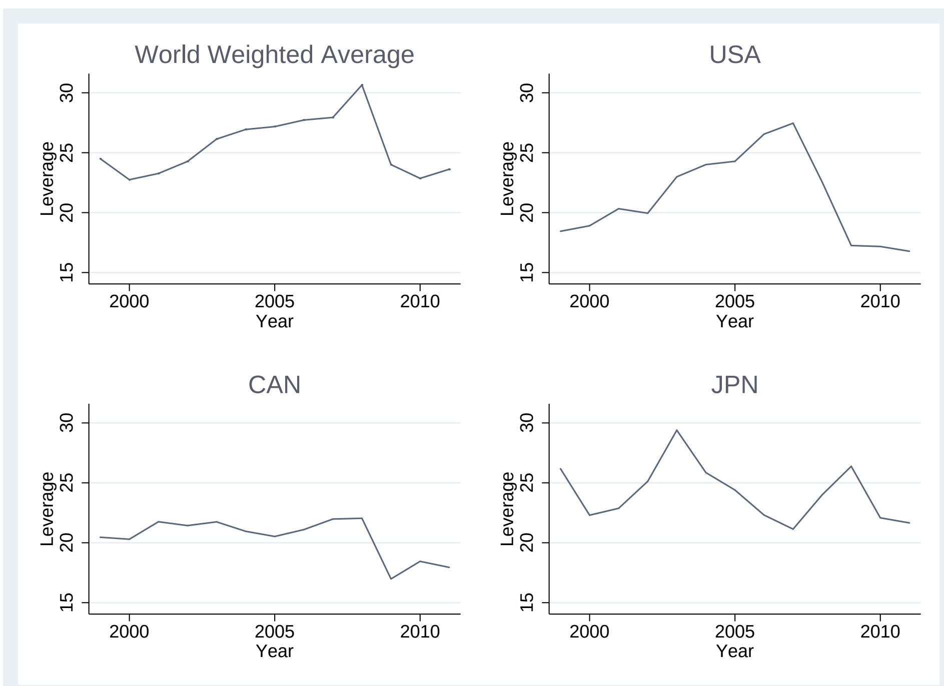

Figure 8: Leverage over time, selected countries

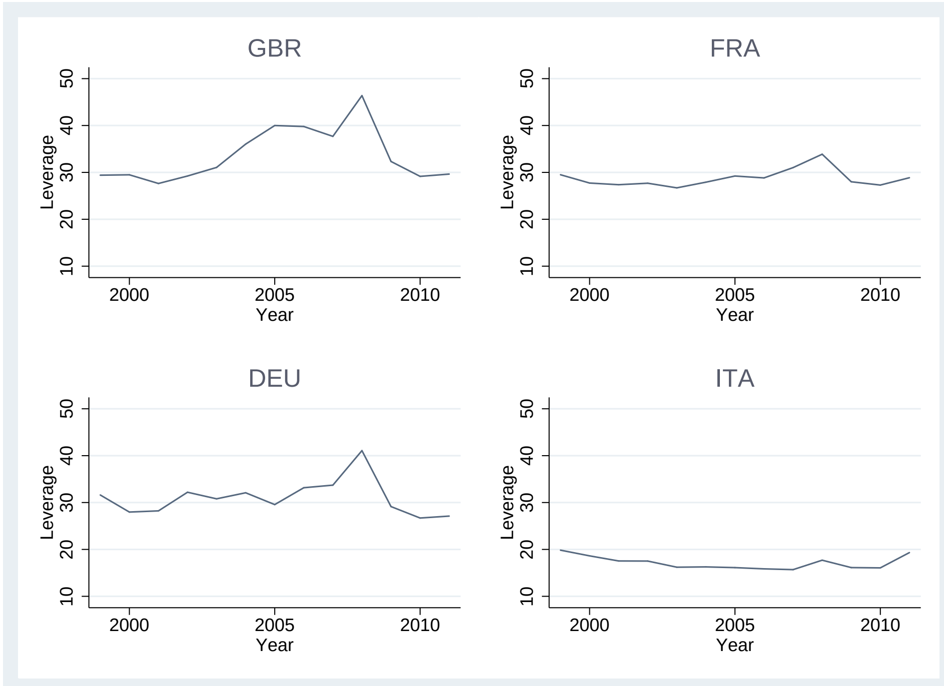

Figure 9: Leverage over time, selected countries

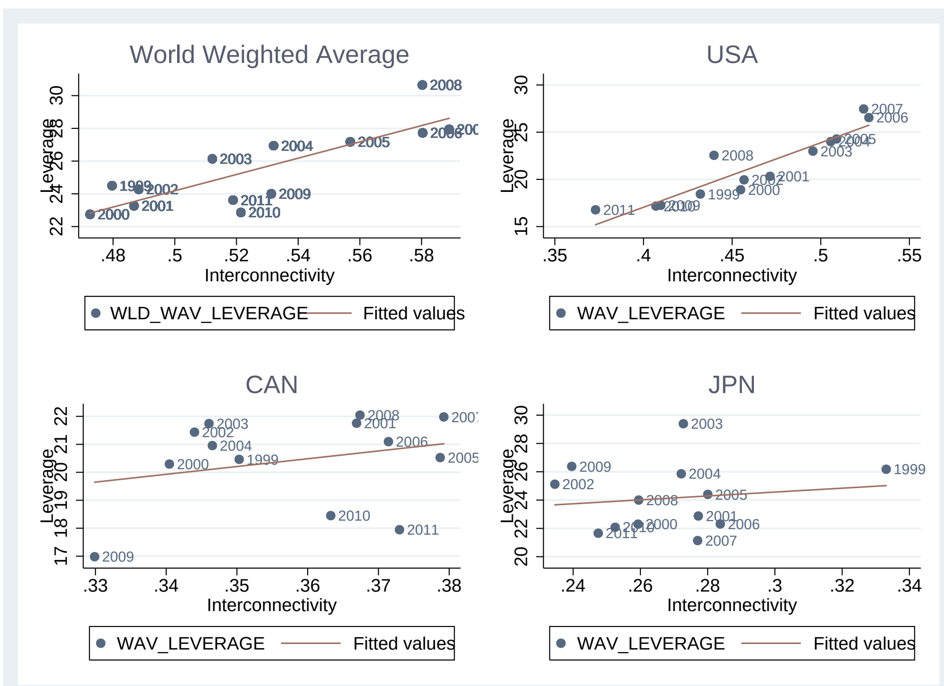

Figure 10: Leverage and Interconnectivity, Across Time, Within Selected Countries

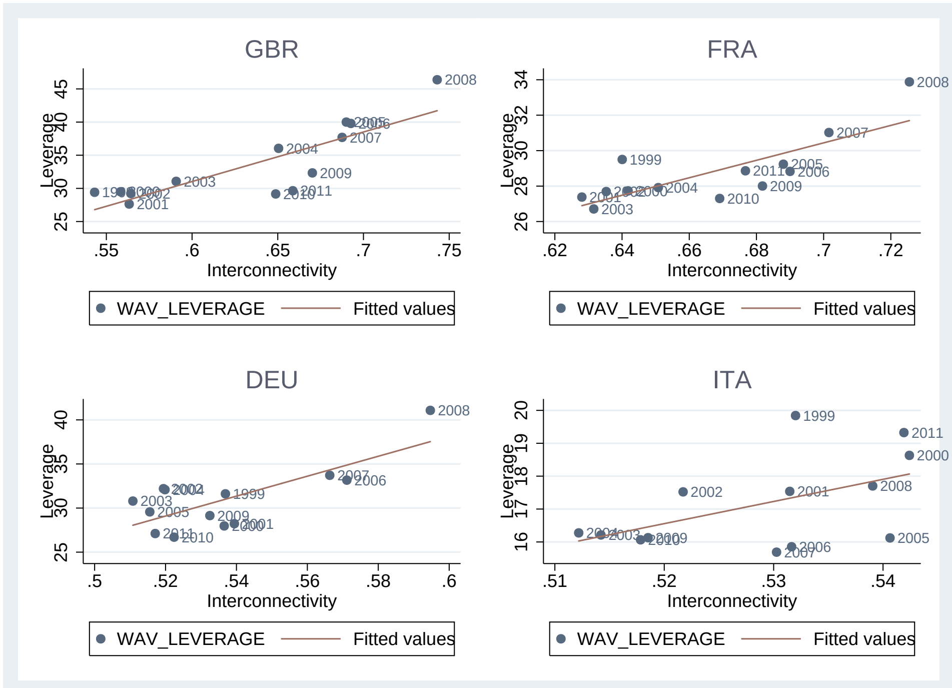

Figure 11: Leverage and Interconnectivity, Across Time, Within Selected Countries

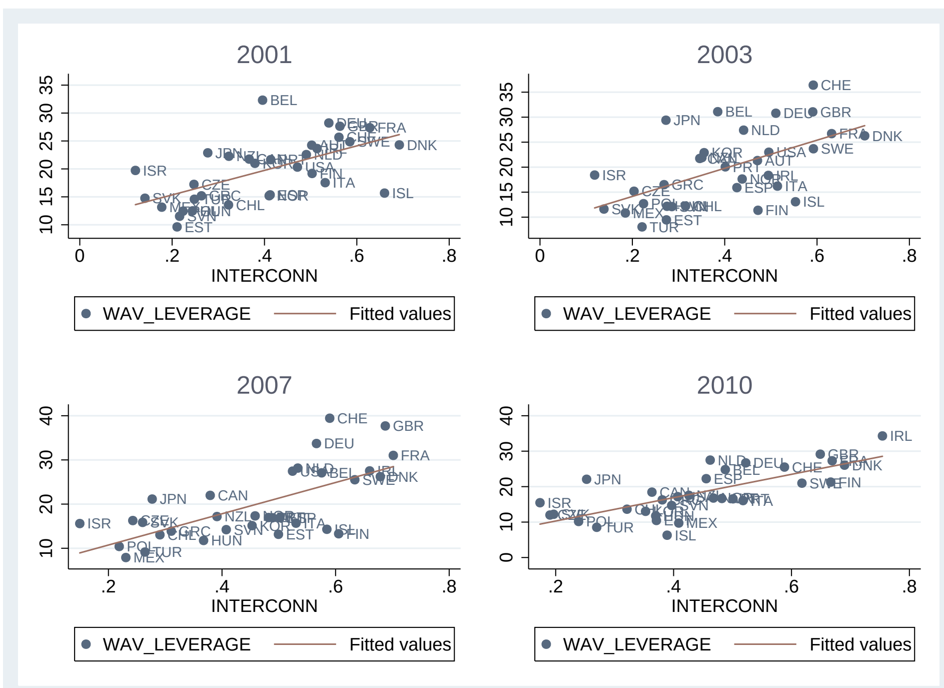

Figure 12: Leverage and Interconnectivity, Across countries, Selected Years

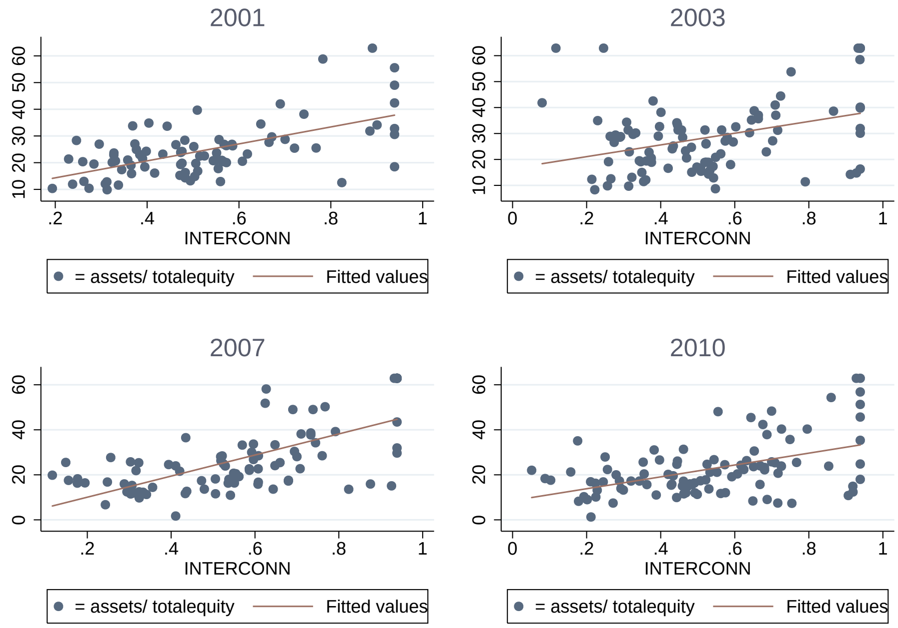

Figure 13: Leverage and Interconnectivity, Across Very Large Firms, Selected Years

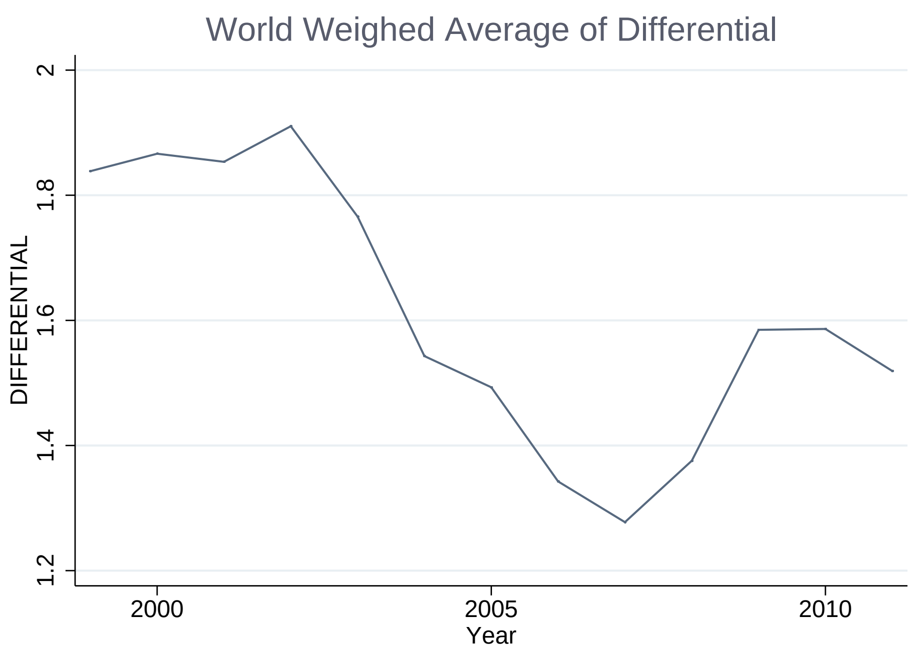

Figure 14: Return Differential over Time

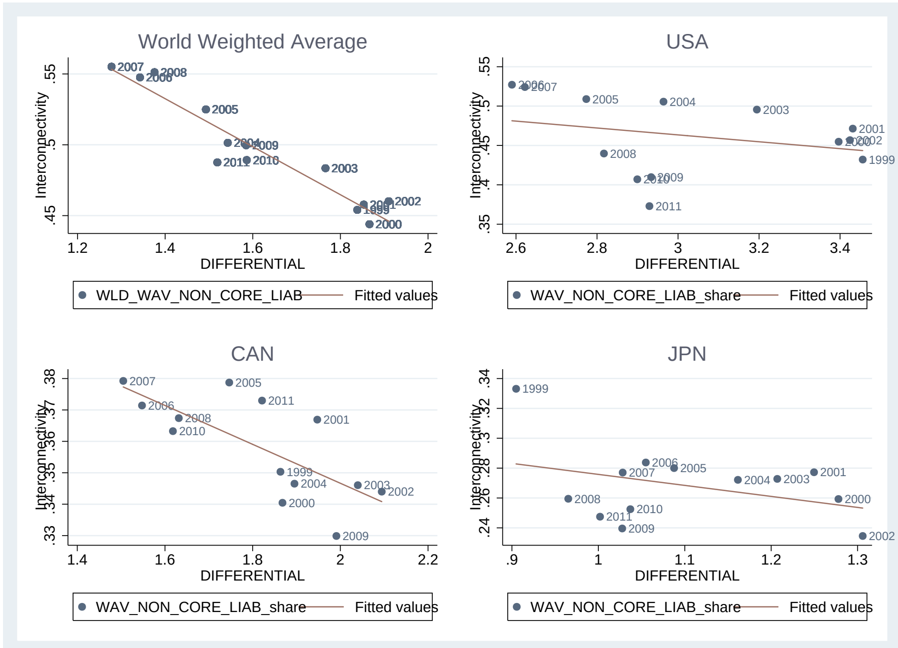

Figure 15: Interconnectivity and Return Differential, Across Time, Within Selected Countries

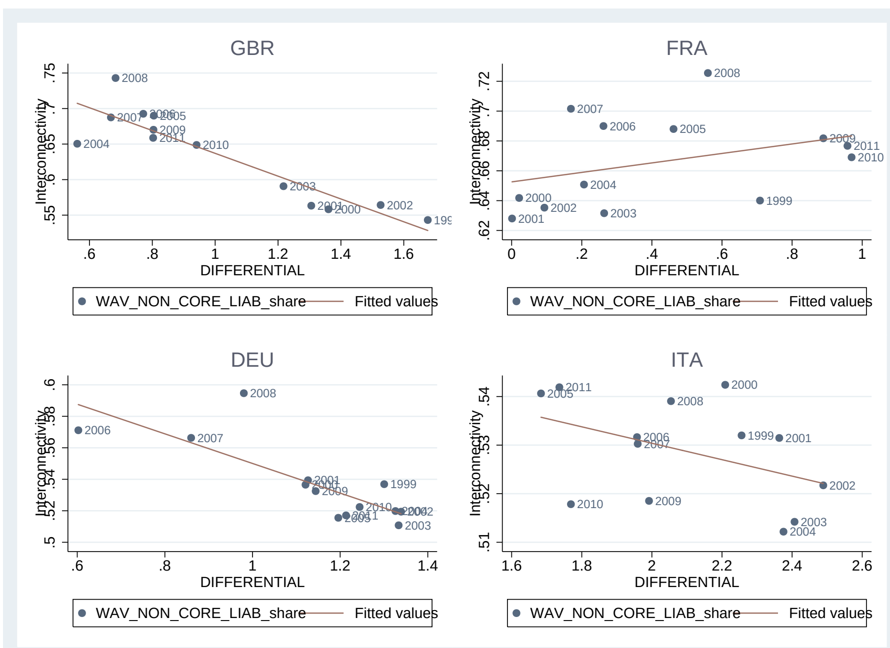

Figure 16: Interconnectivity and Return Differential, Across Time, Within Selected Countries

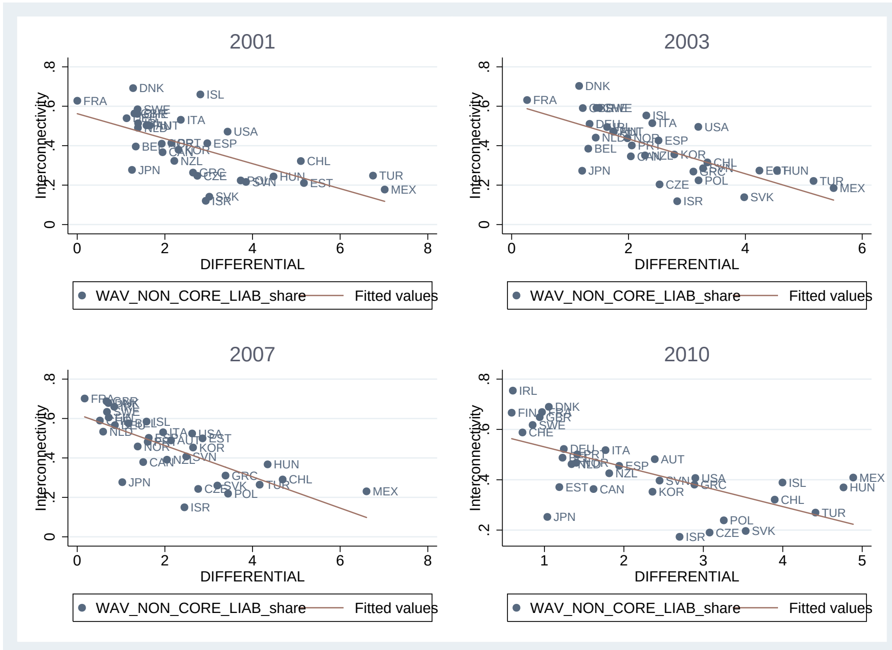

Figure 17: Interconnectivity and Return Differential, Across Countries, Selected Years

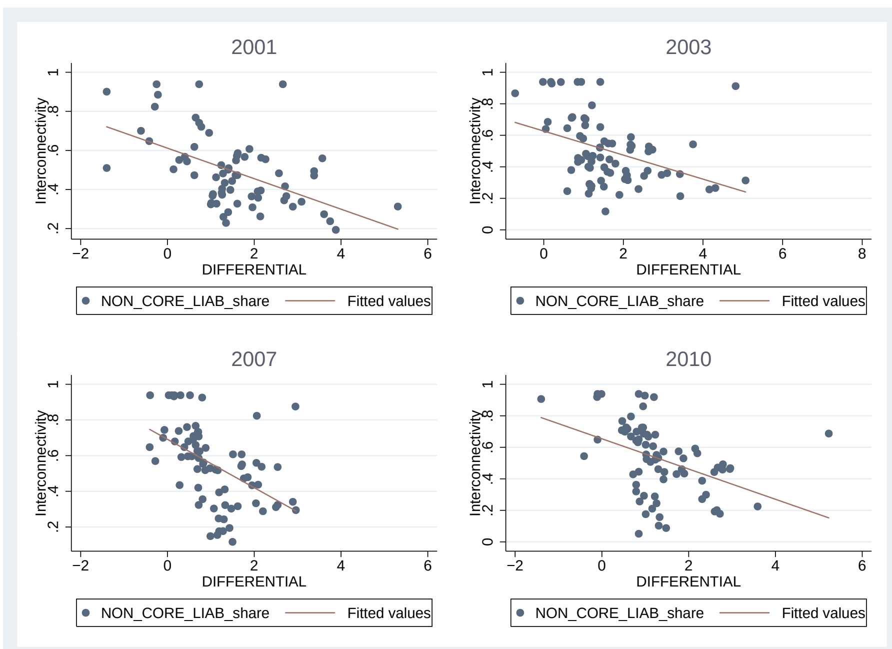

Figure 18: Interconnectivity and Return Differential, Across Very Large Firms, Selected Years