Mutually Reinforcing Debt and Financial Crises in Spain and Ireland: A VAR Approach

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Abstract

In Eurozone countries where banks hold a large portion of their sovereign's debt, structural changes in the comovement of indicators of financial and sovereign stress have taken place since the intensification of the Global Financial Crisis in the fall of 2008. This paper uses VAR to confirm structural change occurs in the relationship between Spanish and Irish sovereign and financial sector stress. I use financial sector equity indices for Spain and Ireland to measure financial sector stress and 10-year sovereign bond yields to approximate the risk of sovereign default. After the beginning of the Global Financial Crisis, sovereign stress newly began to spillover into financial markets. After bank recapitalization in 2010 in Ireland and debt downgrades in Spain, both countries' financial sectors began to Granger cause each other's stress. I provide evidence of a negative domestic feedback loop in Spain and Ireland as well as contagion between these countries through both sovereign bonds and their financial sectors. Declines in Spain and Ireland's economic activity following their financial crisis harmed their ability to service their debt and further degraded the value of sovereign bonds comprising bank capital. Recapitalization and nationalization link the wellbeing of the bank to that of the sovereign (as in Ireland) and so does substantial holdings of public debt by private domestic banks (as in Spain).

1 Introduction

The ongoing financial and debt crises in the Eurozone have highlighted the important ways in which concurrent crises can be mutually reinforcing. Since late 2008, European banks have experienced large asset losses and deteriorating collateral values. At the same time, a

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several-year trend of converging sovereign bond yields was suddenly reversed. The divergence in yields was sharp; Greek 10-year bond yields exceeded 25% while, in a rush to safe assets, German yields reached levels comparable to those of the US. Recent research suggests that the financial sector and sovereigns transmit stress to one another. I identify structural changes in the relationships between sovereigns and their financial sectors in Spain and Ireland as well as crisis contagion across these two countries.

Pisani-Ferry and Merler (2012) identify two of three channels, on which my analysis focuses, that constitute a negative feedback loop. The *collateral channel* enables government default risk to erode bank capital via falling prices of sovereign debt. A sovereign may respond through the *recapitalization channel* to restore balance sheets initially through transfers but while further raising the sovereign risk premium as the total mass of debt grows. A *liquidity channel* also propagates financial sector weakness to sovereigns when credit volumes fall and trigger a decline in real economic activity, which subsequently shrinks the tax-base. Declines in bank capital explain a substantial amount of real economic activity in Europe since 2008 (Gerali et al., 2010; Iacoviello, 2010). Collateral losses reduce the ability of banks to extend credit to the economy; this instigates a credit crunch (Adrian and Shin, 2010; Iacoviello, 2010; Bernanke et al., 1999; Gilchrist et al., 2009). When recapitalization is so costly to the sovereign that in net it reduces bank capital through rising yields, the credit crunch worsens. These declines in economic activity shrink the tax-base on which sovereigns rely to service their debt. Thus a lack of liquidity grows a sovereign's debt burden; the sovereign is pushed closer to default as bond premiums rise due to increases in perceived sovereign risk.

I investigate collateral, recapitalization, and liquidity channels as potential explanations for the development of the financial and debt crises in Spain and Ireland. I use a VAR to quantify structural changes after events to characterize the development of negative feedback loops between the financial sector and sovereigns in these two countries. The data illustrate contagion between Spanish and Irish financial sectors resulting from similar exposure or even exposure to the degrading sovereign debt of the other nation. Similarly, rising yields on Irish or Spanish debt may contribute to increased investor aversion towards a broadly-defined class of struggling Eurozone sovereigns and thus may also act as a means of contagion. I measure

sovereign stress as 10-year sovereign bond yields which rise when risk averse investors demand a higher risk premium. Financial sector stress is measured through financial sector equity indices for Spain and Ireland. The bond data are of monthly frequency and are available from 2000 onward and the financial indices are of daily frequency and available as far back as January of 2005 for Spain and 1998 for Ireland.

I find that statistically significant structural change occurred after the onset of the global crisis and that this pattern further intensified after the recapitalization and nationalization of Anglo Irish (Wall Street Journal, 2012a) and the debt downgrades in Spain (Wall Street Journal, 2012b). Prior to the onset of the Global Financial Crisis (measured as September 2008, when Lehman Brothers filed for bankruptcy), sovereign yields and financial sector indices were best predicted by their own lags and did not Granger cause each other. These series undergo statistically significant structural changes after September 2008. After this date, the financial indicators were Granger caused by each other, suggesting contagion between Spanish and Irish financial markets. Additionally, bonds Granger caused their respective financial sector variables as well. I hypothesize that this follows from investors becoming increasing worried about the worsening fiscal conditions in each country and anticipating the spillover of this stress into the rest of the economy (primarily through financial markets). After the recapitalization and downgrades around August 2010, all variables Granger caused each other as the negative feedback loop between financial and fiscal sectors and across Spain and Ireland intensified. Section 2 reviews related literature and contrasts innovations of my analysis. I present a theoretical framework to explain spilllover between financial and fiscal balance sheets in section 3. In section 4 I discuss features of the data and motivate my modeling methodology. Section 5 analyzes the VAR results and impulse response functions and then discusses their implications. Section 6 concludes.

2 Literature Review

Recent criticism of statistical and mathematical models of default highlights the impracticality of viewing sovereign debt crises as solely a decision based on costs to sovereigns through

international markets. Sovereigns are immune from any legal enforcement of servicing their debt, yet empirically we observe that governments rarely default. There must exist costs to default that prevent sovereigns from always choosing this option. The models of Eaton and Gersovitz (1981) and Arellano (2008) posit that the source of these costs is international and may take the form of trade or capital sanctions. From a game theoretic perspective, trade and capital sanctions are potentially problematic sources of cost when there are many bondholders. Sanctions leave gains from trade and capital markets unexploited and any bondholder is tempted to deviate from punishing the defaulting party (Wright, 2011).

Gennaioli et al. (2012) construct a three-period, small open economy model to investigate channels through which sovereign debt harms financial activity. They suggest that when banks hold a substantial share of government bonds[1], default destroys the capital of banks and reduces their ability to extend credit to the rest of the economy. There is a complementarity between public and private borrowing when bonds have a liquidity value. "Strong" financial institutions, meaning those integrated with much of the domestic economy, will have a larger negative effect on credit markets if the bonds that they hold go into default. Weaker financial institutions create smaller costs after sovereign default and therefore make it more likely for a benevolent government to default.

To test their model predictions, they analyze a dataset of 58 emerging and developed economies from 1980 to 2005. Consistent with their theory, where financial institution quality[2] is higher and intermediaries hold more public debt, declines in aggregate financial activity are more severe after default but the probability default is lower. Gennaioli et al. (2012) provide strong reasoning and robust evidence that domestic costs are important determinants of sovereign default risk. I expand on this line of work by identifying structural turning points in the Spanish and Irish economies related to their domestic costs of sovereign debt crises. Gennaioli et al. (2012) identify a ubiquitous relationship between financial sector and sovereign borrowing, my work augments this study by looking at individual countries in detail

[1] As in the case of Russia in 1998—an event which many models of default have struggled to explain (Gennaioli et al., 2012; Wright, 2011).

[2] Measured by the "creditor rights" score, the leading predictor of credit market development around the world (Gennaioli et al., 2012).

to see how the ways in which these sectors transmit stress to one another evolves over time and also explores contagion between countries. My methodology also has the advantage of controlling for exchange rate risks and monetary policy heterogeneities since I am confining my analysis to two Eurozone economies.

Bolton and Jeanne (2011) introduces a repurchase agreement market that transmits shocks from sovereigns to domestic investors and taxes whose revenue declines along with real economic activity in another three-period, small open economy model. Financial institutions in the Eurozone primarily hold public debt because it can be used as collateral for cheap lending through central bank discount windows. Also, regulations such as the Basel accords require banks maintain certain capital ratios[3]. Bolton and Jeanne model an economy where sovereign bonds specifically serve as collateral for repurchase agreements (repo loans[4]). The prevalent use of sovereign bonds as leveraged collateral in these repurchase agreements on the part of Spanish banks makes them exceptionally vulnerable to sovereign debt crises. As the quality of sovereign debt degrades, so does bank capital. The banks have less collateral to leverage and thus real investment contracts in the economy. This decline in investment shrinks the tax-base available to the government for servicing its debt and thus puts further pressure on the sovereign.

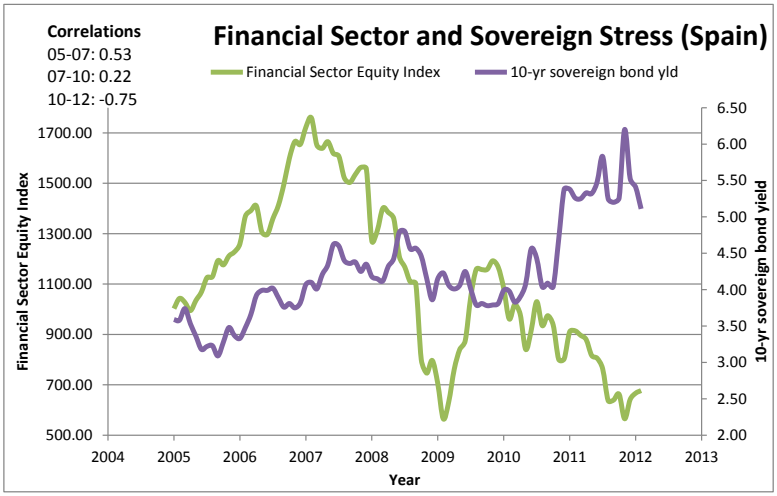

Figure 1: Financial sector and sovereign stress indicators for Spain. Source: Eurostat.

[3]Public bonds have been especially desirable for collateral and capital maintenance in the Eurozone since banks may assign them a zero risk-weighting (Pisani-Ferry and Merler, 2012).

[4]A repo loan is an agreement where the issuer purchases a security, in this case government bonds, which the seller/borrower agrees to repurchase for a higher price at a later date.

Mody and Sandri (2011) perform an analysis of Ireland similar to that of this paper and suggest that recapitalization and bailouts, not large holdings of domestic by Irish banks, are what triggered the Irish crisis. Sovereign spreads throughout the Eurozone began to rise moderately after the US rescue of Bear Stearns in March 2008. Irish sovereign yields began a pattern of responding to financial sector weakness. Investors seemed to recalibrate their estimates of sovereign risk as the Irish financial sector deteriorated. In January of 2009, Anglo Irish Bank was nationalized, sovereign and financial sector stress indicators began to comove contemporaneously.

Figure 2: Dispersion of Eurozone sovereign spreads (basis points). Source: Mody and Sandri (2011).

When the Irish government nationalized Anglo Irish, they incurred significant financial outlays and thus rendered their large debt burden even more difficult to service. Mody and Sandri (2011) suggest that nationalizing Anglo Irish heightened investors' perceptions of financial vulnerability and implied increased interconnectivity between bank balance sheets, thus recapitalization also served to worsen the ongoing financial crisis in this respect. Ejsing and Lemke (2009) find that initially bank risk spreads (as measured by financial sector CDS spreads) did fall in many Eurozone countries around the time of the Anglo Irish nationalization. Yet this seeming success was a pyrrhic victory at best as this induced a marked increased in risk spreads for sovereign bonds.

I augment these studies by juxtaposing the Irish and Spanish crises and the differences in propagation mechanisms underlying the negative feedback loops that both of their sovereign

and financial sectors are facing. The Spanish story is one of rising default probabilities and direct bank exposure to this risk while the Irish episode is characterized by increased uncertainty about financial sector risk coupled with a rising debt burden on the part of the Irish government. Pisani-Ferry and Merler (2012) posited that domestic bank usage of sovereign collateral set the stage for the negative feedback loop between sovereigns and their respective financial sectors. They find domestic banks throughout the EU tend to hold an usually large amount of this debt as collateral compared to the rest of the world. This unique behavior makes European banks exceptionally vulnerable to rising sovereign bonds yields which may degrade their collateral[5].

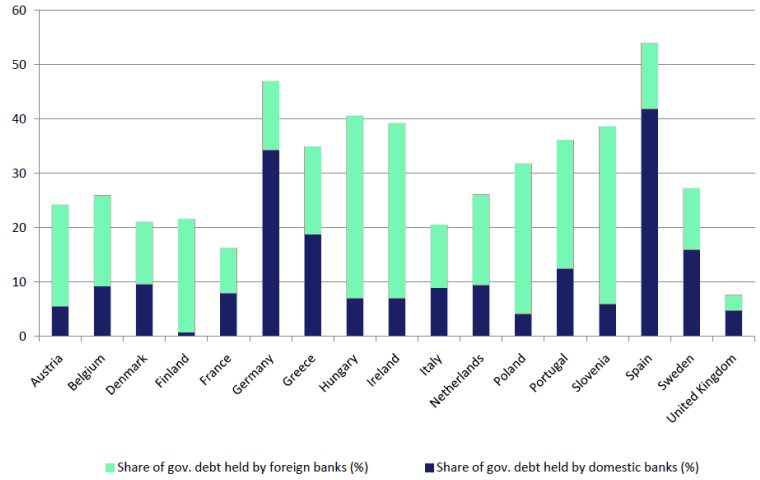

Figure 3: Source: Bolton and Jeanne (2011). From a 2010 survey of 91 of Europe's largest banks.

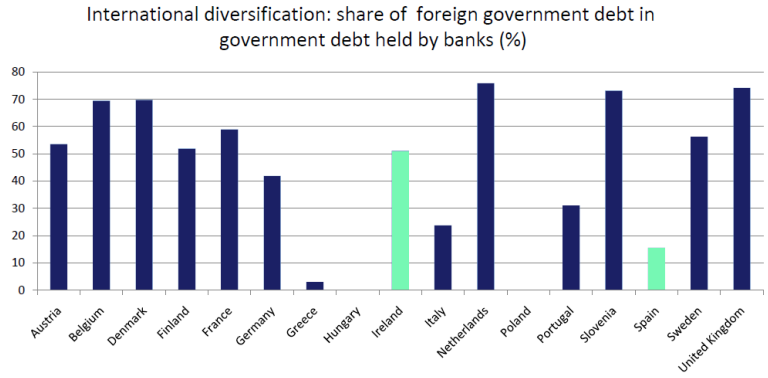

Figure 4: Source: Bolton and Jeanne (2011). From a 2010 survey of 91 of Europe's largest banks.

[5]30% of EU banks attributed poor performance to collateral degradation (ECB Bank Lending Survey, 2012)

Mody and Sandri (2011) and Sgherri and Zoli (2009) find that there was a fundamental change in the relationship between sovereigns and the financial sector after the rescue of Bear Stearns and the collapse of Lehman Brothers in the US. They show that prior to these events, sovereign spreads were largely random in the EU and not predicted by developments in the financial sector. Mody and Sandri (2011) observes that after October 2008, sovereign spreads newly became correlated with (three-week) lagged indicators of financial stress[6]. Another significant regime change is identified by the authors in Ireland following their EU-IMF bailout in 2010. After the Irish banking sector was recapitalized, the same indicators for financial and sovereign stress began to comove contemporaneously and lagged financial stress was no longer a statistically significant predictor of sovereign distress. Latent fundamental factors have compelled European sovereigns and their domestic banks to lock into a negative feedback loop.

3 Theory of Mutual Reinforcement

Fiscal and financial sectors are able to transmit stress to each other through their effects on bank capital and tax revenue, respectively. Sovereign bonds are desired by banks for their liquidity value. Sovereign debt is given a zero-risk weighting[7] for meeting capital adequacy requirements, such as those of the Basel Accords.

Spanish balance sheets directly depend on sovereign debt as it comprises a substantial portion of private bank capital in Spain (as discussed in section 2). Thus when bond prices fall (equivalent to yields rising), the market value of capital is lower. If a Spanish bank was near the limit of its capital adequacy ratio, a decline in the value of capital may trigger deleveraging in order to maintain capital requirements. On the other hand, Irish banks do not hold large amounts of Irish debt. However, the nationalization of Anglo Irish shortly after Lehman went bankrupt and its subsequent recapitalization in 2010 linked the ability of one of Ireland's largest banks to extend financial services to the resources of the government running

[6]Specifically, they find this relationship between sovereign CDS spreads relative to those of the US and use country-specific financial sector equity indices to measure financial stress.

[7]This zero-risk weighting holds for any European sovereign debt, thus in terms of risk, Spanish, Irish, Greek, and German debt are treated identically.

it. Below I theoretically derive the potentiality of negative feedback loops to form as a result of a sovereign budget constraints and the maximization problems solved by banks.

I assume there is a government that every period t must satisfy a budget constraint. It makes exogenous expenditures G_t, receives T_t in tax revenue, and issues inflation-indexed, non-contingent bonds with a gross return of $1/q_t$. The government provides state-contingent capital injections $\mathcal{R}_t$ to a bank.[8] The constraint which the government satisfies is

$$\begin{aligned} G_t + B_{t-1} + \mathcal{R}_t &= T_t + q_t B_t \quad (1) \\ B_{t-1} &= S_t + q_t B_t \geq 0 \quad (2) \end{aligned}$$

Where the government surplus is given by $S_t = T_t - G_t - \mathcal{R}_t$. Iterating the budget constraint backwards yields

$$\begin{aligned} G_t + B_{t-1} + \mathcal{R}_t &= T_t + q_t B_t \\ B_t &= q_t^{-1}(G_t + \mathcal{R}_t - T_t + B_{t-1}) \\ B_t &= -q_t^{-1}(S_t - B_{t-1}) \\ B_t &= -q_t^{-1}[S_t + q_{t-1}^{-1}(S_{t-1} - B_{t-2})] \\ B_t &= -q_t^{-1}[S_t + q_{t-1}^{-1}S_{t-1} + ... + q_0^{-t}S_0] \\ B_t &= \sum_{k=0}^{t}\left(\prod_{k=0}^{k} q_{t-j}\right) S_{t-k}. \end{aligned}$$

This implies that a large debt today B_t is the result of accumulating large budget deficits in the previous periods. The forward iterated budget constraint is:

$$B_t = S_{t+1} + \sum_{k=1}^{\infty}\left(\prod_{j=1}^{k} q_{t+j}\right) S_{t+1+k}. \quad (3)$$

It follows that in order to remain solvent, sovereigns that borrow a large amount at time t need large fiscal surpluses as early as possible. At time t, future realizations of G_{t+i} are unknown.

[8]This formulation is an adaptation of that specified in Sargent (2012). I modify his by making the bond non-contingent and adding recapitalization.

If we assume that there is a known stochastic process that governs $G_t \forall t$ and possibly a process affecting tax revenue (such as total factor productivity), I may define the probability of *not* defaulting:

$$1 - \alpha_t = \Pr\left\{ B_t \leq \mathbb{E}_t \left[S_{t+1} + \sum_{k=1}^{\infty} \left(\prod_{j=1}^{k} q_{t+j} \right) S_{t+1+k} \right] \right\}. \tag{4}$$

I assume that in the event of default the sovereign repudiates a known fraction $\rho \in (0, 1)$ of its debt. Risk neutral creditors optimize by purchasing bonds so that

$$q_t = \bar{q}_t(1 - \alpha_{t+1}\rho) \tag{5}$$

where $\bar{q}_t$ is the default-free interest rate.

Next, I consider a representative investment banker in partial equilibrium. The investment banker maximizes consumption (C_t) over an infinite horizon. They finance consumption through returns on capital (K_t). They are able to augment their investment (X_t) by loans received leveraging assets (sovereign bonds and government recapitalization). Formally, they solve:

$$\max_{\{C_t, X_t, B_t, L_t\}_{t=0}^{\infty}} \quad \sum_{t=0}^{\infty} \beta^t C_t \tag{6}$$

$$\text{s.t.} \quad C_t + X_t + q_t B_t + L_{t-1}(1 + r_{t-1}^l) \tag{7}$$

$$= B_{t-1}(1 - \alpha_t \rho) + r_t(K_t + L_t) + \mathcal{R}_t \tag{8}$$

$$K_{t+1} = (1 - \delta)(K_t + L_t) + X_t \tag{9}$$

$$L_t \leq \gamma(q_t B_t + \mathcal{R}_t). \tag{10}$$

The first order condition associated with bonds is

$$q_t = \frac{\beta \mathbb{E}_t(1 - \alpha_{t+1}\rho)}{1 - \gamma[r_t + (1 - \delta) - \beta(1 + r_t^l)]}. \tag{11}$$

The above equation shows that bond prices are decreasing in the probability of default as well as the fraction that will be repudiated. Additionally, investment bankers are willing to pay more for bonds when loans are cheaper to borrow and when capital fetches a greater return.

The first order condition associated with the Lagrange multiplier on the borrowing constraint is

$$L_t = \gamma(q_t B_t + \mathcal{R}_t). \tag{12}$$

This equation shows that the investment banker's loan demand is increasing in the price of bonds and the amount of recapitalization. The investment banker also has a one-to-one technology that transforms loans into capital that may be rented to firms. Thus capital supply to non-financial corporations is increasing in the price of sovereign bonds and recapitalization as well.

It follows from this theoretical framework that recapitalization faces a trade-off and in net may hurt the economy. Recapitalization increases the ability of investment banks to extend loans to the macroeconomy. However, this raises the amount of future surplus required to service the debt as recapitalization increases the government's expenditure. All things the same, increasing the level of debt leads to a greater probability of default. The financial sector is worse off if the change in the probability is so large that it lower capital more than the size of the recapitalization. If real investment falls, so does real GDP, and thus there is less income available for the government to service the debt, lowering tax revenues.

If this theory holds in practice, one expects that a negative, exogenous shock could lower returns on capital and thus decrease the desirability of bonds (and also their prices). A sufficiently large shock could spur a negative feedback loop and push the government near its fiscal limit increasingly fast. Recapitalization may be enough to boost investment and counteract the feedback loop, but it may also add sufficient stress to strengthen the loop. This may explain Ireland's experience with the debt crisis. In the case of Spain, the debt downgrades by Fitch and Moody in 2010(Wall Street Journal, 2012b)may have effectively increased the dispersion around their fiscal limit. Thus even without the level of debt changing, the downgrade signals a greater probability of default to investors and bond prices fall further as the negative feedback loop in Spain intensifies.

4 Data and Method

To test for the development of a feedback loop I analyze measures of sovereign and financial sector stress through VAR. I measure financial sector stress with a financial sector equity index. The indices for Spain and Ireland directly measure an index of equity share prices for Spanish and Irish firms, respectively. These data are available at a weekly frequency for Spain and Ireland for as far back 2005 for Spain and 1998 for Ireland.[9] For both Spain and Ireland, I use 10-year sovereign bond yields to measure stress in the fiscal component of each economy. These yields are net of taxes and available at a monthly frequency from 1990's.[10] In my analysis I add one to the yield (gross return) and take its inverse to obtain a measure for the price of the bond analogous to that presented in section 3.

VAR is the appropriate method for analyzing the interaction of these time series. Theory suggests that bond prices and the financial sector performance are endogenous. Therefore modeling these series as simultaneously depending on each other's lags is consistent with theory. Additionally, there is no unit root present in the series thus no cointegration is possible. This rules out a vector error correction model. I investigate two dates as potential structural turning points. First, I use September 2008 to mark the beginning of the global financial crisis. This is the month when Lehman Brothers filed for bankruptcy, most financial markets drew down, and many economies entered recessions. In August 2010, the Irish government took a majority stake in Anglo Irish Bank (AIB), nationalizing and recapitalizing one of Ireland's largest financial institutions. In May 2010, Fitch Ratings downgraded Spanish debt from AAA to AA+. In September of 2010, Moody's Investors Service Inc. lowered their rating of Spanish debt one level to Aa1. In order to increase sample sizes associated with the various periods, I use use August 2010 as the event time for the 2010 events for Ireland and Spain. Thus data are divided into three subsamples: Pre-Lehman, Post-Lehman, and Post-AIB.

An initial inspection of the data show that the downturn in equity markets started for Ireland and Spain around approximately the same time: the beginning of 2008. Ireland experienced larger relative declines and a relatively smaller rebound as well after early 2009.

[9] I obtained these data with the help of Theodore Bogusz at the Federal Reserve Bank of Chicago.
[10] I obtained these data from Eurostat.

After the bankruptcy of Lehman Brothers, both countries experienced their most precipitous declines. Since a fleeting rebound in 2009, both financial markets have been in decline. This is illustrated in the figure below.

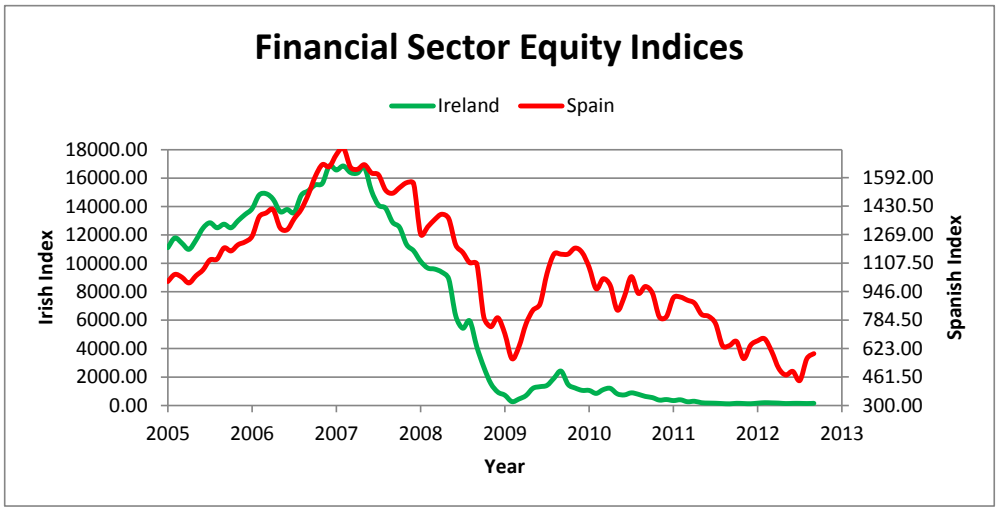

Figure 5: Spanish and Irish financial sectors comove, suggesting contagion.

I plot the financial index against bond prices below. This chart illustrates that both series for Ireland are relatively more variable than those of Spain. A overall pattern of higher bond prices and equity prices is observable over the entire sample period.

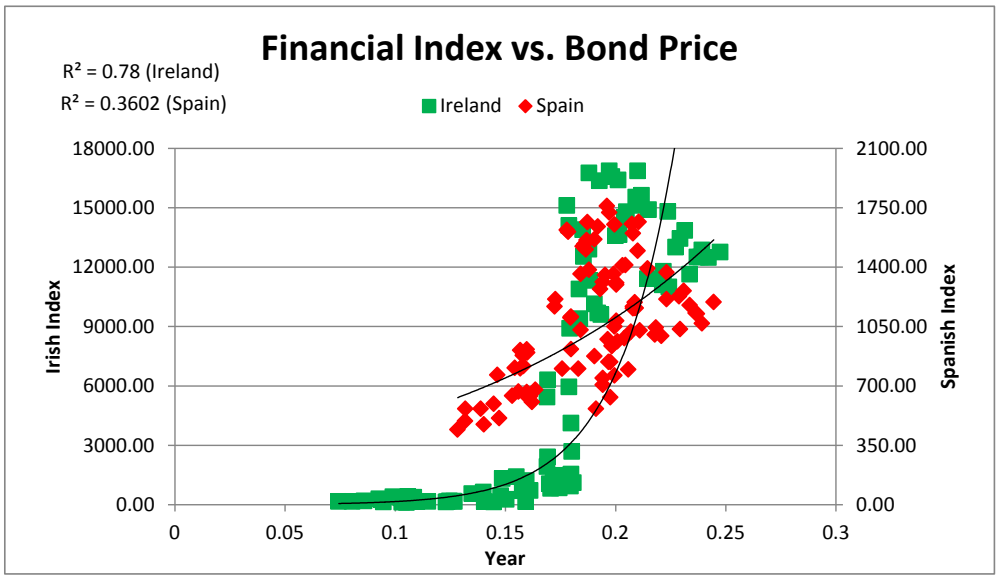

Figure 6: Fitting simple exponential curves to domestic data.

5 VAR Identification of Structural Change

I find evidence that after the bankruptcy of Lehman Brothers as well and post-AIB[11], statistically significant change occurs in the relationship between Irish and Spanish public debt and financial sectors. In my analysis, I first verify statistically significant differences between pre and post-Lehman data in all series except the Irish financial series. Below I describe the fit of the VAR of optimal lag length, what variables are significant predictors, and the directions of Granger causality in these two subsample cases. Next, I also find that there are statistically significant differences for all variables except the Irish financial sector pre-Lehman, post-Lehman, and post-AIB. I describe analysis of the same measures below in order to characterize the nature of the feedback loop which I find has developed.[12]

The Chow test reveals that statistically meaningful change in the relationship of the all the times series (except the Irish financial sector) took place following September 2008. I suspect that this is the case because even prior to Lehman the Irish financial sector is almost statistically significantly predicted by lags of the other variables. Prior to Lehman, the Irish financial sector boomed while the Spanish financial sector did the same and both governments experienced lower sovereign yields in the first portion of the decade following the creation of the Eurozone and its promised stability. I find that the in the pre-Lehman years, each financial sector and Irish bond prices were best predicted by their own lags. Spanish yields had no statistically significant predictors even among its own lags. None of the variables prior to Lehman Granger caused each other.

First I looked at the larger, combined samples of post-Lehman and post-AIB together as one post-Lehman subsample; in this period, a negative feedback loop emerges. Lags of each country's sovereign yields predict the behavior of its financial sector. In Spain, Irish yields are predictive of the Spanish financial sector as well. Ireland led most of the Eurozone internal economic stress relating to global financial conditions, so it may be picking up noise from global macroeconomic activity affecting the Spanish economy. Th Irish financial sector is also now

[11] This is after the Irish recapitalization of Anglo Irish Bank and the Fitch and Moody's downgrades of Spain's debt.

[12] See section A for IRFs and forecast error variance decompositions, section B for Chow test results, and C for analysis of VARs and tests of Granger causality.

predicted by the larger and more developed Spanish financial sector. Each country's bond price is predicted by its own lag and lags of the Spanish financial sector. This is likely the case as the larger Spanish economy might send a stronger signal to investment. It also may be that it was Spanish financial stress that worried investors more about government solvency than stress in the Irish sector. Impulse response functions and forecast error variance decompositions (section A of the Appendix) also support that these variables were newly significant in causing each other. They consistently show that shocks to variables had practically larger and statistically more meaningful effects on each other in the post-Lehman sample versus the pre-Lehman sample. Additionally, more of the variance in these series is explained by other series' behavior.

I find that during the larger post-Lehman period, Spanish yields Granger cause developments in both Irish and Spanish financial sectors. This could stem from greater doubts regarding Spanish government solvency. Irish yields newly Granger cause developments in the Irish financial sector (but not Spanish financial markets). Irish and Spanish financial sectors Granger cause each other, suggesting contagion between financial sectors has now developed. Additionally, Spanish financial sector stress Granger causes bond yields. Both variables Granger causing each other and negative, statistically significant coefficients are evidence that a negative feedback loop has developed between Spain's financial and sovereign sector. The fact the Irish financial sector does not Granger cause sovereign yields suggests that there is less concern among investors that financial declines and government nationalization of AIB will cause the Irish Republic to default. Lastly, since both financial sectors newly Granger cause each other following Lehman, it appears that contagion between both financial markets has developed and as financial conditions deteriorate in Ireland, they similarly do so in Spain.

Next I further divide the post-Lehman era into post-Lehman (2008:M9—2010:M7) and post-AIB (2010:M8—2012:M9) and find that the negative feedback loops intensify following the nationalization of AIB and the Spanish downgrades. In the smaller post-Lehman subsample, nearly every variable is a statistically significant predictor of both Spanish and Irish bond yields. Th financial sectors are predicted by the most recent lags of sovereign yields and most financial lags. All variables Granger cause each other. The Granger causality suggests that a feedback loop has developed between these series. The meaningful correlations between

nearly everything and sovereign yield (as demonstrated by the many statistically significant predictors) suggests that these variables were largely in free fall. I do find a unit root present in this subset which further supports the severity of the sudden crash in prices over this period. I do not difference the variables in the VAR in order to keep as much information and variation in the data informing the Granger causality tests as possible. It appears again that the financial sectors are major contributors to each other's declines and that sovereign stress is further harming financial markets.

Following the nationalization of AIB and the downgrade of Spanish debt, prices enter a more tumultuous free-fall and the feedback loop intensifies. Each times series is predicted by all but one or so lags of other variables at a statistically significant levels. This means that the degree to which these series depend on each other and spur their future action appears to have intensified over this period. In this period I again find that each variable Granger causes each other as well. This is consistent with theory as recapitalization and nationalization of AIB in Ireland made the financial sector more dependent on the ability of the government to support it and increased the expenditure burden of the Irish republic. This is also predicted by theory for Spain. A debt downgrade enters my theoretical framework as a shock that increases the dispersiveness of the fiscal limit. Thus investors' perceptions of default risk grow even without Spanish debt growing further. The already strong dependence of Spanish financial institutions on the Spanish government via their large-scale holdings of Spanish debt means that the feedback arising from now higher yields post-downgrade is further intensified.

6 Conclusion

I reinforce recent evidence of a feedback loop developing between Eurozone sovereigns and their financial sectors following the onset of the global financial crisis and provide novel evidence of financial sector and sovereign contagion as well. Prior to the bankruptcy of Lehman Brothers in September 2008, Mody and Sandri (2011), Ejsing and Lemke (2009), and I find evidence that there was little causal interaction between Eurozone sovereign yields and private financial market activity. The period following the creation of the Eurozone brought about increased

financial integration among members and thus made their financial sectors more exposed to each others' booms and busts. The Eurozone also experienced convergence among sovereign yields until the onset of the crisis, after which a sharp divergence in yields emerges (Mody and Sandri, 2011). The increased financial integration made Spanish and Irish financial markets more capable of mutually reinforcing each others growth and decline. The large holdings of Spanish public debt by Spanish banks made them vulnerable to a negative feedback loop developing between Spain's government and financial sector. Expectations about nationalization and bailing out of the Irish financial sector (which were subsequently confirmed) led the Irish Republic and its financial sector to be at risk for entering a similar feedback loop to that of Spain.

Theory predicts that these feedback loops can be triggered multiple ways. Large exogenous shocks to financial sectors may spur declines and contagion across markets. This shrinks the tax-base available to each sovereign for servicing its debt, raising the risk of default. As default risk rises, as it did in Spain, this degraded bank capital which was substantially comprised of Spanish sovereign debt. In Ireland, large recapitalization measures (and investor anticipation of recapitalization) more closely linked Irish banks and the Irish Republic. Thus concerns about the effect of bailing out the financial sector and its consequences on the Irish budget spurred a feedback loop in Ireland as well as Spain. Realizing recapitalization in Ireland intensified this feedback loop more than its expectation on the part of investors. At nearly the same time as this event, Fitch and Moody's downgraded Spanish debt. This downgrade increased the dispersiveness of the distribution of the fiscal limit and made default more likely at every debt level, similarly intensifying feedback between Spain and its financial markets.

I use VAR to find that structurally significant changes took place in the relationships between Spanish and Irish financial and fiscal sectors. These changes took place after the Lehman bankruptcy in September 2008 and Ireland's nationalization and recapitalization of AIB and the downgrade of Spanish debt. Prior to Lehman, these series did not Granger cause each other and were best predicted by their own lags. Following the onset of the crisis, sovereign stress newly began to spillover into financial sectors and contagion developed between Spanish and Irish financial markets. This is evidenced by statistically significant lags and tests

for Granger causality. After the nationalization of AIB and the Spanish downgrade, the series were all predicted by nearly every lag of every variable and they all Granger caused each other. This suggests intensification of the negative feedback loops following these events.

Future research would benefit from looking at larger sample sizes. An ideal way of obtaining a larger sample size would be to increase the frequency of the data from monthly to weekly. Additionally, a larger sample of Eurozone countries would be worth analyzing as well. This could give us a better since of which financial markets are most closely linked and would better provide evidence for or against the development of feedback loops in crisis countries of Europe (Portugal, Italy, Ireland, Greece, and Spain). This research as it currently stands suggests that policymakers should be cautious about how exposed domestic financial sectors are to sovereign risk. Additionally, recapitalization poses a trade-off which policymakers aught to carefully investigate prior to providing capital injections as it may further deteriorate the economic climate.

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A Impulse Response Functions

A.1 Pre-Lehman Subsample

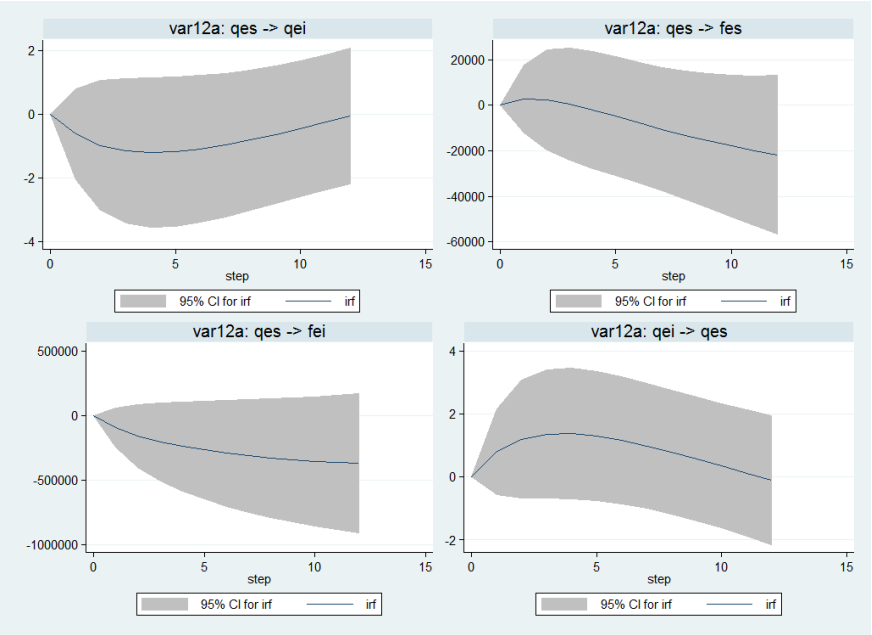

Figure 7: IRFs associated with VAR pre-Lehman subsample (2005:M1—2010:M8).

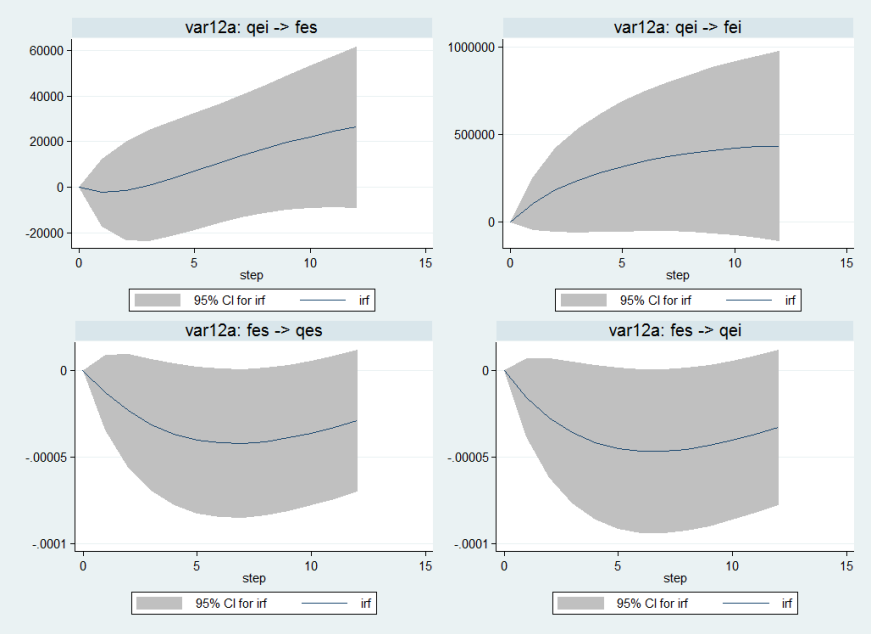

Figure 8: IRFs associated with VAR pre-Lehman subsample (2005:M1—2010:M8).

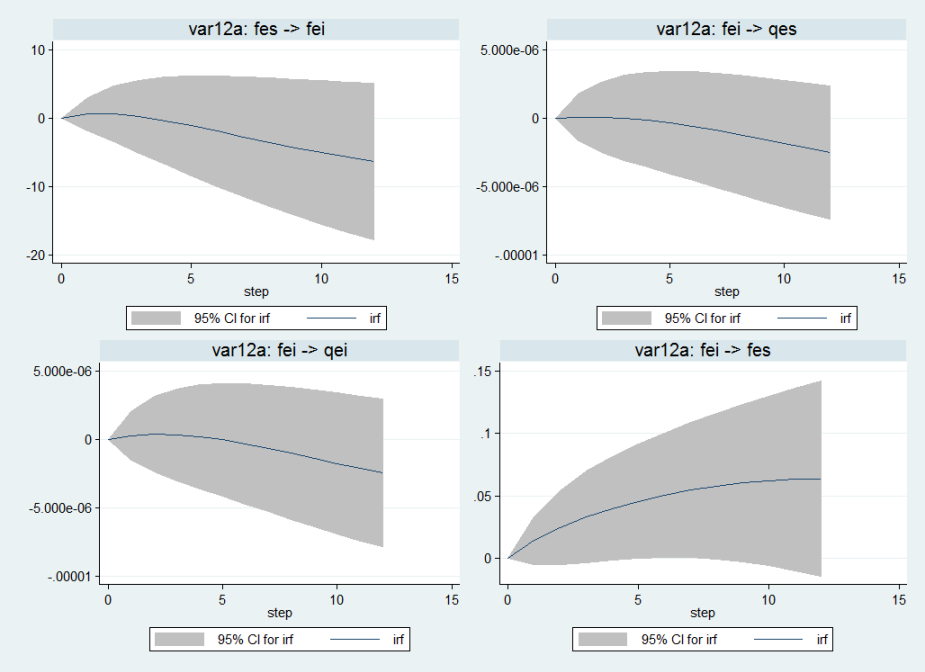

Figure 9: IRFs associated with VAR pre-Lehman subsample (2005:M1—2010:M8).

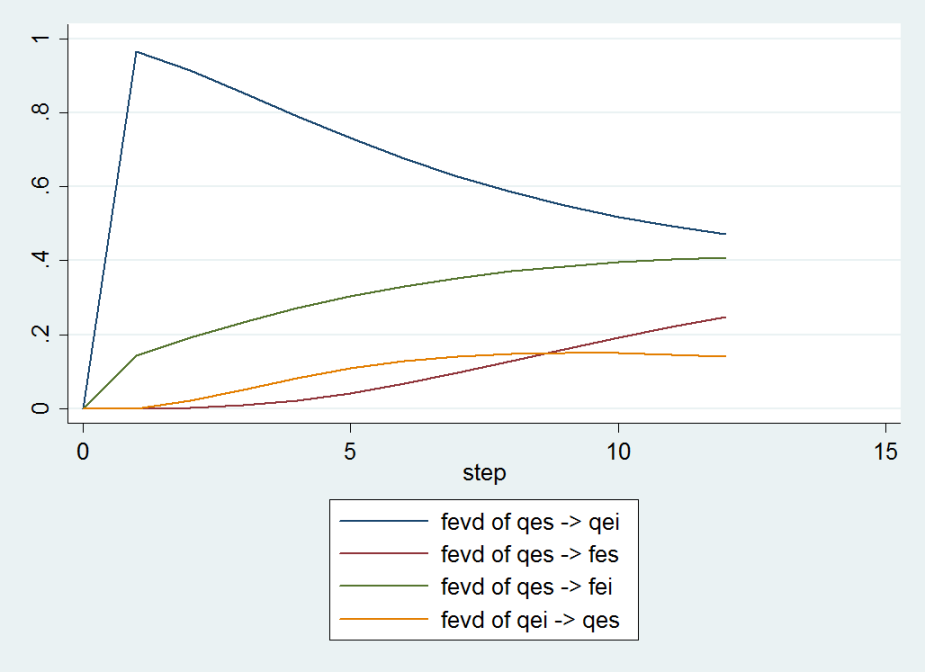

Figure 10: Forecast error variance decompositions associated with VAR pre-Lehman subsample (2005:M1—2010:M8).

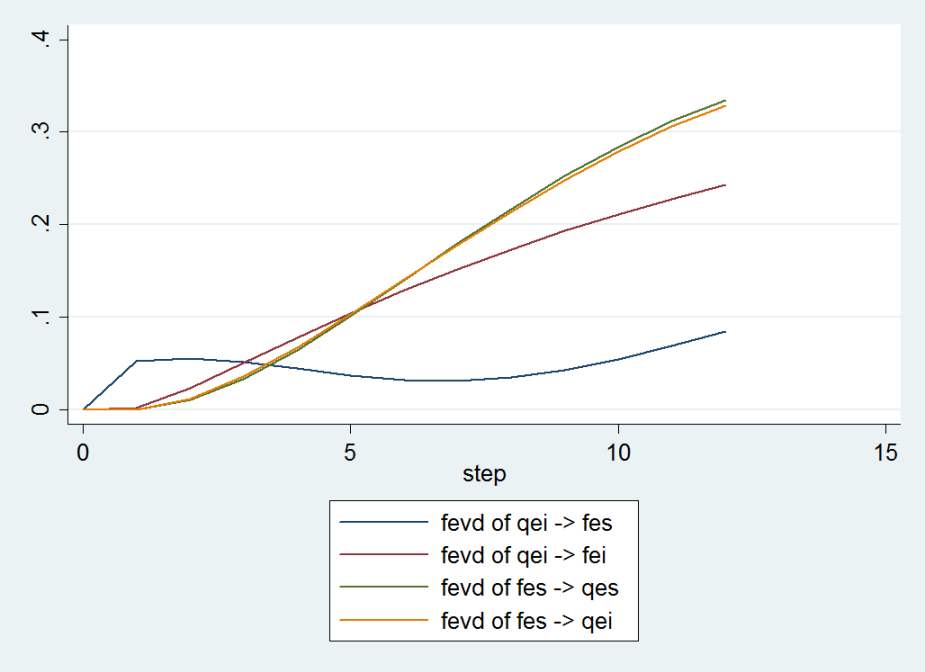

Figure 11: Forecast error variance decompositions associated with VAR pre-Lehman subsample (2005:M1—2010:M8).

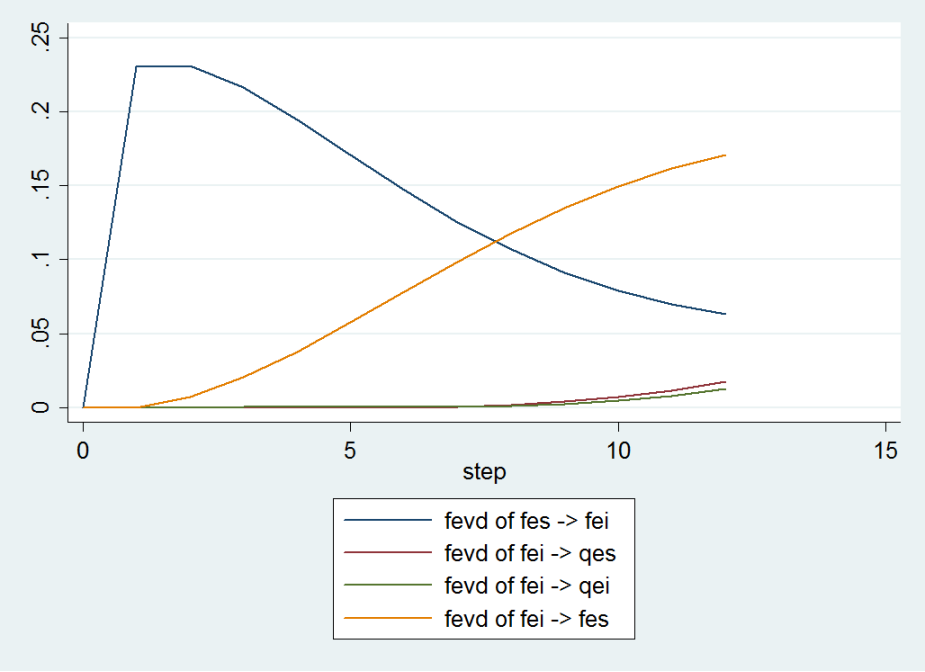

Figure 12: Forecast error variance decompositions associated with VAR pre-Lehman subsample (2005:M1—2010:M8).

A.2 Post-Lehman Subsample

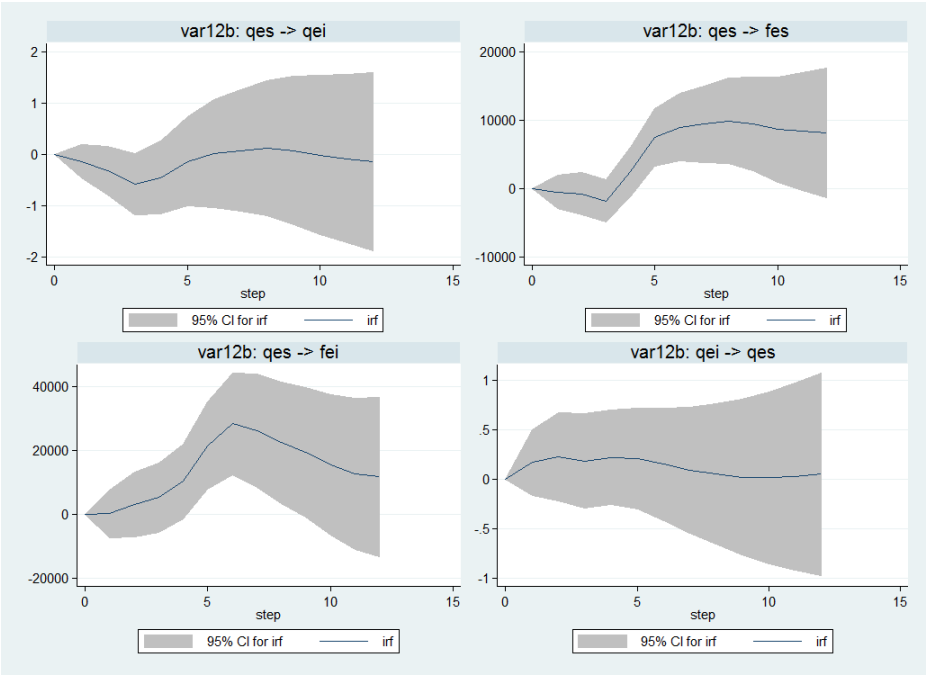

Figure 13: IRFs associated with VAR post-Lehman subsample (2010:M9—2012:M9).

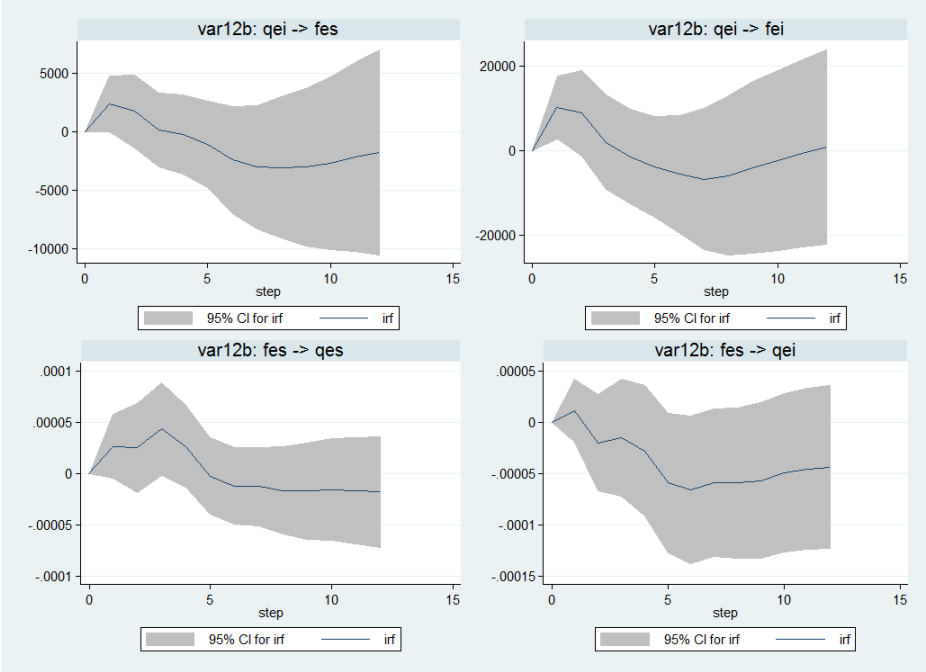

Figure 14: IRFs associated with VAR post-Lehman subsample (2010:M9—2012:M9).

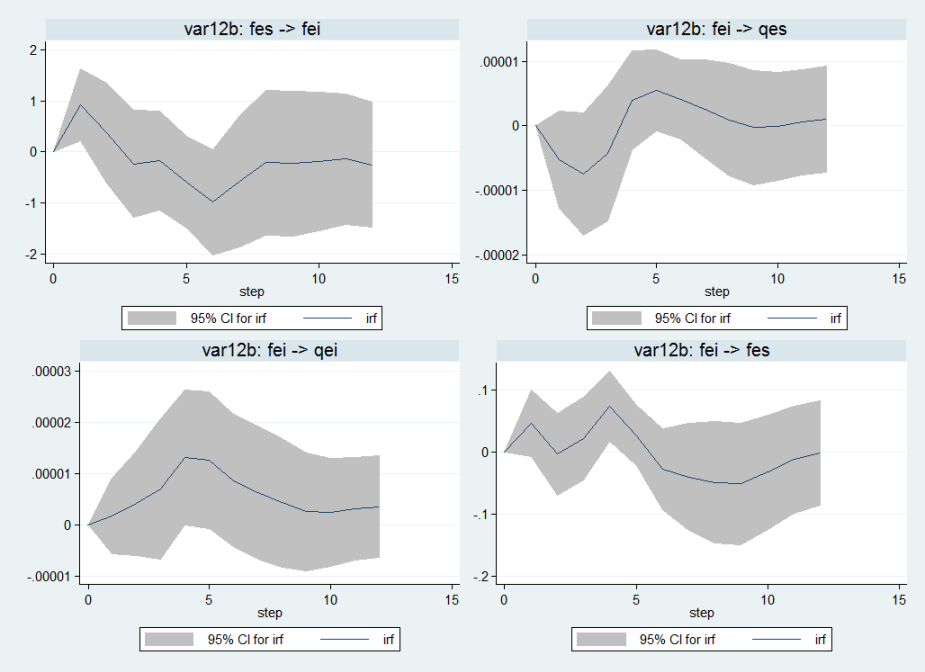

Figure 15: IRFs associated with VAR post-Lehman subsample (2010:M9—2012:M9).

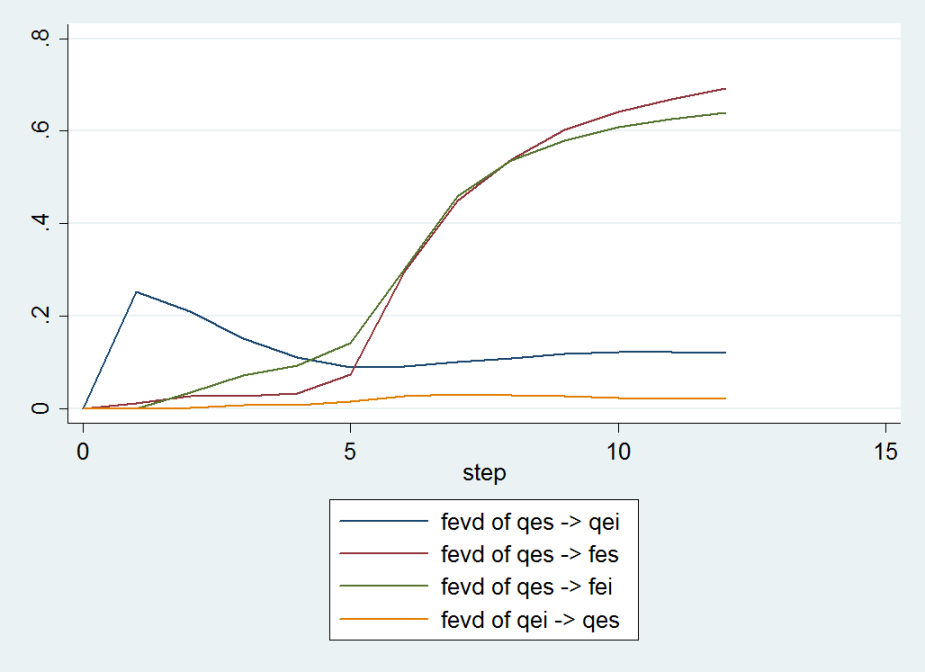

Figure 16: Forecast error variance decompositions associated with VAR post-Lehman subsample (2010:M9—2012:M9).

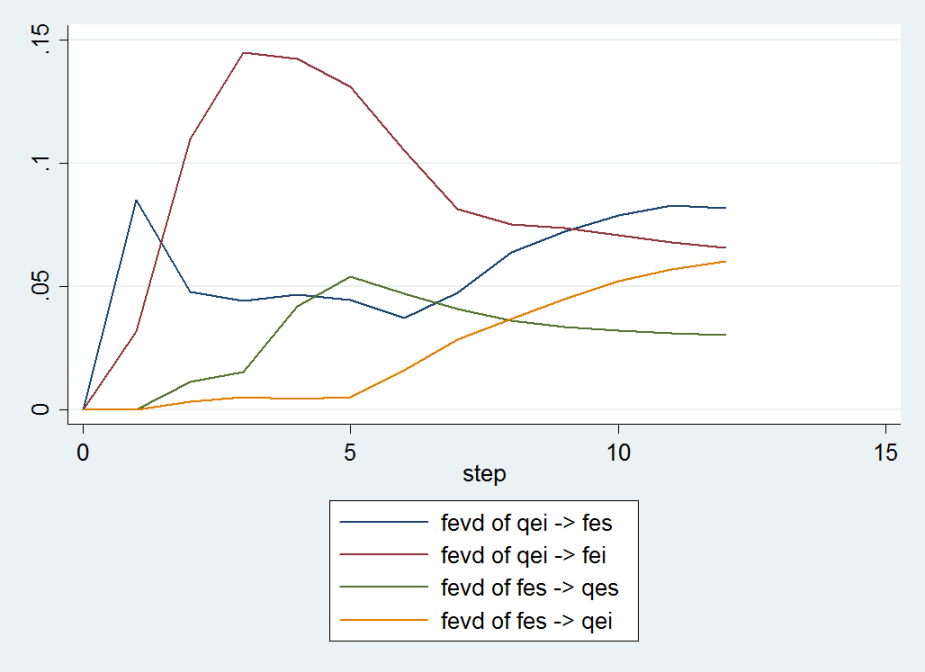

Figure 17: Forecast error variance decompositions associated with VAR post-Lehman subsample (2010:M9—2012:M9).

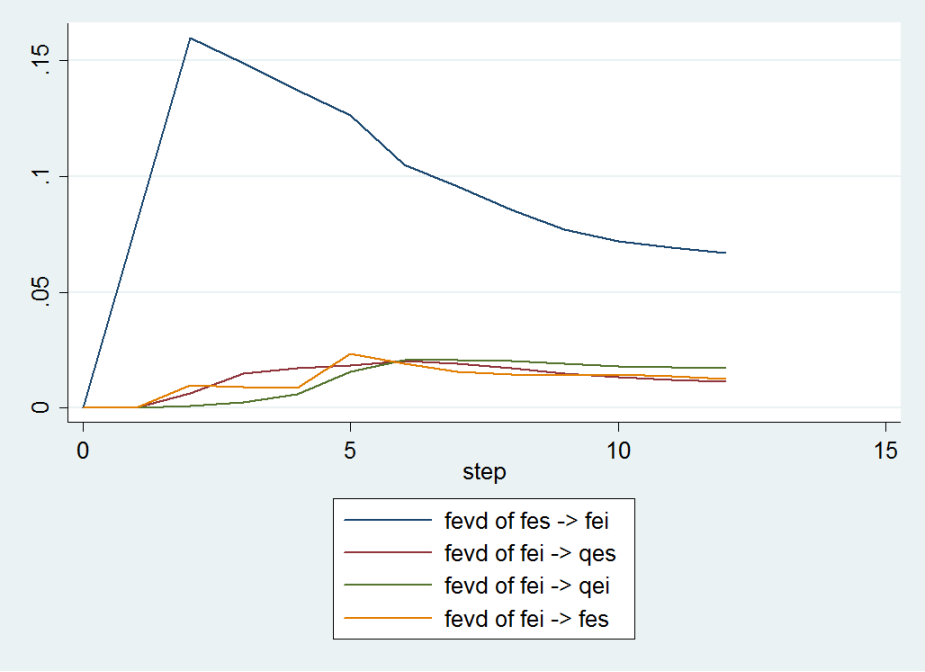

Figure 18: Forecast error variance decompositions associated with VAR post-Lehman subsample (2010:M9—2012:M9).

B Chow Tests

	$\mathbf{q_t^{es}}$	$\mathbf{q_t^{ei}}$	$\mathbf{F_t^{es}}$	$\mathbf{F_t^{ei}}$
Lehman	Yes	Yes	Yes	No
Test Stat	15.47	10.95	10.37	2.02
P-Value	0	0	0	0.085

Table 1: Testing pre-Lehman versus post-Lehman only.

	$\mathbf{q_t^{es}}$	$\mathbf{q_t^{ei}}$	$\mathbf{F_t^{es}}$	$\mathbf{F_t^{ei}}$
Lehman	Yes	Yes	Yes	Maybe
P-value	0	0	0	0.085
AIB	Yes	Yes	Yes	No
P-value	0	0	0	0.5859

Table 2: Testing pre-Lehman versus post-Lehman versus post-AIB.

C VAR Results

	$\mathbf{q_t^{es}}$	$\mathbf{q_t^{ei}}$	$\mathbf{F_t^{es}}$	$\mathbf{F_t^{ei}}$
$\mathbf{R^2}$	0.9171	0.92238	0.9181	0.9516
Sig. predicted by	NA	$q_{t-1}^{ei}*$	$F_{t-1}^{es} * **$	$F_{t-1}^{ei} * **$
Granger Causes	Nothing	Nothing	Nothing	Nothing

Table 3: Pre-Lehman subsample (2005:M1—2008:M8). P-values = 0.05*, 0.01*, 0.001***. 1 lag in VAR as determined by FPE.

	$\mathbf{q_t^{es}}$	$\mathbf{q_t^{ei}}$	$\mathbf{F_t^{es}}$	$\mathbf{F_t^{ei}}$
$\mathbf{R^2}$	0.922	0.9535	0.9397	0.9603
Sig. predicted by	q_{t-1}^{es}, F_{t-4}^{es}	q_{t-1}^{ei}, $F_{t-2,3,4}^{es}$	q_{t-4}^{es}, q_{t-2}^{ei}, $F_{t-1,2,3,4}^{es}$, $F_{t-2,3}^{ei}$	$q_{t-1,2}^{ei}$, $F_{t-1,2,4}^{es}$, F_{t-1}^{ei}
Granger Causes	F^{es}***, F^{ei}**	F^{ei}*	$q^{es} * **$, $F^{ei} * **$	F^{es}*

Table 4: Post-Lehman (large) subsample (2008:M9—2012:M9). P-values = 0.05*, 0.01*, 0.001***. 4 lags in VAR as determined by FPE.

	$\mathbf{q_t^{es}}$	$\mathbf{q_t^{ei}}$	$\mathbf{F_t^{es}}$	$\mathbf{F_t^{ei}}$
$\mathbf{R^2}$	0.9359	0.999	0.9823	0.9955
Sig. predicted by	All except q_{t-3}^{es},$q_{t-4,5}^{ei}$, $F_{t-1,2}^{es}$, $F_{t-1,4}^{ei}$	All except q_{t-5}^{es}, q_{t-4}^{ei}	q_{t-1}^{es}, q_{t-1}^{ei}, $F_{t-1,5}^{es}$, $F_{t-1,4,5}^{ei}$	$q_{t-1,2,4,5}^{es}$, $q_{t-1,2,5}^{ei}$, $F_{t-1,2,3}^{es}$, $F_{t-1,2,3,4,5}^{ei}$
Granger Causes	Everything else***	Everything else***	Everything else***	Everything else***

Table 5: Post-Lehman (small) subsample (2008:M9—2010:M7). P-values = 0.05*, 0.01*, 0.001***. 5 lags in VAR as determined by FPE

	$\mathbf{q_t^{es}}$	$\mathbf{q_t^{ei}}$	$\mathbf{F_t^{es}}$	$\mathbf{F_t^{ei}}$
$\mathbf{R^2}$	0.99	0.989	0.9977	0.9976
Sig. predicted by	Almost everything	Almost everything	Almost everything	Almost everything
Granger Causes	Everything else***	Everything else***	Everything else***	Everything else***

Table 6: Post-AIB subsample (2010:M8—2012:M9). P-values = 0.05*, 0.01*, 0.001***. 6 lags in VAR as determined by FPE.