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Turning It Up To Eleven: Re-Evaluating the Role of Financial Frictions in the 2007–2008 Economic Crisis*

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Abstract

We analyze the role of public and private financial frictions in the 2007–2008 economic crisis in the United States by extending the model of Drautzburg and Uhlig (2015) to eleven observable variables using data on all three interest rates in the model (policy, private and public). We also include a preference shock in the model, and present an alternative method for describing shock decompositions during and preceding the crisis designed to isolate the impact of the pre-crisis shocks. The estimated model produces an intuitive description of the evolution of the postwar U.S. economy overall and of the economic crisis at the end of the sample period. We find, in contrast to Drautzburg and Uhlig, that monetary and fiscal policy shocks played a significant role in mitigating the effects of the financial crisis.

JEL classification: E32, E65

Keywords: DSGE model, Shock decomposition, Financial Frictions, Fiscal Policy

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1 Introduction

Since the 2007–2008 economic crisis, a body of research has emerged designed to understand the forces operating on the economy during and preceding the crisis.[1] Of particular interest is the role played by financial frictions and the differential costs of borrowing for public and private sectors.[2] In this paper we build on the work of Drautzburg and Uhlig (2015) – henceforth DU – extending their model with additional data to fully describe the observed time paths of public, private and policy interest rates.[3] As in DU, we find evidence that in 2008 financial frictions played an important role in the crisis; however, in contrast to DU, our model suggests that fiscal and monetary shocks were important in partially offsetting these effects.

In order to examine the role of fiscal policy during and preceding the 2007–2008 economic crisis DU developed and estimated a model of the U.S. economy with a richly specified fiscal sector. The model extended the literature in several dimensions. In particular it incorporated reduced form financial frictions in the form of interest rate wedges in both public and private credit markets, and allowed government investment to respond endogenously and differentially to shocks in both of them. The model was estimated using ten observable data series from the U.S. economy between the years 1948 and 2008 including a data series for debt. The model thereby provided an estimated value for the stance of fiscal policy with reference to a fiscal policy rule designed to control the level of debt. The estimated model was able to quantify the contribution of the different public and private sector financial frictions to the behavior of the economy in the periods immediately preceding the 2007–2008 crisis. DU found that the financial friction with the largest impact on output in this period was the increase in the spread between government borrowing costs and the Federal Reserve's observed policy interest rate, but that monetary and fiscal policy shocks played only a very limited role.

In this paper we extend the analysis of DU in four ways. First, we include three rather than two observed interest rates, increasing to eleven the number of observed variables. Second, we improve the measure of public debt so that it comprises net federal debt along with state and local debt and extend all interest rate data back to 1948. Third, the inclusion of the additional observed variable necessitates the inclusion of an eleventh exogenous shock and so we incorporate a preference shock. Finally, we also present an alternative method for describing the decomposition of shocks estimated by the model.

Many things helped precipitate the 2007–2008 crisis, but many policy discussions suggest that the behavior of the policy, private and public interest rates all played particular important roles. DU estimated their model effectively using data from only two rates of return. The missing interest rate, representing the government's cost of borrowing, helped equilibrate the model and this led to a counterfactual response of the implied cost of government borrowing. The use of data on all three interest rates in our analysis treats the influence of public and

[1] Key contributions include Gertler and Karadi (2011), Christiano *et al.* (2014), Del Negro et al. (2017).

[2] See e.g. O. Blanchard's AEA Presidential Address, Blanchard (2019), and *op cit.*

[3] Although DU do not model the drivers of differential costs of borrowing along the lines of e.g. Bernanke et al. (1999) and Gertler and Karadi (2011), these can be viewed as a first order reduced form arising from shocks to the net worth of firms or net worth of banks, respectively, in those papers.

private financial frictions more symmetrically and allows the model to better track the observed time paths of the interest rate variables. The inclusion of the preference shock also plays a significant role in our extended model, with large preference shocks having negative impacts on consumption in the third quarter of 2001, coinciding with the events of 9/11, and in the last two quarters of 2008, coinciding with collapse of Lehman Brothers. The estimated model also provides a more intuitive picture of the evolution of the U.S. economy during the six decades following World War II and in particular highlights the impact of the Federal Reserve's tight monetary policy during the 1980's and early 1990's. Finally, the alternative method of shock decomposition that we employ, arguably better isolates the impact of the shocks that actually occurred during the crisis and pre crisis periods, differentiating them from the influence of previously occurring shocks which are incorporated into the initial conditions prior to the crisis. Our presentation of the shock decomposition produces an intuitive description of the 2007–2008 period as one with a number of large offsetting shocks, with positive monetary policy and fiscal policy shocks partially offsetting large negative financial friction and preference shocks.

We set out our extensions of the model in detail in Section 2 before describing our results in Section 3 below.

2 This Paper's Contribution

This paper's three contributions are detailed in the following three subsections. In Section 2.1 we explain the role of the interest rate data in the estimation, as well as our improvements in the interest rate and public debt data. We next describe our modelling of the additional preference shock in Section 2.2 and then our alternative method of shock decomposition in Section 2.3. The impacts of these extensions of the model on the results are explained in detail in Section 3

2.1 Data

Of the eleven data series used in our estimation, eight are taken directly from DU. These are (1) output: chained 2005 real GDP, growth rates; (2) consumption: private consumption expenditure, growth rates; (3) investment: private fixed investment, growth rates; (4) government investment, growth rates; (5) hours worked: civilian employment index $\times$ average nonfarm business weekly hours worked index, demeaned log; (6) inflation: GDP deflator, quarterly growth rates; (7) wages: nonfarm business, hourly compensation index, growth rates; and (8) federal funds rate: converted to quarterly rates. The remaining three are as described in this section: (9) corporate bond yield: Moody's Baa index at quarterly rates, demeaned; (10) net public debt (described below), demeaned log; and (11) long-term (20-year) U.S. Treasury coupon note yield calculated by Ibbotson (2016).

DU's model has three separate interest rates: the rate at which the government borrows, r^b; the corresponding rate for private firms, r^k; and the policy rate determined by the Federal Reserve, r^f. These interest rates implicitly define three corresponding wedges between each of the three pairs as depicted in Figure 1. The wedges represent three potential frictions in the

(a) Drautzburg and Uhlig (2015) (b) This paper

Figure 1: The relationship between the different interest rates and corresponding wedges in the model. Red circles designate the observed time series used to estimate the model in (a) Drautzburg and Uhlig (2015) and (b) this paper.

economy. However, DU's estimation only includes two data series for these variables: data for r^f, along with the wedge ω^b, representing the difference between r^b and r^k. This means that while the distance between r^b and r^k is determined by the data, the levels of these two variables are determined within the model, along with the other two wedges (see Figure 1). Since the behavior of these wedges may have played a significant role in generating the financial crisis, we incorporate the yield on long-term U.S. government bonds calculated by Ibbotson (2016), and in place of the bond yield spread we include the data series Moody's Seasoned Baa Corporate Bond Yield to represent r^k. We choose the long-term interest rate to isolate financial frictions from differences stemming from shifts in the yield curve.[4] Ibbotson provides data for the yields on U.S. government bonds at 5 and 20 year maturities, so the latter together with the data obtained from FRED seems the most appropriate if we want to isolate frictions with as little contamination from the yield curve as possible.

To highlight the importance of including data on government bond yields directly in the model, we plot in Figure 2 this data series alongside the implied interest rate on government debt that is generated by DU's original model and using their data. This shows that in the DU model, the interest rate on government bonds plays a significant role in equilibrating the model, causing it to descend below the zero lower bound on several occasions across the sample period and inducing a counterfactual degree of volatility not observed in the data. Note that the volatility is particularly elevated during the last two quarters of 2008, a phenomenon not observed in the data.

Aside from including the additional time series, the benefit of this approach is that while the yield on corporate bonds and the yield on intermediate-term (5-year) U.S. Treasury coupon notes, calculated by Ibbotson (2016) are available at monthly frequencies for the entire sample period, the yields on 10 year Treasury bonds and the corresponding spread used by DU are only available from April 1954.[5] Figure A1 in the Appendix compares the bond spread implied by our data to the spread data DU use.

In addition to the interest rate on government borrowing, we also introduce an alternative measure of the public debt itself, derived as the sum of federal government debt securities

[4]DU use the series provided by FRED that represents the wedge between corporate bonds with "maturities 20 years and above" and the 10 year treasury bond.

[5]When estimating their model, DU assume the spread is zero from 1948 through 1953.

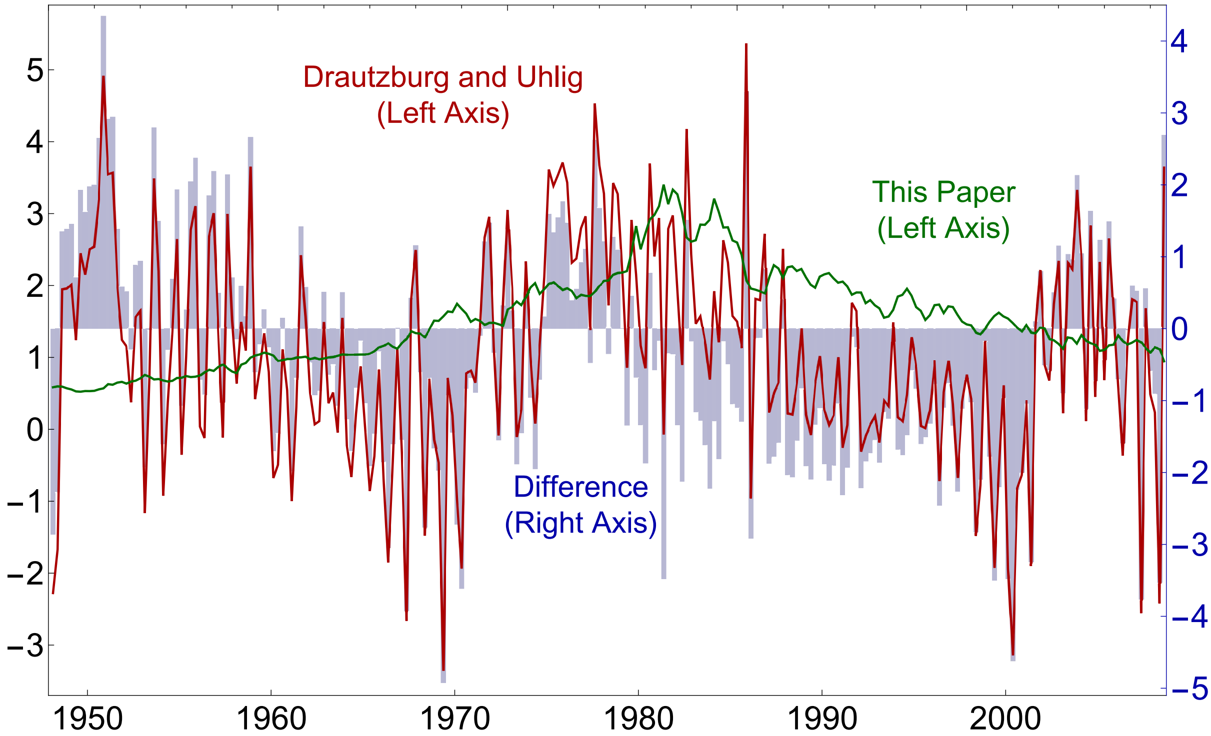

Figure 2: The cost of government borrowing.

and the total liabilities of state and local governments, excluding employee retirement funds (the series FL314122005.Q and FL214090005.Q in the *Financial Accounts of the United States*, published by the Board of Governors of the Federal Reserve System). Unlike the gross federal debt series at par value calculated by the Dallas Federal Reserve and used by DU, our measure of public debt excludes intergovernmental federal debt (particularly nonmarketable debt held by the Social Security Trust Fund), but includes the net public liabilities of states and localities. This better matches the way debt is characterized in the model's government budget constraint.[6] The difference between our data series and the original data series used by DU is depicted in Figure A2 in the Appendix. Though the two series mostly move in tandem, their series begins and ends the sample period approximately 5% of GDP above the series we constructed. During the intervening years the two series mostly diverge in the other direction—their series exceeds ours by over 12% of GDP during the late 1980's. Perhaps most notably, during the period of the financial crisis, their series implies that the debt burden rose by 7.4% in the last quarter of 2008, whereas our series implies a more modest gain of 4.7%.

2.2 The Preference Shock

The inclusion of an additional data series necessitates the inclusion of an additional shock to provide sufficient degrees of freedom for the estimation. We follow Justiniano, Primiceri and

[6]The model does not distinguish between the different levels of government or the different tax rates they impose. At the same time, a dollar of tax collected on earnings either through income tax or the Federal Insurance Contributions Act (FICA) has the same impact on net federal debt (our measure), but if collected through FICA actually increases the stock of gross debt.

Tambalotti (2011) and add a preference shock, which they show has significant explanatory power for consumption movements in post-war U.S. data. Including it has the benefit of incorporating unmodeled effects on consumer demand, such as the impact from the start of the financial crisis of the drop in house prices (Mian and Sufi, 2018). We model the preference shock in a standard way following Lindé and Trabandt (2018) as a multiplicative shock, ς_p, to the discount factor, β, so that optimizing agent j's utility function with an external habit is represented by

$$U = E\left[\sum_{s=0}^{\infty} \varsigma_{p,t}^{s} \beta^s \frac{1}{1-\sigma}(C_{t+s}(j) - hC_{t+s-1})^{1-\sigma} \exp(\frac{\sigma-1}{1+\nu} n_{t+s}(j)^{1+\nu})\right]$$

where

$$\log \varsigma_{p,t} = \rho_P \log \varsigma_{p,t-1} + \varepsilon_{p,t}, \qquad \varepsilon_{p,t} \sim N(0, \sigma_{\varepsilon p}^2)$$

and $C_t(j)$ is time t consumption of optimizing agent j, C_t is the time t aggregate consumption across all optimizing agents,and $n_t(j)$ represents the optimizing agent's time t labor supply.

The preference shocks only enter the Euler equation; the effect of a positive preference shock is to effectively increase the discount factor, which results in higher savings and less consumption in line with intuition.

2.3 Decomposition

The model is solved as a log-linear first order approximation around the steady state which has the form

$$S_t = AS_{t-1} + Be_t \tag{1}$$

$$X_t = CS_t \tag{2}$$

where S_t is a vector of M state variables, X_t a vector of N observables, and e_t a vector of exogenous shocks of dimension equal to or greater than N. Matrices A, B and C are appropriately dimensioned. In DU's model M=66 and N=10. Iterating the state equation forward means that at any point t :

$$X_t = CA^t S_0 + \sum_{j=1}^{t} CA^{t-j} Be_j. \tag{3}$$

One can use this equation for any period to decompose the deviation of a variable from its balanced growth path into the contribution from each exogenous shock and the initial condition. For a stable equilibrium A^t should tend to zero as t becomes larger, and so at the end of the sample almost all the variation in variables is explained by the exogenous shocks. However, the persistence of the effects of shocks means that shock decompositions place significant weight on the impacts of shocks occurring a long time before the event.

One way of accounting for this is to look at the difference in shock decompositions before and after an event that occurred from period t through $t + h$:

$$X_{t+h} - X_t = C(A^{t+h} - A^t)S_0 + \sum_{j=1}^{t} CA^{t-j}(A^h - I)Be_j + \sum_{j=t+1}^{t+h} CA^{t+h-j}Be_j. \tag{4}$$

This is the approach taken by DU, where in their paper t=240, corresponding to the fourth quarter of 2007, and h=4 so that $t + h$, corresponds to the fourth quarter of 2008. We report the shock decompositions using this approach in Table 2 in section 3.2.

An alternative procedure is to subsume all previous shocks into the initial conditions using the following formula:

$$X_{t+h} = CA^h S_t + \sum_{j=t+1}^{t+h} CA^{t+h-j} B e_j. \tag{5}$$

This decomposition isolates shocks occuring from time t from those that occurred in previous periods. This initial condition can be interpreted as the distance that the variable of interest is from its balanced growth path—noting of course that S is a high dimensional vector, and so the dynamics associated with the same aggregate initial conditions will differ depending on its composition. We report the shock decompositions using this approach in Figures 5 and 6 in Section 3.1, and Table 3 in Section 3.2

3 Results

The model is estimated using Dynare.[7] The priors and posteriors of the model's parameters are set out in Tables 4 and 5, In this section we first describe the the shock decomposition for the whole sample period in Section 3.1, and then focus on the period preceding the 2007–2008 crisis in Section 3.2.[8]

3.1 1948–2008

In this section we consider how our augmented version of DU's model can be used to interpret the behavior of output across the entire time period from 1948Q2 to 2008Q4, and how this compares with that obtained using DU's model.

Table 1 compares the historical variance decomposition for both DU's model and our extended model. Broadly, these appear similar in that the three major shocks, monetary policy, technology and private investment together account for around a half or more of the variance in each model. Nonetheless the preference shock we introduce does play a significant role, accounting for nearly 8% of the variance of output in the last column of Table 1. More importantly, once we add the cost of government borrowing as an additional observable variable, the shocks associated with government bonds assume a much greater role in generating fluctuations in output (20.16% for the entire sample), mostly at the expense of shocks to the cost of private investment and to a lesser extent technology. Shifts in the difference between our measure of the cost of government borrowing, the yield on 20-year U.S. Treasury Bonds, and the policy rate, are best interpreted as a proxy for changes in term structure.

[7] We estimate DU's model using the code they supply (see `https://ideas.repec.org/c/red/ccodes/14-44.html`). We are able to replicate their estimated model, aside from the variance decomposition, for the whole sample period. We provide our own estimates for this in Table 1.

[8] We have programmed a general code in Matlab for calculating this shock decomposition that can be implemented for a model estimated using DYNARE 4.56, available upon request.

Table 1: Variance Decomposition 1948Q1 to 2008Q4 for this paper versus Drautzburg and Uhlig's model. †Drautzburg and Uhlig (2015) ††Drautzburg and Uhlig's model using new corporate bond spread data. †††Drautzburg and Uhlig's model using new corporate bond spread and new debt data.

Shocks	Drautzburg and Uhlig†	Drautzburg and Uhlig††	Drautzburg and Uhlig†††	This paper
Technology	18.61	18.18	21.24	13.54
Price Markup	8.27	7.17	8.50	5.85
Wage Markup	8.57	8.38	9.54	1.99
Monet. Pol.	19.83	20.71	18.48	20.84
Lab. Tax	8.47	8.84	6.73	2.93
Gov. Spending	3.84	3.95	4.79	4.02
Priv. Inv.	18.88	20.43	20.40	10.31
Gov. Inv.	5.87	5.49	6.11	5.45
Corp Bond Spread	1.52	1.24	1.55	1.60
Gov. Bond Spread	6.14	5.61	2.66	26.67
Pref. Shock	-	-	-	6.80

We are using the posterior modes for these calculations.

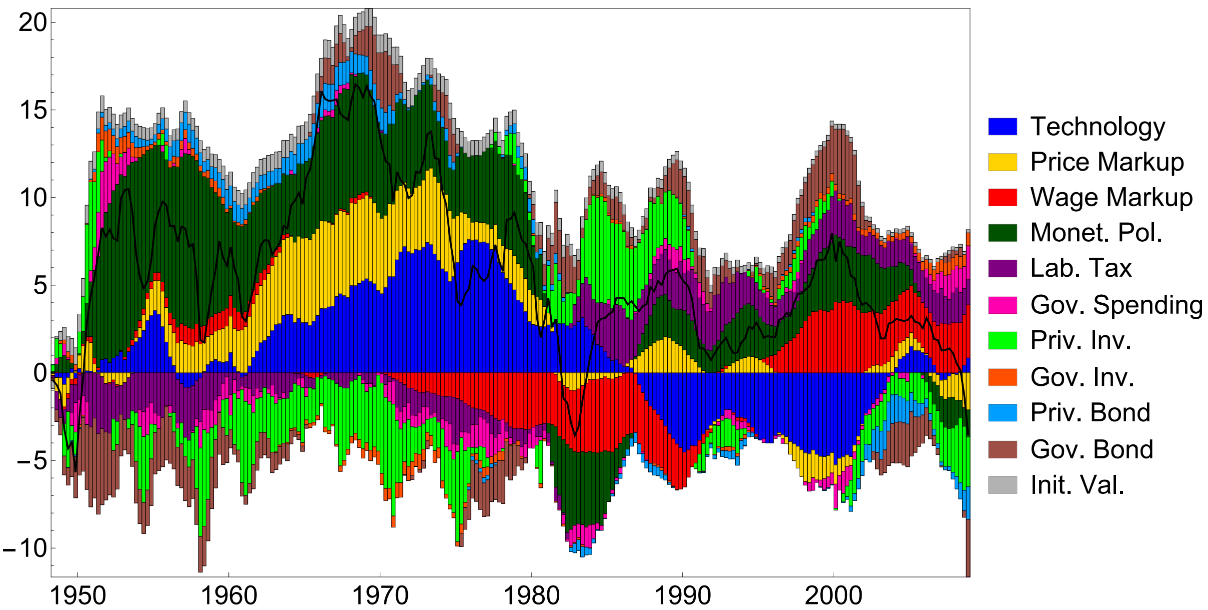

Figure 3: Shock decomposition 1948Q2–2008Q4, DU model, calculated using the decomposition formula (5).

Table 1 displays the averages for the whole sample period; however, the relative importance of specific shocks differs over time in interesting and significant ways. In Figures 3 and 4 we illustrate the evolution of the shock decompositions for both models over time using the shock decomposition formula of equation (5), where the shock decompositions in each time period sum to the log of output relative to trend. While the patterns of output decomposition in Figures 3 and 4 are broadly similar, there are, however, important differences. Particularly noticeable is the asymmetric distribution (far more positive than negative) of shocks in Figure 3, implying

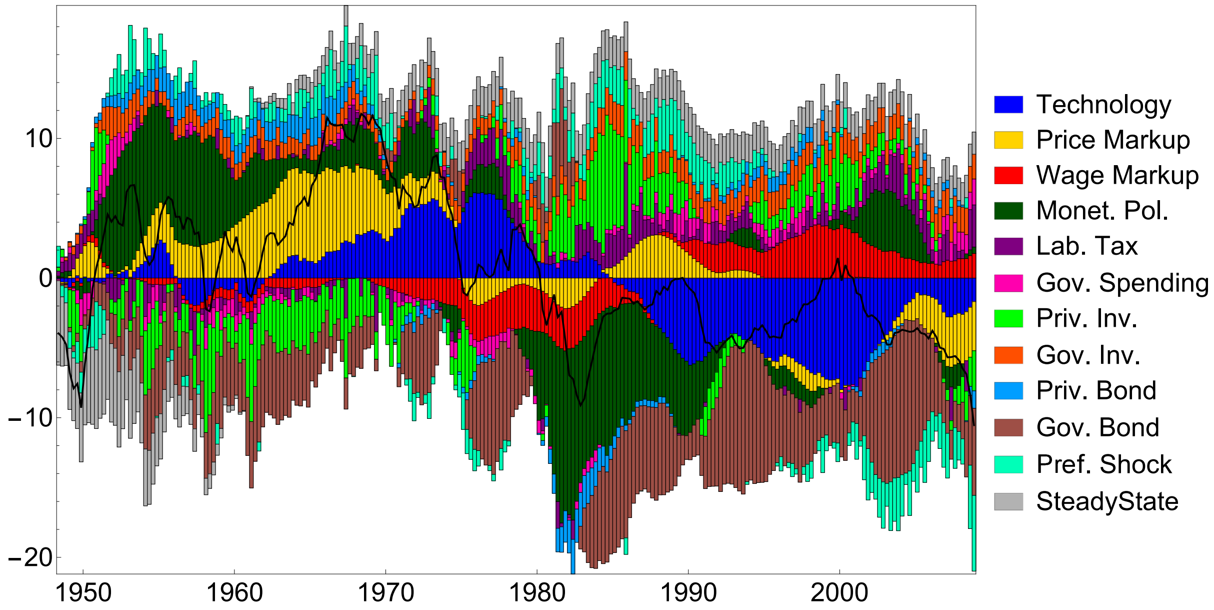

Figure 4: Shock decomposition 1948Q2–2008Q4, our model, calculated using the decomposition formula (5).

that in the original model output is nearly always above the value associated with balanced growth. By contrast, in the extended model presented in Figure 4, the initial conditions in 1948 imply output is below the values associated with balanced growth, but then output fluctuates closer to and often below the horizontal axis, implying that the model is perhaps producing a somewhat more intuitive measure of trend growth.

Table 1 shows that the variance decomposition of the two models assigns nearly identical values to monetary policy, between 19% and 21% of the total variation in output. Figures 3 and 4 also show broadly similar patterns: expansive monetary policy, during the 1950's 60's and 70's, followed by a sharp contraction during the 1980's associated with the anti-inflationary policies instituted by Fed Chairman Paul Volcker, followed by a resumption of expansionary policy. Nevertheless, whereas in the original model Volcker's policy seems to have only a modest and relatively transitory impact on output, beginning in 1981 and ending by 1986, our model suggests that its impact began as early as 1979 and continued till 1992 and the end of the Bush administration.

Throughout much of the last half of the twentieth century the influence of preference shocks in Figure 4 is typically positive, but it turns decidedly negative in the third quarter of 2001 and remains negative thereafter, suggesting a long-lasting decline in the value of $\varsigma_{p,t}$ beginning in the third quarter of 2001 (coinciding with the events of 9/11), intensifying during most of 2003 (the U.S. invasion of Iraq), and then gradually dissipating by the end of 2005. A new sharp decline appears in the last two quarters of 2008, coinciding with the first and second bail-outs of Fannie Mae and Freddie Mac in July and September 2008 and the collapse of Lehman Brothers, also in September 2008.[9] Overall, the introduction of the preference shock significantly reduces the

[9]We find the preference shocks, but not the other shocks are negatively correlated with the cyclically adjusted price earnings ratio calculated by Robert Shiller `http://www.econ.yale.edu/~shiller/data/ie_data.xls`. This

roles played by the shocks to the wage markup, private investment and the labor tax. At the same time the additional shock actually raises the importance of the shocks to the corporate bond spread and the price markup.

At the beginning of 1948, nine quarters after the end of the second world war, the U.S. debt burden was 90.2% of GDP. It declined steadily during the nearly three decades that followed, reaching a low point of 33.3% in the last quarter of 1974. From then the debt burden rose—first gradually, reaching 39.2% in the first quarter of 1978 before slightly receding, and then increasing again at an accelerated pace from the fourth quarter of 1981, coinciding with the enactment of the first phase of the Economic Recovery Tax Act on October 1 of that year until the second quarter of 1995 when it reached 68.5%.[10] Having declined during the subsequent period to 53.7% of GDP in the second quarter of 2001, it rose rapidly following the events of September 2001 and all that followed.

The impact of this history on output in is expressed directly through the labor tax and indirectly through the government bond spread. If we divide the entire sample period in two, we can see in Figure 4, that the impact of the labor tax initially fluctuates around zero during the period till the end of 1974 when the debt was declining, but raises output in the years that follow as it fails to adjust enough to stabilise the debt. By contrast, the impact of the spread between the government's cost of borrowing and the monetary policy rate is negative across the two periods, but greater in the second, reflecting the significantly higher spreads in Figure A1 that accompanied the rising debt.

3.2 2007–2008

The paper makes two contributions to the explanation of the 2008 crisis: the extension of the model to include data on the interest rate of government debt, together with an additional preference shock; and the use of a different decomposition method. We demonstrate the significance of these two contributions in turn.

Table 2 compares the shock decompositions of the original DU model and the extended model during and immediately prior to the 2007–2008 crisis using DU's original shock decomposition method (corresponding to equation 4 in section 2.3). Column 2 reproduces DU's results for the shock decomposition in the period 2007(Q4)–2008(Q4). This shows that in the DU model financial frictions in the government debt market were the largest driver of the fall in output in this period, contributing -3.76, out of a total fall of -4.60. Financial frictions in the corporate bond market were the next biggest driver, contributing -1.41 with positive technological progress of 0.895 being the largest countervailing factor. Column (1) performs the same analysis for the two-year period 2006(Q4)–2008(Q4). The results for this period also show large negative effects of financial friction in the public and private bond markets, but also significant negative shocks to prices and private investment and positive influences of government

suggests that investors bid up the price of equities, relative to earnings, in response to a rise in the willingness to defer consumption and save.

[10] Congress passed the legislation on August 4, 1981, and President Ronald Reagan signed into law on August 13, 1981.

Table 2: Historical Decomposition of Quarters Immediately Preceding 2008 Recession
Comparison of Original Drautzburg Uhlig Model with this Paper using Original Decomposition

Shock	Drautzburg & Uhlig		This Paper	
	2006(4)–2008(4)	2007(4)–2008(4)	2006(4)–2008(4)	2007(4)–2008(4)
Technology	0.951	0.895	0.752	0.827
Price Markup	−1.455	−0.743	−0.070	0.072
Wage Markup	0.316	0.143	0.586	0.370
Monetary Policy	−0.088	0.216	1.744	2.044
Labor Tax	−0.435	−0.258	1.095	2.492
Gov. Spending	0.800	0.596	0.550	0.476
Private Inv.	−1.032	−0.302	−2.556	−1.510
Gov. Inv	0.064	0.030	−0.084	−0.079
Corp Bond Spread	−1.457	−1.410	−1.824	−1.654
Govt Bond Spread	−2.979	−3.760	−3.369	−4.300
Initial Conds	−0.020	−0.010	−0.054	−0.027
Preference			−2.232	−3.381
Sum	−5.334	−4.603	−5.462	−4.667

Notes: Estimates from posterior mode. The Drautzburg and Uhlig model estimates use the original dataset.

spending as well as of technology.

The results for the same exercise using our extended model are shown in columns (3) and (4) of Table 2. With regard to financial frictions the key results of DU remain, with financial frictions in both the corporate and government bond markets being important with the latter being the most significant. However, there are also important differences. Our extended model gives a prominent role to preference shocks and a much greater role to negative private investment shocks. There is also a much greater positive influence of both monetary and fiscal policy shocks during the crisis period. Thus the overall picture from the extended model is one of the economy being hit by significant countervailing shocks, with large negative financial frictions and private investment shocks mitigated by significantly expansionary shocks to both monetary and fiscal policy.

The decomposition method in Table 2 conflates the shocks occurring in the time period with those occurring beforehand, as detailed in section 2.3. Therefore in Table 3 we repeat the analysis using the alternative shock decomposition method corresponding to equation 5 in section 2.3 above. This places the influence of all shocks occurring before the considered time period into the initial conditions, which therefore have a much greater share of the decomposition. These initial conditions have contrasting effects on income in the two models. In the DU model the initial conditions have a positive effect on income, whereas those for the extended model have a negative effect. This is a consequence of the asymmetric and predominantly positive nature of the shock distribution in the DU model described in section 3.1. Thus in the DU model the economy is well above its trend level at the beginning of the crisis period. In the extended model, however, shocks are more evenly distributed and immediately prior to the crisis the economy is below its trend level, due *inter alia* to strong negative preference shocks associated with the slowdown in consumption in the early part of the decade (see Figure 4). Also note that

Table 3: Historical Decomposition of Quarters Immediately Preceding 2008 Recession
Comparison of Original Drautzburg Uhlig Model with this Paper using Alternative Decomposition

Shock	Drautzburg & Uhlig		This Paper	
	2006(4)–2008(4)	2007(4)–2008(4)	2006(4)–2008(4)	2007(4)–2008(4)
Technology	1.304	0.856	0.653	0.586
Price Markup	−0.373	−0.396	−0.880	−0.635
Wage Markup	−0.180	−0.019	−0.188	−0.079
Monetary Policy	−0.168	0.167	1.738	2.227
Labor Tax	0.001	0.269	3.847	4.016
Gov. Spending	0.114	0.063	0.278	0.123
Private Inv.	−2.470	−1.836	−2.614	−2.218
Gov. Inv.	0.489	0.196	0.773	0.268
Corp Bond Spread	−1.544	−1.454	−1.780	−1.682
Gov. Bond Spread	−3.406	−3.630	−5.458	−4.912
Initial Conds	2.929	2.479	−2.993	−4.315
Preference			−3.932	−3.935
Sum	−3.305	−3.305	−10.556	−10.556

Notes: Estimates from Posterior mode with the Drautzburg and Uhlig model using their original

although Tables 2 and 3 use the same data and estimated models, the sum effects of the two different shock decomposition methods differ because the original DU decomposition displays the difference between the contribution of the shock in 2008(Q4) and that either one or two years previously. In contrast, the total effect for the alternative decomposition method given in Table 3 is the level of income relative to trend in 2008(Q4).

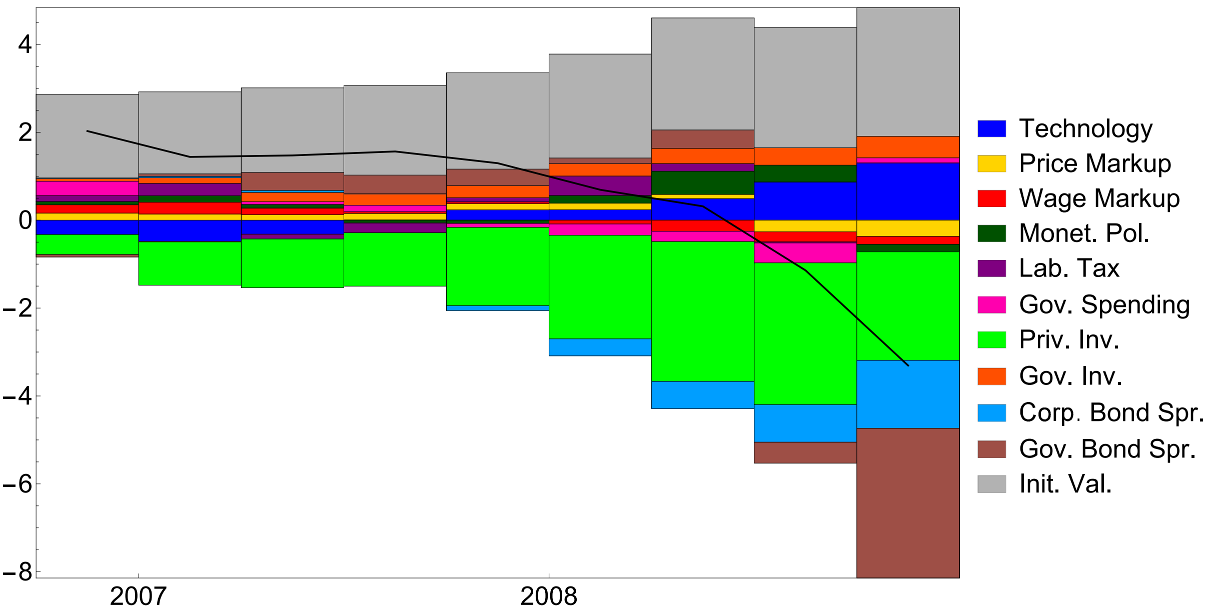

Figure 5: Drautzburg and Uhlig Original Model with Alternative Shock Decomposition Method

The advantage of the alternative decomposition method is demonstrated in Figures 5 and 6, which plot the alternative decomposition for the original DU model and the extended model respectively. Figure 5 shows that focusing on the shocks that occur within the time period under

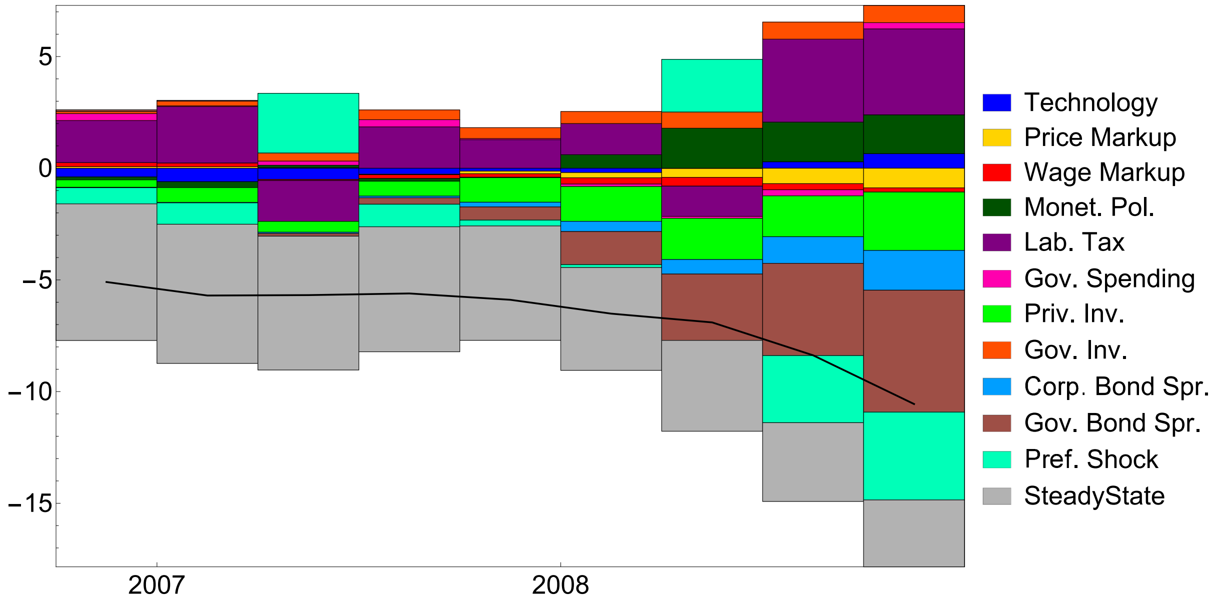

Figure 6: Extended Model with Alternative Shock Decomposition Method

consideration gives a much greater role to private investment shocks rather than the government bond shock in the original DU model. This is because the original DU decomposition method obscured the effect of private investment due to its differencing methodology: private investment was significant throughout the period, when focusing on the last five quarters, it was effectively netted out. In contrast, the government bond shock is significant only at the end of the period, and so is not affected adversely by the differencing method. Figure 5 also shows the corporate bond wedge steadily growing throughout 2008 which accords with intuition. The analysis for the extended model also benefits from the alternative decomposition method. Figure 6 shows that the focus on shocks occurring within the period again highlights the importance of private investment shocks, and again illustrates that most of the financial friction shocks occur in the final two quarters of 2008. Figure 6 also shows that in contrast to the DU model, monetary and fiscal policy have significant positive impacts on output in the extended model. Fiscal policy shocks are mostly positive throughout the period but increase in scale in the last two quarters of 2008. Monetary policy shocks do not become large until 2008. Figure 6 also nicely illustrates the description of the economy during this period as one of multiple strong offsetting shocks, with positive shocks to labor taxation and monetary policy partially offsetting negative shocks to preferences, private investment and financial frictions in the government and corporate bond markets.

4 Conclusion

In this paper we have extended DU's analysis of the 2007–2008 crisis by extending the dataset to include three rather than two observed interest rates, by improving the measure of public debt and extending all interest rate data back to 1948, by incorporate a preference shock into the model and by providing an alternative method for describing the decomposition of shocks estimated by the model. Our results provide an intuitive account of the 2007–2008 period which suggests that large financial frictions, an increase in the long-term spreads, negative investment and preference shocks all played significant roles in the crisis, partially mitigated by offsetting fiscal and monetary policy shocks.

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Appendix

A: Additional Data Figures

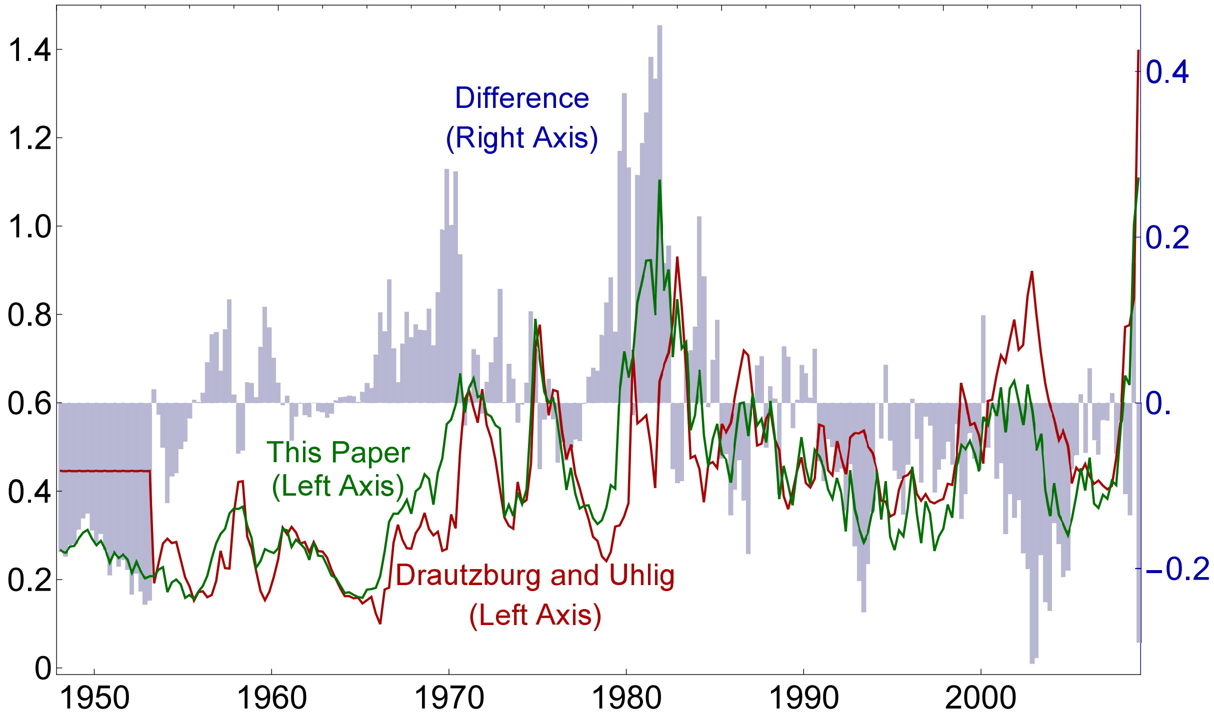

Figure A1: Spread

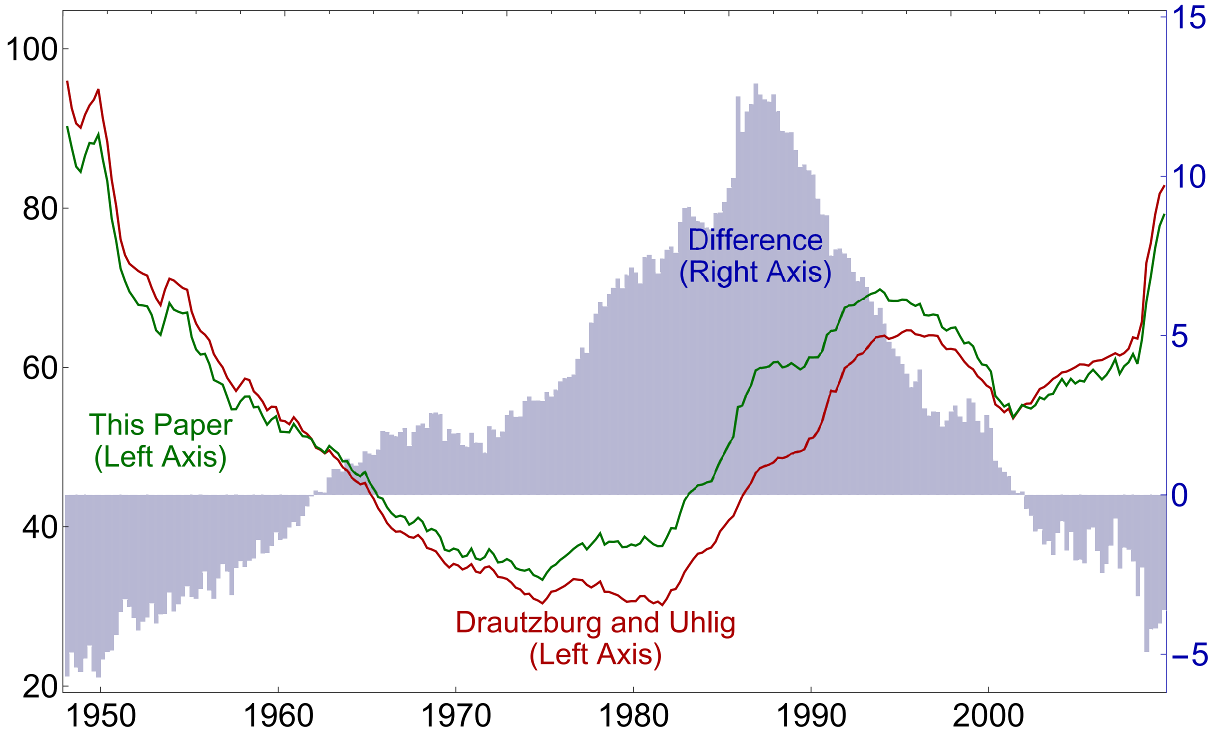

Figure A2: Public debt series in Drautzburg and Uhlig (2015) and in this paper divided by nominal GDP (left axis) and the difference between them (right axis).

B: Estimation

Table 4: Results from Metropolis-Hastings (parameters), 1,000,000 draws from which we drop the first 200,000.

	Prior			Posterior			
	Dist.	Mean	Stdev.	Mean	Stdev.	HPD inf	HPD sup
Capital share α	norm	0.300	0.0500	0.237	0.0118	0.2181	0.2567
Risk aversion σ	norm	1.500	0.1000	1.275	0.0999	1.1103	1.4377
Habit h	beta	0.700	0.0500	0.720	0.0380	0.6603	0.7830
Inv. lab. elast. ν	norm	2.000	0.1000	2.046	0.0999	1.8846	2.2140
Disc. factor $100 \times \frac{1-\beta}{\beta}$	gamm	0.250	0.1000	0.182	0.0685	0.0723	0.2888
Calvo wage ζ_w	beta	0.400	0.1000	0.884	0.0210	0.8550	0.9210
Calvo price ζ_p	beta	0.400	0.1000	0.747	0.0490	0.6682	0.8242
Wage index ι^w	beta	0.400	0.1500	0.441	0.0939	0.2833	0.5918
Price index ι^p	beta	0.400	0.1500	0.142	0.0645	0.0397	0.2394
Cap. util. ψ_u	beta	0.400	0.1500	0.286	0.0755	0.1607	0.4095
$1 + \frac{\text{Fixed cost}}{\text{GDP}}$	norm	1.250	0.1250	1.915	0.0627	1.8151	2.0209
Taylor smoothing ρ_R	beta	0.750	0.1000	0.897	0.0163	0.8712	0.9246
Taylor infl. ψ_1	norm	1.500	0.2500	1.322	0.1675	1.0237	1.5625
Taylor out. gap. ψ_2	norm	0.125	0.0500	0.088	0.0215	0.0541	0.1223
Taylor Δout. gap. ψ_3	norm	0.125	0.0500	0.058	0.0091	0.0427	0.0726
$\frac{\text{Gov. spending}}{\text{GDP}}$	norm	0.500	0.2500	0.328	0.0506	0.2432	0.4097
Adjust. cost	norm	4.000	1.5000	4.851	0.8601	3.4358	6.2438
Gov. adjust. cost	norm	4.000	1.5000	5.966	1.1526	4.0353	7.8092
Trend $\mu - 1$	norm	0.400	0.1000	0.490	0.0085	0.4768	0.5046
Budg. bal. speed $\frac{\psi_\tau - 0.025}{0.175}$	beta	0.300	0.2000	0.009	0.0077	0.0001	0.0198
Mean spread ω^f	gamm	0.500	0.1000	0.472	0.0489	0.3930	0.5523
Mean gov. interest	gamm	0.500	0.1000	0.897	0.1054	0.7231	1.0692
Mean infl.	gamm	0.625	0.1000	0.416	0.0635	0.3111	0.5182
Mean hours	norm	0.000	2.0000	1.720	0.6989	0.5815	2.8510
Mean bonds	norm	0.000	0.5000	-0.021	0.5062	-0.8577	0.8016
AR(1), technology ρ_a	beta	0.500	0.2000	0.947	0.0136	0.9252	0.9692
AR(1), gov. bond spread ω_f	beta	0.500	0.1000	0.933	0.0142	0.9135	0.9529
AR(1), pref. shock ρ_P	beta	0.500	0.1000	0.158	0.0425	0.0872	0.2238
AR(1), gov. spending ρ_g	beta	0.500	0.2000	0.994	0.0023	0.9901	0.9976
AR(1), inv. price ρ_x	beta	0.500	0.1000	0.517	0.0548	0.4278	0.6081
AR(1), monetary ρ_r	beta	0.500	0.1000	0.269	0.0466	0.1913	0.3442
AR(1), price markup ρ_π	beta	0.500	0.1000	0.812	0.0645	0.7131	0.9219
AR(1), wage markup ρ_w	beta	0.500	0.1000	0.791	0.0675	0.6840	0.8979
AR(1), tax ρ_τ	beta	0.500	0.2000	0.365	0.0630	0.2632	0.4708
AR(1), gov. inv. price$\rho_{x,g}$	beta	0.500	0.2000	0.974	0.0073	0.9617	0.9855
AR(1), corp. spread	beta	0.500	0.2000	0.917	0.0179	0.8882	0.9462
MA(1), Price markup $\theta^{\lambda,p}$	beta	0.500	0.2000	0.562	0.1333	0.3505	0.7808
MA(1), Wage markup $\theta^{\lambda,w}$	beta	0.500	0.2000	0.661	0.1100	0.4863	0.8359

Table 5: Results from Metropolis-Hastings (standard deviation of structural shocks)

	Prior			Posterior			
	Dist.	Mean	Stdev.	Mean	Stdev.	HPD inf	HPD sup
s.d. tech.	invg	0.100	2.0000	0.469	0.0221	0.4331	0.5054
s.d. bond	invg	0.100	2.0000	0.199	0.0092	0.1840	0.2141
s.d. pref.	invg	3.000	2.0000	8.347	1.4228	6.0421	10.7815
s.d. gov.	invg	0.100	2.0000	0.350	0.0164	0.3225	0.3761
s.d. tax	invg	3.000	2.0000	4.584	0.2222	4.2169	4.9404
s.d. mon. pol.	invg	0.100	2.0000	0.214	0.0105	0.1963	0.2308
s.d. price mark.	invg	0.100	2.0000	0.175	0.0229	0.1373	0.2125
s.d. wage mark.	invg	0.100	2.0000	0.216	0.0190	0.1853	0.2478
s.d. corp. spread	invg	0.100	2.0000	0.072	0.0033	0.0662	0.0769
s.d. inv. price	invg	0.100	2.0000	1.197	0.1055	1.0244	1.3678
s.d. gov. inv. price	invg	0.100	2.0000	0.850	0.1114	0.6749	1.0181