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ABSTRACT

What causes banking crises? An empirical investigation*

We add the Bernanke-Gertler-Gilchrist model to a modified version of the Smets-Wouters model of the US in order to explore the causes of the banking crisis. We test the model against the data on HP-detrended data and reestimate it by indirect inference; the resulting model passes the Wald test on output, inflation and interest rates. We then extract the model's implied residuals on US unfiltered data since 1984 to replicate how the model predicts the crisis. The main banking shock tracks the unfolding `sub-prime' shock, which appears to have been authored mainly by US government intervention. This shock worsens the banking crisis but `traditional' shocks explain the bulk of the crisis; the non-stationarity of the productivity shock plays a key role. Crises occur when there is a `run' of bad shocks; based on this sample they occur on average once every 40 years and when they occur around half are accompanied by financial crisis. Financial shocks on their own, even when extreme, do not cause crises --- provided the government acts swiftly to counteract such a shock as happened in this sample.

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1   Introduction

Since the banking crisis macroeconomic models have come under severe criticism, not merely in the popular media but also among economists and policymakers, for failing to predict the crisis. While clearly the models deny that it is possible to predict crises, so that this criticism is ill-founded, nevertheless they did fail — much more seriously — to predict the possibility of crisis because they contain no mechanisms that could produce it. Thus they had complete asset markets and no banking sector, so that *a fortiori* no banking crisis could occur. Furthermore they embodied only stationary shocks so that permanent shocks to the level of trend output, such as appear to characterise crisis episodes, were not examined; true, in the background there was possibly a non-stationary trend in productivity (typically removed by filtering from the model data) but there was not much focus on this in practice. A further issue concerns their ability to fit the facts; economists such as Heckman have attacked the lack of empirical content in macro models, implying that it is hardly surprising they could give little guidance to policy in the crisis.

In this paper we address these issues, building on recent work: we integrate a banking sector model into a widely-used DSGE model; we test the model against the data and re-estimate it to enable it to fit if possible; and we apply it to unfiltered data so that nonstationary shocks are included. Finally we use it to give an account of what produced this banking crisis and relate this finding to the current policy debate.

Since the crisis, much work has been done to incorporate a banking sector into DSGE models. The banking models involve a friction in the intermediation process so that the interest margin required reflects the risk of loan default. This risk varies with the state of the economy. The exact transmission between the state and the risk-premium differs across the various banking models that have been proposed but that of Bernanke, Gertler and Gilchrist (1999) has been designed to capture many of the common features of these models; it is their set-up that we therefore use here as a representative one. In it, the IS curve now includes a variable risk-premium which is related to the economic state. We do not aim to build a new DSGE model but rather, using the indirect inference testing method, to assess the importance and necessity of the inclusion of a banking sector. We examine the relative empirical performance of models with and without a banking transmission and to establish within models with this transmission how far the banking element contributes to the overall explanation of crisis episodes.

We use the method of indirect inference in preference to Bayesian or Maximum Likelihood methods of testing and estimation because we have found in recent work (Le et al., 2012a) that the Wald test in indirect inference has considerably greater power than the equivalent tests available with these other methods in testing the whole model against the data; this also means that it is proof against the 'weak identification' that has recently concerned modellers, e.g. Canova and Sala (2009). In fact we have found (Le et al., 2012b) that the Smets and Wouters (SW) model we use here appears to be identified according to a numerical test based on indirect inference. Thus we use the Wald test to allow the data to reject potential models as a whole and we then use a powerful Simulated Annealing algorithm to search over the model's permissible parameter range for any set that could achieve non-rejection.

An important part of the explanation for 'crisis' episodes lies in the permanence of crisis shocks; thus after the Great Depression US output failed to catch up with its previous level for a decade, and similarly after the oil crisis of the mid-1970s the level of output was permanently reduced so that initial estimates of 'excess capacity' based on the previous output trend had to be revised downwards sharply. In the latest Great Recession it appears that much the same is happening; for example excess capacity in the UK is now officially estimated to be around 3%, whereas if the previous output trend level prevailed it would be around 13%. Thus the trend level seems to take

a permanent hit in these crisis episodes. Furthermore the same appears to be true in reverse for periods of strong growth, such as the US in the late 90s and early 2000s; the output trend in these periods gets shifted upwards permanently. This suggests that the productivity and perhaps other shocks hitting the economy are non-stationary. Hence here our aim is to model the economy with and without banking under potentially nonstationary shocks.

As the banking crisis originated and was at its most damaging in the US, we focus our efforts on models of the US economy. Our strategy is to take a well-known and empirically relatively successful model of the US, that of Smets and Wouters (2007, SW), and add to it the banking model due to Bernanke, Gertler and Gilchrist (1999, BGG). Variants of the combination of SW and BGG have been used in recent papers by Christiano, Motto & Rostagno (2010) for the US and Eurozone separately; Gilchrist et al. (2009) for the US alone and Fahr et al (2011) for the Eurozone alone. They find that shocks that come from the financial sector have an important role in explaining macroeconomic fluctuations. All these authors use the Bayesian approach to estimating the model parameters.

What distinguishes our work from these papers is two main departures noted above. First, we introduce non-stationary shocks, which we argue give us insight into the nature of crises. Second, we test the overall models we use against the data by indirect inference. If, as we find, the original (usually Bayesian) parameters do not pass the test, we search for parameters that get closest to the data according to this test; and we only finally use a parameter set that passes the test. We think this empirical hurdle is necessary in this particular area because while it is possible to construct models that generate large financial accelerator effects by suitable choice of priors, the parameter sets that pass this test of overall fit to the data do not give anywhere near such large effects; it seems they cannot be found in the data.

Thus we build on the work of Le et al. (2011) in finding a version of the SW model that passes quite stringent tests of overall model fit to the data, and use this version as the starting point for this exercise.

The paper is organised as follows. We begin in section 2 by giving a brief account of the modified SW model and the BGG banking sector model. In section 3 we examine the results of empirical tests of the SW model, both with and without the addition of the BGG banking sector model; we re-estimate these versions of the model to obtain versions that get closest to the data; this is done on stationary data, for which testing and estimation methods are fully developed[1]. In section 4, we apply the model as re-estimated to the original unfiltered data and consider what light it sheds on the causes of this banking crisis as well as of crises and banking crises in general. Section 5 concludes and draws out some implications for policy.

2   The SW and BGG models

2.1   The SW model of the US economy

One of the main issues that emerged from the first type of calibrated DSGE model, the real business cycle (RBC) model, was its failure to capture the stylised features of the labour market observed in actual data. Employment was found to be not nearly volatile enough in the RBC model compared with observed data, and the correlation between real wages and output was found to be much too high (see, for example, King, Plosser and Rebelo, 1988). The clear implication is that in the RBC model real wages are too flexible. The Smets-Wouters model (2007) marks a major development

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[1]The extension of these testing and estimation methods to non-stationary data is discussed in Davidson et al. (2010). Work developing these methods is ongoing.

in macroeconometric modelling based on DSGE models. Its main aim is to construct and estimate a DSGE model for the United States in which prices and wages, and hence real wages, are sticky due to nominal and real frictions arising from Calvo pricing in both the goods and labour markets, and to examine the consequent effects of monetary policy which is set through a Taylor rule. It may be said, therefore, to be a New Keynesian model. SW combine both calibration and Bayesian estimation methods and use data for the period 1966Q1–2004Q4.

Unusually, the SW model contains a full range of structural shocks. In the EU version — Smets and Wouters (2003) — on which the US version is based, there are ten structural shocks. These are reduced to seven in the US version: for total factor productivity, the risk premium, investment-specific technology, the wage mark-up, the price mark-up, exogenous spending and monetary policy. These shocks are generally assumed to have an autoregressive structure. The model finds that aggregate demand has hump-shaped responses to nominal and real shocks. A second difference from the EU version is that in the US version the Dixit-Stiglitz aggregator in the goods and labour markets is replaced by the aggregator developed by Kimball (1995) where the demand elasticity of differentiated goods and labour depends on their relative price. A third difference is that, in order to use the original data without having to detrend them, the US model features a deterministic growth rate driven by labour-augmenting technological progress.

Smets and Wouters made various tests of their model. Subsequently Del Negro, Schorfheide, Smets and Wouters (2007, DSSW) further examined it by considering the extent to which its restrictions help to explain the data. Estimating the SW model using Bayesian methods, they approximate it by a VAR in vector error-correction form and compare this with an unrestricted VAR fitted to actual data that ignores cross-equation restrictions. They introduce a hyperparameter λ to measure the relative weights of the two VARs. $\widehat{\lambda}$ is chosen to maximise the marginal likelihood of the combined models. DSSW find that this estimate of λ is a reasonable distance away from $\lambda = 0$, its value when the restrictions are ignored, but is also far away from $\lambda = \infty$, its value when the SW restrictions are correct.

It should be noted that none of these exercises in evaluating the SW model were a test of specification in the classical sense. Le et al. (2011) proposed such a test, a Wald test based on indirect inference which compares the model's VAR representation with the VAR coming from the data, and showed that over the full post-war sample the original SW New Keynesian (NK) model was rejected. In addition, they examined an alternative version in which prices and wages were fully flexible but there was a simple one-period information delay for labour suppliers. This 'New Classical (NC)' version was also rejected. They also proposed a hybrid model that merged the NK and NC models by assuming that wage and price setters find themselves supplying labour and intermediate output partly in a competitive market with price/wage flexibility, and partly in a market with imperfect competition. They assumed that the size of each sector depended on the facts of competition and did not vary in the sample but they allowed the degree of imperfect competition to differ between labour and product markets. The basic idea was that economies consist of product sectors where rigidity prevails and others where prices are flexible, reflecting the degree of competition in these sectors. Similarly with labour markets; some are much more competitive than others. An economy may be more or less dominated by competition and therefore more or less flexible in its wage/price-setting. The price and wage setting equations in the hybrid model are assumed to be a weighted average of the corresponding NK and NC equations. It turned out that this combined model got much closer to the data for the full sample, when the rigidity was quite limited.

Essentially, the NK model generated too little nominal variation while the NC model delivered too much. However the hybrid model was able to reproduce the variances of the data; and it is this key feature that enables it to match the data overall more closely. Nevertheless, it failed to

match certain features of the data, notably the behaviour of interest rates in relation to other major macro variables. In view of this failure, it seemed that the problem could lie in the specification of monetary policy, and in particular the use of one monetary regime for the whole sample from the 1950s to the 2000s. They therefore tested for structural change during this period and duly found parameter breaks in two places: 1965 and 1984. These were natural places to find such breaks because of changes that occurred in the monetary regime. The earlier break is associated with the emergence of serious inflation for the first time; the later break with the shift towards interest rate setting that followed from the adoption of (implicit) inflation targeting.

Le et al. (2011) found that for the third and last sub-period (1984Q3–2004Q2), a version of the model very close to SW's original NK model was not rejected by the Wald test on the main macro variables' behaviour. Accordingly it is this version of the model on a sample from 1984 that we use here. Being very close to the original version, with a high degree of nominal rigidity both in labour and product markets, it behaves very like a standard New Keynesian model. In it, because capacity utilisation is fairly flexible, output is strongly affected by shocks to demand and this in turn — via the Phillips Curve — moves inflation and then — via the Taylor Rule — interest rates. Supply shocks can affect demand directly (e.g. productivity shocks change the return on capital and so affect investment) and also play a role as 'cost-push' inflation shocks (e.g. price/wage mark-up shocks). Persistent shocks to demand raise Tobin's Q persistently and produce an 'investment boom' which, via demand effects, reinforces itself. Thus the model acts as a 'multiplier/accelerator' of shocks both on the demand and the supply side.

2.2 The BGG model of the banking sector together with the SW model

The BGG financial sector produces certain changes in the model of Smets and Wouters (2007) in the form used here as modified by Le et al. (2011) but much remains unchanged.

The household sector is unchanged. Households maximise a utility function by choosing goods and labour over an infinite life. They exhibit some consumption habit behaviour. A part of labour is supplied to an imperfect labour market where households act as price-setters and the rest is supplied to a perfectly competitive labour market. This results in a hybrid wage equation, where the aggregate wage is the weighted average of wages obtained in the perfect and imperfect labour markets. Thus the aggregate wage equation and consumption Euler equation remain unchanged.

In the government sector both monetary and fiscal policy also remain the same.

The BGG model incorporation divides the production side into three distinct participants: as previously, retailers and intermediate goods producers (now called entrepreneurs for a reason described later) and in addition, capital producers. Retailers function in the same way as before, operating in perfect competition to produce final goods by aggregating differentiated intermediate products using the Dixit-Stiglitz technology. With the assumption that retail output is made up of a fixed proportion of intermediate goods in an imperfectly competitive market and intermediate goods sold competitively, the aggregate price is a weighted average of prices received in the two types of market. As a result, the aggregate price equation is unchanged. Capital producers operate in a competitive market and take prices as given. They buy final consumption goods and transform them into capital to be sold on to entrepreneurs.

The difference in BGG lies in the nature of entrepreneurs. They still produce intermediate goods, but now they do not rent capital from households (who do not buy capital but only buy bonds or deposits) but must buy it from capital producers and in order to buy this capital they have to borrow from a bank which converts household savings into lending. On their production side, entrepreneurs face the same situation as in Le et al. (2011). They hire labour from households for wages that are partly set in monopolistic, partly in competitive labour markets; and they buy capital

from capital producers at prices of goods similarly set in a mixture of monopolistic and competitive goods markets. Thus the production function, the labour demand and real marginal cost equations are unchanged. It is on their financing side that there are major changes. Entrepreneurs buy capital using their own net worth, pledged against loans from the bank, which thus intermediates household savings deposited with it at the risk-free rate of return. The net worth of entrepreneurs is kept below the demand for capital by a fixed death rate of these firms $(1-\theta)$; the stock of firms is kept constant by an equal birth rate of new firms. Entrepreneurial net worth therefore is given by the past net worth of surviving firms plus their total return on capital minus the expected return (which is paid out in borrowing costs to the bank) on the externally financed part of their capital stock — equivalent to

$$n_t = \theta n_{t-1} + \frac{K}{N}(cy_t - E_{t-1}cy_t) + E_{t-1}cy_t + enw_t \tag{1}$$

where $\frac{K}{N}$ is the steady state ratio of capital expenditures to entrepreneurial net worth and θ is the survival rate of entrepreneurs. Those who die will consume their net worth, so that entrepreneurial consumption is equal to $(1-\theta)$ times net worth. In logs this implies that this consumption varies in proportion to net worth so that:

$$c_t^e = n_t \tag{2}$$

In order to borrow, entrepreneurs have to sign a debt contract prior to the realisation of idiosyncratic shocks on the return to capital: they choose their total capital and the associated borrowing before the shock realisation. The optimal debt contract takes a state-contigent form to ensure that the expected gross return on the bank's lending is equal to the bank opportunity cost of lending. When the idiosyncratic shock hits, there is a critical threshold for it such that for shock values above the threshold, the entrepreneur repays the loan and keeps the surplus, while for values below it, he would default, with the bank keeping whatever is available. From the first order conditions of the optimal contract, the external finance premium is equated with the expected marginal product of capital which under constant returns to scale is exogenous to the individual firm (and given by the exogenous technology parameter); hence the capital stock of each entrepreneur is proportional to his net worth, with this proportion increasing as the expected marginal product rises, driving up the external finance premium. Thus the external finance premium increases with the share of the firm's capital investment that is financed by borrowing:

$$E_t cy_{t+1} - (r_t - E_t\pi_{t+1}) = \chi(qq_t + k_t - n_t) + epr_t \tag{3}$$

where the coefficient $\chi > 0$ measures the elasticity of the premium with respect to leverage. Entrepreneurs leverage up to the point where the expected return on capital equals the cost of borrowing from financial intermediaries. The external finance premium also depends on an exogenous premium shock, epr_t. This can be thought of as a shock to the supply of credit: that is, a change in the efficiency of the financial intermediation process, or a shock to the financial sector that alters the premium beyond what is dictated by the current economic and policy conditions.

Entrepreneurs buy capital at price qq_t in period t and uses it in $(t+1)$ production. At $(t+1)$ entrepreneurs receive the marginal product of capital rk_{t+1} and the ex-post aggregate return to capital is cy_{t+1}. The capital arbitrage equation (Tobin's Q equation) becomes:

$$qq_t = \frac{1-\delta}{1-\delta+R_*^K}E_t qq_{t+1} + \frac{R_*^K}{1-\delta+R_*^K}E_t rk_{t+1} - E_t cy_{t+1} \tag{4}$$

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The resulting investment by entrepreneurs is therefore reacting to a Q-ratio that includes the effect of the risk-premium. There are as before investment adjustment costs. Thus, the investment Euler equation and capital accumulation equations are unchanged from Le et al. (2011). The output market-clearing condition becomes:

$$y_t = \frac{C}{Y}c_t + \frac{I}{Y}inn_t + R_*^K k_y \frac{1-\psi}{\psi} rk_t + c_y^e c_t^e + eg_t \tag{5}$$

3 Testing the SW model with and without the BGG model

3.1 The method of indirect inference

We evaluate the models' capacity in fitting the data using the method of Indirect Inference originally proposed in Minford, Theodoridis and Meenagh (2009) and subsequently with a number of refinements by Le et al. (2011) who evaluate the method using Monte Carlo experiments. The approach employs an auxiliary model that is completely independent of the theoretical one to produce a description of the data against which the performance of the theory is evaluated indirectly. Such a description can be summarised either by the estimated parameters of the auxiliary model or by functions of these; we will call these the descriptors of the data. While these are treated as the 'reality', the theoretical model being evaluated is simulated to find its implied values for them.

Indirect inference has been widely used in the estimation of structural models (e.g., Smith, 1993, Gregory and Smith, 1991, 1993, Gourieroux et al., 1993, Gourieroux and Monfort, 1995 and Canova, 2005). Here we make a further use of indirect inference, to evaluate an already estimated or calibrated structural model. The common element is the use of an auxiliary time series model. In estimation the parameters of the structural model are chosen such that when this model is simulated it generates estimates of the auxiliary model similar to those obtained from the actual data. The optimal choices of parameters for the structural model are those that minimise the distance between a given function of the two sets of estimated coefficients of the auxiliary model. Common choices of this function are the actual coefficients, the scores or the impulse response functions. In model evaluation the parameters of the structural model are taken as given. The aim is to compare the performance of the auxiliary model estimated on simulated data derived from the given estimates of a structural model—which is taken as a true model of the economy, the null hypothesis — with the performance of the auxiliary model when estimated from the actual data. If the structural model is correct then its predictions about the impulse responses, moments and time series properties of the data should statistically match those based on the actual data. The comparison is based on the distributions of the two sets of parameter estimates of the auxiliary model, or of functions of these estimates.

The testing procedure thus involves first constructing the errors implied by the previously estimated/calibrated structural model and the data. These are called the structural errors and are backed out directly from the equations and the data[2]. These errors are then bootstrapped and used to generate for each bootstrap new data based on the structural model. An auxiliary time series model is then fitted to each set of data and the sampling distribution of the coefficients of the auxiliary time series model is obtained from these estimates of the auxiliary model. A Wald statistic is computed to determine whether functions of the parameters of the time series model estimated on the actual data lie in some confidence interval implied by this sampling distribution.

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[2]Some equations may involve calculation of expectations. The method we use here is the robust instrumental variables estimation suggested by McCallum (1976) and Wickens (1982): we set the lagged endogenous data as instruments and calculate the fitted values from a VAR(1)—this also being the auxiliary model chosen in what follows.

Following Minford, Theodoridis and Meenagh (2009) we take a VAR(1) for the three macro variables (interest rate, output gap and inflation) as the appropriate auxiliary model and treat as the descriptors of the data the VAR coefficients and the variances of these variables. The Wald statistic is computed from these[3]. Thus effectively we are testing whether the observed dynamics and volatility of the chosen variables are explained by the simulated joint distribution of these at a given confidence level. The Wald statistic is given by:

$$(\Phi - \overline{\Phi})' \sum\nolimits_{(\Phi\Phi)}^{-1} (\Phi - \overline{\Phi}) \tag{6}$$

where Φ is the vector of VAR estimates of the chosen descriptors yielded in each simulation, with $\overline{\Phi}$ and $\sum_{(\Phi\Phi)}$ representing the corresponding sample means and variance-covariance matrix of these calculated across simulations, respectively.

The joint distribution of the Φ is obtained by bootstrapping the innovations implied by the data and the theoretical model; it is therefore an estimate of the small sample distribution[4]. Such a distribution is generally more accurate for small samples than the asymptotic distribution; it is also shown to be consistent by Le et al. (2011) given that the Wald statistic is 'asymptotically pivotal'; they also showed it had quite good accuracy in small sample Monte Carlo experiments[5].

This testing procedure is applied to a set of (structural) parameters put forward as the true ones (H_0, the null hypothesis); they can be derived from calibration, estimation, or both. However derived, the test then asks: could these coefficients within this model structure be the true (numerical) model generating the data? Of course only one true model with one set of coefficients is possible. Nevertheless we may have chosen coefficients that are not exactly right numerically, so that the same model with other coefficient values could be correct. Only when we have examined the model with all coefficient values that are feasible within the model theory will we have properly tested it. For this reason we later extend our procedure by a further search algorithm, in which we seek other coefficient sets that could do better in the test.

Thus we calculate the minimum-value full Wald statistic for each period using a powerful algorithm based on Simulated Annealing (SA) in which search takes place over a wide range around the initial values, with optimising search accompanied by random jumps around the space[6]. In effect this is Indirect Inference estimation of the model; however here this estimation is being done to find whether the model can be rejected *in itself* and not for the sake of finding the most satisfactory estimates of the model parameters. Nevertheless of course the method does this latter task as a by-product so that we can use the resulting unrejected model as representing the best available

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[3]Note that the VAR impulse response functions, the co-variances, as well as the auto/cross correlations of the left-hand-side variables will all be implicitly examined when the VAR coefficient matrix is considered, since the former are functions of the latter.

[4]The bootstraps in our tests are all drawn as time vectors so contemporaneous correlations between the innovations are preserved.

[5]Specifically, they found that the bias due to bootstrapping was just over 2% at the 95% confidence level and 0.6% at the 99% level. They suggested possible further refinements in the bootstrapping procedure which could increase the accuracy further; however, we do not feel it necessary to pursue these here.

[6]We use a Simulated Annealing algorithm due to Ingber (1996). This mimics the behaviour of the steel cooling process in which steel is cooled, with a degree of reheating at randomly chosen moments in the cooling process—this ensuring that the defects are minimised globally. Similarly the algorithm searches in the chosen range and as points that improve the objective are found it also accepts points that do not improve the objective. This helps to stop the algorithm being caught in local minima. We find this algorithm improves substantially here on a standard optimisation algorithm. Our method used our standard testing method: we take a set of model parameters (excluding error processes), extract the resulting residuals from the data using the LIML method, find their implied autoregressive coefficients ($AR(1)$ here) and then bootstrap the implied innovations with this full set of parameters to find the implied Wald value. This is then minimised by the SA algorithm.

estimated version. The merit of this extended procedure is that we are comparing the best possible versions of each model type when finally doing our comparison of model compatibility with the data.

3.2 Tests of the models

Our starting point for the inclusion of banking in the SW model is that it would be useful to include it provided that there is no worsening in the model's empirical performance. We have accordingly tested the model over two main sample periods. One is the majority of the post-war period but ending in 2004 before the banking crisis struck. The other starts in the 1984 and includes the banking crisis period, ending in 2009.

What we find is fairly encouraging for the model cum banking sector; we can find a numerical version for both periods that fails to be rejected by the sample data on the three key macro variables output, inflation and interest rates; we show these results in full in Tables 2 and 1 for the 1984-2009 period; these are the estimates we use in what follows. For a wider set of variables including consumption or investment, the model is severely rejected, as generally found with such models.

The addition of the external premium endogenises an element in the Q equation that previously simply entered that equation's error term: now this is made dependent on the lagged state instead of merely reacting to its own past. What we find is that adding this endogenisation somewhat alters the other estimated coefficients; in particular it reduces the estimated share of imperfect competition in both labour and product markets.

Weighted Model for the period of 1984.03-2009.02 (Y, π, R)				
	With Financial Accelerator		Without Financial Accelerator	
Coefs	Start Values	Simulated Annealing Values	Start Values	Simulated Annealing Values
ρ_g	0.5856	0.6100	0.6952	0.6537
ρ_{g-prod}	0.0132	0.0061	-0.0792	-0.0562
ρ_{pref}	-0.0329	0.0074	-0.0479	-0.0687
ρ_{invest}	0.4713	0.3380	0.2704	0.2667
ρ_{mon}	0.0926	0.0867	0.0926	0.1361
ρ_{prod}	0.8816	0.7795	0.8816	0.7923
$\rho_{priec-markup}$	0.2743	0.2532	0.2947	0.3176
$\rho_{wage-markup}$	0.1808	0.4315	0.2163	0.2905
$\rho_{labsupply}$	0.8430	0.8414	0.8429	0.8007
$\mu_{price-markup}$	-0.4738	-0.5597	-0.5139	-0.5548
$\mu_{wage-markup}$	-0.1202	-0.3013	-0.1485	-0.2237
$\mu_{labsupply}$	-0.1387	-0.1554	-0.1394	-0.2652
$\rho_{premium}$	0.8417	0.8334		
$\rho_{networth}$	0.4690	0.3941		

Table 1: Shock Processes (1984Q3-2009Q2)

	With Financial Accelerator		Without Financial Accelerator	
Coefs	Start Values	Simulated Annealing Values	Start Values	Simulated Annealing Values
φ	5.74	6.8927	5.74	5.2529
σ_c	1.38	1.2595	1.38	1.5700
λ	0.71	0.7626	0.71	0.8165
ξ_w	0.70	0.5469	0.70	0.6107
σ_L	1.83	2.3007	1.83	1.8375
ξ_p	0.66	0.913	0.66	0.7540
ι_w	0.58	0.5358	0.58	0.6430
ι_p	0.24	0.3258	0.24	0.2266
ψ	0.54	0.2970	0.54	0.4591
Φ	1.60	1.5998	1.60	1.8124
r_p	2.50	3.3254	2.50	2.2737
ρ	0.60	0.7697	0.60	0.6651
r_y	0.08	0.0966	0.08	0.0680
$r_{\Delta y}$	0.22	0.2129	0.22	0.2432
$\bar{\pi}$	0.78	0.7800	0.78	0.7800
$100(\beta^{-1} - 1)$	0.16	0.1600	0.16	0.1600
$\overline{L}$	0.53	0.5300	0.53	0.5300
$\bar{\gamma}$	0.43	0.4300	0.43	0.4300
α	0.19	0.1786	0.19	0.1637
ω^w	0.80	0.3909	0.80	0.9447
ω^r	0.80	0.1053	0.80	0.7380
χ	0.07	0.0425		
WALD	288.3178	19.8524	117.1084	20.0596
T-stat	12.8509	1.1056	8.196	1.1582

Weighted Model for the period of 1984Q3-2009Q2 (Y, π, R)

Table 2: Coefficient Estimates (1984Q3-2009Q2)

The conclusion that comes from the comparison is that while one can model the economy without the banking sector, there is also no empirical loss in including banking. Since we would wish to do so for reasons of theoretical completeness unless it failed empirically, this suggests we should do so. The resulting model with the financial accelerator, as estimated by Simulated Annealing for the 1984-2009 period, has impulse response functions for key variables shown in Figure 1. Given that it passes the Wald test, it generates 95% confidence limits for implied VAR responses that easily encompass the data-based VAR responses to key shocks; in Figure 2 we show the monetary shock VAR IRFs and the model 95% bounds as an example.
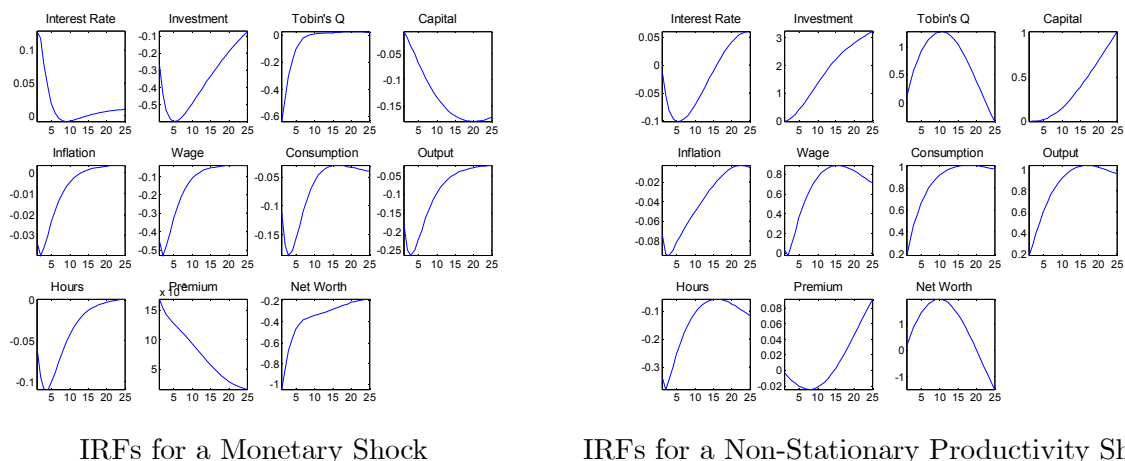

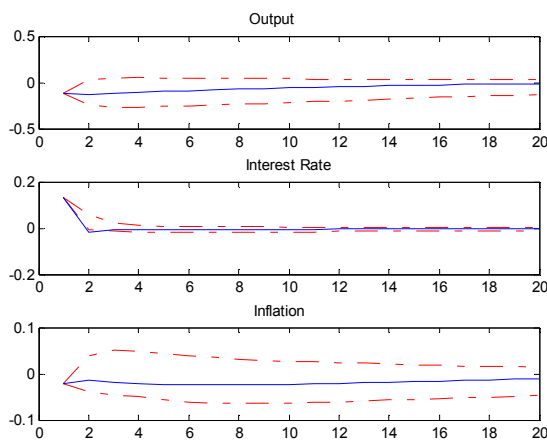| IRFs for a Monetary Shock | IRFs for a Non-Stationary Productivity Shock |

Figure 1: IRFs for key variables

Figure 2: VAR IRFs for a Monetary Shock

4 What does the model with financial rigidity say about the origins of the banking crisis?

Having established a model that integrates the banking sector and fits the data, we now go on to apply it to the recent crisis episode in the US. To do this we extract the model shocks from the unfiltered data and fit to each an ARMA time-series process over the period. Table 3 shows the status of each shock and also the ARMA parameters. We find that productivity unambiguously has a unit root. The External Premium is borderline not trend-stationary with an estimated root of around unity but this is heavily affected by the last 8 observations; without these it is clearly trend-stationary and this fits with our theoretical assumptions that the external premium should return to some normal level somewhat above zero. To reflect this we give it a root below unity but only just, so that it is not treated as permanent but is very highly persistent over the crisis period. The other shocks are all either stationary or trend-stationary; where there is some ambiguity in the tests (e.g. government spending or labour supply) we adopt the estimated time-series coefficients. The price mark-up (reflecting the volatile rate of change of oil and commodity prices) is close to white noise, as are consumer preferences and net worth.

	ADF p-value[+]	KPSS statistic	Conclusion	Coefficient AR	MA	Prod. shock
Government Spending	0.4459	0.2129	Stationary	0.8992		0.2078
Preferences	0.0000	0.1621	Stationary	0.0162		
Investment	0.0137	0.2284	Stationary	0.4896		
Taylor Rule	0.0000	0.1020	Trend Stat.	0.3515		
Productivity	1.0000	1.1805***	Nonstat.	0.2478		
Price Mark-up	0.0000	0.1282	Stationary	0.0977	-0.2048	
Wage Mark-up	0.0199	0.2690	Stationary	0.9252	-0.6546	
Labour Supply	0.8495	0.2738	Stationary	0.9872	-0.0949	
Premium	0.0647	0.0821	Trend Stat.	0.999		
Net Worth	0.0001	0.5792**	Stationary	0.0266		

[+] p-value of 0.05 is the 5% confidence limit for rejecting the unit root.
**(***) KPSS rejects stationarity at 5%(1%).

Table 3: Stationarity of Shocks and ARMA Parameters(1984Q3-2009Q2)

Plainly the crisis had international ramifications but we cannot identify the causality of these in a US-only model. The shocks that show up in the model are partly coming from these international effects; most obviously commodity price shocks that enter through the 'price mark-up' here are themselves responding to the US crisis. A further, similar limitation of our account is our inability to analyse connections between the shocks to the model. No doubt the banking shocks we identify had simultaneous and lagged effects on the non-banking shocks; but also vice versa, the non-banking on the banking. The sample episode is too short to establish which way such effects might go or even if they exist, tempting as it might be to run some regressions to detect them. The model assumes that each shock is separate from the others and only related to its own past. The model then disentangles how each shock works through the economy to affect final outcomes. Anyone that wished to take matters further would have to model the interactions of the shocks themselves through a wider model, such as one of political economy.

4.1 The errors driving the episode

We begin by showing the behaviour of the main model errors (i.e. the total cumulated innovations) during the crisis episode, which we treat as 2006Q1 to 2009Q2. We have not included the 'recovery period' at this stage, though this would be interesting; our focus is on the period when the economy first went into recession and then bottomed out.
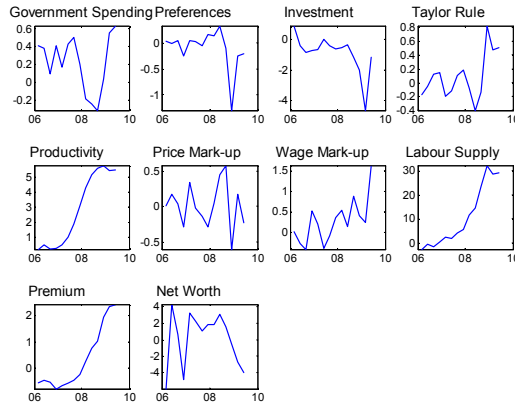

Figure 3: Accumulated Shocks from 2006Q1–2009Q2

We can immediately single out from these errors four key ones which behaved in a particularly persistent way during the crisis period: productivity (as we would expect), the Taylor Rule, labour supply and the External Finance Premium. These four turn out to have been the main drivers of the economy during this episode.

Productivity grew powerfully in the early stages of the period but stalled and fell in the heart of the crisis.

The Taylor Rule error forced up the interest rate steadily against the Rule's dictates: this was the operation of the zero bound.

Labour supply refers to the competitive sector wage equation which suffered from upward 'wage push' (equivalently a fall in labour supply) throughout the period until the heart of the crisis when it was partially reversed, presumably by the extreme labour market conditions. According to the model this error is the product of real wage 'push'. This may have resulted from the remarkable rise in oil and commodity prices over this period, which sharply reduced real wages; seen as abnormal it may have caused a reduction of labour supply (a real wage resistance) through intertemporal substitution. It could also be that the collapse of employment, particularly in construction, led to the redundancy of unskilled and (through FIFO) younger workers in the main; the fact that older and skilled workers were more likely to be kept on may thus have raised the average wage bill, even while productivity soared. This would suggest we should link the productivity and wage push errors. There is no obvious other cause: the policies of the Obama administration (on union power and Obamacare) only came in for the last two quarters of our period when wage push fell back. As this was the competitive sector it should not have been wage 'stickiness'; indeed the fact that it accumulated and only went into reverse after 3 years suggests it cannot have been.

Finally, the error in the External Finance Premium equation is large, rising and persistent, only easing off slightly just before the end of the episode. What this reveals is that, even when a banking sector is included in the model, it cannot account for the behaviour of the Premium. There is a

large additional and cumulative shock at work, specific to the episode. In the Smets-Wouters model without the banking shock, essentially the same shock is found; the difference is simply that it is an exogenous shock to the market cost of capital, rather than to the bank lending rate. In a way this is already evident from the fact that the two models fit the post-1984 data equally well. The banking sector is not adding any explanatory power, though it is, as we have said, more coherent theoretically. This model cannot explain why the risk premium rose. This error therefore can be thought of as reflecting the fear of a 'run on the banks', emanating from the specific circumstances affecting banks in the crisis: the sub-prime write-off, the Lehman collapse and so on.

It is worth dwelling on the possible sources of this shock, which we will call 'the Sub-Prime' shock since plainly it is associated with the way large amounts of sub-prime mortgage debt were first bundled up as securities, then sliced up by 'risk status' and repackaged as non-transparent Collateralised Debt Obligations, then resold around the world to credulous banks mostly in Europe, to be held in unknown quantities on these banks' balance sheets, creating huge uncertainty about which banks were at risk — as in the card game, which turns on who will wind up holding the Queen of Spades.

The origins of this process may well lie deep in US politics, going back to Clinton, as US Presidents and Congress mandated that the Federally-backed Fannie Mae and Freddie Mac (and to some extent the banks) should lend at least specified minimum shares of their portfolios to poor households. Table 4 details how this compulsion escalated in the 1990s and 2000s and Figure 4 shows the rise of US real house prices, which may have encouraged politicians to see housing equity as a way of spreading wealth across poorer parts of society. This political intervention invites comparison with the South Sea Bubble, in which the UK government encouraged investors to buy shares in the South Sea Company which in turn held UK government debt.

The Sub-Prime shock reached its peak after the collapse of Lehman. After this governments all over the world, including the US, were forced to bail out their insolvent banks and the size of the shock eventually diminished (after our sample ends) as this government backing allayed concerns over the remaining banks' viability. Thus the shock we find here seems to be associated with government intervention both in its initial propagation and in its cleaning-up afterwards.
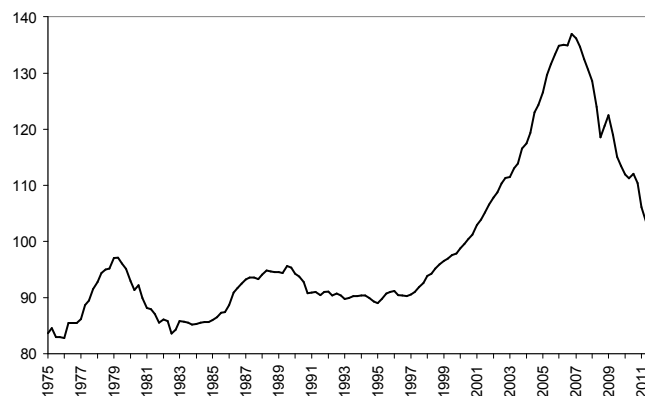

Figure 4: US Real House Price Index (2000=100): 1975-2009 (Federal Housing Finance Agency)

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Political and Legislative Targets	
1)	1996 HUD target for Freddie Mac and Fannie Mae: 42% of mortgages to go to borrowers with income below area median (50% 2000; 52% 2005).
2)	1996 HUD target for 'special affordable' (borrowers with less than 60% of area median) was 12% (20% 2000; 22% 2005).
3)	Community and Reinvestment Act of 1977 (Carter) strengthened in 1995 for ordinary banks.
Effects on Home Ownership	
1)	1994-2006, US home ownership rate up 9.4% (to 70% of population). Hispanics up by 20.2%; Asians by 17.2%; African Americans by14%; non-Hispanic Whites by 8.2%.
2)	Hispanic population 44% Pacific; 30% South; Asian population 49% Pacific. African American 45% South.

Source: Nunes (2009).

Table 4: Evidence of Political Effect

4.2 A stochastic variance decomposition of the episode

We next look at the variance decomposition of such episodes. This analysis treats the episode stochastically — that is, we take the shocks in the episode and replay them by redrawing them randomly and repeatedly with replacement to see what a typical crisis episode would be like. Our variance decomposition is therefore for such a typical episode.

	Int. rate	Investment	Inflation	Real Wages	Consumption	Output	Employment
Government Spending	1.5	0.1	0.2	0.2	0.4	0.7	0.8
Preferences	6.2	0.0	0.5	19.5	2.9	3.1	1.4
Investment	6.1	4.6	1.0	4.0	1.5	2.1	1.6
Taylor Rule	9.9	0.7	5.0	13.1	1.7	3.9	2.2
Productivity	6.5	0.5	14.8	19.5	25.6	22.6	7.1
Price Mark-up	10.2	0.5	35.7	12.9	1.5	3.2	1.8
Wage Mark-up	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Labour Supply	15.8	3.7	34.1	27.0	58.5	51.5	75.7
Premium	38.2	80.0	7.6	3.2	6.7	11.4	8.2
Net Worth	5.6	9.7	1.1	0.4	1.1	1.6	1.3
TOTAL	100	100	100	100	100	100	100
Banking Shocks	55.2	90.6	13.8	16.9	10.0	17.6	12.5
Non-Banking Shocks	44.8	9.4	86.2	93.1	90.0	82.4	87.5

Table 5: Variance Decomposition for Crisis Period

What we see from Table 5 is that only 18% of the output variance is due to financial shocks; and the rest is due to the usual non-banking shocks. For investment the share of financial shocks is very high (91%); but this gets dampened in its effect on GDP partly because interest rates react to

them and partly because it is a small part of GDP. Accordingly we see that interest rates are also highly affected (55%) by the financial shocks. As for inflation only 14% comes from this financial side.

What we see here is that there was a distinct role for financial shocks (essentially the Sub-Prime shock) in such episodes. However, the bulk of the variation comes from the other shocks: labour supply and productivity, plus for inflation the price mark-up. We can think of the crisis as being the result mainly of normal poor macro shocks (slowing of productivity growth, wage push, oil shock) with the Sub-Prime shock adding a nasty extra twist (about 2.5% extra off GDP at the bottom of the recession in real time as we will see in the next section). Thus turning it from a nasty (moderate crisis) episode into a 'Great Recession' episode.

The failure of fiscal policy to show up through the government spending effect is not really surprising: the fiscal response largely took the form of transfers, such as financial bail-outs (of AIG, Fannie and Freddie) and 'cash for clunkers'. Such transfers have no identifiable effect within this model; but one can think of them as already embodied in the Sub-Prime shock as a mitigating response, as discussed above; since clearly the risk premium and net worth shocks would have been much worse without this government cash infusion, which is acting like a supply of credit to both the cash-starved banks and the private sector. Thus these direct banking shocks are recorded net of this public response; unfortunately we have no way of disentangling the total banking shock from the mitigating effect of such government direct intervention in the financial system. We suggested above that the peaking of the Sub-Prime shock after Lehman was due to the government intervention; thus government was undoing the damage its intervention had created. We could use this possibly as an identifying device for that part of the shock due to fiscal intervention; however we have not done so here as there are only three observations after Lehman.

4.3   Accounting for this particular banking crisis episode

We can also decompose what actually happened in the precise episode that occurred according to the model as a result of these shocks. We do this in the charts that follow for the main macro variables.
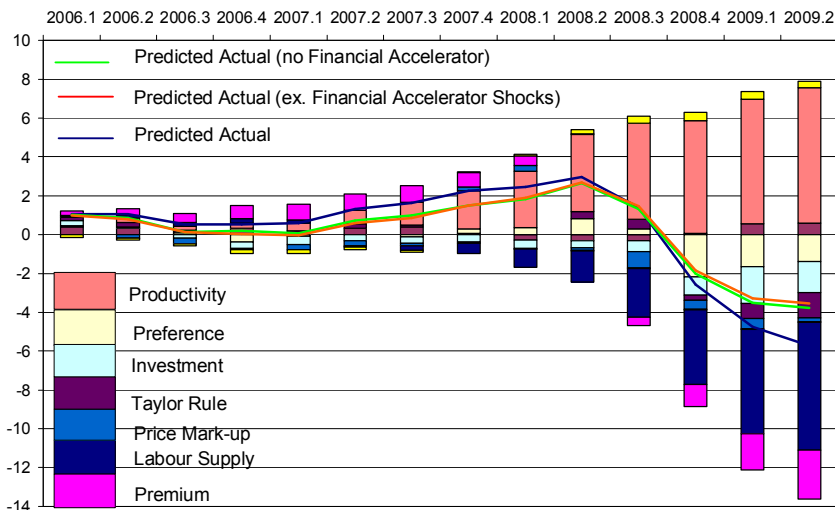

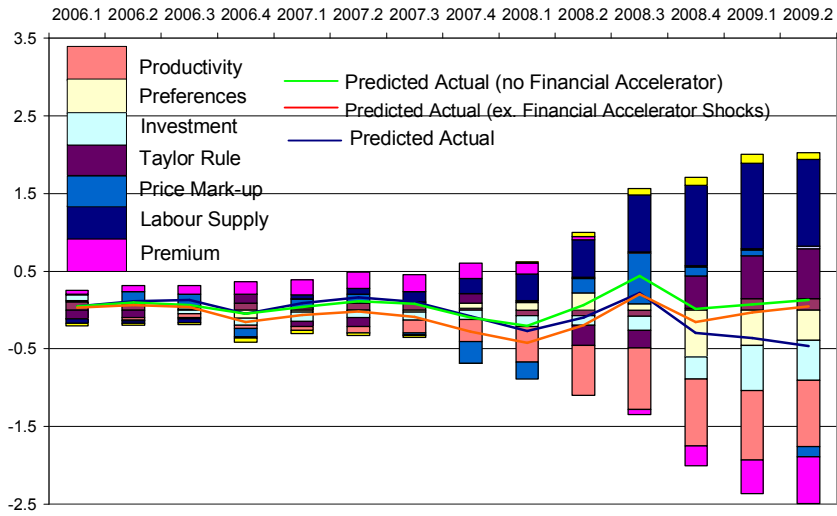Figure 5: Shock Decomposition for Output During the Banking Crisis Episode

Figure 6: Shock Decomposition for Interest Rate During the Banking Crisis Episode
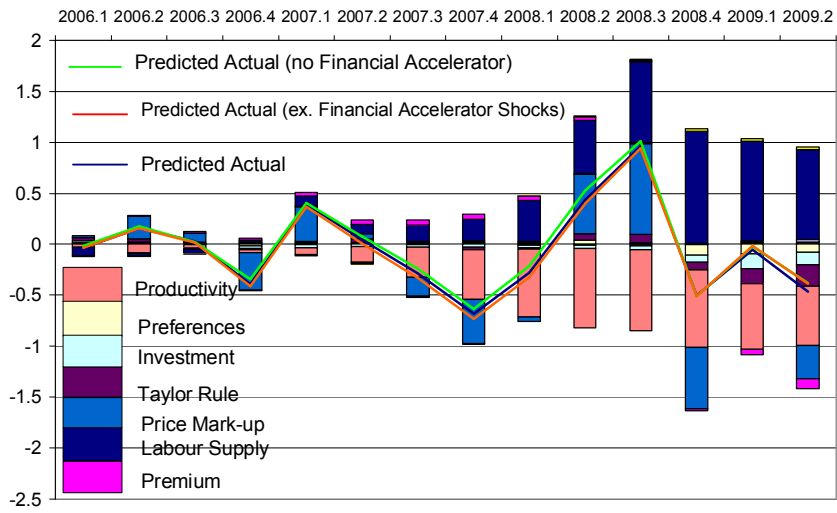

Figure 7: Shock Decomposition for Inflation Rate During the Banking Crisis Episode

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If we focus first on output (Figure 5), we see that the Sub-Prime shock contributes about 2.5% to the downturn by 2009Q2, the bottom of the recession. The main other negative element is the labour supply shock. The Taylor Rule and investment shocks tip output down further. However, what stops the downturn from turning into a rout is a strong positive productivity shock.

We show three lines on the chart: the total predicted, the predicted total without financial shocks, and the total predicted without either financial shocks or any financial transmission. The last two hardly differ, showing that financial transmission of non-financial shocks is modest in this episode: the effect of the non-financial shocks is occurring through the usual non-financial channels. The financial effect is coming from the financial shocks themselves.

If we turn to interest rates (Figure 7), we see in the final two quarters, 2009Q1 and Q2, how the investment, productivity and Sub-Prime shocks were pulling rates down, but this was offset to some extent by the labour supply (wage push) and the Taylor Rule (zero bound) shocks.

Finally on inflation (Figure 6), we see how the price mark-up shock has both negative and positive effects during the episode as oil and commodity prices first surged, and later fell back sharply as the recession took hold in 2008Q4 — see Figure 8. The labour supply and productivity shocks largely offset each other, implying that inflation remained surprisingly stable during the episode; by the end the Taylor Rule and investment shocks were driving inflation down but not into the deflationary range. Notice that the banking shock has only a very small negative effect on inflation — this is because its negative current effect on output (itself not large) triggers an offsetting downward effect on interest rates which reduces the future output effect.
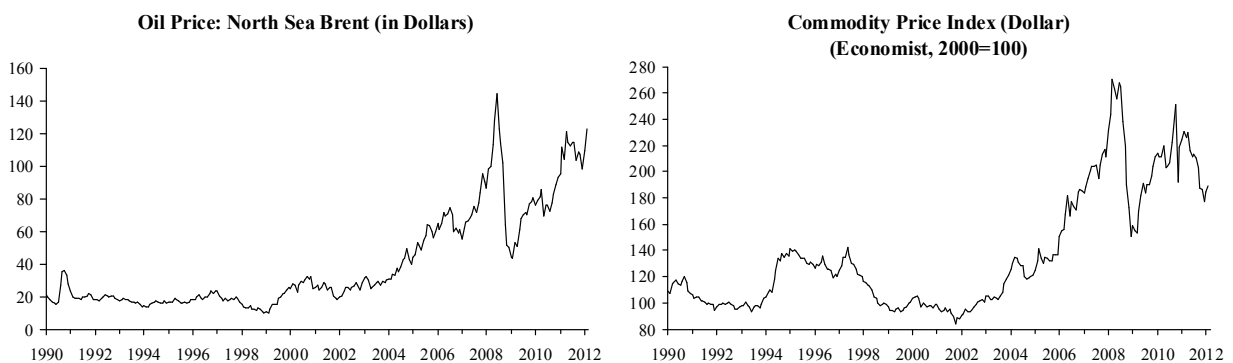

Figure 8:

The overall interpretation coming from this analysis is of a crisis triggered by severe exogenous shocks, and exacerbated by a large financial shock, itself offset by large fiscal intervention. The zero bound added some further pressure. Notice that this is not a crisis 'created by the financial system'. Even if one identifies the Premium error as due to aggressive bank lending on mortgages, we have seen that this aggression had its origins in political pressure and legislation forcing housing loans to poor households.

4.4 What is and causes a (financial) crisis?

If we take a longer perspective than just this crisis, we can ask: what is a crisis and what causes it, according to our analysis of this US sample? Let us define a 'crisis' as a severe downturn in output, a large part of which is permanent; and a financial crisis as a crisis in which there is also a financial

collapse of some sort. What does this model have to say in general about the causes of these? We examine this question by inspecting the bootstrap experience (potential scenarios over the period) from the model and its normal shocks; for this we use the shocks from the period 1984-2007 so that we do not reuse the shocks from this crisis period itself. Plainly we know that these shocks generate crisis; and we want to discover whether this experience is unique.

We find the following regularities:

a) Crisis is a normal part of capitalism: this economy will generate crises regularly from 'standard' shock sequences. We illustrate this from some of the bootstrap simulations/scenarios produced from the shocks of the 1984–2007 period (i.e. sans crisis). In around half of them there were quite serious interruptions of activity, which satisfy the definition of crisis. If we define a crisis as a fall in GDP of at least 5% with at least 10 quarters before output returns to its previous peak, then we find that a crisis on average will occur about every 50 years.

We also ran the scenarios with the full set of shocks including the crisis period, 1984–2009; this not surprisingly produced a somewhat greater average frequency, of one about every 40 years. Since the main shock specific to the crisis period of 2006–9 is the Sub-Prime shock, one can think of this extra frequency as the result of this shock being included.

If one defines a Great Depression as a fall in GDP of 10% or more lasting for 5 years or more (before GDP returns to its previous level) then they occur on average once every 400 years — the same frequency on both sets of shocks.

Plainly these figures are affected by the nature of the sample shocks; here we have used the experience of the last three decades, which apart from the crisis itself was the period of the Great Moderation. As we know that the variance of shocks in this period was markedly lower than in earlier post-war US history, extending our sample backwards in time would no doubt change our estimates in detail. However, the last three decades seems the most relevant experience for today's policymakers.

b) When there is crisis, there is roughly half the time also financial crisis; we measure this here by the appearance of an abnormal premium rise accompanying a crisis fall in output. This is shown for the same scenarios by showing the corresponding external premium behaviour.
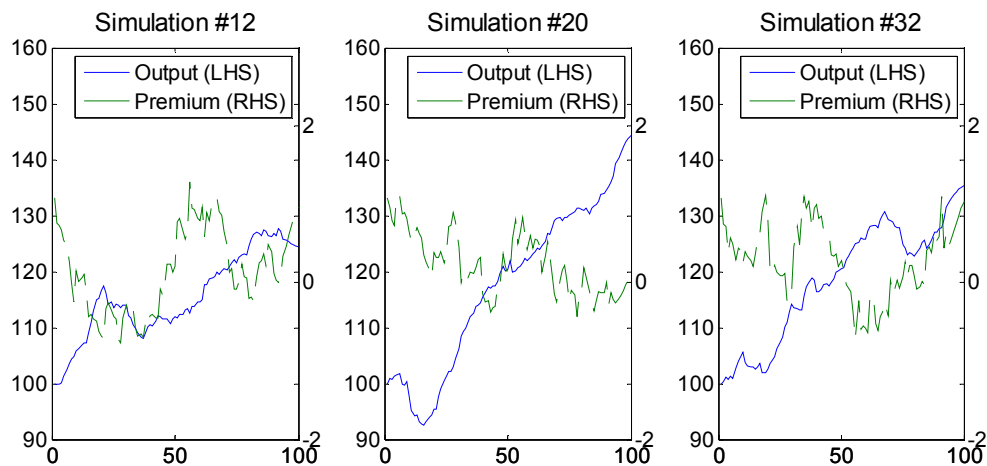

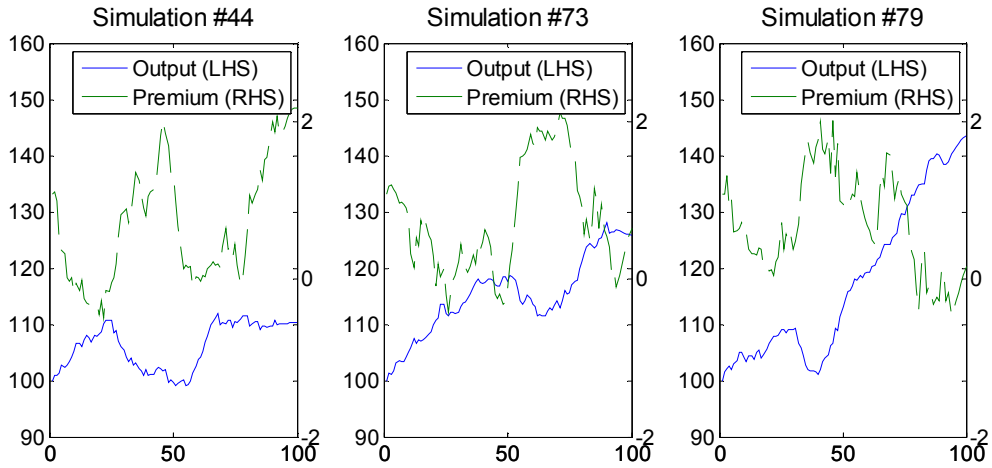Figure 9: Crises Not Accompanied by Financial Crisis

Figure 10: Crises Accompanied by Financial Crisis

c) An extreme financial shock is not required to produce a financial crisis. This is evident from the charts above since the financial shocks from 1984-2007 were none of them extreme and yet we clearly got several financial crises. The figure that follows shows the premium shock during this sample period, the only financial shock that contributed to the crisis; as can be seen it varies on a small scale, compared with its severity over the crisis (to the right of the red line).
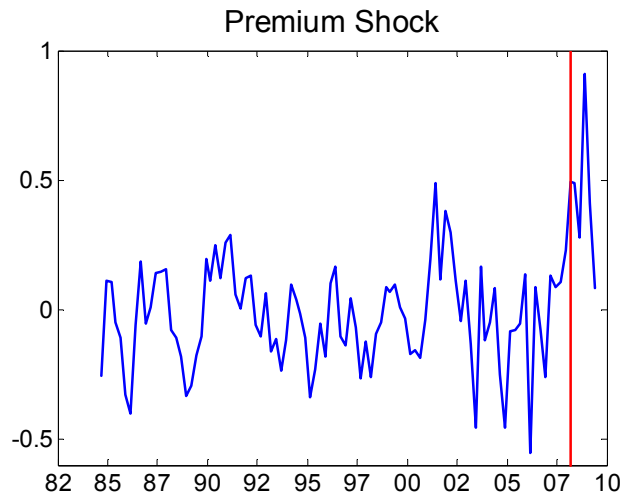

Figure 11: Premium Shock for the 84-09 Period

d) A financial shock is not sufficient to produce a crisis, even though it produces a rise in the premium. To check this point we redid these scenarios with just the two financial shocks including the crisis period values; thus this shock series includes both normal and extreme financial shocks. If financial crisis can be the result of extreme financial shocks, we should obtain a few at least. However what we see is that even though our financial shock series is effectively non-stationary it does not cause a crisis; all it does is cause run-ups in the financial premium, but these do not count

as financial crises if there is no accompanying crisis (i.e. there is a partially-permanent downturn in output). Here we should emphasise that the extreme financial shocks in the sample included the effects of massive government intervention, which occurred largely because of the experience of the Great Depression when there was no such intervention; thus this particular finding relies crucially on the assumption that financial shocks are accompanied by vigorous lender-of-last-resort activity by governments.
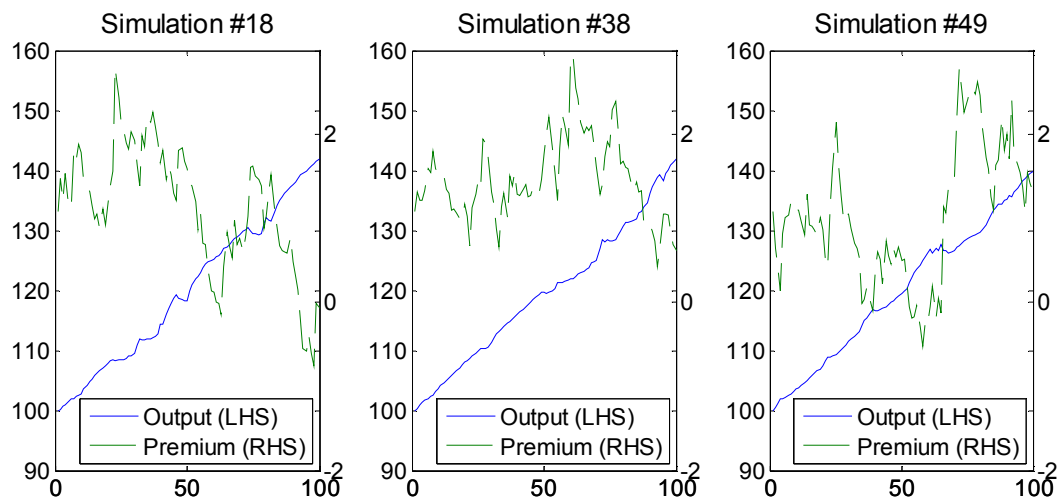

Figure 12: Simulation with only Financial Shocks

5   Conclusions

We have taken the Smets-Wouters model of the US, derived from Christiano et al. (2005), but here in the form as modified by Le et al.(2011) to allow for more heterogeneity in price/wage behaviour, and we have integrated into it the banking/financial accelerator model of Bernanke et al. (1999) in order to discover how far the banking crisis might have been caused by non-banking and by banking shocks. We began by comparing the performance of this model with the original SW model without the banking sector and we found, rather significantly, that the ability of the two to fit the overall data could not really be distinguished, either for the whole post-war period or for the later post-1984 period, once we had re-estimated each model to get it as close as possible to the data on the indirect inference test we are using. We took this to mean that while undoubtedly banking shocks were occurring even in the non-banking version, they would show up there as exogenous errors.

We then used the version with the banking sector with its re-estimated parameters to carry out an accounting exercise in the shocks causing the crisis episode. We did a variance decomposition to establish what a typical crisis generated by these shocks if redrawn randomly would be caused by. We then looked at the decomposition for this particular episode. Finally we ran a variety of simulations bootstrapped from different sets of the shocks in our sample (over the last three decades, on the grounds that this is of most relevance today) to shed light on the causes of crisis and banking crisis.

Our conclusion is perhaps rather startling: the banking crisis was mainly the result of non-banking shocks impacting through the usual non-financial channels on the US economy. The main non-bank shocks to output were from productivity (largely positive) and labour supply (negative

from 'wage push'). Monetary policy shocks, apparently related to the zero bound problem, also contributed. The banking shock was a specific result of the Sub-Prime process, which was largely produced by political pressure; it contributed a further 2.5% drop in output; however, government direct fiscal action through transfers was designed to alleviate this shock.

We interpret these results as telling us that the banking system is integral to the functioning of the capitalist economy but that it is essentially responsive to the economy; nor does its transmission mechanism worsen economic instability. The sources of boom and slump remain those identified in non-banking models: shocks to productivity, including importantly those coming from the commodity sector, and to some extent shocks to the household sector mainly via labour supply. However we have also identified an independent shock to the banking sector, the Sub-Prime shock. This did not emerge from 'normal banking behaviour', as is made clear by its status as a pure shock. It seems to have arisen as the result of a political process that compelled the Federal mortgage agencies to create sub-prime loans on a large scale. It was also alleviated by government fiscal intervention; this was clearly an important element in this financial crisis, and markedly different from what happened in the inter-war period.

The model also tells us that crises are regular occurrences in capitalist economies and that they frequently have as their by-product financial crisis in the sense that the premium rises sharply. These crises/financial crises occur in spite of there being no extreme financial shocks such as occurred in the recent episode; so serious financial shocks are not required for crises to happen. Furthermore, extreme financial shocks on their own of the type identified in this sample do not cause crises; all they do is cause temporary recessions. Thus both crises and financial crises result from non-financial shocks; financial shocks if extreme enough will add an extra layer of recession. Again, we must stress the caveat that the financial shocks identified in this sample all occurred in a political environment where the government acted as lender of last resort; absent this, the scale of these shocks would have been no doubt very different.

Is there then a role for regulation of bank behaviour in such a system? Plainly regulation could not have stopped this bank crisis since it was not caused by bank behaviour. In some countries other than the US (e.g. Spain and Australia) banks were prevented from buying sub-prime CDOs by central banks that did not permit the 'special vehicles' through which these were usually held. In the US the crisis could have been prevented by not compelling the banking system to make sub-prime loans; conditional on this political compulsion occurring, it is hard to see how the crisis could have been averted. The fissile parcel was bound to be passed around, until eventually it exploded somewhere in the banking system. The experience of other countries suggests that their regulators should have stopped the parcel being passed across the Atlantic or else that other measures, such as creating far greater transparency in instruments such as these CDOs, should have been adopted. This points to a regulative system that puts backstop prudential limits in place.

None of this has much to do with the currently proposed regulation of the banking system in the US and elsewhere. For example the Dodd-Frank legislation, which seems motivated by the aim of 'stopping future crises', represents a huge intervention in banking activity, that seems likely to badly distort and even stifle the bank transmission mechanism.

As far as fiscal and monetary policy go, we have found in common with many others that the zero bound is a problem, though its quantitative effect in this episode seems to have been small. We have also found that public spending shocks have had little effect. However fiscal policy mainly operated in this episode via large transfers to the banking and non-bank business sector; these transfers are wrapped up in the 'banking shocks' since they impacted directly on the credit risk-premium. Fiscal policy was effectively policy for credit supply from the taxpayer (as was Quantitative Easing which started in 2008 Q4); it appears that this fiscal policy was effective, if we compare the Great Depression where its absence seems to have led to a much larger shock.

6 Appendix SWUS Model Listing with Banking

Consumption Euler equation

$$c_t = \frac{\frac{\lambda}{\gamma}}{1+\frac{\lambda}{\gamma}}c_{t-1}+\frac{1}{1+\frac{\lambda}{\gamma}}E_tc_{t+1}+\frac{(\sigma_c-1)\frac{W_*L_*}{C_*}}{\left(1+\frac{\lambda}{\gamma}\right)\sigma_c}(l_t-E_tl_{t+1})-\left(\frac{1-\frac{\lambda}{\gamma}}{\left(1+\frac{\lambda}{\gamma}\right)\sigma_c}\right)(r_t-E_tp_{t+1})+eb_t \quad (7)$$

Investment Euler equation

$$inn_t = \frac{1}{1+\beta\gamma^{(1-\sigma_c)}}inn_{t-1}+\frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}}E_tinn_{t+1}+\frac{1}{\left(1+\beta\gamma^{(1-\sigma_c)}\right)\gamma^2\varphi}qq_t+einn_t \quad (8)$$

Tobin Q equation

$$qq_t = \frac{1-\delta}{1-\delta+R_*^K}E_tqq_{t+1}+\frac{R_*^K}{1-\delta+R_*^K}E_trk_{t+1}-E_tcy_{t+1} \quad (9)$$

Capital Accumulation equation

$$k_t = \left(\frac{1-\delta}{\gamma}\right)k_{t-1}+\left(1-\frac{1-\delta}{\gamma}\right)inn_t+\left(1-\frac{1-\delta}{\gamma}\right)\left(1+\beta\gamma^{(1-\sigma_c)}\right)\left(\gamma^2\right)(\varphi)(enn_t) \quad (10)$$

Price Setting equation

$$rk_t = \omega^r\left[\overline{\frac{1}{\alpha\left(\frac{1}{1+\beta\gamma^{(1-\sigma_c)}\iota_P}\right)\left(\frac{\left(1-\beta\gamma^{(1-\sigma_c)}\xi_p\right)\left(1-\xi_p\right)}{\xi_p\left((\phi_p-1)\epsilon_p+1\right)}\right)}}\left\{\begin{array}{c}p_t-\frac{\beta\gamma^{(1-\sigma_c)}\iota_P}{1+\beta\gamma^{(1-\sigma_c)}\iota_P}E_tp_{t+1}-\frac{\iota_P}{1+\beta\gamma^{(1-\sigma_c)}\iota_P}p_{t-1}+\left(\frac{1}{1+\beta\gamma^{(1-\sigma_c)}\iota_P}\right)\\\left(\frac{\left(1-\beta\gamma^{(1-\sigma_c)}\xi_p\right)\left(1-\xi_p\right)}{\xi_p\left((\phi_p-1)\epsilon_p+1\right)}\right)\left((1-\alpha)w_t-ea_t\right)-ep_t\end{array}\right\}\right]$$
$$+(1-\omega^r)\left[\frac{ea_t}{\alpha}-\frac{1-\alpha}{\alpha}w_t\right] \quad (11)$$

Wage Setting equation

$$w_t = \omega^w\left[\begin{array}{c}\frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}}E_tw_{t+1}+\frac{1}{1+\beta\gamma^{(1-\sigma_c)}}w_{t-1}+\frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}}E_tp_{t+1}-\frac{1+\beta\gamma^{(1-\sigma_c)}\iota_w}{1+\beta\gamma^{(1-\sigma_c)}}p_t\\+\frac{\iota_w}{1+\beta\gamma^{(1-\sigma_c)}}p_{t-1}-\frac{1}{1+\beta\gamma^{(1-\sigma_c)}}\left(\frac{\left(1-\beta\gamma^{(1-\sigma_c)}\xi_w\right)\left(1-\xi_w\right)}{\left(1+\epsilon_w(\phi_w-1)\right)\xi_w}\right)\\\left(w_t-\sigma_ll_t-\left(\frac{1}{1-\frac{\lambda}{\gamma}}\right)\left(c_t-\frac{\lambda}{\gamma}c_{t-1}\right)\right)+ew_t\end{array}\right]+$$
$$(1-\omega^w)\left[\sigma_ll_t+\left(\frac{1}{1-\frac{\lambda}{\gamma}}\right)\left(c_t-\frac{\lambda}{\gamma}c_{t-1}\right)-(\pi_t-E_{t-1}\pi_t)+ew_t^S\right] \quad (12)$$

Labour demand

$$l_t = -w_t+\left(1+\frac{1-\psi}{\psi}\right)rk_t+k_{t-1} \quad (13)$$

Market Clearing condition in goods market

$$y_t = \frac{C}{Y}c_t + \frac{I}{Y}inn_t + R_*^K k_y \frac{1-\psi}{\psi}rk_t + c_y^e c_t^e + eg_t \tag{14}$$

Aggregate Production equation

$$y_t = \phi \left[\alpha \frac{1-\psi}{\psi}rk_t + \alpha k_{t-1} + (1-\alpha) l_t + ea_t \right] \tag{15}$$

Taylor Rule

$$r_t = \rho r_{t-1} + (1-\rho)(r_p p_t + r_y y_t) + r_{\Delta y}(y_t - y_{t-1}) + er_t \tag{16}$$

Premium

$$E_t cy_{t+1} - (r_t - E_t p_{t+1}) = \chi (qq_t + k_t - n_t) + epr_t \tag{17}$$

Net worth

$$n_t = \frac{K}{N}(cy_t - E_{t-1}cy_t) + E_{t-1}cy_t + \theta n_{t-1} + enw_t \tag{18}$$

Entrepreneurial consumption

$$c_t^e = n_t \tag{19}$$

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