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Accounting for the Great Recession in the UK: Real Business Cycles and Financial Frictions.*

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Abstract

Using the business cycle accounting (BCA) framework pioneered by Chari, Kehoe and McGratten (2006) we examine the 2008-09 recession in the UK. There has been much commentary on the financial causes of this recession, which we might have expected to shock the equation governing the intertemporal rate of substitution in consumption. However, the recession appears to have been mostly driven by shocks to the efficiency wedge in total production, rather than the intertemporal consumption, labour or spending wedge. From an expenditure perspective this result is consistent with the observed large falls in both consumption and investment during the recession. To assess this result we also simulate artificial data from a DSGE model in which asset price shocks dominate and find no strong role for the intertemporal consumption wedge using the BCA method. This result does not imply that financial frictions did not matter for the recent recession but that such frictions do not necessarily impact only on the intertemporal rate of substitution in consumption.

JEL Classification: E31; E40; E51.

Keywords: Business Cycle Accounting, Major Recessions, TFP, Financial Frictions.

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1 Introduction

In the second quarter of 2008, the U.K. economy slid into its deepest postwar recession. The proximate cause has frequently been reported as the global financial crisis and that year's failure of large US 'bulge bracket' investment banks: Bear Stearns and, with powerful ramifications, Lehman brothers. Following the collapse of Lehman Brothers a number of UK commercial banks were placed into majority public ownership. As every schoolboy now knows, the increase of systemic risk in the banking system led to the increase in the cost of loans to households and firms and coupled with a fall in global demand, led to a sharp fall in investment and consumption. GDP fell sharply with output as much as 10-12% below trend in the first quarter of 2009 by some estimates. Over this period central banks were forced to look for alternative instruments to stimulate economic activity, as the main tool of monetary policy makers - the short run interest rate - was constrained to the zero lower bound. There has been a hesitant and faltering recovery as expansionary fiscal policy has also reached its limits. In this paper we will assess this demand-side story as the cause of the 'great recession' alongside an influential supply side model.

A useful way of thinking about a deep recession is that it represents a persistent deviation in output from its natural, or flex-price, level. And so we can use Chari, Kehoe and McGrattan's (2006) Business Cycle Accounting (BCA) framework. The BCA framework decomposes the deviation in the economy from its flex price equilibrium into four sets of residuals (henceforth wedges) which act like time varying taxes on: labour supply; productive efficiency, investment and total expenditure. Within this framework these wedges correspond to a whole host of distortions used widely in the DSGE literature, such as sticky wages and prices (for the labour wedge), external finance premia (the investment wedge) or distortionary taxes (expenditure wedge). As such the BCA framework appears to be a natural candidate to assess the causes of the recent recession in terms of these distortionary wedges.

To assess the results, we also provide a simple demand decomposition of the recession period, which uncovers each components of individual growth to overall output growth. The results of this decomposition provide a clear characterisation of this recession, as consumption and investment-led, and points researchers as to how shocks from more complex models should move economic variables. Finally, we shall also provide some insight to how financial shocks from an extended version of the Bernanke, Gertler and Gilchrist model (Bernanke and Gertler, 1999) which includes an asset price (or bubble) shock map into the BCA analysis. We run the model with a high degree of asset price variation and then extract the simulated data and re-estimate using the BCA estimation process and assess whether an investment wedge is then found to have driven the asset price bubble economy.

As Rouwenhorst (1995) explains, the consumption Euler equation in the standard optimising framework is the asset price equation which equates one unit of consumption across time periods from t to t+j, or put alternatively is the asset pricing kernel (or stochastic discount factor) for future expected returns. CKM (2006) explain that financial frictions, map directly into a wedge that separates consumption from its optimal value given the Euler equation. An example of this could be consumers or firms facing liquidity constraints which reduces their ability to access capital markets. A shock which leads to a tightening of the liquidity constraint reduces the ability of consumers to access capital markets and constrains current consumption to lower levels. Consumers and firms

would then invest for future consumption implying a higher asset price and a lower rate of return. In the absence of the shock to the liquidity constraint consumers would not elect to deter consumption as the marginal utility gained from consuming an extra unit of current consumption is relatively high compared to the marginal utility of deferring consumption to future periods and so deviations in consumption from the optimal plan may be thought to arise directly from a change in financial frictions. Therefore, where the discounted future return on an asset and current consumption are not equal the difference will be captured by the so-called investment wedge in the CKM framework.

As a result we have some clear measure on the recent UK recession: the shocks that drove the recession reduce both consumption and investment, according to our expenditure decomposition, and hence are either according to the BCA methodology efficiency or labour wedges. This is because the investment wedge drives consumption and investment in opposite directions and the expenditure wedge does not have sufficient variation in the estimation. Our estimation of the BCA model suggests that the main cause of the 'great recession' is variation in the efficiency wedge of production, which provides a significant explanation of the variation in output, rather than the other wedges.[1] To check this finding we run a counterfactual analysis of the BCA experiment, using a version of the BGG model which includes a dominant asset price (bubble) shock. This shock then drives our artificial economy on which we run a BCA decomposition but find that this shock also does not appear as a consumption, investment wedge in the BCA analysis. This implies that it is entirely possible for asset price shocks to show up in other wedges in the BCA framework and that ascribing a causal role to efficiency or labour wedges may not strictly imply that the shocks emanated from those sectors alone. At one level we therefore argue that DSGE modelers may have to continue to think about how asset pricing equations and the role of asset prices affect the wider economy, as their impacts in general equilibrium may be to shift labour supply or, indeed, the ratio of outputs to inputs.

The structure of the paper is as follows, section 2 introduces the BCA literature and some of the recent papers focusing on the 'Great Recession', section 3 outlines the methodology behind BCA and the estimation strategy employed. Section 4 outlines the results and section 5 provides a summary.

2 Literature Review

The BCA framework introduced by Chari, Kehoe and McGrattan (2006), sought to decompose the economy into wedges that affected the equilibrium allocations of labour supply, intertemporal efficiency and productive allocations. They showed that it was possible to map defined distortions from complicated models into a simple growth model and that these distortions would map one on one into a particular wedge. The underpinning idea of these wedges were a set of equivalence results, the examples they gave were that the effects of sticky prices or unionisation would appear as a labour wedge through the disconnect between the marginal product of labour and the marginal rate of consumption, labour. Financial accelerator type mechanisms would appear through

[1] The investment wedge provides a secondary role falling slightly at the time of the recession, pari passu it however would exaggerate the movements of GDP over the projected recovery period. The labour wedge plays little to no role in explaining the recession as it remains relatively constant throughout the recessionary period and then falls through the projected recovery. There is also little role for the expenditure wedge.

the investment wedge, the disconnect between the intertemporal rate of substitution, consumption and marginal product of capital. Finally they showed that input financing constraints would show up as an efficiency wedge a total factor productivity parameter. The applied the methodology to the U.S. for the 'Great Depression' era and the recession in the 1980s, after the wedges had been measured, they then simulated counter factual economies where only one wedge or a combination of wedges were allowed to vary over time while all others were held constant at their steady state values. Their results suggested that for both recessionary periods that the efficiency and labour wedges were the most important causes of the recessions.

In terms of the most recent recession much of the recent discussion has focused around the role that financial frictions, falls in investment and asset prices can lead to wider effects on the economy. One such example is given by Martin (2010) who provides an in-depth look at the factors that caused the U.K. economy to be weak before concentrating on the causes of the 'Great Recession'. Martin argues that the main drivers of the recession were a large collapse in world trade, falls in private wealth due to the collapse in the housing market and the stock market as well as the financial crisis. He argues that bank lending may have reached a shortfall of around 8% around the peak of the crisis. He notes however there appears to be a delayed impact from the onset of financial crisis to the wider economy, he notes two contributing factors; firstly that there may have been expectational effects due to the failure of Lehmans leading to an increase in precautionary saving for the future. A second explanation for the depletion of liquidity cushions for households and non-financial firms, essentially at the beginning of the financial crisis given the constrained credit conditions households and firms reduced their holdings of liquid assets in order to maintain pre-crisis levels of consumption once these liquid assets had run out households and firms had to cut spending.

Chari, Christiano and Kehoe (2008), provide a dissenting view as to the 'Great Recession', it is important to note that they do not argue that there is no large financial shock, rather they argue that the financial crisis may not be the main cause of the recession and that rather it may appear as an effect, their analysis focus' on the change (or the lack thereof) in the spreads. They note that the interest rate on commercial paper had not increased by much for AA-rated non-financial companies whereas it had risen markedly for the financial companies. They note that on aggregate non-financial firms can cover their capital costs entirely through retained earnings and that 80% of all of the borrowing from non-financial firms happens outside of the banking system. The also argue that the increase in spreads that occurred could just be due to an increase of perceived risk and a rebalancing of banks balance sheets as opposed to any underlying large scale market failure around lending and borrowing. Essentially under this view non-financial firms ability to source investment funds appear to be unaffected by the problems in the financial sector, furthermore the small rise in spreads that we have seen may just be the result of normal reactions to a recession.

Kersting (2006) has applied BCA for the 1980's recession and recovery for the U.K. and finds that the most important cause was the labour wedge while the efficiency wedge played a secondary role in understanding the business cycle episode. The investment wedge over this period moves in a counter-cyclical fashion, suggesting that the alleviation of financial frictions actually stopped the U.K. economy from being in a steeper recession.

There have been two interesting extensions to the BCA methodology, while outside of the scope of this paper highlight the flexibility and usefulness of the framework, firstly

Otsu (2010) who provides an open economy version and concludes that efficiency and labour wedges are the most important cause of the increased output correlation between countries. Sustek (2010) provides a nominal extension to BCA and shows through equivalence results that complicated nominal models can also be mapped into a growth model adjusted for nominal effects as, monetary wedges and bond price wedges, the nominal business cycles accounting exercise finds that the nominal wedges have little to no effect on real variables but can help to explain puzzles in the bond market.

Christiano and Davies (2006) criticise the flexibility of the BCA framework as they suggest that without placing identifying restrictions on the reduced form of the VAR estimations it is impossible to gauge the effects of spillovers between wedges. They place restrictions on the primitive shocks and estimate a rotation decomposition, they create a statistic which shows the importance of each wedge. Their findings show that different identification restrictions will lead to the same values of the likelihood function but indicate different levels of importance of the investment wedge. While Christiano and Davies (2006) caveat is beyond the scope of this paper, it is an important point to note, subsequently when assessing the importance of each wedge that it does not rule out models in which financial shocks could lead to movements in other wedges and vice-versa.

In this paper we shall provide the background to the recession by showing the contributions of the determinants of demand, followed by decomposing the economy by the BCA methodology. Our final exercise in this paper is to use artificial data created via a modified version of the Bernanke, Gali and Gertler financial accelerator model (Bernanke and Gerter (1999)) This follows on from CKM (2006) original paper where they showed that through equivalence results that frictions which appear explicitly in complicated models will appear as only one wedge in the prototype growth model. We are interested in how the 'bubble shock' in the modified BGG model, a shock which effects the net worth of entrepreneurs and therefore the external finance premium (the financial distortion) will manifest itself in the BCA methodology. We do this firstly as a robustness check of the CKM equivalence results and secondly the results from this exercise may provide us with an alternative view of the causes of the current recession.

2.1 Decomposing supply and demand

This subsection provides the background for the later discussion about the results of the BCA decomposition, we calculate two simple decompositions using the determinants of supply and demand. These two decompositions provide both some background to the recession, but also may highlight some important points for the results of the BCA decomposition presented later.

For our simple demand decomposition we take advantage of the expenditure definition of output shown by (1), to which we calculate the year on year changes of each of the expenditure components and scale them by their relative contributions to over all output ((2) provides an example for how this would be done for consumption).

$$Y_t = C_t + X_t + G_t + (EX_t - IM_t), \tag{1}$$

$$\frac{C_{t-4}}{Y_{t-4}} \times \frac{C_t - C_{t-4}}{C_{t-4}}. \tag{2}$$

In order to decompose supply we calculate a simple growth accounting exercise.

Given data on output, labour hours and the capital stock. We assume a simple Cobb-Douglas production function with the form:

$$Y_t = K_t^{\alpha}(Z_t L_t)^{1-\alpha}, \tag{3}$$

taking logs and defining growth as $g_y = \frac{Y_t - Y_{t-1}}{Y_t}$, (which follows for g_k and g_l) we get the following;

$$g_y = \alpha g_k + (1-\alpha) g_l + (1-\alpha) g_z \tag{4}$$

by re-arranging we can calculate the Solow residual and uncover the contributions of the factor inputs to the production function.

Figure 1 shows the main contributions of the expenditure components of growth to the overall level of GDP growth were investment and consumption, with the contribution of investment providing the largest fall in GDP. It is important to note that investment falls to negative levels just before the beginning of the recession in 2008 Q1 while the contribution of consumption to overall output growth begins after the onset of the recession by a quarter in 2008 Q3. Both investment and consumption are negative throughout the recession and are slow to return to positive growth, the main driver in the recovery period appears to be investment, while consumption growth remained sluggish through the recession and the subsequent recovery. This point is re-iterated in Table (1) which quantifies the contributions of the expenditure components as an average for both the period of the recession and the preceding years back to 1971 Q1. Average growth for the U.K. is 2.26% over this sample period, the main contribution to growth is supplied by consumption with investment and government expenditures making up the rest, over this period net exports contributed slightly negatively to average growth. The recessionary period highlights how sharp the fall in GDP was the average over the period was around 4.5%, reaching a trough in 2009 of approximately 5.9%. The table shows that the fall in investment was equally as sharp falling over 4% while consumption fell by roughly 3.5% in comparison to average before the recession. GDP growth was slightly held up by net exports which grew by over 1%, government spending decreased slightly over this period. Overall, the expenditure decomposition shows that the recession was investment and consumption led and importantly that the two series co-move throughout the whole recession with the exception of the quarter before the recession.

For the supply side decomposition we find that during normal periods of growth that TFP contributes to most of the growth of GDP contributing around 60% which the capital stock contributes towards around 30% of GDP growth, the contribution of labour is relatively small and provides the final 10%. During the recession the main driver of GDP growth is TFP which fell of 4% and contributed to 80% of the fall in GDP, the labour input fell around 1.75% which equates to a contribution in the fall of GDP of around 40%. The contribution of capital over this period remained relatively constant to the pre-recession levels and even increase a fraction, it contributed positively to GDP around 15 %. The simple decompositions provide a precursor to the main BCA experiment in that the demand side decomposition shows that the majority of the fluctuations in GDP are due to movements in investment and consumption while the simple growth accounting exercise highlights the role of TFP as the driver of GDP.

3 Methodology

In this section we will explain the underlying model behind the BCA methodology while explaining the meaning behind the theoretical underpinnings of these wedges, we shall also outline the estimation procedure while highlighting other options which can be used as alternatives to the ones that we employ in this paper. We finally explain the method used to decompose the business cycle episodes in to the contributions of the wedges.

3.1 Model

The model is the standard form of the general equilibrium with time varying wedges included, consumers maximise utility given the choice of consumption and labour;

$$\max_{c_t l_t} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) N_t, \tag{5}$$

subject to the budget constraint,

$$c_t + (1 + \tau_{xt}) x_t = (1 - \tau_{lt}) w_t l_t + r_t k_t + T_t, \tag{6}$$

where c_t is consumption at time t x_t is investment, τ_{xt} and τ_{lt} are the time varying tax rates on investment and labour, w_t is the wage rate, r_t is the real interest rate T_t are lump sum taxes, N_t is population, β is the discount factor, and k_t is the capital stock, firms try to maximise profits.

$$\max_{k_t l_t} A_t F(K_t, (1 + \gamma)^t l_t) - w_t l_t - r_t k_t, \tag{7}$$

where A_t represents the efficiency wedge and like standard real business cycle models this parameter is exogenously determined from the model the parameter $(1 + \gamma)$ is the rate of labour augmenting technical progress. The law of motion of capital is given by;

$$(1 + \lambda) k_{t+1} = (1 - \delta) k_t + x_t, \tag{8}$$

Where $(1 + \lambda)$ is the growth rate of the population which is a constant and δ is the depreciation rate.

The equilibrium conditions of the economy are as follows (for derivation of the log linearised model and technical notes about the maximum likelihood estimation see Appendix);

$$c_t + x_t + g_t = y_t, \tag{9}$$

$$y_t = Z_t F(K_t, (1 + \gamma)^t l_t), \tag{10}$$

$$-\frac{U_{lt}}{U_{ct}} = (1 - \tau_{lt}) A_t (1 + \gamma)^t F_{lt}, \tag{11}$$

$$U_{ct}(1 + \tau_{xt}) = \beta E_t U_{ct+1} \left[Z_{t+1} F_{kt+1} + (1 - \delta)(1 + \tau_{xt+1}) \right]. \tag{12}$$

The wedges thus can be described as the following, the parameter A_t is the efficiency wedge at time t, the efficiency wedge will capture any distortion which causes firms to allocate resources inefficiently. The labour wedge is described by $(1-\tau_{lt})$, this captures any effects which separate the marginal rate of labour from the marginal rate of substitution of consumption and labour. The investment wedge is given by $\frac{1}{(1+\tau_{xt})}$ which captures anything which separates the consumption and the asset pricing kernel. It is important to note that the wedges do not pick out a single type of distortion within the wedge rather it is captures all possible distortions which may affect labour, investment and efficiency.

3.2 Estimation Strategy

It is possible to calculate the labour and the efficiency wedge from their first order conditions once the functional forms of the production and the utility are chosen. As with CKM (2003, 2006), Kersting (2008) both choose Cobb-Douglas productions function and a log linear utility function with the form $U(c,l) = logc_t + \psi log(1-l_t)$ where ψ is the time allocation parameter. The following expressions are the calculations for the efficiency wedge and the labour wedge.

$$Z_t = \frac{\left(\frac{y_t}{k_t^{\alpha}}\right)^{\frac{1}{1-\alpha}}}{l_t}, \tag{13}$$

$$(1-\tau_{lt}) = \frac{\psi}{(1-\alpha)}\frac{c_t}{y_t}\frac{l_t}{(1-l_t)}, \tag{14}$$

The investment wedge can also be calculated with the following expression:

$$\beta E_t \frac{1}{c_{t+1}}\left(\frac{\alpha k_{t+1}}{y_{t+1}} + (1+\tau_{xt+1})(1-\delta)\right) = (1+\lambda)(1+\tau_{xt})\frac{1}{c_t}. \tag{15}$$

As a result of the expectational component of equation (15) the calculation of the investment wedge is more difficult. There are two strategies employed in order to estimate this wedge. The simplest way to achieve this is to assume that agents have perfect foresight about the wedges and the underlying stochastic process of the economy as CKM (2003) and Kobayashi and Inaba (2006). Using these assumptions allows the researcher to ignore the expectational component and move all of the time dependant variables back a period, for which (15) can then be re-arranged for $(1+\tau_{xt})$ calculated as a backward looking difference equation. This does however require an initial value of τ_{xt} in order to start the series, for this the steady state values of the investment wedge can be used.

The other method which is more commonly used and favoured here ((for instance Chakraborty (2004), Kersting (2008), Ahearne et al (2006) and CKM (2007)) is to estimate the wedges using the Kalman filter and a maximum likelihood procedure. To do this the decision rules and the steady states are worked out. The reduced form of the system equation is then worked out and estimated, in this case the reduced form of the structural system corresponds to the following VAR (1) system.

$$s_{t+1} = P_0 + Ps_t + Q\varepsilon_t, \tag{16}$$

where $s_t = \left[\begin{array}{cccc} Z_t & \tau_{lt} & \tau_x & g_t \end{array} \right]'$[2]. Following CKM the model is solved using the method of undetermined coefficients[3] and the likelihood function is then maximised using the one step ahead predictions of the Kalman filter.

Once the wedges have been estimated the next step is to do the accounting procedure, to do this we pass the wedges back through the model one by one holding the other wedges fixed at a steady state levels[4]. This procedure then shows us the path the economy would have taken had only one wedge been active through the time series.

3.3 Model Solution

The labour and efficiency wedges can be calculated from the first order conditions (6) and (7), however the investment wedge depends on expectations of the future levels of consumption, labour, capital stock and the wedges, as such the decision rules on the model depend on the future values of these variables. In order to measure the investment wedge we estimate the underlying stochastic process of the model. We assume that the wedges follow an AR (1) process such as that described in (12) and use Kalman filtering and maximum likelihood methods to solve for the decision rules. Once we have estimated the underlying stochastic process we then have all of the measured wedges we can write the decision variables as a function of s_t and k_t. We can then proceed with the decomposition, as mentioned before if we put the time series for each of the wedges jointly through the model it will replicate output exactly. In order to asses the contribution of each of the wedges we pass the measurements of the wedges back through the decision rules for the economy but restrict the other wedges to remain at their steady state levels. For example if we wished to view the contribution of the efficiency wedge to output we would apply the following (taking a steady state value of 2006); $s_{eff} \left[\begin{array}{cccc} z_t & \tau_{l2006} & \tau_{x2006} & g_{2006} \end{array} \right]$ and k_t would then give us, y_{eff}, x_{eff} , more explicitly the contribution to the fluctuations of fundamental variables due to only fluctuations in the efficiency wedge.[5]

3.4 Data

In order to estimate the stochastic process and create the time series for the wedges we use per capita data on output, investment, labour hours and government spending[6], we use the available series for the dates between 1974 Q2 to 2010Q4. As is common with estimation involving filters there may be biases induced when the time series ends below or above trend and therefore skewing the results. In order to avoid this we use forecasted series for the mentioned variables which extends the sample through to 2015 Q4. We use

[2]For details of the deriviation of the state space estimatable equation as well as the deriviation of the capital stock see the Appendix.

[3]The more commonly used perpetual inventory method is equally usable here.

[4]Note: Koybayashi and Inaba (2005) found evidence that the choice of the steady state may be important to the results. In this paper we choose 2006 Q1 to fix our steady states, this period incorporates low volatility and therefore this period should not be too far from a theoretical steady state. We also considered Kerstings (2008) steady state of 1979 the results were robust to these choices. However, setting the steady state before the 1992 recession changed the results for this period.

[5]The results are robust to different values for steady states and initialisations and are available on request.

[6]See Data Annex 1 for more details

the forecasted values as made available by the *Office for Budgetary Responsibility*[7] which covers the main parts of the data series used in the construction of the data set needed for the BCA experiment. For the series of output, government consumption and gross capital formation we calculated the year on year growth level for the forecasted series and then using these growth rates we extend the series. For the labour hours, we use the forecasted for total hours and trend population 16+, as the population does not exactly match that used in our original series the resulting calculation will be smaller, in order to make these compatible we adjust the values upwards so that the final non-forecasted point in the *OBR* series is at the same value as our data set, and the average difference between the two data sets is used to increase the forecasted values.

4 Results

4.1 Business Accounting for the Great Recession

Figures 2 and 3 present the results of the decomposition states using the data for the U.K. economy. Figure 2 shows the counter factual paths the economy would have taken had only one wedge been active while all other wedges are held at their steady state values. Figure 2 shows that both the investment and efficiency wedges fall around the beginning of the recession at the same time as output and that they both add negative pressure on output. The investment wedge only falls a small amount while the efficiency wedge provides an almost exact characterisation of the variation of output over this period. The labour wedge remains relatively constant throughout the recession and only begins to fall once output growth picks up and returns towards its normal trend levels. As the simulation with only the efficiency wedge and the realised path of output are almost the same, this suggests that any class of friction which works through the efficiency wedge are the most important in explaining the most recent recession. While we see evidence that a shock has affected the investment wedge the overall effects are not large enough to cause such a large fall as seen in the actual data series, we also see that during the recovery period the investment wedge grows much faster that output growth contributing positively to the movements in output. Subsequently we can say that frictions which work through an investment wedge may have a minor secondary role in explaining the 'great recession, while those that work through the labour wedge are largely unimportant.

Figure 3 shows simulations of the counter factual economies had all the wedges except one been allowed to vary over time. The results here reinforce those from figure 2, the combination of the investment wedge and efficiency wedges provide a good characterisation of output. It is interesting to note that around the recovery period as output is increasing there is a fall in the simulation of the combined efficiency wedge and investment wedge. This supports the results presented by Martin (2010) who suggested that there was a delay in the effect of the financial shock affecting the wider economy through the financial channels. The secondary importance of the investment wedge and the irrelevance of the labour wedge are confirmed through the simulations which exclude the efficiency wedge, in which although there is a fall in the simulated level of output it is small and remains relatively constant throughout the whole business cycle.

[7] The data sets are available as supplementary materials from the *Economic and Fiscal Outlook 2011* and are available from the *Office for Budgetary Responsibility* website, http://budgetresponsibility.independent.gov.uk/economic-and-fiscal-outlook-march-2011/.

4.2 Explaining the Business Cycle Accounting results

The impulse responses, which are available on request, for the efficiency and the labour wedges are standard and well known in RBC theory, that a shock to either of these wedges will lead to positive co-movements in consumption and investment as an effect of a positive shock. A positive shock to the investment wedge mentioned previously will lead to a divergence between consumption and investment due to increasing the present value of consumption over the present value of future consumption. These impulse responses along with the expenditure decomposition can help to explain the results from the BCA simulations. Firstly from Figure 1 there is only one period at the beginning and one at the end of the recession where consumption and investment have diverged and in both cases the corresponding consumption growth is very close to 0%. There are two likely periods where we could expect to see a shock affecting the investment wedge and as the size of the divergence between consumption and investment is not large the size of the shock is likely to be small. As is also shown throughout the rest of the recession and recovery, consumption and investment positively co-move leaving the candidate explanations as being either the labour of efficiency wedges (or a combination of the two). Overall, the expenditure decomposition provides an insight in to why for the most recent recession the investment wedge is unlikely to provide a good explanation for the variation in output.

4.3 Business Cycle Accounting for the BGG model

In order to investigate where the shocks which are investment related in nature appear in the BCA methodology we propose to use the a log linearised version of the Kansas City Federal Reserve version of the BGG model (see Bernanke and Gertler (1999)),[8] from which we create an artificial data series by using Monte Carlo simulations.[9] The data series is then scaled to appropriate steady state levels and then passed through the estimation procedure and then the counter factual levels of output for the artificial series are simulated. The BGG model is a standard New Keynesian model with the added extension of the existence of credit markets which are subject to frictions, the frictions lead to a financial accelerator (FA) mechanism which leads to it costing firms more to source loans externally rather than internally, as such this will then effect investment otherwise termed as the external finance premium. The external finance premium is inversely related to the net worth of the borrowers, as such the external finance premium will be counter cyclical, as such shocks to fundamental which increase (decrease) output will magnify the response of investment and also therefore output. The key extension of the Bernanke and Gertler (1999) version is to include bubble shock which allows the market value of net worth to deviate from the fundamental values of net worth, and therefore affect real activity through the decrease in the external finance premium.

While we would expect to see the bubble shock of the model appear through the Euler equation as an investment wedge Figure 4 highlights a rather surprising result, that the bubble shock appears almost entirely as a labour wedge. The investment wedge moves weakly and countercyclically to the movements in output[10]. The result

[8] The key log-linearised equations are presented in the Appendix along with the parameterisations used.

[9] We allow the bubble shock to be both positive and negative.

[10] We tested all of the shocks within the BGG framework, these are a shock to government spending,

is particularly surprising as the bubble shock would represent a similar story to a fall in the quality of collateral which could be viewed as a similar story to the fall in asset prices as with our experiments with the actual data series we see very little effects on the investment wedge our candidate explanation. The disconnect here between financial frictions and the investment wedge suggest that researchers may have to rethink the role of the financial frictions working through the asset pricing equation as a transmission mechanism for financial shocks and develop models which affect the real economy in alternative methods, such as through the TFP parameter and the labour supply equation. The results from the Monte Carlo and those of the BCA experiment for the great recession suggest that if we are to believe that the much of the debate around the causes of the recession being due to a large shock to investment, falls in asset prices is correct we must look outside of frictions which affect the Euler equation for answers of how falls in asset prices and investment frictions may affect the wider economy.

5 Conclusion

In this paper, we examine the 'Great Recession' in the UK via a simple demand decomposition and through the lens of Chari, Kehoe and McGrattan's (2006) Business Cycle Accounting methodology. The demand decomposition clearly shows that the recession was primarily associated with large falls in investment and consumption, with investment contributing most throughout the recession, and also showed that the fall in investment led the fall in output. The results of the BCA experiment suggested that the efficiency wedge could explain the variations in output almost perfectly, and that the investment wedge had a very minor secondary role. To further investigate these findings we use simulated data from the BGG model which contains a well defined financial friction in the form of the external finance premium and included a bubble shock - wedge between fundamental and market asset prices - and the results showed that the bubble shock would appear almost entirely as a labour wedge in this model with the investment wedge moving counter cyclically to output. We interpret this result as telling us that financial frictions may not appear only in the investment wedge.

The results of the Monte Carlo analysis do not necessarily contradict the results from the BCA experiments rather it questions the way in which shocks and frictions to financial markets affect the real economy. In other words, just because a shock may emanate from financial markets, it does not imply that it will necessarily impact on the marginal rate of substitution in consumption. In the case of the BGG model, the shock to asset prices leads to greater variation in labour supply over the business cycle - as increases (decreases) in collateral value induce more (fewer) working hours in general equilibrium. We need therefore to understand better the implications of financial frictions for general equilibrium outcomes.

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Appendix

Annex 1: Data

All data can be found on the office for national statistics website, under the time series data section unless otherwise specified.

Output per capita = (GDP + Services from consumer durables + depreciation from consumer durables - V.A.T) / Working age population

GDP = GDP chained volume measure, seasonally adjusted, 2005 prices £ million. Accronym: ABMI

Services from consumer durables = The service from the stock of consumer durables, in order to create the stock of consumer durables, the series consumption of consumer durables is cumulated assuming a 16.5 depreciation rate. An added assumption is that in 1964, all purchases of consumer durables were for replacement purposes. Services from the stock of consumer durables are then assumed to be 4%.

Total expenditure on durables = Chained Volume measure, Seasonally adjusted, 2005 prices £million. Acronym: UTID

Working age population = 16-59/64 Seasonally adjusted, thousands. Acronym: YBTF

Labour input per Capita = (Total weekly hours worked / Working age population)/100

Total weekly hours worked = Total actual weekly hours worked, Millions, Seasonally adjusted. Acronym:YBUS

The labour input per capita is divided by 100, to account for the total possible hours workable in one week.

Investment per capita = (Gross fixed capital formation + changes in private inventories +Total expenditure on durables - Sales Tax $\times$ Share of durables in total consumption) / Working age population

Gross fixed capital formation = Chained volume measure, seasonally adjusted, 2005 prices £ million. Acronym: NPQT

Changes in private inventories = Chained Volume measure, seasonally adjusted, 2005 prices £ million. Acronym: CAFU

Sales Tax = Central Government: Taxes on production & Imports receivable: VAT: £ million, current prices not seasonally adjusted Acronym: NZGF.

In order to make the sales tax series consistent with the rest of the data series, it had to be seasonally adjusted and also deflated so that there were constant prices. To seasonally adjust the data a 4 Quarter average was taken. The data series was deflated using the retail price index (RPI), which can be found in full on the *ecowin* programme.

RPI = Retail price index rebased so that 2005 = 100. Ecowin code: ew:gbr11800, NSO Accronym: CHAW.

Share of consumer durables in total consumption = Total expenditure on durables / (Total expenditure on durables + Total expenditure on non-durables + Total expenditure on services).

Total expenditure on non-durables = Chained volume measure, seasonally adjusted, 2005 prices £ million. Acronym: UTIL

Total expenditure on services = Chained volume measure, seasonally adjusted, 2005 prices £ million. Acronym: UTIP.

Government spending per capita = (Total government spending + Net exports) / Working Age population.

Total Government spending = Chained volume measure, seasonally adjusted, 2005 prices £ million. Acronym: NMRY.

Net exports = (Exports - Imports)

Exports = Goods and Services, Chained volume measure, seasonally adjusted, 2005 prices £ million. Acronym: IKBK

Imports = Goods and Services, Chained volume measure, seasonally adjusted 2005 prices £ million. Acronym:IKBL.

We used series from the *Economic and Fiscal Outlook* published by the Office for Budgetary Responsibility (published on the 23rd of march) in order to create the series leading past those which are available from the ONS.

Annex 2

Log Linear conditions for the BGG model with a bubble shock

Resource constraint,

$$y_t = \frac{C}{Y}c_t + \frac{C^e}{Y}c_t^e + \frac{I}{Y}i_t + \frac{G}{Y}g_t, \tag{17}$$

Euler equation,

$$E_t = c_t + \sigma r^n, \tag{18}$$

Entrepreneurial consumption,

$$\begin{aligned} c_t^e &= \frac{K}{N}r_t^q - \left(\frac{K}{N}(1-\frac{K}{N})\psi\right)r_{t-1} - \left(\frac{K}{N}(1-\frac{K}{N})\psi\right)k_{t-1} - \\ &\left(\frac{K}{N}(1-\frac{K}{N})\psi\right)q_{t-1} + \left(\frac{K}{N}\left\{(1-\frac{K}{N})\psi + \frac{N}{K}\right\}\right)n_{t-1}, \end{aligned} \tag{19}$$

Production function,

$$y_t = z_t + \alpha k_{t-1} + (1-\alpha) l_t, \tag{20}$$

Labour supply equation,

$$y_t + x_t + \frac{1}{\sigma} c_t = \gamma_l h_t \tag{21}$$

Phillips curve,

$$E[\pi_{t+1}] = \lambda E[x_{t+1}] + \gamma_f E[\pi_{t+2}] + \gamma_b \pi_t, \tag{22}$$

Relationship between asset valuations and investment,

$$q_t = \phi(i_t - k_t), \tag{23}$$

Net worth accumulation,

$$\begin{aligned} n_t &= \chi r_t^k - \chi \left(1 - \frac{N}{K}\right) r_{t-1} - \chi \left(1 - \frac{N}{K}\right) \psi k_{t-1} - \chi \left(1 - \frac{N}{K}\right) \psi q_{t-1} \\ &\quad \left(\chi \left(1 - \frac{N}{K}\right) \psi + \frac{N}{K}\right) n_{t-1} + \left(\chi(1 - \gamma rkss) + \frac{N}{K}/\gamma\right) y_t, \end{aligned} \tag{24}$$

Ex-post price of external funds,

$$E[r_{t+1}^k] = (1-\epsilon)(x_t + y_t - k_{t-1}) + \epsilon q_t - q_{t-1}, \tag{25}$$

Relation of external price of funds and the interest rate,

$$E[r_{t+1}^k] - r_t = -\psi(n_t - q_t - k_{t-1}), \tag{26}$$

External finance premium,

$$s_t = E[r_{t+1}^k] - r_t, \tag{27}$$

Monetary policy,

$$r_t^n = \rho_n r_{t-1}^n + \rho_\pi \pi_t + \rho_y y_t + \varepsilon_{i,t}, \tag{28}$$

Real interest rate,

$$r_t = r_t^n - E[\pi_{t+1}], \tag{29}$$

Law of motion for capital,

$$k_t = \delta i_t + (1-\delta) k_{t-1}, \tag{30}$$

Driving process for government and technology;

$$g_t = \rho_g g_{t-1} + \epsilon_{g,t}, \tag{31}$$

$$z_t = \rho_z z_{t-1} + \epsilon_{z,t}. \tag{32}$$

Annex 3
Estimates of the Stochastic process

Below are the estimates of the stochastic process as described in (16).

$$P_0 = \begin{bmatrix} 0.149 \\ (0.005) \\ 0.349 \\ (0.002) \\ 0.645 \\ (0.014) \\ -1.21 \\ (0.003) \end{bmatrix} \quad P = \begin{bmatrix} 0.971 & 0.075 & 0.013 & -0.020 \\ (0.009) & (0.012) & (0.005) & (0.004) \\ -0.135 & 1.189 & 0.089 & -0.091 \\ (0.004) & (0.010) & (0.008) & (0.006) \\ 0.194 & -0.309 & 0.854 & 0.134 \\ (0.009) & (0.029) & (0.020) & (0.016) \\ -0.193 & 0.120 & 0.071 & 0.879 \\ (0.023) & (0.012) & (0.013) & (0.008) \end{bmatrix}$$

$$Q = \begin{bmatrix} 0.010 & & & \\ (0.001) & & & \\ 0.000 & 0.006 & & \\ (0.000) & (0.000) & & \\ 0.002 & -0.013 & 0.012 & \\ (0.001) & (0.001) & (0.002) & \\ 0.004 & 0.006 & 0.017 & 0.005 \\ (0.001) & (0.001) & (0.000) & (0.000) \end{bmatrix}$$

BCA for the recession.

$$P_0 = \begin{bmatrix} -0.191 \\ -0.384 \\ 0.580 \\ -1.488 \end{bmatrix} \quad P = \begin{bmatrix} -0.011 & 0.062 & 0.615 & 0.242 \\ 0.568 & 0.915 & -0.633 & -0.631 \\ 0.530 & -0.056 & 0.437 & -0.01 \\ -0.199 & 0.014 & 0.137 & 1.055 \end{bmatrix}$$

$$Q = \begin{bmatrix} 0.005 & & & \\ -0.004 & 0.162 & & \\ 0.007 & -0.018 & 0.004 & \\ 0.005 & -0.002 & -0.000 & 0.000 \end{bmatrix}$$

BCA for the simulated BGG data.

As mentioned in CKM (2006) the estimates of the stochastic processes don't appear to make too much difference to the simulation and decomposition parts of the BCA experiment. For the stochastic process we find that the diagonal elements of the P matrix are high correlations which are close to 1, and even larger than one in the case of the labour supply. The possible reason for this is that the per capita labour hours over this period is downward sloping over our sample period, which may lead to the greater than 1 coefficient on labour. For the artificial data we find that the cross correlations are much greater than that found in the real data and that the coefficient on the efficiency and investment wedges are much smaller.

Tables

Table 1: Demand and Supply contributions for the recession and artificial data created from the BGG model with a bubble shock.

	1975 Q1 - 2008 Q3	2008 Q4 - 2009 Q4	BGG Model
Output	2.26	-4.43	2.32
Demand			
% Contribution			
C	1.60	-1.93	-1.11
I	0.40	-3.80	3.43
G	0.36	0.24	N/A
NX	-0.10	1.05	N/A
Supply			
% Contribution			
K	0.67	0.70	
L	0.08	-1.67	
TFP	1.37	-3.45	

Table 2: Parameterisations used for the BCA model on an annualised basis

Parameter	Value	Definition
g_z	1.02	Growth rate of technology
g_n	1.015	Growth rate of population
δ	.0464	Depreciation rate
β	.9722	Discount factor
α	0.35	Capital share
ψ	2.24	Frisch Elasticity
σ	1.000001	Parameter of households risk aversion

Table 3: Parameterisations of the BGG model

Parameter	Value	Definition
β	0.99	Discount factor
$\frac{C}{Y}$	0.568	Steady state level of household consumption
$\frac{C^e}{Y}$	0.0541	Steady state level of entrepreneurial consumption
$\frac{I}{Y}$	0.1779	Steady state level of Investment
$\frac{G}{Y}$	0.2	Steady state level of government consumption
σ	0.1	Elasticity of consumption in Euler equation
ϕ	1	Elasticity of asset prices to investment
δ	0.25	Depreciation rate
ψ	0.05	Scaling parameter (Tobin's Q)
α	0.35	Capital share
χ	2.1	Scaling parameter coefficient on output (Net Worth accumulation)
γ	0.9728	Scaling parameter coefficient on output (Net worth accumulation)
γ_b	0.9	Coefficient on contemporaneous inflation (Phillips curve)
γ_l	1.33	Coefficient on labour hours worked (Labour supply)
γ_c	$1/\sigma$	Coefficient on consumption (Labour supply)
γ_f	0.5	Coefficient on forward looking inflation (Phillips curve)
γ_y	0.5	Coefficient on output (Taylor Rule)
ρ_n	0.9	Persistence of interest rate
ρ_g	0.9	Driving process for government
ρ_z	0.9	Driving process for technology
λ	0.024	Coefficient on marginal cost
ϵ	0.99	Weighting parameter in return on asset equation

Annex 4
Figures

Figure 1: Expenditure decomposition

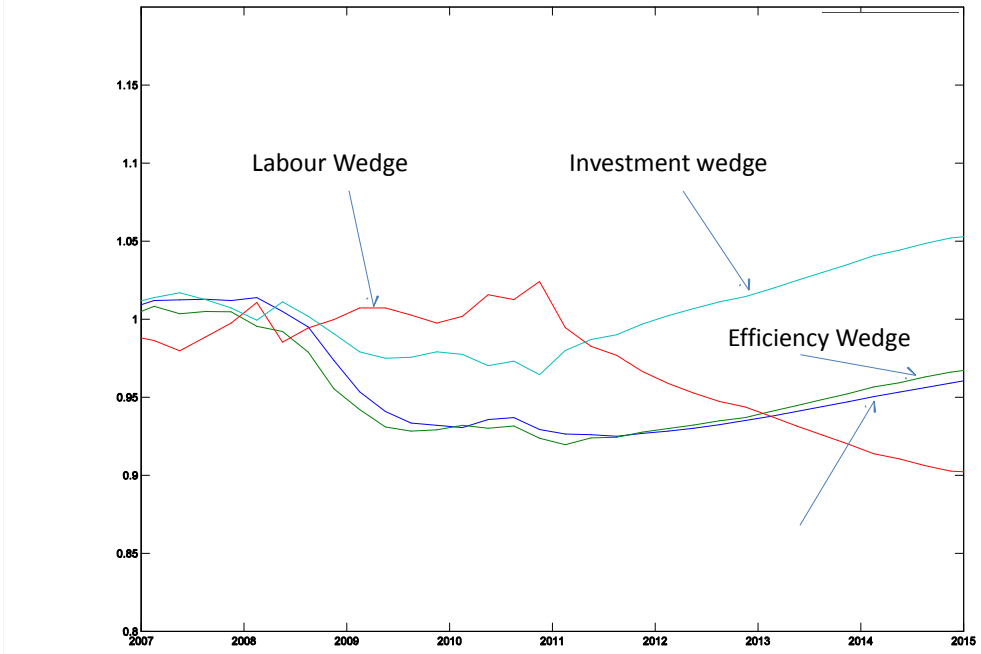

Figure 2: BCA decomposition with one wedge allowed to vary over time.

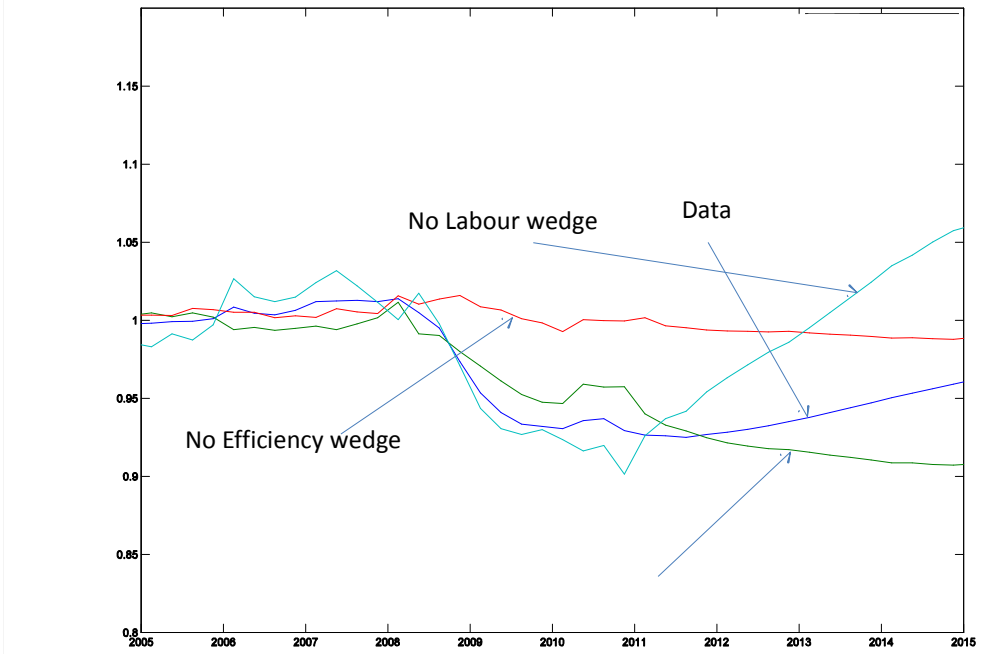

Figure 3: BCA decomposition with all but one wedge to vary over time.

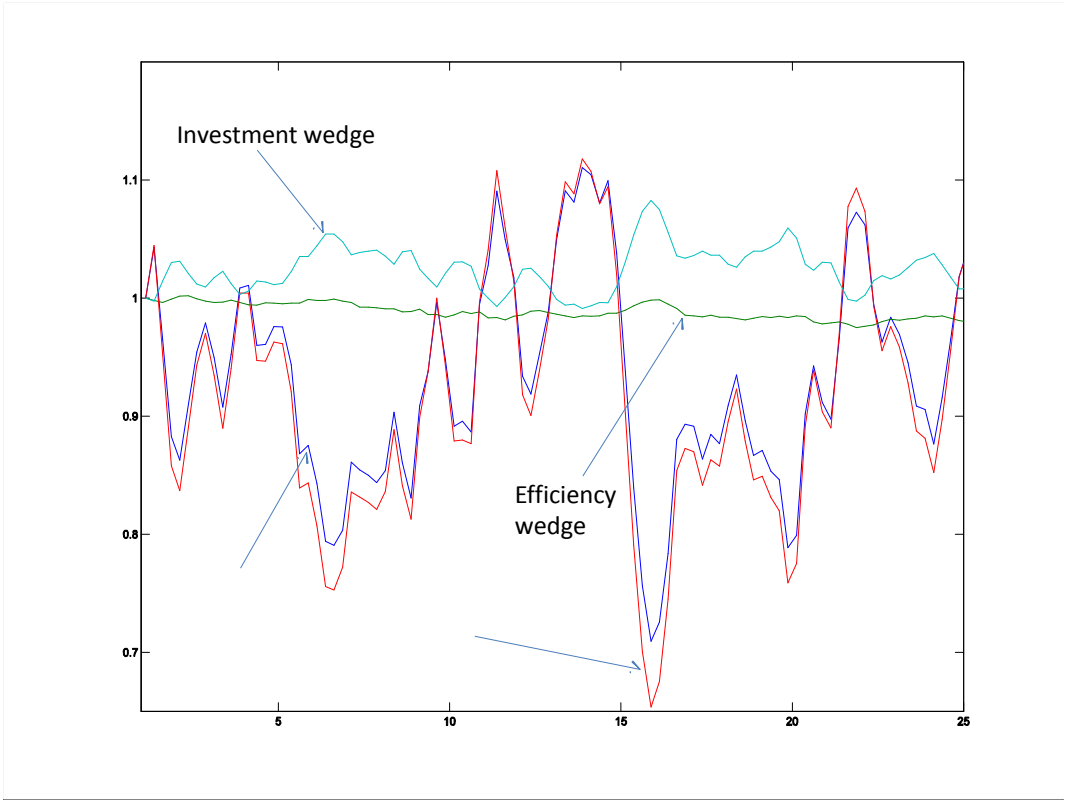

Figure 4: BCA decomposition for artificial data from the BGG model.