Estimating the effect of South Africa's banking sector fragility during the global financial crisis

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September 2, 2011

Abstract

In this paper we augment a standard small open economy New Keynesian DSGE model to account for the health of South Africa's banking sector. As a proxy for the health of the overall banking sector, we calculate the distance-to-default of South Africa's four largest banks. Our results indicate that developments in the health of the banking sector over the past few years have played a substantial role in South African economic activity. In addition, we show that the inclusion of a measure of banking sector health in the DSGE model improves the overall forecasting performance of the model.

JEL Classification: C15; C51; E17; E20; G21.
Keywords: Dynamic stochastic general equilibrium, Financial-real linkages, Distance-to-default.

Preliminary and incomplete. Please do not quote.

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1 Introduction

The global financial crisis has brought the interdependance of financial markets and the real economy to the forefront of macroeconomics. It is now evident that a properly functioning financial sector is vital to the overall health of an economy. Van den Heuvel (2009) finds that shocks to a bank's profits, for example through higher loan defaults, lead to a persistent decline in the bank's lending activity. In turn, reduced lending activity, i.e. the lack of access to credit, constrains real economic activity. The decline in economic activity puts further pressure on asset values and company profits, inducing more defaults in the real sector and further loan losses in the banking sector. An adverse feedback loop arises in which, according to Bernanke (2009), weakening economic and financial conditions become mutually reinforcing. Davis (2010) notes that this adverse feedback loop may explain a large part of the Unites States' recession that followed the financial crisis of 2008.

In this paper we attempt to quantify the contribution of the changes in the health of the South African banking sector to the country's real economic activity. To achieve this purpose, we augment a standard small open economy New Keynesian DSGE model to account for the health of South Africa's banking sector. As a proxy for the health of the overall banking sector, we calculate the distance-to-default of South Africa's four largest banks.

Although the first developments in the literature on financial shocks, frictions and intermediaries in DSGE models were more than two decades ago (see Bernanke and Gertler (1989)), the strand of literature has grown exponentially since the onset of the global financial crisis. For example, Christiano *et al.* (2010), Goodfriend and McCallum (2007), Gertler and Kiyotaki (2009) and Jerman and Quiadrini (2009), amongst others, all attempt to incorporate financial shocks and intermediaries in a DSGE setup. A general finding in all of these studies, is that DSGE models that account for the financial sector tend to outperform standard DSGE models in explaining real macroeconomic variables (see Arend (2010) for a useful survey of the literature). However, what is also evident from these studies, is that there is no consensus on how to model financial intermediaries in a DSGE context. In addition, no agreement exists on whether financial disruptions in these models should be between banks and households, banks and firms, or banks and other banks.

Against this background of a lack of agreement on how to model financial intermediaries in the microfounded structure of DSGE models, we follow the International Monetary Fund's (IMF) approach (see for example Carabenciov *et. al.* (2008)) of a fairly non-microfounded modelling of these financial linkages. Moreover, given that there is also no consensus on the nature of the financial disturbances, we opt for the distance-to-default measure, as this variable could conceptually encompass the interdependant financial health of banks, firms and households (see discussion on the distance-to-default measure below).

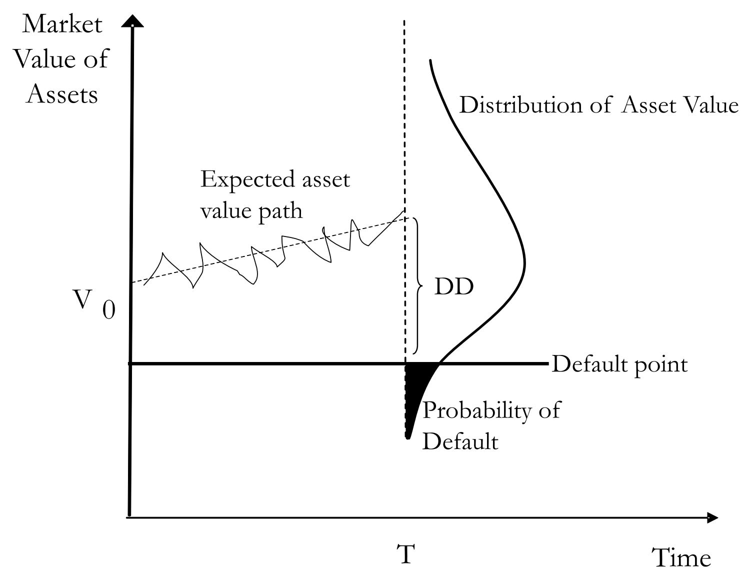
The paper is laid out as follows: Firstly, the use of the distance-to-default measure is justified. Secondly, we discuss how this measure of banking sector health is modelled and incorporated into a DSGE model. Thirdly, the modified model is estimated and evaluated bases on its in-sample forecasting ability, before we conclude with the findings of the study.

2 Measuring banking sector fragility

2.1 Distance-to-default

This paper will measure South African banking fragility by using the distance-to-default (DD) measure; where the banking sector is proxied by South Africa's four largest banks. Distance-to-default is based on the contigent claims approach (CCA), which developed from the pioneering work on option pricing theory of Black and Scholes (1973) and Merton (1973). A Contigent claim can be defined as a financial asset whose payoff at a future date is dependant on the value of another asset. Three principles underpin the contingent claims approach. The first is that assets are used to determine the values of liabilities. Secondly, there is a need to account for the differing priorities of liabilities and lastly that assets are governed by stochastic processes.

Figure 1: Distribution of asset values and default probability



Source: Gray and Malone (2008)

The benefit of the CCA is the use of forward-looking information to derive indicators of financial vulnerability. It allows for the construction of risk adjusted balance sheets that reveal underlying risk. Such balance-sheet risks are important indicators of the potential default of firms, i.e. when the value of the firm's assets fall below that of its liabilities and debt payments can no longer be serviced. Following Bohn and Crosbie (2003), a firm's probability of defaulting is determined by three main elements:

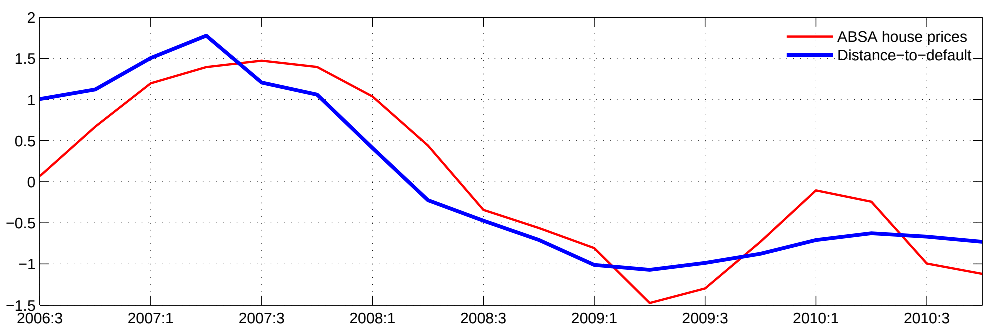
1. the market value of its assets
2. uncertainty or risk surrounding the asset values
3. and the book value of liabilities

The distance-to-default of a firm incorporates these elements as it relates the net worth of the firm (where net worth refers to the market value of the firm's assets minus the book value of its liabilities), to the size of a one standard deviation move in the asset value of the firm. A firm will default when its net worth reaches zero. The asset risk is measured by the asset volatility – the standard deviation of the annual percentage change in the asset value. Distance-to-default is then calculated as the ratio of the net worth to the standard deviation move in the asset value:

$$\text{DD} = \frac{\text{Market Value of Assets} - \text{Default Point}}{\text{Market Value of Assets} \times \text{Asset Volatility}} \tag{1}$$

Figure 1 illustrates how future asset value uncertainty, relative to the default point (promised payments on debt), determines the risk of default. Asset price uncertainty is represented by the probalility distribution at time period T.

Figure 2: ABSA house prices and Distance-to-default

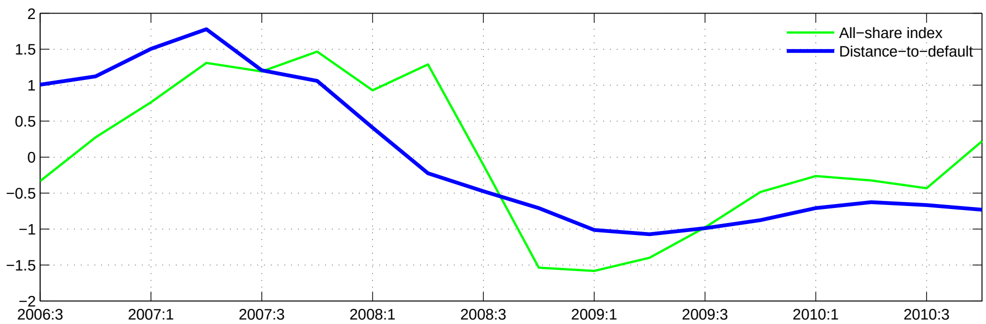


Source: ABSA and Moody's KMV

Conceptually, the distance-to-default measure of the banking sector could summarise the overall financial health of an economy. In real economic conditions where borrowers' balance sheets warrant fairly aggressive lending on the part of banks, the increase in bank assets is normally reflected by an increase in equity, hence increasing their distance to default. The increased credit availability would then feed back positively into the real economy. Alternatively, the distance-to-default measure will also reflect a shock that originated in the financial sector. For example, if banks were to write off so-called "toxic assets" (i.e. assets for which a secondary market suddenly ceases to exist), this forced balance sheet adjustment will result in the bank moving closer to its distress barrier – the point where it can no longer service its required debt payments. Subsequently, the bank will reduce its lending activity. Limited availability of credit would in turn constrain real economic activity, potentially eroding borrowers' balance sheet positions. Weaker borrower balance sheets will most likely lead to an increase in the number of loan defaults, resulting in further reductions of bank lending activity – the so-called adverse feedback loop.

Figures 2 to 4 illustrate how the distance-to-default measure (i.e. the financial health of South

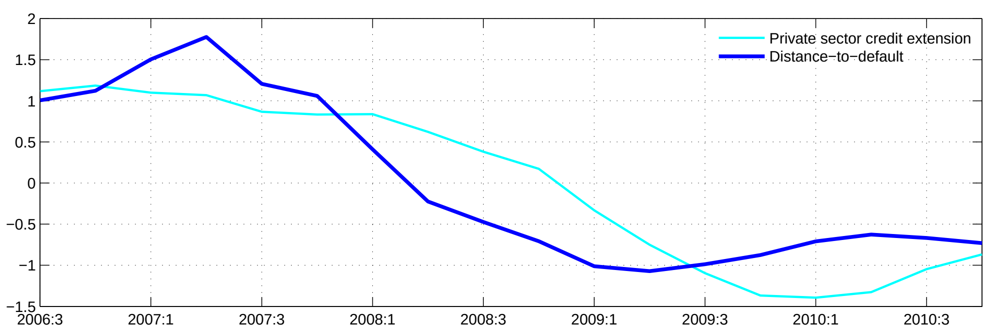
Figure 3: All-share index and Distance-to-default



Source: SARB and Moody's KMV

Africa's banking sector) correlates with indicators of the financial health of borrowers. The balance sheet positions of borrowers is proxied by house prices (i.e. assets of households) and the share market (corporate assets), while bank lending activity is reflected by private sector credit extension.

Figure 4: Private sector credit extension and Distance-to-default



Source: SARB and Moody's KMV

3 Modelling distance-to-default

Carabenciov *et al.* (2008) have developed a structure which models real-financial linkages in a monetary policy model. As a proxy for financial conditions, the authors use the bank lending tightness (BLT) indicator from the Federal Reserve Board's quarterly Senior Loan Officer Opinion Survey on Bank Lending Practices. According to Carabenciov *et al.* (2008), banks are assumed to adjust their lending behaviour according to their view of the expected state of the real economy one year ahead. That is, if the output gap y_{t+4} is expected to be positive (a strong economy), there will be a tendency to ease lending conditions, and *vice versa*:

$$BLT_t = \overline{BLT}_t - \kappa y_{t+4} + \varepsilon_t^{BLT} \tag{2}$$

where $\overline{BLT}_t$ is the equilibrium level of bank lending tightness. In turn, the output gap in Carabenciov *et al.* (2008) is affected by η_t^{BLT}, a distributed lag of the disturbance term ε_t^{BLT}:

$$\begin{aligned} \eta_t^{BLT} &= \theta \left[0.04(\varepsilon_{t-1}^{BLT} + \varepsilon_{t-9}^{BLT}) + 0.08(\varepsilon_{t-2}^{BLT} + \varepsilon_{t-8}^{BLT}) \right. \\ &+ \left. 0.12(\varepsilon_{t-3}^{BLT} + \varepsilon_{t-7}^{BLT}) + 0.16(\varepsilon_{t-5}^{BLT} + \varepsilon_{t-6}^{BLT}) + 0.20\varepsilon_{t-5}^{BLT}\right] \end{aligned} \tag{3}$$

Hence, if lending conditions were to be tighter than might have been anticipated given expectations on the future state of the real economy (i.e. a positive ε_t^{BLT}), the effect will be a reduced output gap and a weaker economy. The values of the coefficients imposed in Eq. (3) are intended to reflect a pattern in which a tightening of the bank lending conditions variable is expected to negatively affect aggregate demand in a hump-shaped fashion, with an initial buildup and then a gradual rundown of the effects.

Anvari and Chamberlain (2011) show that with a few minor adjustments, the structure of Carabenciov *et al.* (2008) can be used for the modelling of distance-to-default in a monetary policy model. Accordingly, Eq. (2) becomes:

$$DD_t = \overline{DD}_t + \kappa y_{t+4} + \varepsilon_t^{DD} \tag{4}$$

Moreover, Anvari and Chamberlain (2011) find that a distributed lag of shorter length than employed in Carabenciov *et al.*'s (2008) bank lending tightness is sufficient to affect the hump-shape for distance-to-default:

$$\eta_t^{DD} = \theta \left[\frac{1}{11}\varepsilon_t^{DD} + \frac{2}{11}(\varepsilon_{t-1}^{DD} + \varepsilon_{t-4}^{DD}) + \frac{3}{11}(\varepsilon_{t-2}^{DD} + \varepsilon_{t-3}^{DD})\right] \tag{5}$$

4 DSGE-DD: Distance-to-default in a DSGE model

In order to assess the contribution of the fragility of South Africa's banking sector to the recession, a standard small open economy New Keynesian dynamic stochastic general equilibrium (DSGE) model is adapted to account for the distance-to-default measure (DSGE-DD hereafter) discussed in the previous section. The standard DSGE model largely matches the models used in Steinbach *et al.* (2009) and Gupta and Steinbach (2011). It contains nominal rigities in the form of Calvo

(1983) staggered wage and price setting, partial indexation of domestic prices to their past inflation, partial indexation of wages to past consumer price inflation, as well as incomplete exchange rate pass-through over the short run. In addition, external habit formation in consumption provides some real rigity. Apart from being modelled as a closed economy and abstracting from wage rigidities, the foreign economy is similar in structure to the domestic economy.

The key equations of the model are:

$$\begin{aligned}
c_t &= \frac{1}{1+h}c_{t+1} + \frac{h}{1+h}c_{t-1} - \frac{1-h}{(1+h)\sigma}(r_t - E_t\pi_{t+1} + \eta_t^d - \eta_{t+1}^d + \eta_t^{DD}) && (6)\\
\pi_t^h &= \frac{\omega}{1+\omega\beta}\pi_{t-1}^h + \frac{\beta}{1+\omega\beta}E_t\pi_{t+1}^h + \frac{(1-\theta_h)(1-\theta_h\beta)}{\theta_h(1+\omega\beta)}mc_t && (7)\\
\pi_t^w &= \alpha\pi_{t-1} + \beta E_t\pi_{t+1}^w - \alpha\beta\pi_t + \frac{(1-\theta_w)(1-\theta_w\beta)}{\theta_w(1+\xi_w\varphi)}\mu_t^w && (8)\\
mc_t &= rw_t - a_t + \gamma s_t + \varepsilon_t^p && (9)\\
\pi_t^f &= \beta E_t\pi_{t+1}^f + \frac{(1-\theta_f)(1-\theta_f\beta)}{\theta_f}\psi_t && (10)\\
\psi_t &= \psi_{t-1} + \Delta e_t + \pi_t^* - \pi_t^f && (11)\\
\pi_t &= (1-\gamma)\pi_t^h + \gamma\pi_t^f && (12)\\
r_t &= \rho_r r_{t-1} + (1-\rho_r)[\phi_\pi\pi_{4,t+4} + \phi_y y_t] + \varepsilon_t^r && (13)\\
q_t &= \phi_q E_t q_{t+1} + (1-\phi_q)q_{t-1} - \left[(r_t - E_t\pi_{t+1}) - (r_t^* - E_t\pi_{t+1}^*)\right] + \eta_t^{DD} && (14)\\
y_t &= a_t + l_t && (15)\\
y_t &= (1-\gamma)c_t + \eta\gamma(2-\gamma)s_t + \gamma y_t^* + \eta\gamma\psi_t && (16)\\
y_t^* &= hy_{t-1}^* + \frac{\sigma}{\sigma^*}(c_t - hc_{t-1}) - \frac{1-h}{\sigma^*}q_t && (17)
\end{aligned}$$

Eq. (6) is the consumption Euler equation. Consumption, denoted by c_t, depends on past values of consumption, expectations about future consumption in $t+1$, as well as the *ex ante* real interest rate, $r_t - E_t\pi_{t+1}$. In addition, shocks to consumption may emanate from the preference (demand) shock η_t^d, which is assumed to follow the AR(1) process $\eta_t^d = \rho_d\eta_{t-1}^d + \nu_t^d$, where $\nu_t^d \sim$ i.i.d $N(0, \sigma_d^2)$. The parameter h in Eq. (6) represents the degree of habit formation in consumption and σ is the inverse of the intertemporal elasticity of substitution for consumption. Following Smets and Wouters (2007), we augment the consumption Euler equation with a so called net-worth shock. For the purposes of our analysis, the net-worth shock represents the distributed lag of shocks to the net worth of banks η_t^{DD}, as discussed in the previous section.

In Eqs. (7) and (8) a Phillips-curve type relationship holds for both domestic inflation π_t^h and nominal wage inflation π_t^w. Domestic inflation depends on its own lagged values, expected future inflation and marginal costs, mc_t, whereas wage inflation is partially indexed to consumer price inflation. The key parameters that govern the dynamics of these two equations are: (i) the discount factor β; (ii) the degrees of indexation to past inflation, ω and α; and (iii) the degree of price stickiness reflected by the Calvo (1983) parameters θ_h and θ_w.

Marginal costs reflect real wage (rw_t) increases that exceed productivity gains (a_t), the terms of trade (s_t) and a price markup shock (ε_t^p). The price markup shock is assumed to follow an AR(1) process $\varepsilon_t^p = \rho_p \varepsilon_{t-1}^p + \nu_t^p$, where $\nu_t^p \sim$ i.i.d $N(0, \sigma_p^2)$.

Imported inflation, denoted by π_t^f in Eq. (10), is a function of expected future imported inflation as well as the degree of imperfect exchange rate pass-through, ψ_t. Imperfect exchange rate pass-through results from deviations of the law-of-one-price in Eq. (11), where Δe_t is the change in the nominal exchange rate and π_t^* represents foreign inflation. Eq. (12) relates CPI inflation to domestic and imported inflation, where γ is the degree of openness.

A Taylor-type rule describes the behaviour of the monetary authority in Eq. (13), where ρ_r, ϕ_π and ϕ_y are the respective weights on policy smoothing, expected one-year-ahead consumer price inflation ($\pi_{4,t+4}$) and the output gap.

The real exchange rate (q_t) is represented by the UIP condition in Eq. (14). Here, the Smets and Wouters (2007) net worth shock also enters the uncovered interest parity condition in the form of a risk premium. In addition, the functional form of the UIP condition follows the modified specification of Adolfson *et al.* (2006), in order to induce some persistence in the exchange rate dynamics.

Finally, productivity and labour are the only factors of production in Eq. (15), aggregate demand in the domestic economy is expressed as Eq. (16), while the model is closed by the consumption risk sharing condition in Eq. (17).

5 Estimation

5.1 Data

The model is estimated with Bayesian techniques on 44 data observations, covering the sample 2000Q1 to 2010Q4. Seven observable variables are employed during estimation, four for the domestic economy and three for the foreign economies. The observable variables are: π_t – Headline Consumer Price Index (CPI) inflation at quarterly non-annualised rates (seasonally adjusted);[1] y_t – Real Gross Domestic Product at market prices (seasonally adjusted); r_t – the Repurchase rate of the South African Reserve Bank (quarterly, non-annualised); and DD_t – distance-to-default for South Africa's four largest banks, which was calculated using data from Moody's KMV. The

[1] From 2009Q1 to 2010Q4, the headline CPI for all urban areas is used, whereas CPIX inflation (i.e. CPI excluding mortgage and interest payments) for all metropolitan and urban areas is used prior to 2009Q1.

foreign economy observable variables are: π_t^* – South Africa's trading partner wholesale prices (trade-weighted, seasonally adjusted and quarterly, non-annualised); y_t^* – South Africa's trading partner GDP (trade-weighted, seasonally adjusted); and r_t^* – a trade-weighted combination of the ECB's key interest rate and the US Federal Funds rate (quarterly, non-annualised).[2]

5.2 Parameter estimates

The prior specifications of the model's parameters largely match those found in the literature. However, given the notorious identification issues associated with the estimation of DSGE models (see Lubik and Schorfheide (2005) as an example), a number of parameters were calibrated. Parameters were calibrated if their prior and posterior distribution were identical, i.e. indicating that the data has no information regarding the specific parameter. Table 1 lists these parameters. The

Table 1: Key Calibrated Parameters

β	φ	ξ_w	h	γ	θ_w	ω	ρ_r	θ	ρ_r^*	ρ_p^*	ω^*
0.99	3	1	0.7	0.2	0.5	0.25	0.73	1	0.8	0.8	0.5

calibrated values for both the domestic and foreign economy's discount factor, the Frisch elasticity of labour supply, and the labour demand elasticity are standard in the literature. The degree of habit formation for both economies is set to 0.7. The import share in the domestic economy of 0.2 follows Steinbach *et al.* (2009). The Calvo parameter for wages θ_w is calibrated to 0.5, while the partial price indexation parameter is set to 0.25. The domestic economy's Taylor rule smoothing parameter of 0.73 follows Ortiz and Sturzenegger (2007). The parameter that governs the magnitude of the distributed lag of shocks to distance-to-default is calibrated to 1. Carabenciov *et al.* (2011) estimate this parameter at 1.017 for the bank lending tightness in the United States. For the foreign economy, the Taylor rule smoothing parameter is calibrated to 0.8, persistence of price shocks are 0.8, while the degree of price indexation is set to 0.5 – all fairly common calibrations in the literature.

The posterior estimates of the remaining parameters are presented in Table 2. With respect to the domestic economy's estimates, the consumption substitution elasticity matches the estimates of Justiniano and Preston (2010) for Australia and New Zealand. The degree of substitution between domestic and foreign goods is estimated to be slightly lower than Chari, Kehoe and McGratten's (2002) calibration of 1.5. The posterior estimates of the Calvo parameters suggest that domestic prices are reoptimised more frequently when compared to imported prices. Nominal wages, being indexed to previous CPI inflation to a high degree, accurately reflects the wage formation process in South Africa. With the weight on inflation in the Taylor rule being lower than expected, while

[2] In order to be consistent with the log-linearised model specification, all series were detrended prior to estimation.

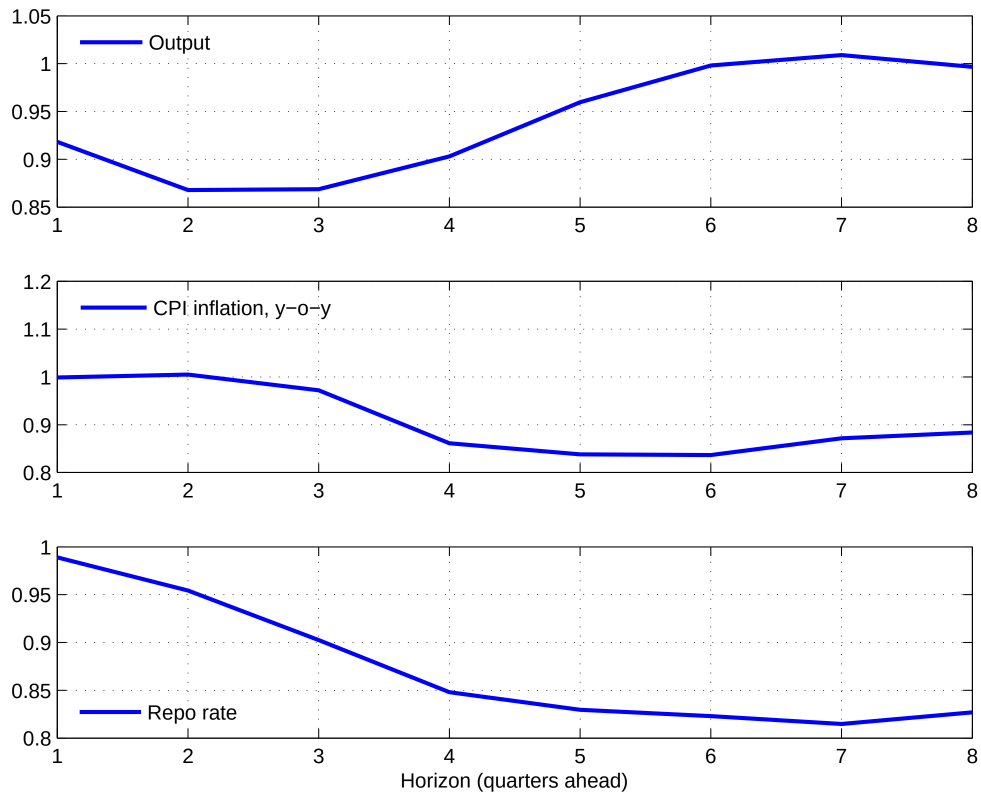
Table 2: Prior Distributions and Posterior Estimates

Parameter description		Prior density	Prior mean	Prior std dev	Posterior mean	Posterior 90% interval
			Domestic economy			
Structural parameters						
Consumption substitution elasticity	σ	N	1	0.2	1.062	[0.770 ; 1.341]
Home/foreign substitution	η	G	1	0.2	1.277	[0.984 ; 1.578]
Calvo: domestic prices	θ_h	B	0.75	0.1	0.692	[0.602 ; 0.788]
Calvo: imported prices	θ_f	B	0.75	0.1	0.917	[0.879 ; 0.955]
Indexation: wages	α	B	0.75	0.1	0.743	[0.584 ; 0.906]
UIP: smoothing	ϕ_q	B	0.8	0.1	0.829	[0.710 ; 0.957]
Taylor rule weights						
Inflation	ϕ_π	G	1.5	0.125	1.298	[1.180 ; 1.417]
Output gap	ϕ_y	G	0.125	0.031	0.132	[0.091 ; 0.175]
Distance-to-default weight						
Output gap	κ	G	1	0.1	1.158	[1.005 ; 1.300]
Persistence parameters						
AR(1): price markups	ρ_p	B	0.8	0.1	0.338	[0.226 ; 0.444]
AR(1): productivity	ρ_a	B	0.8	0.1	0.859	[0.740 ; 0.981]
AR(1): demand	ρ_d	B	0.8	0.1	0.705	[0.639 ; 0.778]
Standard deviations of domestic shocks						
iid shock: productivity	σ_a	IG	1	∞	0.623	[0.282 ; 0.942]
iid shock: demand	σ_d	IG	1	∞	1.027	[0.790 ; 1.277]
iid shock: price markups	σ_p	IG	1	∞	6.263	[2.855 ; 10.01]
iid shock: wage markups	σ_w	IG	1	∞	2.314	[0.261 ; 5.070]
iid shock: monetary policy	σ_r	IG	1	∞	0.177	[0.145 ; 0.209]
iid shock: distance-to-default	σ_{DD}	IG	1	∞	0.440	[0.358 ; 0.520]
			Foreign economy			
Structural parameters						
Calvo: prices	θ^*	B	0.75	0.1	0.790	[0.754 ; 0.824]
Taylor rule weights						
Inflation	ϕ_π	G	1.5	0.125	1.486	[1.282 ; 1.699]
Output gap	ϕ_y	G	0.125	0.031	0.101	[0.061 ; 0.141]
Persistence parameters						
AR(1): productivity	ρ_a^*	B	0.8	0.1	0.165	[0.106 ; 0.215]
Standard deviations of foreign shocks						
iid shock: productivity	σ_a^*	IG	1	∞	3.947	[2.548 ; 5.376]
iid shock: price markups	σ_p^*	IG	1	∞	0.634	[0.253 ; 1.005]
iid shock: monetary policy	σ_r^*	IG	1	∞	0.155	[0.128 ; 0.184]

the weight on output is slightly higher – it perhaps reflects that the South African Reserve Bank follows a fairly pragmatic approach in the making of its monetary policy decisions, i.e. by reacting sufficiently to inflationary pressures, whilst taking account of the state of the real economy. The estimated weight on expected output in $t+4$, κ, indicates that the distance-to-default of the banking sector almost moves one-for-one with the expected output gap. Apart from price markup shocks, the persistence parameters are in line with prior expectations. The magnitude of price markup shocks dominate the standard deviations of the shock processes.

In the foreign economy, it appears as if prices are re-optimised less frequently when compared to the domestic economy. While the weight on output in the Taylor rule is lower than in the domestic economy, the weight on inflation is slightly higher for the foreign economy. However, a direct comparison of the inflation parameter in the Taylor rule to its domestic counterpart is complicated by the fact that inflation in the foreign economy is proxied by foreign wholesale prices, as opposed to CPI inflation in the domestic economy. The persistence parameter of productivity shocks in the foreign economy is lower than anticipated, whereas the magnitude of the standard deviation of productivity shocks dominates.

Figure 5: RMSE comparison



6 Model evaluation

We evaluate the inclusion of the distance-to-default structure in the DSGE model by analysing its in-sample forecasting accuracy. This is achieved through comparing the one-to-eight quarter ahead root mean squared errors (RMSEs) of the DSGE-DD model to those of the standard DSGE model which excludes the distance-to-default structure.

The relative RMSEs of these forecasts are compared in Figure 5 and Table 3. A relative RSME of less than one implies that the RMSE of the DSGE-DD model is lower than that of the standard

DSGE model.

The Diebold-Mariano test confirms that the DSGE-DD model is more accurate in forecasting output up to three quarters ahead, whereafter there is no significant difference in accuracy between the two models. With respect to forecasting inflation, there is no significant difference in accuracy over a horizon of up to three quarters, whereafter the DSGE-DD model shows significantly improved forecasting ability. Similarly, we find that the DSGE-DD model forecasts the Repurchase rate more accurately over a horizon of three to eight quarters.

Table 3: Relative RMSEs

Quarters ahead	Output	Inflation	Repurchase rate
1	0. 918*	0. 999	0. 989
2	0. 868**	1. 005	0. 954
3	0. 869*	0. 972	0. 902*
4	0. 903	0. 861**	0. 848**
5	0. 96	0. 838***	0. 830**
6	0. 998	0. 837***	0. 823***
7	1. 009	0. 871**	0. 815***
8	0. 997	0. 884***	0. 827***

Note: *(**)[***] indicate 10%, (5%), [1%] level of significance for the Diebold-Mariano test statistic.

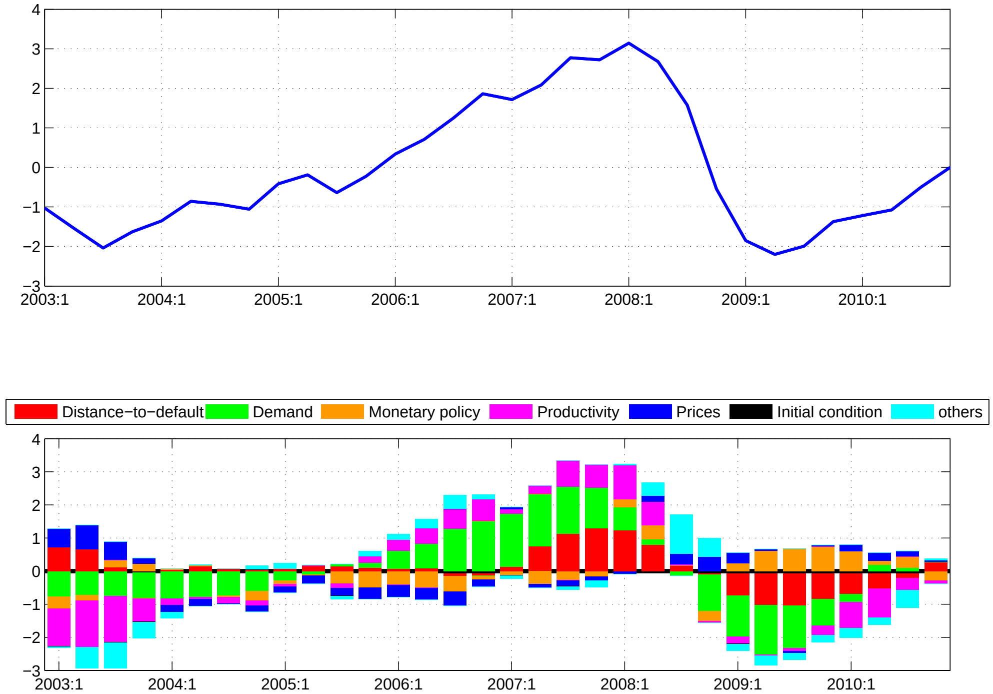
7 Results

Including the distance-to-default measure for South Africa's four largest banks in the DSGE model enables us to quantify the contribution of bank balance sheet fragility to the recession of 2008 and 2009. Figure 6 decomposes detrended output into the structural shocks that contribute to the movements in GDP. Of relevance here is the contribution of distance-to-default shocks, i.e. shocks to the net worth of South Africa's banking sector. Accordingly, banking fragility contributed as much as one percentage point to the decline in output during the recession of 2009. Interestingly, the bank lending exuberance that preceded the financial crisis of 2008, appears to have contributed to the overheating of the economy during 2007 and early 2008.

8 Conclusion

The global financial crisis has brought the interdependance of financial markets and the real economy to the forefront of developments in macroeconomic models. Accordingly, we incorporate a measure of banking sector health – the distance-to-default of South Africa's four largest banks

Figure 6: Shock decompostion of output



– into a New Keynesian DSGE model of South Africa. The inclusion of the distance-to-default measure proved not only to improve the overall forecasting accuracy of the DSGE model, but also allows for the quantification of the impact of changes in the health of the banking sector on the real economy. To this extent, our findings indicate that the deterioration in the health of the banking sector during the financial crisis contributed substantially to the depth of the recession in 2008 and 2009.

References

Adolfson, M., S. Lasen, J. Lind and M. Villani (2006) Evaluating An Estimated New Keynesian Small Open Economy Model, manuscript, Sveriges Riksbank.

Anvari, V. and Chamberlain, D.R. (2011). From bank lending tightness to distance-to-default. Unpublished manuscript, Research Department, South African Reserve Bank.

Arend, M. (2010) Financial Shocks, Financial Frictions and Financial Intermediaries in DSGE Models: Comments on the Recent Literature. MPRA Paper No. 22957.

Bernanke, B.S., and Gertler, M., (1989) Agency Costs, NetWorth, and Business Fluctuations. *American Economic Review*, Vol. 79, pp. 14-31.

Bernanke, B.S. 2009. Semiannual Monetary Policy Report to the Congress Before the Committee on Banking, Housing and Urban Affairs, U.S. Senate, Washington, D.C., February.

Black, F. and Scholes, M. (1973) The pricing of options and corporate liabilities. *Journal of Political Economy*, Vol. 81, pp. 637-654

Bohn, J. and Crosbie, P. (2003) Modelling default risk. *Moody's KMV*

Calvo, G. (1983). Staggered prices in a utility-maximising framework, Journal of Monetary Economics, Vol. 12, pp. 983-998.

Carabenciov, I., Ermolaev, I., Freedman, C., Juillard, M., Kamenik, O., Korshunov, D., Laxton, D. and Laxton, J. (2008) A Small Quarterly Multi-Country Projection Model with Financial-Real Linkages and Oil Prices. *IMF Working Paper Series*, No. WP/08/280, International Monetary Fund.

Chari, V.V., Kehoe, P. and McGratten, E. (2002). Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates? Review of Economic Studies, Vol. 69, pp. 533-563.

Christiano, L.J., Motto, R., and Rostagno, M., 2010. Financial Factors in Economic Fluctuations. ECB Working Paper No. 1192.

Davis, S. 2010. The Adverse Feedback Loop and the Effects of Risk in both the Real and Financial Sectors. Federal Reserve Bank of Dallas Working Paper No. 66.

Gertler, M., and Kiyotaki, N., 2009. Financial Intermediation and Credit Policy in Business Cycle Analysis, October, mimeo.

Goodfriend, M., and McCallum, B.T., 2007. Banking and Interest Rates in Monetary Policy Analysis: A Quantitive Exploration, Journal of Monetary Economics, 54, pp. 1480-1507.

Gray, D.F. and Malone, S.W. 2008. Macrofinancial risk analysis. Wiley Finance Series.

Gupta, R. and Steinbach, M.R. (2011). A DSGE-VAR Model for Forecasting Key South African Macroeconomic Variables. UP working paper No. 201019.

Jerman, U., and Quadrini, E, (2009). Macroeconomic Eects of Financial Shocks, NBER Working Paper 15338.

Justiniano, A and Preston, B. (2010). Monetary Policy and Uncertainty in an Emprical Small Open Economy Models. Journal of Applied Econometrics, 25, 93-128.

Lubik, T. and Schorfheide, F. (2005). A Bayesian look at new open economy macroeconomics. NBER Macroeconomics Annual, pp. 313-366.

Merton, R.C. (1973) The theory of rational option pricing. *Bell Journal of Economics and Management Science*, Vol. 4, pp. 141-183

Ortiz, A. and Sturzenegger, F. (2007). Estimating SARB'S Policy Reaction Rule. South African Journal of Economics, Economic Society of South Africa, 75, 659-680.

Smets, F. and Wouters, R. (2007). Shocks and frictions in US business cycles: A Bayesian DSGE approach. American Economic Review, 97, 586-606.

Steinbach, M.R., Mathuloe, P.T. and Smit, B.W. (2009). An open economy New Keynesian DSGE model of the South African economy. South African Journal of Economics, 77, 207-227.

Van den Heuvel, S. J. (2009). The Bank Capital Channel of Monetary Policy, Federal Reserve Board.