NEWS SHOCKS, PRECAUTIONARY SAVINGS AND THE LABOUR MARKET

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Abstract

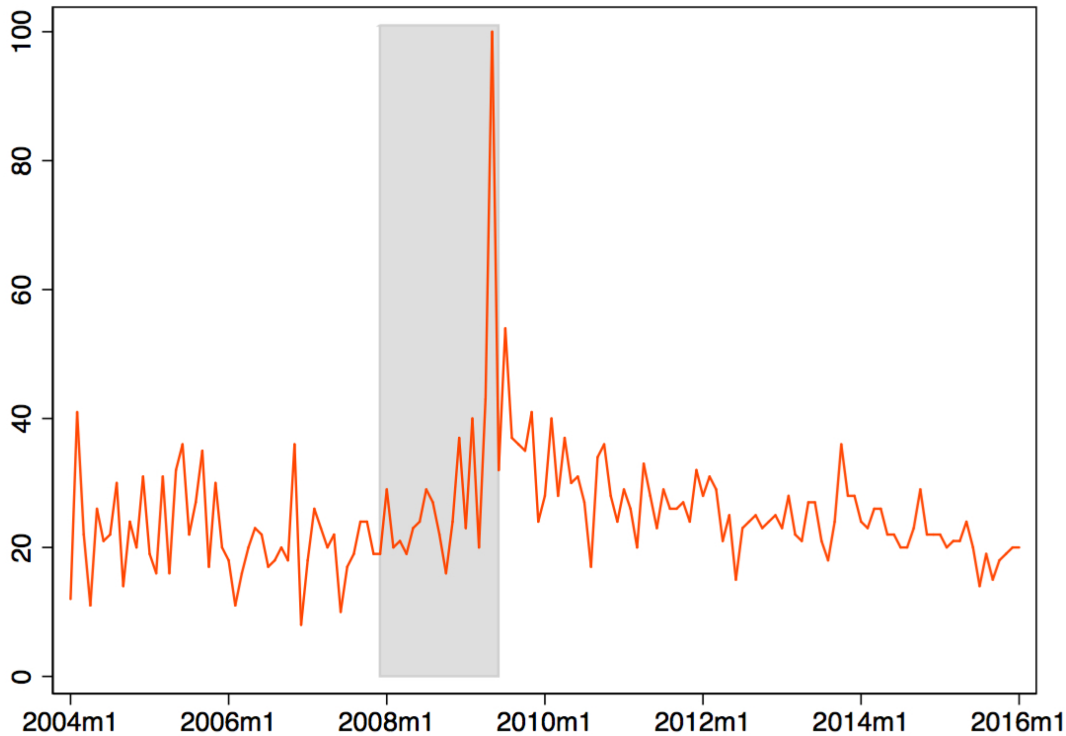
The idea that news about the future can produce macroeconomic fluctuations has a long history, with modern evidence suggesting this phenomenon is indeed present empirically. The precise transmission mechanism of news shocks is less clear however. This paper proposes a channel whereby frictional labour markets and the precautionary savings motive of households interact to propagate the shock. Bad news about future fundamentals reduces the vacancy posting incentive of firms, worsening the employment prospects of households. They then hedge against the increased likelihood of a substantial income drop by hoarding liquid assets and reducing their spending, triggering a downturn which exacerbates labour market conditions. Robust evidence of this channel's prevalence is presented through results of a local projection method. News is more potent during low-wealth periods - times when the precautionary motive is heightened. The results are reconciled in a heterogeneous agent New Keynesian model featuring financial and labour market frictions.

1 Introduction

The idea that expectations matter for equilibrium outcomes has been a central doctrine in macroeconomics dating back at least to the work of Pigou and Keynes in the early 20th century. From the former originates the concept of Pigovian cycles, where good news about the future creates an increase in economic activity today, as forward-looking agents modify their current behavior in response. This news induced expansion is distinctly absent from the standard Real Business Cycle (RBC) model, which explains aggregate fluctuations through unanticipated innovations to productivity. As Figure 1 illustrates, the Great Recession - the longest and most extreme drop in economic activity since the Great Depression - provoked a renewed interest in the importance of Keynes' animal spirits which inherently refer to swings in expectations. A concept which also explicitly features a large role for expectations is the phenomenon of precautionary savings. This refers to risk averse households, who fear future idiosyncratic employment risk, saving more of their income today in order to accumulate a buffer against these shocks and enable consumption smoothing. The more pessimistic agents are about the future, the stronger this motive is.

There is, therefore, a natural connection between news shocks and precautionary savings. This paper investigates the latter as a transmission mechanism for the former, with the labour market acting as the intermediary between the two. I first show, through the lens of a local projection method, that labour market aggregates exhibit a strong contractionary response to 'bad news' shocks about total factor productivity (TFP), and these can explain a substantial proportion of business cycle fluctuations in these variables. Vacancy posting is a form of durable investment, and as such, bad news about the future induced firms to cut back on their vacancy posting due to the lower expected return. This worsens the labour market prospects of households and increases the level of idiosyncratic income risk, as unemployment spells become more likely. Real non-durable consumption and real GDP also increase in response to news shocks. Results of variance decomposition exercises suggest that news shocks can explain a large fraction of volatility in these aggregate variables over business cycle frequencies. These findings are shown to be robust to a number of extensions and robustness tests.

Figure 1: The index of Google searches for the term 'animal spirits' 2004-2016, the grey bar denotes an NBER recession period, source: Google Trends



Second, I present evidence which suggests that the precautionary savings channel encapsulates the transmission mechanism of news to aggregate fluctuations. This is achieved by examining the differing responses of consumption and output in low- and high-wealth states. As highlighted by Heathcote and Perri (2018), periods of low wealth represent times at which the precautionary savings motive of household is particularly sensitive to changing expectations. During these periods, households are poorly equipped to smooth consumption in the face of unemployment risk by using their existing wealth stock as a buffer, and consequently experience a sharp rise in their desire to save. I show that both consumption and output are much more responsive to news shocks in low-wealth states relative to high-wealth states.

Finally, I reconcile these results in a heterogeneous agent New Keynesian (HANK) model with incomplete markets and frictional labour markets (Ravn and Sterk, 2017; 2018). In the model, a 'bad news' shock causes firms to post fewer vacancies, as it expects matches to be less profitable in the future, resulting in a lower chance of unemployed workers finding a job. These worsening labour market conditions result in increased precautionary saving, as households cannot purchase state-contingent insurance contracts and only have the option of government-provided unemployment benefits which are well below the market wage. Price rigidity then causes declining goods demand to spillover to the firm-side as they cut back further on the number of vacancies posted and unwittingly amplify the shock further. The eventual result of a bad news shock is a large drop in output before the change in TFP is actually realised. This slump in output is also demonstrated to occur following a noise shock, despite TFP never actually changing. Lastly, it is shown that the contractionary response is greatly alleviated when markets are complete (eliminating the precautionary motive) and/or when labour markets do not feature search-and-matching frictions.

1.1 Related literature

The seminal work of Beaudry and Portier (2004; 2006) marks a natural starting point when looking at the modern literature on news shocks. They exploit the well-documented property that stock price innovations represent changes to the discounted sum of future profits and hence can be used as a mechanism to gain information about TFP news shocks. A vector error correction model (VECM) with TFP and stock prices is estimated with two different methods used to determine TFP news shocks, both relying on the identifying assumption that a news shock moves stock prices immediately but has no contemporaneous effect on TFP. Their results suggest significant anticipation effects are present, running contrary to the view of 'surprise' technology shocks emphasized in the canonical RBC model. Results also suggest that total hours and consumption both rise in response to these TFP news shocks and they can produce aggregate fluctuations. In fact, roughly half of the output variance can be explained by the Beaudry-Portier shocks at the ten quarter forecast horizon which indicates that they are a highly important determinant of business cycles. Beaudry and Lucke (2009) corroborate these results in a structural VAR where they allow for cointegration. Again the identified news shocks are found to precede TFP growth and these shocks are found to both cause expansionary movement in macroeconomic aggregates and explain over half of the variance in these variables. They also include surprise shocks to productivity, monetary shocks and preference shocks but determine that it is the TFP news shocks which are the primary cause of aggregate fluctuations, again finding that these anticipated technological shocks can explain over half of the variance in economic activity. I use the Beaudry-Portier shocks as the measure of identified news shocks throughout Sections 2 and 3.

Barsky and Sims (2011) use a different identification strategy to attempt to recover news shocks. Their scheme utilises the maximum forecast error variance approach, identifying news shocks as those which are orthogonal to current changes in TFP and explain the highest proportion of TFP variance in the future. They estimate a SVAR with TFP, output, consumption and hours included. They find a contractionary response of hours, investment and output to a 'good news' shock, in contrast with Beaudry and Portier (2006) and more in line with the predictions of the standard RBC model. Also, their identified news shock does not contribute a large part of the variance in output and is not found to be responsible for most US recessions since 1961. However, Beaudry and Portier (2014) show that when stock prices are also included in the VAR, the expansionary response of hours, consumption and output re-emerges once again and closely mirrors those in Beaudry and Portier (2006). Ramey (2016) notes that the correlation between the Barsky-Sims and Beaudry-Portier shocks is very low at just 0.25, suggesting that each identification scheme recovers fundamentally different types of shock. Other papers which have demonstrated expansionary effects of news shocks include Beaudry et al. (2011) and Miranda-Agrippino et al. (2018).

This paper also dovetails with the work of Angeletos and La'O (2013) and Angeletos et al. (2018), who study the role of expectations via the diffusion of optimistic and pessimistic sentiment waves. They concentrate on the case where these changes to expectations occur independently of underlying fundamentals in the economy, which captures the idea of animal spirits in a form most literally alluded to by Keynes. Chahrour and Jurado (2018) prove an important observational equivalence result between news and noise, implying that the models with news shocks can be rearranged into an environment where agents receive noise-plagued signals about future economic fundamentals, highlighting the close link between the news shock and beliefs literature. Jurado (2016) finds a significant and roughly equal role for both news and noise in explaining output fluctuations in a rich estimated DSGE model which correctly distinguishes between the two[1]. Noise shocks are considered in the framework of the theoretical model in Section 6.

News-induced expansions (Pigovian cycles) have been studied in other environments previously. As Beaudry and Portier (2004) illustrate, the standard RBC model cannot generate Pigovian cycles, as a 'good news' shock causes labour supply to contract contemporaneously because the current period becomes a relatively inefficient time in which to work, as agents anticipate that the returns to labour will be higher in the future. This causes output to contract from the production function. Several papers have outlined conditions under which Pigovian cycles are possible. Jaimovich and Rebelo (2009) show that with variable capital utilization, investment adjustment costs and a form of preferences which allows the strength of the wealth effect, through which the aforementioned labour supply contraction operates through in standard RBC models, to be parameterised. They also examine a model extension where labour adjustment is costly, which is similar in spirit to the search-and-matching frictions I include. Den haan and Kaltenbrunner (2009) and Faccini and Melosi (2018) both study news shocks in models with search-and-matching frictions modeled explicitly, and both find that these environments are capable of generating expansionary movements in the labour market in response to a 'good news' shock. The output effects in Faccini and Melosi (2018) are negligible in the periods prior to the TFP increase realising however which does not fit the estimated impulse response functions shown in Section 2, which feature a much smoother increase in output upon the arrival of the news. Markets are complete in all three of the preceding models also, and the precautionary savings channel is not examined as a channel for news shocks to feed through to real activity as is the case in the model presented in Section 4.

Several other papers emphasise the precautionary savings mechanism as being fundamental in

[1] In Chahrour and Jurado (2018), it is shown that previous studies which attempted to do this such as Schmitt-Grohe and Uribe (2012) underestimated the quantitative importance of noise shocks.

amplifying different types of shocks. Ravn and Sterk (2017) focus on the impact of a shock to the job loss rate and show that the increased threat of becoming unemployed spurs employed workers to reduces their consumption, which triggers a contraction in economic activity when wages and prices are inflexible. Den haan et al. (2018) look at a similar feedback mechanism between the goods market and the labour market which occurs via precautionary saving as a result of unemployment risk. Guerrieri and Lorenzoni (2017) develop a model where a tightening of credit causes a substantial recession via heightened precautionary saving and depressed aggregate demand consequently. Beaudry et al. (2018) show that excess capital accumulation[2] can cause a precautionary savings motive to emerge as a liquidation in the durable goods sector spills over into the non-durable goods sector, with the labour market acting as the transmission mechanism here as it does in my model. Heathcote and Perri (2018) look at the effects of liquid wealth levels on precautionary savings, and find that the effects of an expectations shock become strengthened when liquid wealth is low. The expectations shock is modeled through perfect foresight however, rather than being explicitly part of the environment as is the case in my model. Many papers such as McKay and Reis (2016; 2018), Ravn and Sterk (2018) and Bayer et al. (2019) also feature similar incomplete markets models with heterogeneous agents but focus instead on exploring different issues. While not featuring any household heterogeneity or incomplete markets, Petrosky-Nadeau et al. (2018) show that a model featuring labour market frictions, when solved accurately, is capable of producing realistic disaster dynamics in response to large, unanticipated TFP shocks.

The rest of the paper proceeds as follows. Section 2 presents empirical evidence on the response of key macroeconomic variables to news shocks. Section 3 contains further evidence on the precautionary savings channel of news shocks. Section 4 describes the model, with its calibration described in Section 5 and results presented in Section 6. Section 7 concludes.

[2]News shocks, which end up not materialising, are briefly discussed as a potential source of the over-accumulation.

2 Empirical Evidence

In this section, I provide baseline results for the effects of news shocks on key labour market variables, output, consumption, inflation and the Federal Funds rate in order to assess the proposed transmission mechanism. Firstly, I examine the response of each variable in the set to a news shock through the lens of Jorda's (2005) local projection method. While Beaudry and Portier (2006, BP) examine the response of hours worked to news shocks, the response of additional labour market variables is not considered.[3] Focusing solely on hours worked gives a somewhat incomplete summary of the labour market as it ignores the inherent dynamics of the bilateral matching process between searching workers and firms and abstracts from the extensive margin of labour adjustment. Investigating the response of vacancies and employment can shed light on the transmission mechanism of news shocks to the labour market and the real economy. Secondly, I perform a variance decomposition exercise as I attempt to assess the contribution of news shocks to explaining business cycle fluctuations in the set of aggregate variables. Results of various robustness tests are also discussed.

2.1 Estimation method, data, and the identification of news shocks

In order to assess either the effect of news shocks on the variable set or their relative importance over the business cycle, a measure of identified news shocks are necessary. I focus primarily on the Beaudry-Portier shock identified with short-run restrictions (denoted BPSR henceforth). This identification scheme captures news shocks by imposing an impact restriction on a VECM with TFP and stock prices, and so identifies a news shock as the change in stock prices orthogonal to current economic conditions. Long run restrictions are also used as an alternative means of identification, but the correlation between the short-run and long-run shocks is extremely close to unity so each identification strategy essentially recovers the same shock.[4] As Ramey

[3] They find a significant, hump-shaped increase in hours worked in response to both the shocks which reaches a peak after roughly 5 quarters and persists for 10 to 12 quarters

[4] This is not the case for the Barsky and Sims (2011) news shocks, which have very little correlation with the Beaudry-Portier shocks and can therefore be interpreted as a fundamentally different shock. See Beaudry and Portier (2014) for a further discussion of this point.

(2016) finds, both of the estimated BP shocks exhibit neither serial correlation nor are Granger-caused by macroeconomic variables, suggesting that the shocks are unanticipated and are indeed news, meriting their choice in the estimation procedure that follows. While Beaudry and Portier (2006) also report an identification scheme where consumption is included as a third variable and a VECM is used, Kurmann and Mertens (2014) highlight issues with this system being unidentified. Beaudry and Portier (2014) show that the results of the bivariate specification are robust to the addition of additional variables, and provide an extensive discussion of the identification scheme. The BPSR series of news shocks is extended beyond its original sample period of 1948:I - 2000:IV to end in 2015:II for the purposes of all further analysis.

To ascertain how variables respond to news shocks, I follow Jorda (2005) and estimate the impulse response functions (IRFs) directly over a range of horizons. While a VAR is often used to both identify the shock and produce the IRF, it can be advantageous to divorce the two procedures. The local projection method offers a means of implementing once identified shocks have been obtained. The most notable benefit of this method is that, when the IRF is produced by taking the moving average representation of a VAR, it becomes a non-linear function of the parameter estimates. Whilst this is optimal when the VAR is correctly specified, any misspecification causes the errors to compound over the horizon of the IRF. In a local projection, because the estimate of the response of the given variable to each shock is estimated separately for each time horizon and these are then combined to produce the complete response function, the previous issue is alleviated. There can be a potential tradeoff between improving robustness and sacrificing the degree of precision in the estimates however, as the standard errors are often higher in a Jordá projection relative to using a VAR, which results in wider confidence intervals in the IRF.

Let ε_t denote the identified news shock in period t (the BPSR shock in the baseline specification), Y_i the (log of) the relevant variable of interest and h the horizon length. The local projection is then:

$$Y_{i,t+h} = \gamma t + C_i^h + \alpha_i^{h'} X_t + \beta_i^h \varepsilon_t + \omega_{i,t+h}$$

The $h+1$ equations are then estimated by OLS for each variable in the set, with β_i^h giving the estimated impulse response of Y_i, h periods after a shock to ε_t. The parameter estimates are then plotted as a function of h to produce the IRF. $\upsilon_{i,t+h}$ is the error term, which will be serially correlated, necessitating the use of Newey-West standard errors with a $h-1$ autocorrelation lag in each individual equation. X_t is a vector of controls, consisting of two lags of the following variables: the shock (ε_t), the dependent variable (Y_i), real GDP and real stock prices.[5]A log-linear trend is also included. I set $h = 20$ and work with quarterly data. The variables of interest I choose to investigate initially are vacancies measured as Barnichon's (2010) composite Help Wanted Index, unemployment, real non-durable consumption, real GDP, the CPI inflation rate[6] and the Federal Funds rate. Further labour market variables are then considered in Section 2.3. The sample period is 1954:I - 2015:II, and all data (apart from vacancies) is taken from Federal Reserve Bank of St Louis (FRED), with monthly data transformed to quarterly frequency by simply taking three month averages.

To quantify the overall importance of news shocks in explaining business cycle movements in the set of endogenous variables, I perform a forecast error variance decomposition (FEVD). I follow Ramey (2016) and perform this in a VAR with the shock, the endogenous variables (all in logs) and real stock prices as a control. A log-linear trend is included, two lags are used[7], and the shock is ordered first. For expositional clarity, given the precautionary savings mechanism of interest, the impact of negative news shocks are estimated. With the Beaudry-Portier identification scheme, a 'bad news' shock amounts to a decrease in stock prices orthogonal to contemporaneous TFP.

2.2 Baseline Results

The results of the baseline local projections are presented in Figures 2 and 3. Figure 2 makes it clear that a 'bad news' shock generates a contraction in the labour market, as firms respond

[5]Other studies using the local projection method, such as Coibion et al. (2017), merely include lags of the dependent variable as a control. I include the two other macro variables for the sake of robustness, but results do not change substantially when either or both are removed.

[6]Due to the presence of negative values, the inflation rate is not transformed by taking logs.

[7]This is based upon results of lag selection tests using the Hannan-Quinn information criterion.

by cutting back on their vacancy posting, while more workers flow into unemployment. The responses of both variables is strong and precisely estimated, with meaningfully tight confidence intervals over the first 5 quarters following the shock. This is in spite of the tendency of IRFs computed from local projection to yield higher standard errors relative to using a VAR to estimate the IRF. The hump-shaped response of both variables is akin to the response of hours worked evident in the BP results. The timing is also very similar here as the peak of the shock's effect occurs after roughly 5 quarters - the point where BP find the response of TFP reaches its maximum. The increase persists for 10-12 quarters and, after this point, the response of both variables is not significantly different from zero.

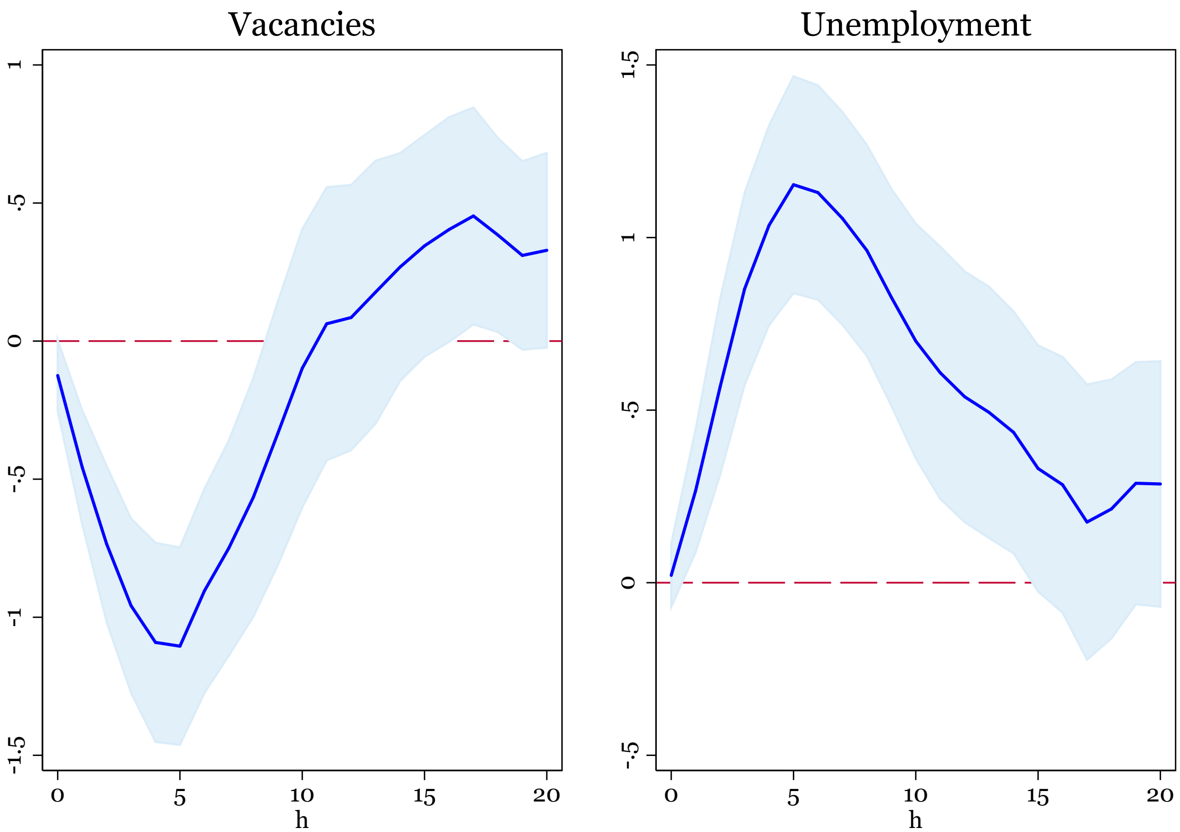
Figure 3 corroborates some further BP results as non-durable consumption and output also display a sizeable decrease, albeit in less of a parabola shape, with narrow confidence intervals. Interestingly, non-durable consumption responds immediately upon impact of the news shock, as the t statistic for $\beta^0_{nondurcons}$ is 3.22 with a corresponding p-value of 0.001. This suggests that the consumption-saving decisions of households are very sensitive to news, providing initial evidence of the precautionary saving channel of news at work. The β^0_i coefficient is not significant at the 95% level for any of the five other variables[8]. It is, however, significant at the 90% level for vacancies which adds credence to the idea that firms adjust their vacancy posting in a highly forward-looking manner in line with the key mechanism highlighted in the theoretical model of Section 4. The 'bad news' shock leads to a sharp fall in the Federal Funds rate,while the response of inflation is not significantly different from zero over any of the five year horizon.

Figure 4 shows the results of the forecast error variance decompositions for each variable in the endogenous set, with bootstrapped confidence intervals computed for 1000 repetitions. These demonstrate that news shocks are a powerful driver of fluctuations in both unemployment and vacancies - over 40% and close to 30% respectively over the 4-12 quarter business cycle frequency. A considerable fraction of the forecast error variance of output (non-durable consumption) can be apportioned to the news shock also, as the shock explains roughly 25% (20%) over the same business cycle horizon. The shock is not an important factor in contributing to price level

[8] The β^1_i coefficient is significant at the 95% level for all variables apart from inflation.

movements.

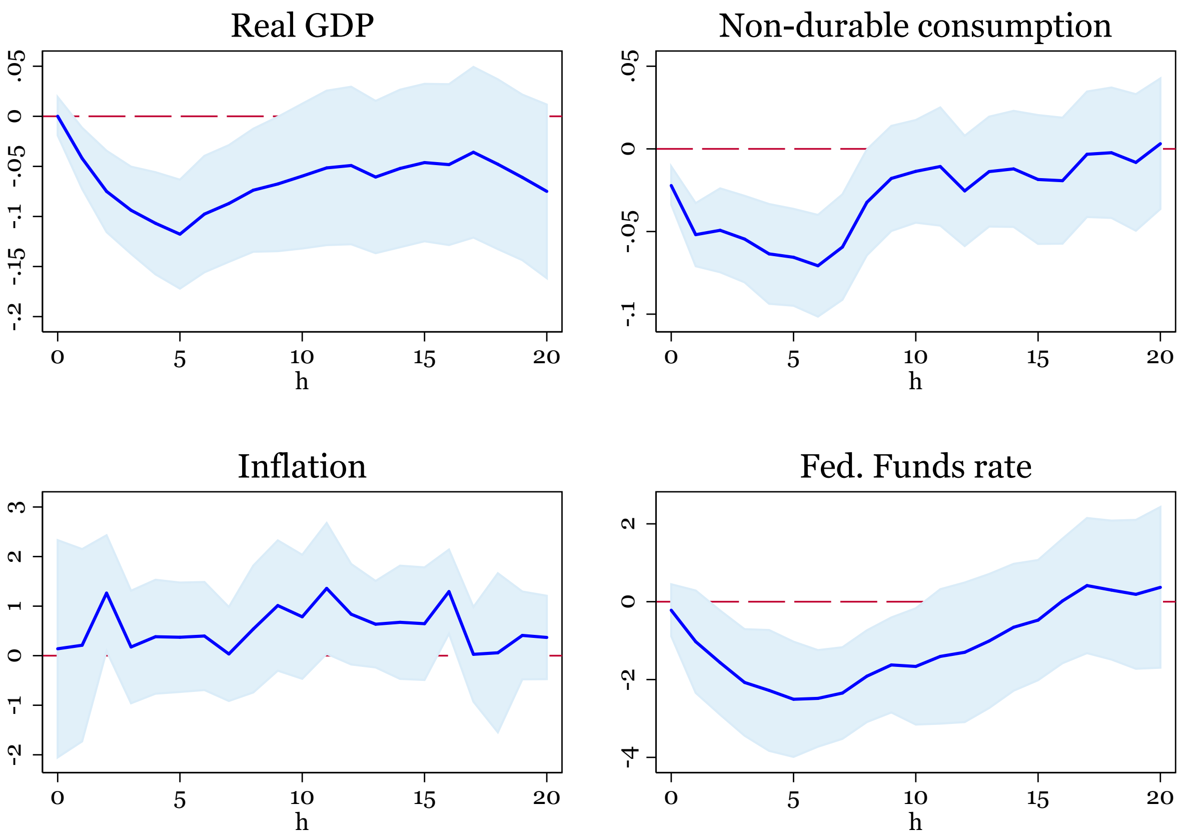
Figure 2: Estimated IRFs from a local projection for vacancies and unemployment to a negative Beaudry-Portier news shock.



Note: The light blue shaded area denotes the 90% confidence intervals.

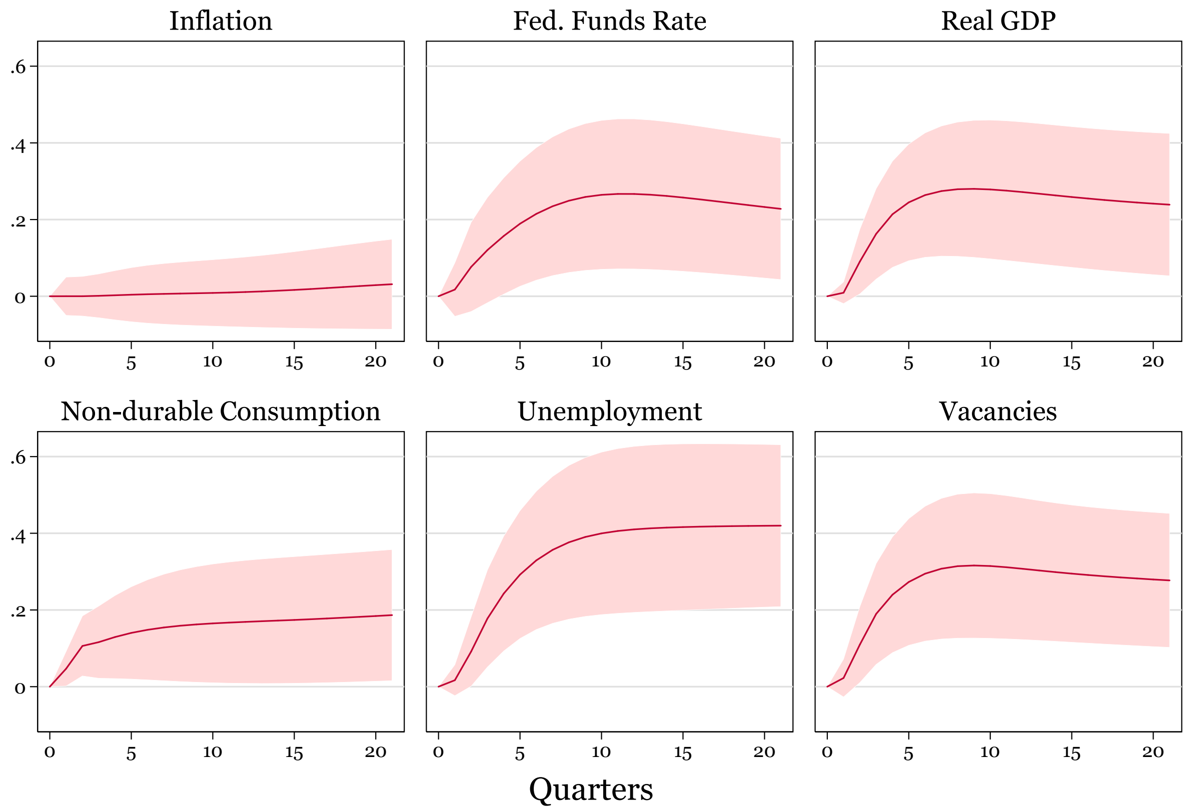
Taken together, the results of the IRFs and FEV decompositions are illustrative of two key points. First, it provides evidence that the vacancy posting decision firms make comprises a strong forward-looking element and, as such, adjustments to expectations about the future are an important factor in explaining aggregate vacancy fluctuations. Second, the results suggest that the labour market is a key conduit for news shocks to ultimately impact on levels of real activity in the economy. The next section will further explore precautionary savings as a key component of the shock's transmission mechanism.

Figure 3: Estimated IRFs from a local projection for real non-durable consumption, real GDP, the CPI and the Federal Funds rate to a negative Beaudry-Portier news shock.



Note: The light blue shaded area denotes the 90% confidence interval at each horizon.

Figure 4: Results of forecast error variance decompositions.



Note: The light red bands denote the 95% confidence intervals computed from a bootstrap procedure.

2.3 Labour market flows

To further examine the effect of news shocks on the labour market, I now consider the response of a set of labour market variables which are integral to capturing fluctuations in unemployment. For all of these I convert the monthly data from Elsby et al. (2015) to a quarterly frequency. [9] The first variable I consider is the flow hazard from unemployment to employment - the job

[9] They extend the time series of CPS data back to 1967 and implement several adjustments for various forms of measurement error. My results here remain robust to using unadjusted labour market flow data also.

finding rate. Standard search-and-matching models predict that a fall in vacancies posted should decrease the probability that workers are able to successfully match with employers, meaning we should expect to see a marked increase in the job finding rate in response to a 'good news' shock. As postulated by Elsby et al. (2009), fluctuations in unemployment outflows alone do not offer a full account of unemployment increases in recessions. While the rate of unemployment inflow is assumed to be constant in the majority of the literature, this paper argues that movements in the rate of layoffs are key to understand cyclical unemployment fluctuations. Further to this, Ravn and Sterk (2017) show that many salient features of the Great Recession can be explained by the rise in job losses which primarily occurred in 2008 and 2009. In light of this, I investigate the job loss rate as the second additional labour market variable. The final two transition rates I look at are flows from unemployment to nonparticipation, and vice versa. While the preceding analysis has primarily occurred through the underlying assumption that it is firms who respond to news shocks, this is now widened in order to examine how households adjust their labour force entry decision subsequent to receiving new information about the future. Elsby et al. (2015) stress the importance of a stock-flow approach to the participation rate, which subsequently yields a substantial implied role for this participation margin in contributing to unemployment fluctuations, with the two flow probabilities selected being of utmost importance.

The same structure is retained in the local projection which yields the estimated IRFs, while for the variance decompositions the shock is ordered first in the VAR with the four flow variables and two lags. Real stock prices and real GDP are once again included as controls.

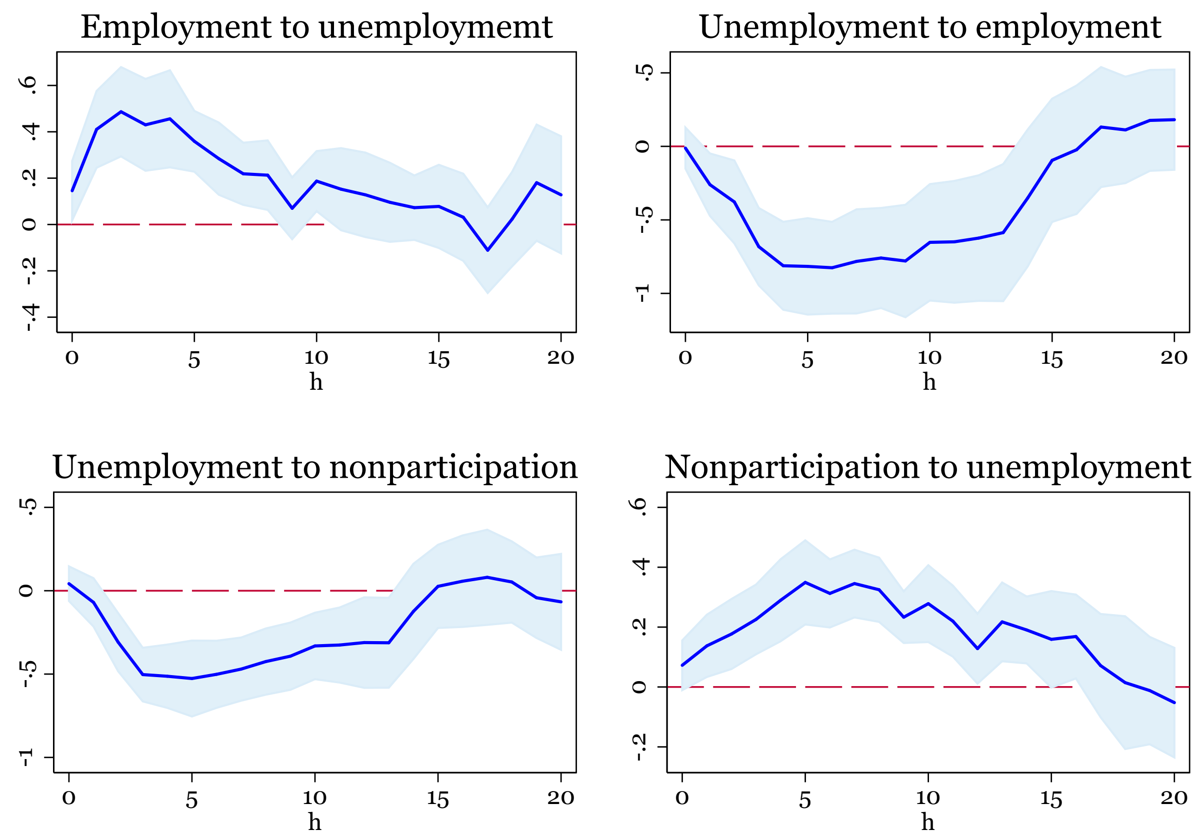
Figure 5 displays the IRFs produced from the local projections. The upper right panel clearly illustrates that the job finding rate displays a pronounced increase after a 'good news' shock is realised. This would be expected given the expansionary response of vacancies in Figure 3, as a tighter labour market raises the probability that a searching worker is able to match with a firm. The decrease in the job loss rate depicted in the upper left panel would not necessarily be expected purely following previous results, however, as firms react to pessimism about future fundamentals by increasing the number of workers they layoff. Also of note is the response of the job loss rate on the shock's impact, as it is significantly different from zero (p=0.05), implying that firm's layoff decisions are particularly responsive to news. Recessions typically exhibit a sharp increase in the number of job losses at their onset, and the results here suggest that consequently news could play a crucial role in contributing to the early parts of economic downturns. The combined effect of a higher job loss probability and a lower job finding probability combine to result in a large spike in income risk, as unemployment spells become more likely.

The two nonparticipation margins display the cyclical movements which Elsby et al. (2015) allude to. After receiving bad news about the future, more workers enter the labour force as unemployed workers, while fewer unemployed workers flow out of the labour force. One possible theoretical explanation Elsby et al. give, and find some empirical support for, is the idea of the added worker effect. This refers to the tendency for nonparticipant individuals within a given household to look for a job in response to another member of the household losing theirs. If workers anticipate job losses following a news shock, it could be the case that this added worker effect kicks in prior to the job losses actually occurring. Regardless of the precise mechanism, the IRF results certainly suggest that the participation decision has a strong forward-looking component to it, mimicking the dynamics of the job loss and job finding rates. See Figure A1 for results of variance decompositions for the two nonparticipation variables.

Variance decomposition results are found in Appendix A. Over business cycle frequencies, news shocks contribute to a considerable proportion of variance in all four flows- between around 20%. This is a comparable fraction to that of vacancies and unemployment. These results reinforce the idea that news shock produce a significant response in the flow transition rates, and are an important source of fluctuations in these variables over the business cycle.

The robustness of these baseline results are tested with respect to a shorter sample length and two alternative identifications of news shocks. Full details, including IRFs and FEV decomposition results, can be found in Appendix A. Results are ultimately shown to be robust to all of these. The effect of a confidence shock is also considered.

Figure 5: Estimated IRFs from a local projection for the four labour market flow variables to a negative Beaudry-Portier news shock.



Note: The light blue shaded area denotes the 90% confidence interval at each horizon.

3 The Precautionary Savings Channel of News Shocks

The results of the preceding section illustrate that the labour market is an important transmission mechanism for news shocks, while the expansionary response of output and consumption is also demonstrated. However, apart from the sharp impact response of consumption to a news shock, the results so far neither support nor rule out precautionary savings as a conduit.

In order to address this, the section proceeds in two ways. Firstly, asset markets are investigated - specifically the response of liquid assets and volatile stocks - as movements in these variables can be illuminative of the mechanism. It is also established that a bad news shock results in a rise in levels of idiosyncratic income risk faced by households - a necessary condition for news shock to be transmitted through the precautionary savings channel. Secondly, it is shown that the response of consumption (and many other variables) is much greater in low-wealth states- periods where households are limited in their ability to buffer against shocks and the precautionary savings motive becomes strengthened.

3.1 Precautionary savings and asset markets

First, I examine the response of the ratio of liquid-to-illiquid assets measured from flow of funds data, including it in the standard local projection framework. As Bayer et al. (2019) highlight, the precautionary motive can manifest itself through a portfolio rebalancing towards assets with a greater degree of liquidity. This allows risk averse agents to better smooth their consumption by hedging against the possibility of a large future income drop. The liquidity ratio is defined as the ratio of net liquid assets to net illiquid assets, taken from Flow of Funds data. Liquid assets comprise cash, deposits, debt securities and loans as assets net of consumer credit, depository institution loans and all other loans. All other assets are treated as illiquid[10].

The left panel of figure 6 demonstrates that a bad news shock leads to a sizeable and immediate flight to liquidity, suggesting that pessimistic expectations of future conditions triggers this self-insurance response. The proportion of liquid assets remains elevated for an extended period of time, implying that the mechanism is highly persistent. This substitution from illiquid to liquid assets puts downward pressure on interest rates, as figure 3 illustrated. The result here also helps to understand why a sizeable fraction of variance in the Fed Funds rate ($\approx 25\%$) over business cycle frequencies are explained by the news shock. When interest rates are at their zero lower bound (ZLB) this downward adjustment cannot occur, resulting in larger consumption drops.

[10] The definition of both of these concepts is the same as in Appendix G of Bayer et al. (2019).

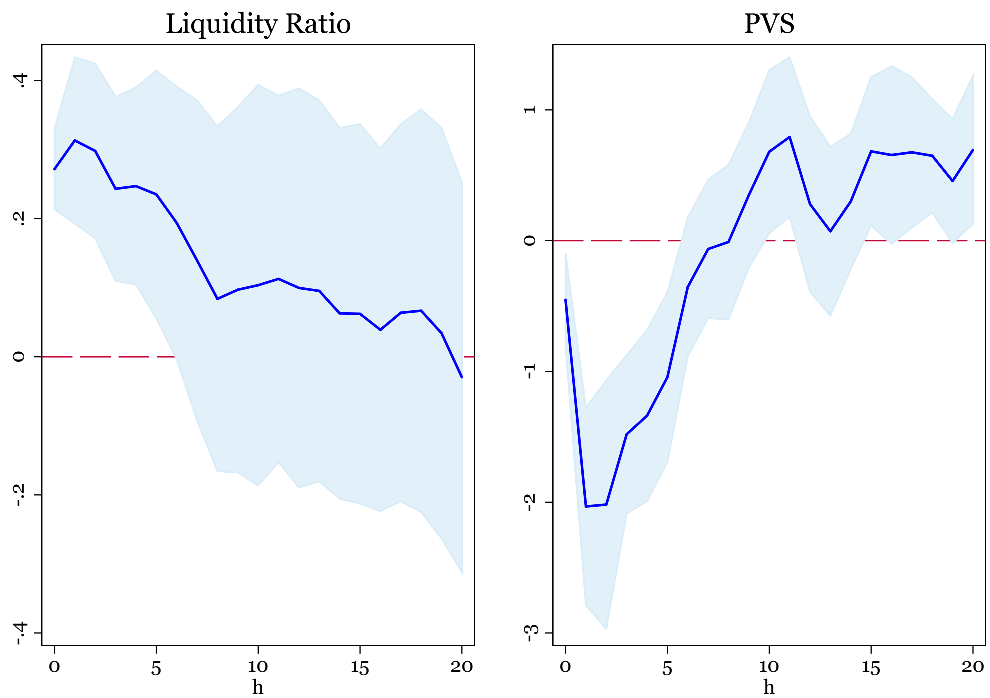
News shocks may have had a role to play during the Great recession, a period when the ZLB was binding in the US and many other economies.

Next, the response of a proxy for precautionary savings is examined in the aftermath of a news shock. Pflueger et al. (2018) measure the level of aggregate precautionary savings by looking at the price of volatile stocks (PVS). They exploit the fact that when levels of household risk are high, the subsequent precautionary savings motive pushes down the price of high-volatility stocks relative to low-volatility ones, and thus this price ratio can be informative for our purposes. Under our identification strategy, real stock prices change on the impact of a news shock by construction. It may, therefore, be thought that a news shock is also likely to move PVS for the same reason. However, the correlation between real stock prices and PVS is very close to zero, so movements in the latter after a news shocks can be considered to be genuinely informative about the precautionary savings motive. Note that stock prices are also included as a control variable in the local projection, which further mitigates this concern.

The IRFs estimated from the local projection show that PVS exhibits a sharp and immediate decline in response to the shock ($p(\beta_0^{PVS} = 0) = 0.033$) as the precautionary savings motive is triggered, remaining depressed over the next 6 quarters before returning to its steady state value.

The message of these two results taken together is clear: asset markets provide salient evidence that a bad news shock causes a significant and prolonged rise in precautionary savings.

Figure 6: Estimated IRFs from a local projection for the liquidity ratio and the Pflueger et al. (2018) price-of-volatile stocks (PVS) series to a negative Beaudry-Portier news shock.



Note: The light blue shaded area denotes the 90% confidence interval at each horizon.

3.2 Wealth state-dependence

Next, the response of consumption to news shocks in high- and low-wealth states is explored. As Heathcote and Perri (2018) encapsulate, periods of low wealth levels function as times when households are poorly equipped to cushion the impact of idiosyncratic unemployment risk. This consequently means that the precautionary saving channel is significantly stronger in times when many households are wealth-poor. Heathcote and Perri demonstrate theoretically that under low wealth, shifts in expectations about unemployment risk cause sharp swings in desired expenditures. Conversely, when wealth is high consumers have a sufficient buffer stock and as such the response of consumption is more muted following a shift in expectations. The precise source of these expectation changes is left undetermined. This section attributes these swings in perceived unemployment risk to news shocks, and investigates the mechanism empirically. Previous results clearly show that a 'bad news' shock does indeed dramatically increase unemployment risk. When wealth is high, the precautionary savings channel is effectively switched off and so a relatively muted response of variables in the high-wealth state indicates the channel's importance for news shock. A stronger response of consumption to news shocks in times of low wealth provides evidence of the precautionary savings channel at work, while a response that is invariant to wealth levels suggests that the mechanism is weak or possibly non-existent.

Smooth transition local projection. In order to proceed, a means of investigating the response of consumption in high- and low-wealth states is required. The econometric method used to accomplish this is the smooth transition local projection (STLP) of Tenreyro and Thwaites (2016), who examine the response of output to monetary shocks in booms and recessions. The primary advantage of this framework over alternatives such as a regime-switching VAR is that one can remain agnostic on the exact dynamics of how the economy transitions from one wealth state to the other. It therefore accounts for the propensity for the news shock to induce such a transition. The IRFs produced from a regime-switching VAR feature the underlying assumption that the shock causes no such transition, which may be deemed implausible. The continuity obtained by using the local projection framework is an added benefit.

The STLP specification for variable i is given by:

$$Y_{i,t+h} = \gamma t + F(z_t)(C_{i,t+h}^{h,HW} + \alpha_i^{h,HW'} X_t + \beta_i^{h,HW} \varepsilon_t) + (1 - F(z_t))((C_{i,t+h}^{h,LW} + \alpha_i^{h,LW'} X_t + \beta_i^{h,LW} \varepsilon_t)) + \omega_{i,t+h}$$

$F(z_t)$ is the wealth-regime indicator function which takes values between 0 and 1. A state-dependent constant, $C_{i,t+h}^{h}$, is included. The impulse response of the variable to a news shock in a high-wealth state at horizon h is given by $\beta_i^{h,HW}$, while the impulse response of the variable to a news shock in a low-wealth state at horizon h is given by $\beta_i^{h,LW}$. The vector of controls contains one lag of the dependent variable and a log-linear trend is once again included. Following

Tenreyro and Thwaites (2016), the logistic function is selected as the state indicator function:

$$F(z_t) = \frac{exp(\Omega\frac{(z_t-\Gamma)}{\sigma_z})}{1+exp(\Omega\frac{(z_t-\Gamma)}{\sigma_z})}$$

The state variable z_t is chosen to be the seven quarter lagging moving average[11] of the growth rate of real net worth which Heathcote and Perri (2018) identify as a measure of aggregate wealth in the economy. The parameter Ω governs the dynamics of the regime-switching process. As $\Omega \to \infty$, the model becomes a discrete regime-switching process, whilst lower values imply a smoother transition process between regimes. Again, following Tenreyro and Thwaites, the parameter is calibrated as $\Omega = 3$ to give a moderate level of regime-switching severity, and the parameter Γ is set such that 20% of periods in the sample are designated as low-wealth states. Newey-West standard errors are again computed with $h-1$ autocorrelation lags.

Figure 7 displays the impulse response functions of non-durable consumption to a 'bad news' shock in a low- and high-wealth state. This clearly illustrates that when wealth levels are low, consumption declines significantly in response to the shock, whereas in high-wealth states there is no such decline in expenditure in the immediate aftermath of the shock. Also of note is that the responses only differ to a substantive degree over the first six quarters after the shock's arrival. This state dependence, which is evident and particularly strong near the realisation of news, is consistent with the precautionary savings channel outlined. In order to formally test for state-dependence, the p-values for the hypothesis test of $(\beta^{h,HW}_{nondurcons} - \beta^{h,LW}_{nondurcons}) = 0$ for various values of h are displayed in appendix B. These results show that the response of consumption is significantly more negative in the low-wealth state after one and two quarters after which the responses once again become aligned.

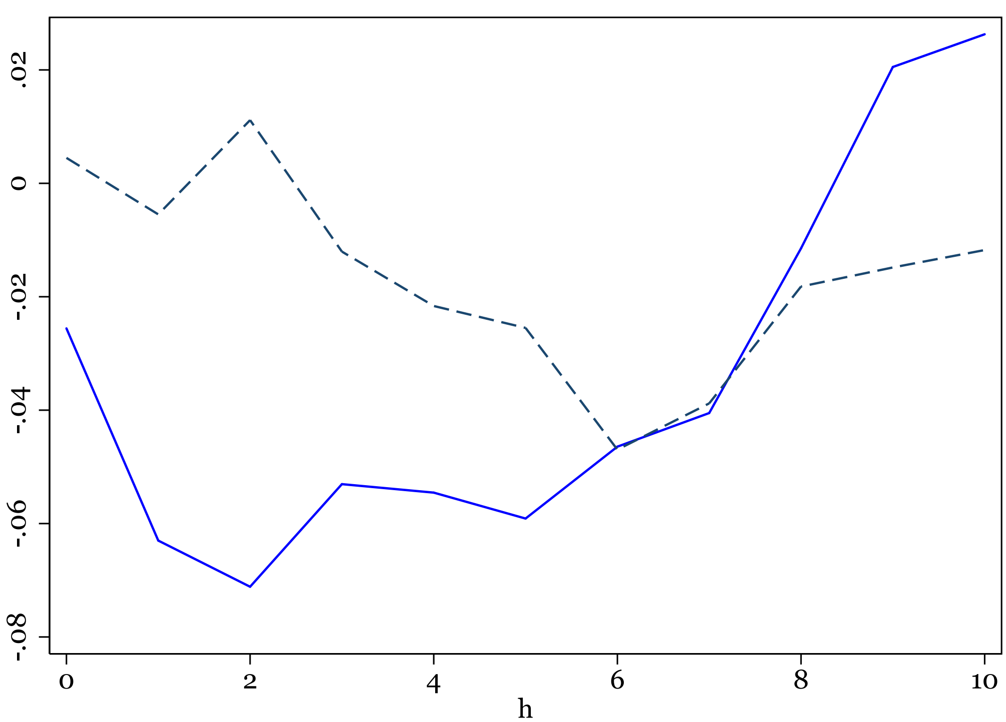
The IRFs of GDP, vacancies, unemployment and the Federal Funds rate in each state is displayed in Figure 8[12]. These all display similar state-dependence, exhibiting a much more pronounced decline in response to a 'bad news' shock in the low-wealth state relative to the high-wealth

[11] A lagging moving average is used to avoid lead values of the dependent variable from appearing as regressors.

[12] State dependence tests for inflation revealed little difference in response between wealth states and as such the IRF for inflation is omitted

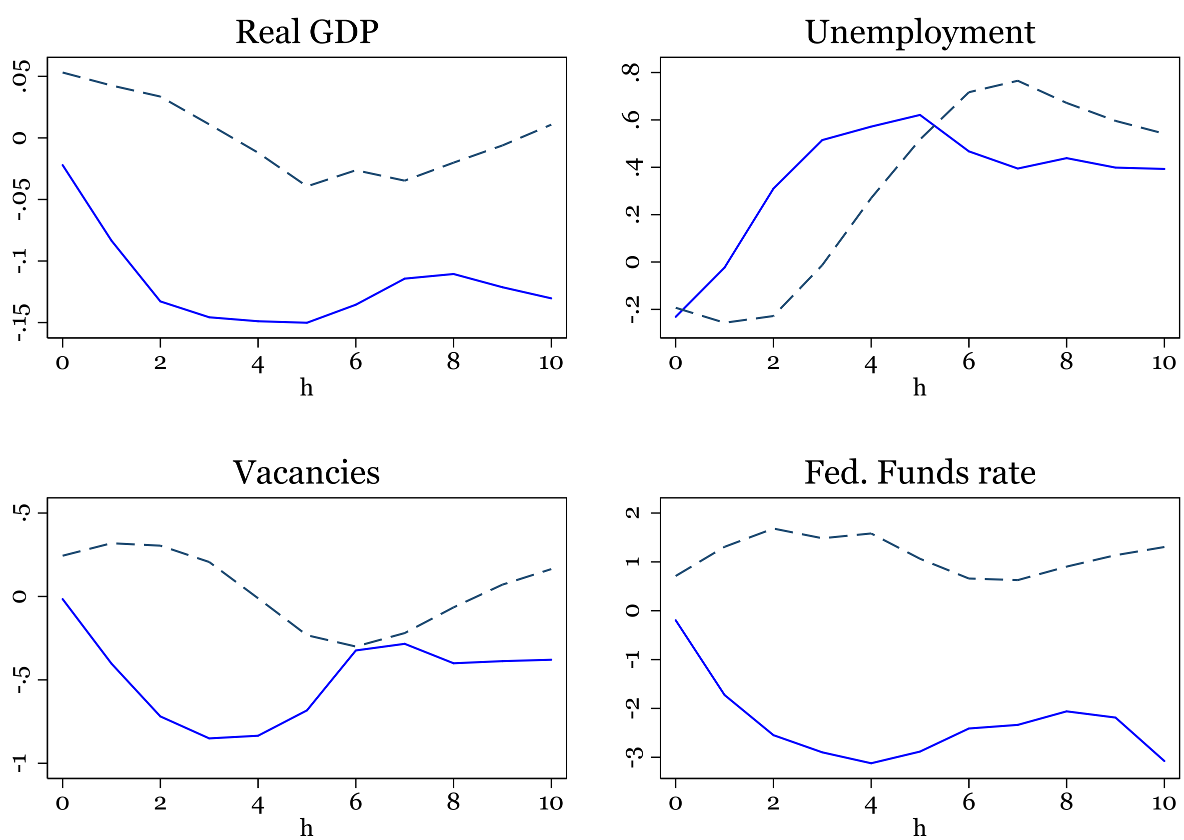
state. The responses are consistent with the general equilibrium effects which emerge from the response of consumption. There seems to be very strong state-dependence present in output, which plummets in response to the 'bad news' shock in the low-wealth state, but actually rises slightly in the high-wealth state. See Appendix B for the results for the hypothesis test $(\beta_i^{h,HW} - \beta_i^{h,LW}) = 0$ for each of these variables. The null hypothesis of no state-dependence in the response is rejected at the 95% confidence level for at least one quarter in the year following the shock for real GDP, vacancies and the Federal Funds rate. The large decline in the Fed Funds rate in the low-wealth state is indicative of the strong precautionary savings response resulting in a flight to liquidity. Unemployment does not exhibit a significantly different response in the two states.

Figure 7: The IRF of real non-durable consumption to a negative Beuadry-Portier news shock in a low-wealth state (light blue solid line) and in a high-wealth state (dark blue dashed line).



Appendix B shows that these findings robust to alternative values of the regime-switching parameter, Ω, as well as a different percentage of low-wealth state periods used as a calibration target for the parameter Γ. The use of two alternative state variables is also considered. The first of these is a twenty quarter lagging moving average of the real net worth growth rate, capturing longer term wealth dynamics. The second is the log of real net worth detrended with a Hodrick-Prescott filter. State-dependent responsiveness of the five variables remains present in all of these robustness tests.

Figure 8: The IRFs of real GDP, vacancies, unemployment and the Federal Funds rate to a negative Beuadry-Portier news shock in a low-wealth state (light blue solid line) and in a high-wealth state (dark blue dashed line).



Threshold VAR. State-dependence is now investigated through the lens of a threshold VAR (TVAR). The specification is as follows:

$$X_t = I_{t-1}\Theta_{LW}(L)X_{t-1} + (1 - I_{t-1})\Theta_{HW}(L)X_{t-1} + u_t$$

where $X_t = [\varepsilon_t, Y_{i,t}]$, i.e. the Beaudry-Portier shock is ordered first and the macroeconomic variable of interest ordered last. I_{t-1} is a binary indicator variable for a low-wealth state, $\Theta(L)$ is a lag polynomial and finally, $u_t \sim N(0, \Psi)$ with $\Psi = I_{t-1}\Psi_{LW} + (1 - I_{t-1})\Psi_{HW}$. The indicator variable is constructed by first detrending the log of real net worth with a second-degree polynomial trend. Periods where real net worth is $> 10\%$ below its trend are denoted as low-wealth states with $I_t = 1$. Four lags are used in the TVAR, the sample is kept consistent with the STLP, and the five macroeconomic variables used are also kept the same.

The key difference between the TVAR and STLP specifications relates to the assumption as to the shock's impact on the state variable. In the STLP, the estimated IRFs incorporate the potential for the shock to induce a regime shift from a high-wealth state to a low-wealth state or vice versa. The IRFs estimated from the TVAR feature the implicit assumption that the state does not change throughout the horizon. While for more transitory state-variables, this assumption may be troublesome, the average duration of a low-wealth state is 13 quarters. This adds plausibility to this assumption when interpreting the short-run impact of the news shock in each state. Figuere A14 in Appendix B displays the IRFs from the TVAR specification. These again provide evidence in favour of state-dependent responsiveness to the shock. During low-wealth states, the responsiveness of output, consumption, vacancies and the Fed. Funds rate is substantially greater than when wealth is at its trend level. This key result is therefore not merely a product of the econometric method used.

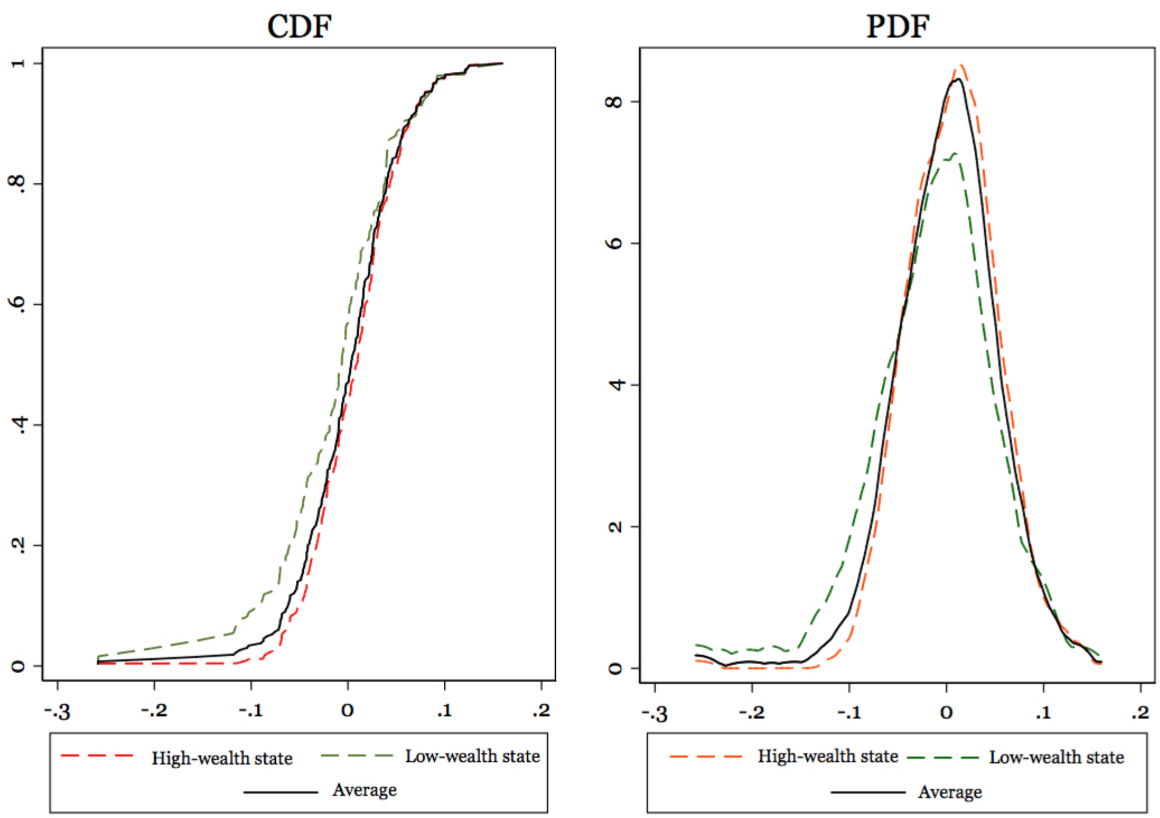
Robustness tests. One possibility is that larger news shocks are more common in low-wealth states and this consequently is what shapes the results. The CDF and PDF for the shocks in each regime can be seen in Figure 9. These show that there is indeed evidence that this is true to some extent as large negative shocks are slightly more common when wealth is low, although the difference in the distributions is not substantial. While this is an interesting finding in and of itself, alone it is not sufficient to prove that the distribution of news shocks is drives the previous results. To test this, I include the cubed news shock, ε_t^3, in the baseline local projection specification:

$$Y_{i,t+h} = \gamma t + C_i^h + \alpha_i^{h'} X_t + \beta_i^h \varepsilon_t + \eta_i^h \varepsilon_t^3 + \omega_{i,t+h}$$

If large shocks have a greater effect proportionally than small shocks, the coefficients η_i^h would be positive and significant. Broadly speaking, this is found to not be the case. Table A6 in Appendix B contains the full results for the hypothesis tests of η_i^h. The only two exceptions are unemployment and inflation, for which larger shocks do seem to have a stronger proportional effect than small shocks. However, the response of unemployment was not found to differ particularly between wealth-states originally, and the response of inflation is not different from zero in the baseline results, making this a rather moot point. The possibility that the higher occurrence of large, negative shocks in low-wealth states is driving results can therefore be definitively ruled out.

These results suggest convincingly that news shocks have a significantly more powerful impact when levels of wealth are low. While large negative news shocks are found to be marginally more common in low-wealth states, the result are not driven by this. The results are robust to using a TVAR rather than the baseline STLP specification, as well as varying the regime-switching parameter and wealth state variable. Although these findings do not emphatically preclude alternative explanations, they certainly add credence to the precautionary savings channel as a key vehicle through which news shocks are transferred to the wider economy. The following section illustrates the mechanism though a DSGE model.

Figure 9: CDF and PDF of the Beaudry-Portier news shock in the low-wealth state, the high-wealth state and the average distribution.



4 Model

The model is a heterogeneous agents model with search-and-matching frictions in the labour market, nominal rigidities in the goods market and financial market frictions in the form of incomplete markets. The environment is a simplified and modified version of Ravn and Sterk (2017) . It is shown that a bad news shock results in contractionary responses similar to those present in the empirical results, and that this relies crucially upon the precautionary savings motive of employed workers.

Households . There is a unit continuum of single-member households, indexed by $i \in (0, 1)$, who are risk averse, have an infinite horizon and are either employed or unemployed in a given period t. Their objective is to maximise the expected present value of their utility streams according to their discount factor β. They gain utility from consumption and disutility from working.

If a household is employed, they earn a real wage W_t and lose their jobs with an exogenous probability ρ in each period. Unemployed individuals produce ζ units of the aggregate consumption good via home production. This is strictly less than the real wage, and so unemployed workers seek employment by searching in the frictional labour market. An unemployed worker successfully finds a job with endogenous probability η_t.

At the start of each period, new matches are formed between unemployed workers and vacant firms as hiring takes place. Production and consumption then occurs. Following this, a fraction (ρ) of employed workers lose their jobs, and this constitutes the source of idiosyncratic income risk. It is not possible to purchase insurance against unemployment, and households must self-insure via government bonds in order to smooth consumption. Let $B_t(i)$ denote worker i's holding of government bonds in period t. The worker maximises utility subject to a budget constraint and a borrowing constraint in each period. The full household problem is then:

$$\max E_t \textstyle\sum_{t=0}^{\infty} \beta^t [\frac{C_t(i)^{1-\sigma}}{1-\sigma} - \vartheta N_t(i)]$$

s.t

$$C_t(i) + B_t(i) \leq N_t(i)W_t + (1 - N_t(i))\zeta + \frac{R_{t-1}}{\pi_t} B_{t-1}(i)$$

$$B_t(i) \geq B^{limit}$$

Substituting into the budget constraint:

$N_t(i) = 0$ if worker i is unemployed in period t,

$N_t(i) = 1$ if worker i is employed in period t.

The borrowing limit is given by B^{limit}, the gross nominal interest rate by R and finally the net inflation rate by π. $C_t(i)$ represents a CES aggregator of differentiated consumption goods:

$$C_t(i) = \left(\int_j (C_t(i,j))^{1-1/\gamma} dj \right)^{\frac{1}{1-1/\gamma}}$$

The elasticity of substitution between varieties of the consumption goods is given by γ and is strictly greater than one.

The problem of both employed and unemployed worker's can be summarised by a Bellman equation for each group. The Bellman equation for employed workers is:

$$V^e(B(i),\Gamma) = \max_{C(i),B'(i)} \left\{ U(C(i),N(i)) + \beta E(1-\rho(1-\eta'))V^e(B'(i),\Gamma') + \beta E\rho(1-\eta')V^u(B'(i),\Gamma') \right\}$$

subject to the budget constraint and borrowing constraint with $N_t(i) = 1$. Γ is the aggregate state vector. The Bellman equation for unemployed workers is:

$$V^u(B(i),\Gamma) = \max_{C(i),B'(i)} \left\{ U(C(i),N(i)) + \beta E\eta'(i)V^e(B'(i),\Gamma') + \beta E(1-\eta')V^u(B(i)',\Gamma') \right\}$$

subject to the budget constraint and borrowing constraint with $N_t(i) = 0$.

Production. There is a continuum of capitalists, indexed by $j \in (0,F)$, $F < 1$, who are risk neutral and own firms which operate in monopolistic competition. Entrepreneurs have the same discount factor as households and are the only agents entitles to the firm's earnings. They also consume and save, but face the same borrowing constraint as households. Firms produce a differentiated good with linear production technology:

$$Y_t(j) = A_t N_t(j)$$

where $Y_t(j)$ is the output of firm j in period t, A_t is aggregate TFP and $N_t(j)$ is the number of workers employed by firm j in period t. Aggregate TFP is exogenous and stochastic, with anticipated and unanticipated components. It follows the stochastic process:

$$log(A_t) = \phi_A log(A_{t-1}) + \Psi_t^A$$

$$\Psi_t^A = \varepsilon_t^A + \varepsilon_{t-4}^A + \varepsilon_{t-8}^A$$

where $\phi^A \in (-1, 1)$, $\varepsilon_{t-k}^A \sim N(0, \sigma_k^2)$ for $k = 0, 4, 8$. Following Chahrour and Jurado (2018), this can be re-written in an observationally equivalent noise formulation. In this framing, agents receive three signals, $s_{8,t}^A$, $s_{4,t}^A$ and $s_{0,t}^A$ about future realisations of the TFP shock, which are contaminated with noise:

$$s_{8,t}^A = \Psi_{t+8}^A + \upsilon_{8,t}^A$$

$$s_{4,t}^A = \Psi_{t+4}^A + \nu_{4,t}^A$$

$$s_{0,t}^A = \Psi_t^A$$

The noise shocks are denoted by $\upsilon_{8,t}^A$ and $\upsilon_{4,t}^A$. The response of the endogenous variables to both news and noise shocks will be considered in the model results.

The firm's employment evolves according to the law of motion:

$$N_t(j) = (1 - \rho)N_{t-1}(j) + H_t(j)$$

with $H_t(j)$ denoting firm j's hires in period t. In order to hire workers, firms choose their number of vacancies, $v_t(j)$, which have a positive unit cost of κ. Any given vacancy is filled with endogenous, time-varying probability η_t^v and firms are large enough that this corresponds to the proportion of vacancies which result in hires. This leads to the following condition:

$$H_t(j) = v_t(j)\eta_t^v$$

Real marginal costs for firm j are given by:

$$MC_t = (\frac{1}{A_t})(W_t + \frac{\kappa}{\eta_t^v} - \beta E_t \left[(1-\rho)\frac{\kappa}{\eta_{t+1}^v} \right])$$

Price and wage setting. It is costly for firms to adjust the price of their good,$P_t(j)$, as they face Rotemberg-style quadratic price adjustment costs. Prices are set such as to maximise:

$$\max E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{P_t(j)}{P_t} Y_t(j) - W_t N_t(j) - \kappa v_t(j) - \frac{\theta}{2} \left(\frac{P_t(j) - P_{t-1}(j)}{P_{t-1}(j)} \right)^2 Y_t \right]$$

s.t

$$Y_t(j) = A_t N_t(j)$$

$$Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\gamma} Y_t$$

$$N_t(j) = (1-\rho)N_{t-1}(j) + H_t(j)$$

where P_t is the aggregate price level, $Y_t = \left(\int_j Y_t(j)dj) \right)$ is aggregate output and W_t is the real wage. The parameter θ determines the extent of nominal rigidities present. The demand constraint emerges from the consumer's decision problem.

In symmetric equilibrium, relative prices are equal to 1 and marginal cost is equal across all firms, meaning the j index can now be dropped. The first-order condition for the firm's problem is:

$$1-\gamma+\gamma MC_t=\theta\pi_t(1+\pi_t)-\theta\beta E_t\pi_{t+1}(1+\pi_{t+1})\frac{Y_{t+1}}{Y_t}$$

Wages are set in a Nash bargaining process between households and firms. The two parties bargain cooperatively with bargaining power which may be unequal. The problem is given by:

$$\max[V_t^e(i)-V_t^u(i)]^{\chi}(S_t^f)^{1-\chi}$$

where:

$$V_t^e(i)=\frac{C_t^e(i)^{1-\sigma}}{1-\sigma}-\vartheta+\beta E_t(1-\rho(1-\eta_{t+1}))V_{t+1}^e(i)+\beta E_t\rho(1-\eta_{t+1})V_{t+1}^u(i)$$

$$V_t^u(i)=\frac{C_t^u(i)^{1-\sigma}}{1-\sigma}+\beta E_t(1-\eta_{t+1})V_{t+1}^u(i)+\beta E_t\eta_{t+1}V_{t+1}^e(i)$$

$$S_t^f=\frac{\kappa}{\eta_t^v}$$

with $C_t^e(i)$ and $C_t^u(i)$ denoting the optimal consumption level chosen by an employed and unemployed worker respectively. The expression for S_t^f follows from the fact that, should the bargaining process fail, the firm would have to incur hiring costs of $\frac{\kappa}{\eta_t^v}$ to replace the worker. The first order conditions for the problem give the solution:

$$(1-\chi)[V_t^e(i)-V_t^u(i)]=\chi\left(\frac{\kappa}{\eta_t^v}\right)$$

Entrepreneur consumption-saving. The entrepreneur's Bellman equation that pins down their consumption-saving decisions solves:

$$V^{ent}(B^{ent}(j), N(j), \Gamma) = \max_{d(j), b^{ent'}(j), h(j)} \left[D(j) + \beta E V^{ent}(B^{ent'}(j), N'(j), \Gamma' \right]$$

s.t

$$D(j) + B^{ent'}(j) + WN(j) + \kappa v(j) = \frac{P(j)}{P} Y(j) - \frac{R_{-1}}{1+\pi} B^{ent}(j)$$

$$Y(j) = AN(j)$$

$$B^{ent}(j) \geq B^{limit}$$

where $D(j)$ and $B^{ent}(j)$ are the consumption and bond holdings of entrepreneur j respectively.

Labour market matching. The labour market features matching frictions a la Diamond-Mortensen-Pissarides. Timing is as follows in each period:

1. The aggregate labour market shocks realise.

2. Unemployed workers match with firms who post vacancies.

3. Production and consumption occur.

4. Job separations take place.

This timing structure implies that workers have the opportunity to search for a new job immediately after being separated from their previous one. Aggregate hires are determined by a Cobb-Douglas matching function:

$$M(u_t, v_t) = u_t^{\alpha} v_t^{1-\alpha}$$

with $\alpha \in (0,1)$, $v_t = \left(\int_j v_t(j)dj\right)$ and $u_t = 1 - \left(\int_j N_t(j)dj\right)$. The job finding rate and vacancy filling rate are given by:

$$\eta_t = \frac{M(u_t, v_t)}{u_t} = (\frac{v_t}{u_t})^{1-\alpha}$$

$$\eta_t^v = \frac{M(u_t, v_t)}{v_t} = (\frac{v_t}{u_t})^{-\alpha}$$

Monetary policy. Monetary policy follows a standard inflation-targetting Taylor rule:

$$R_t = \overline{R}\left(\frac{1+\pi_t}{1+\overline{\pi}}\right)^{\delta}$$

where $\overline{R}$ and $\overline{\pi}$ denote the steady state interest rate and inflation target respectively, while δ is a parameter reflecting how responsive the monetary authority is to inflation.

Equilibrium. Following Ravn and Sterk (2017), Heathcote and Perri (2018),McKay and Reis (2016) and much of the literature, the following borrowing constraints are imposed:

$$B_t(i) \geq 0 \forall i$$

$$B_t^{ent}(j) \geq 0 \forall j$$

These constraints imply that bonds are in zero net supply and the wealth distribution is degenerate. In equilibrium, both households and entrepreneurs live hand-to-mouth and simply consume their income in each period, implying there is no heterogeneity between households of the same employment status, allowing the i subscript to be dropped. The following conditions hold in equilibrium:

$$C_t^e = W_t$$

$$C_t^u = \zeta$$

The equilibrium definition is the same as in Appendix 1 of Ravn and Sterk (2017). The full set of equilibrium equations can be found in Appendix C. Four key equations characterise the model's equilibrium:

$$W_t^{-\sigma} = \beta E_t \frac{R_t}{1+\pi_t} \left\{ (1-\rho(1-\eta_{t+1}))W_{t+1}^{-\sigma} + \rho(1-\eta_{t+1})\zeta^{-\sigma} \right\}$$

$$MC_t = (\frac{1}{A_t})(W_t + \frac{\kappa}{\eta_t^v} - \beta E_t \left[(1-\rho)\frac{\kappa}{\eta_{t+1}^v} \right])$$

$$1 - \gamma + \gamma MC_t = \theta\pi_t(1+\pi_t) - \theta\beta E_t \left[\pi_{t+1}(1+\pi_{t+1})\frac{Y_{t+1}}{Y_t} \right]$$

$$R_t = \overline{R} \left(\frac{1+\pi_t}{1+\overline{\pi}} \right)^{\delta}$$

The first of these is the household's Euler equation for bonds. The presence of idiosyncratic income risk shows up through the labour market variables which feature in the equation, meaning that deteriorating labour conditions stimulate precautionary savings[13]. While this does not show

[13] Further discussion of the endogenous earnings risk wedge present in the Euler equation can be found in Ravn and Sterk (2018), who discuss conditions under which earnings risk is pro- and counter-cyclical. The presence of wage rigidly in the model means that earnings risk is counter-cyclical here, which Ravn and Sterk find to be the plausible case empirically.

up in realised saving, due to the zero net supply of bonds, it does operate via adjustment in the real interest rate which then subsequently leads to changes in other endogenous variables. The second equation is the firm's real marginal cost and the third is its FOC for price setting. The presence of nominal rigidities mean that it is costly for firms to adjust prices and cause them to adjust real marginal cost by instead varying their hiring levels in response to changing demand conditions. The final equation is the Taylor rule, which pins down the nominal interest rate and ensures there is a unique, stable equilibrium.

5 Calibration.

The time frequency in the model is quarterly to facilitate direct comparison with the empirical results. The model is calibrated to either match a steady-state target or according to microeconomic evidence. The discount factor, β, is set at 0.99, which implies a subjective discount rate of 4 percent per annum. The steady-state interest rate is below $\frac{1}{\beta}$ due to the presence of idiosyncratic income risk. The monetary authority targets a stable price level, resulting in $\overline{\pi} = 0$. The semi-elasticity of the nominal interest rate to deviations of inflation from target, δ, is set at 1.5, which is standard.

The coefficient of relative risk aversion is set to 1.5, and the vacancy posting κ is set to 0.19 as in Ravn and Sterk (2017). A key parameter in the model is ζ, as this determines the amount by which consumption decreases upon the transition from employment to unemployment. Chodorow-Reich and Karabarbounis (2016) estimate this decrease to be 21 percent empirically, while other studies have estimated it to be closer to 13 percent. I calibrate the parameter such that the average consumption drop falls in this range, at 18 percent. The price adjustment parameter, θ, is set to 58.7, which implies that prices adjust on average every 4 quarters. The elasticity of substitution,γ, is set at 6 which produces a steady-state markup of 20%. The elasticity of the matching function (with respect to unemployment) is set at 0.65 which falls in upper part of the range estimated by Pissarides and Petrongolo (2001). The worker's bargaining parameter, χ, is set to 0.04 following Hagedorn and Manovskii (2008). This implies a realistic wage elasticity to TFP of roughly 0.34. The disutility of work parameter, ϑ, is set to target a steady-state unemployment rate of 6%. The TFP persistence parameter, ϕ^A, is set to 0.95, which is a standard value. The separation rate, ρ, is set to 0.044 which corresponds to a monthly unemployment inflow rate of approximately 1.5% from the CPS. Table 1 provides a full summary of the model's calibrated parameters.

Table 1: Parameter values

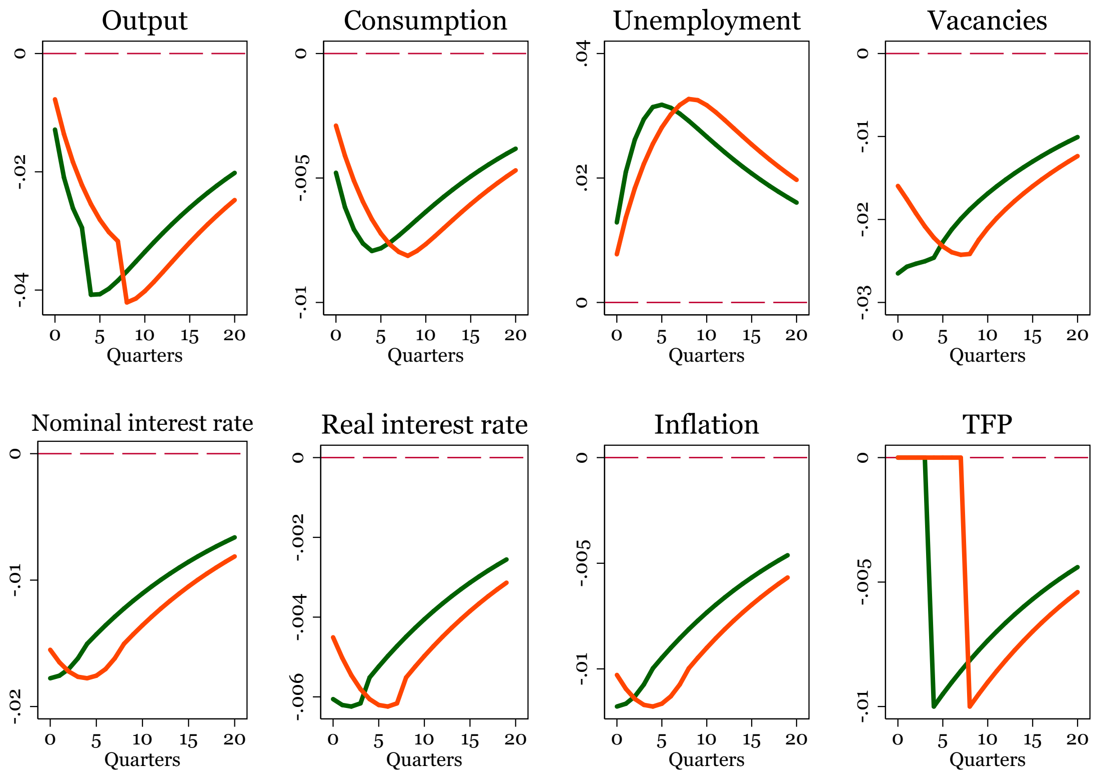
Parameter	**Value**	**Target/Source**
β	0.99	Subjective discount rate of 4% per year
σ	1.5	Ravn and Sterk (2017)
ζ	0.68	Consumption loss of 18% upon unemployment,
		Chodorow-Reich and Karabarbounis (2016)
θ	58.7	Average price duration of 4 quarters
γ	6	Steady-state markup of 20%
κ	0.19	Ravn and Sterk (2017)
ρ	0.044	Monthly unemployment inflow rate of 1.5% from CPS
ϑ	0.225	Steady-state unemployment rate of 6%
χ	0.04	Hagedorn and Manovskii (2008)
α	0.65	Pissarides and Petrongolo (2001)
δ	1.5	Standard value
$\overline{R}$	1.005	Steady state annualised nominal interest rate of 2%
$\overline{\pi}$	0	Zero steady-state inflation
ϕ^A	0.95	Standard value

6 Results

Baseline results. The model is solved numerically with a standard first-order perturbation method and IRFs for a -1% shock to ε_{t-4} and ε_{t-8} are computed. As Figure 10 shows, news shocks of both anticipation horizons cause a contraction in output. The mechanism is as follows: a drop in expected future productivity causes firms to post fewer vacancies. Hiring is a form of forward-looking investment, and lower expected TFP induces firms to curtail this, as the marginal benefit of posting a vacancy is lowered. This fall in vacancies decreases the probability of finding a job once unemployed. From the Euler equation, this generates a precautionary savings motive amongst households due to lower expected income. The desire to smooth consumption places downward pressure on nominal interest rates, and inflation consequently from the interest rate rule. From the New Keynesian Phillips curve, and as a result of nominal rigidities, marginal costs fall by further cutbacks in vacancy posting. This serves to deteriorate labour market conditions further, amplifying the shock. Before TFP changes, output falls due to the reduction in employment - a Pigovian cycle. The movement of output, is in line with the empirical results as it exhibits an immediate, hump-shaped decline as the news shock arrives. The response of unemployment, vacancies, consumption and the nominal interest rate also echo the movement pattern seen in the estimated IRFs. The only variable which does not match up is inflation, which declines following a bad news shock in the model but is more or less unmoved in the empirical results.

The role of precautionary savings and labour market frictions. In order to isolate the precise roles of precautionary savings and frictional labour markets, it is instructive to look at two counterfactual economies. In the first, there is complete markets which eliminates all idiosyncratic risk, while search frictions remain present in the labour market. In the second, there is a spot labour market where the probability of transitioning to unemployment (p^{eu}) is entirely exogenous each period, but markets are incomplete. Full details of these models can be found in the Appendix D, but the respective Euler equations are:

Figure 10: Model IRFs for a -1% shock to ε_{t-4} and ε_{t-8}.



Note: The green line denotes the IRF for ε_{t-4} and the orange line denotes the IRF for ε_{t-8}.

$$C_t^{-\sigma} = \beta E_t \frac{R_t}{1+\pi_{t+1}} C_{t+1}^{-\sigma}$$

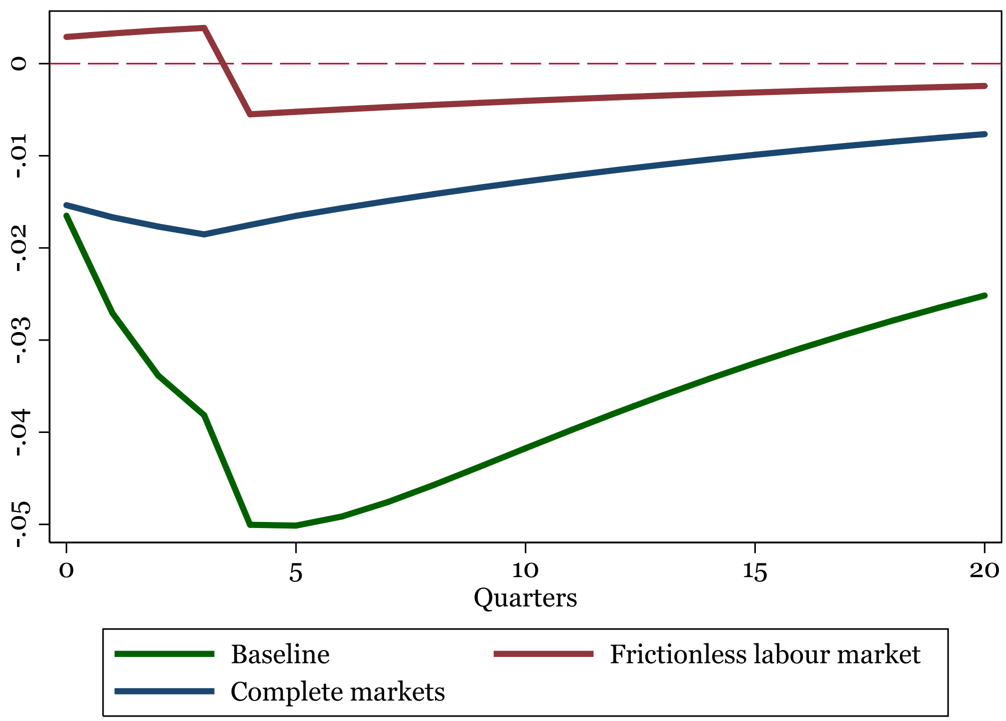
$$W_t^{-\sigma} = \beta E_t \frac{R_t}{1+\pi_t} \left\{(1-p^{eu}))W_{t+1}^{-\sigma} + p^{eu}\zeta^{-\sigma}\right\}$$

In the first economy there is full risk-sharing, which means that deteriorating labour markets do not directly affect the consumption-saving decision. In the second economy, idiosyncratic risk is entirely exogenous, meaning there is still a precautionary savings motive, but firms and workers can match with other in a frictionless manner each period.

Figure 11 compares the IRFs for consumption and output in these two economies to the baseline results. In the complete markets economy, labour market frictions mean that firms still have a reduced incentive to post vacancies after a bad news shocks, as their labour demand falls in response to poor expected future conditions. This leads to a lower level of employment, reducing output and consumption via general equilibrium effects. The shock is not amplified beyond the firm's vacancy posting decision, as the lower job finding rate does not have a spillover effect on the consumption-saving decision of households as they are insured against the risk of joblessness. For this reason, the magnitude of the output drop is dramatically lower than in the baseline economy. These results dovetail with the results in Section 3, which show that when levels of wealth are lower in the economy and households are less insured against income losses, news shocks have higher potency.

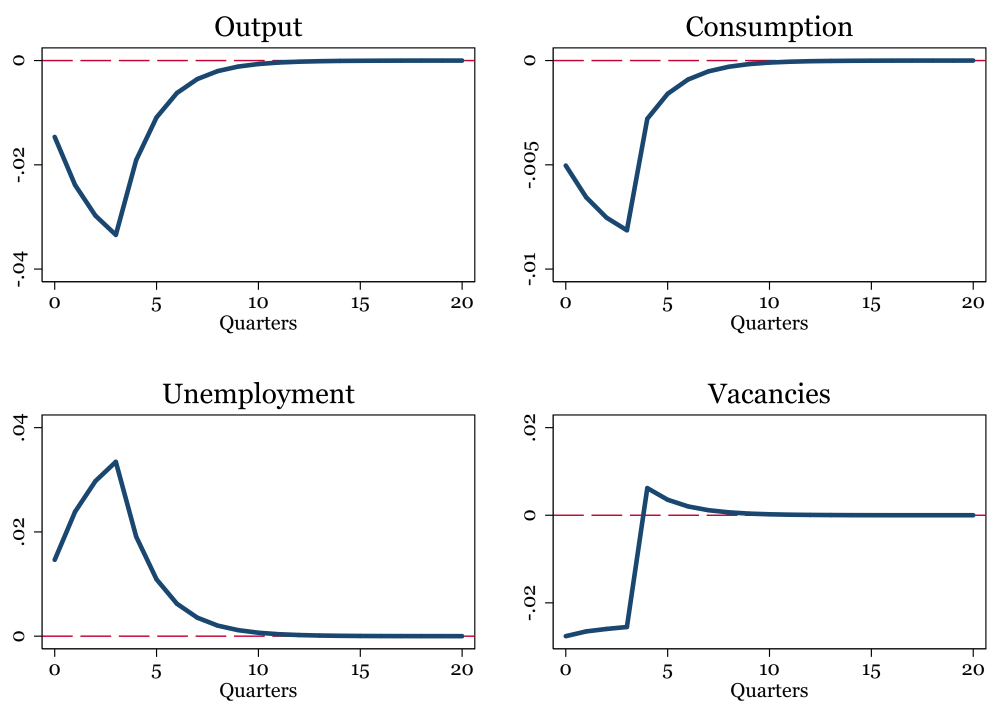
In the economy which features frictionless labour markets but retains idiosyncratic risk, the sign of the output response is reversed as a bad news shock leads to a counterfactual boom in the periods prior to TFP changing. This is because the effect the shock has on labour supply - bad news makes today a relatively efficient time for households to work, shifting the labour supply curve outwards. This increases employment and output subsequently from the production function. As firms are able to hire and fire workers costlessly each period, the labour demand decision is not forward-looking and is not influenced by expectations of future productivity. It is not until TFP actually falls that firms reduce their labour demand and output falls. This lack of an immediate downturn in the labour market means that levels of idiosyncratic risk do not change for households, and the strength of the precautionary motive stays constant.

Figure 11: Comparison of the IRFs of output to a -1% shock to ε_{t-4} in the baseline economy and two counterfactual economies.



Noise shocks. As illustrated in Section 4, the news shocks can be re-framed as noise shocks in an observationally equivalent manner following Chahrour and Jurado (2018). Figure 12 presents the IRFs for output, consumption, unemployment and vacancies following a -1% noise shock relating to TFP 4 quarters ahead. These show that the expectation that TFP will be lower in the future causes the same contractionary response upon the realisation of the shock as in the news framework. When firms realise that their pessimistic expectations have not been borne out in reality, they restore their level of vacancy posting slightly above its steady state level to compensate for the workers they have foregone due to paused hiring. The presence of search-and matching frictions in the labour market mean that unemployment adjusts sluggishly, taking an additional 6 quarters to return to its steady-state value. This leads to a depressed job finding rate which persists, producing a heightened precautionary savings motive amongst employed workers. This causes consumption and output to also take an extended period of time to return to their normal levels. These results highlight that pure 'animal spirits' shocks can produce a deep recession and slow recovery via the interaction of the two key mechanisms in the model, and could potentially be informative as to why the US economy experienced such a sluggish transition back to normal employment levels following the Great Recession.

Figure 12: IRFs for a -1% noise shock pertaining to TFP 4 quarters ahead.



7 Conclusion

Evidence has been presented to suggest that news shocks are a key feature of business cycles. The key message of this paper is that two ingredients are key to the considerable impact of news: precautionary savings and frictional labour markets. After a bad news shock, the labour market experiences a pronounced downturn, operating through the forward-looking vacancy channel. Empirical results suggested that a large fraction of volatility in vacancies and unemployment can be attributed to news shocks. This increase in uninsurable unemployment risk causes households to hedge against the anticipated loss of expected income by reducing consumption immediately. Asset market evidence and the higher potency of news in low-wealth, low-insurance regimes point towards the existence of this precautionary savings transmission mechanism. The theoretical heterogeneous agent New Keynesian model presented was able to generate responses of key variables which echo those seen in the data. The combination of incomplete markets and labour market frictions were shown to be crucial for news to generate aggregate fluctuations. Noise shocks were shown to induce a persistent slump in unemployment, consumption and output despite the anticipated TFP decrease never being realised.

The paper opens up several areas for possible future exploration. On the empirical side, using microdata on consumption and wealth a la Heathcote and Perri (2018) would be another way of examining how the impact of news shocks vary by wealth level. While the model was kept simple and tractable in order to clearly illustrate the key mechanism at play, several salient features could be added in order to further understand how news affects agents' behaviour. Firstly, the model abstracted from the zero lower bound on interest rates, which was a defining characteristic of the Great Recession. As both the empirical and theoretical results demonstrated, bad news puts substantial downward pressure on interest rates due to the inter-temporal substitution by households and the central bank's abidance by a Taylor rule. This acts as a dampener on the shock. When rates cannot fall any further and this shock absorber is not active, the magnitude of the impacts would be greater. In the future I plan to investigate this quantitatively in a DSGE model estimated with Bayesian methods in order to shed light on the exact contribution of news and noise in the Great Recession. Secondly, the model does not incorporate an explicit role for firm entry and exit. An abundance of recent research, e.g. Sedlacek and Sterk (2017) has shown that this is an important element of the business cycle. Intuitively, there are many reasons to believe that the firm entry/exit decision has a strong forward-looking component to it. Its sensitivity to news and noise would be an interesting avenue to investigate in further research.

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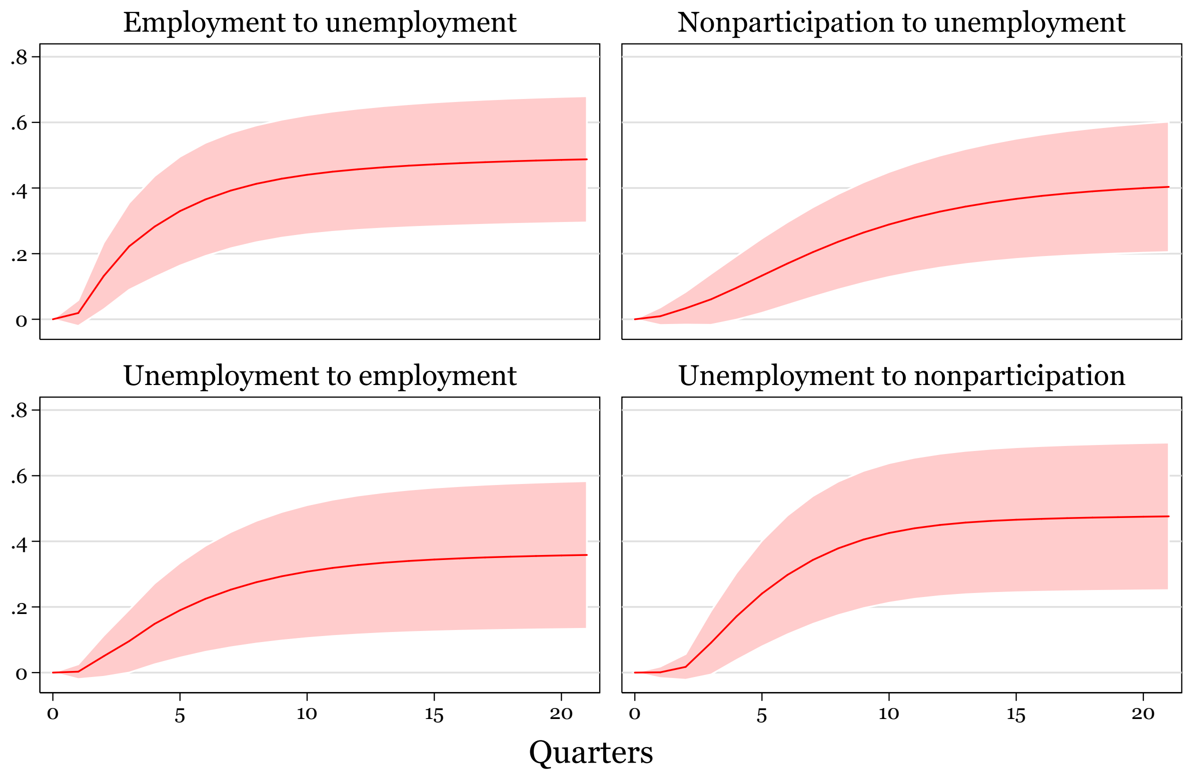
Appendix A

Figure A1: Variance decompositions for the labour market flow variables.



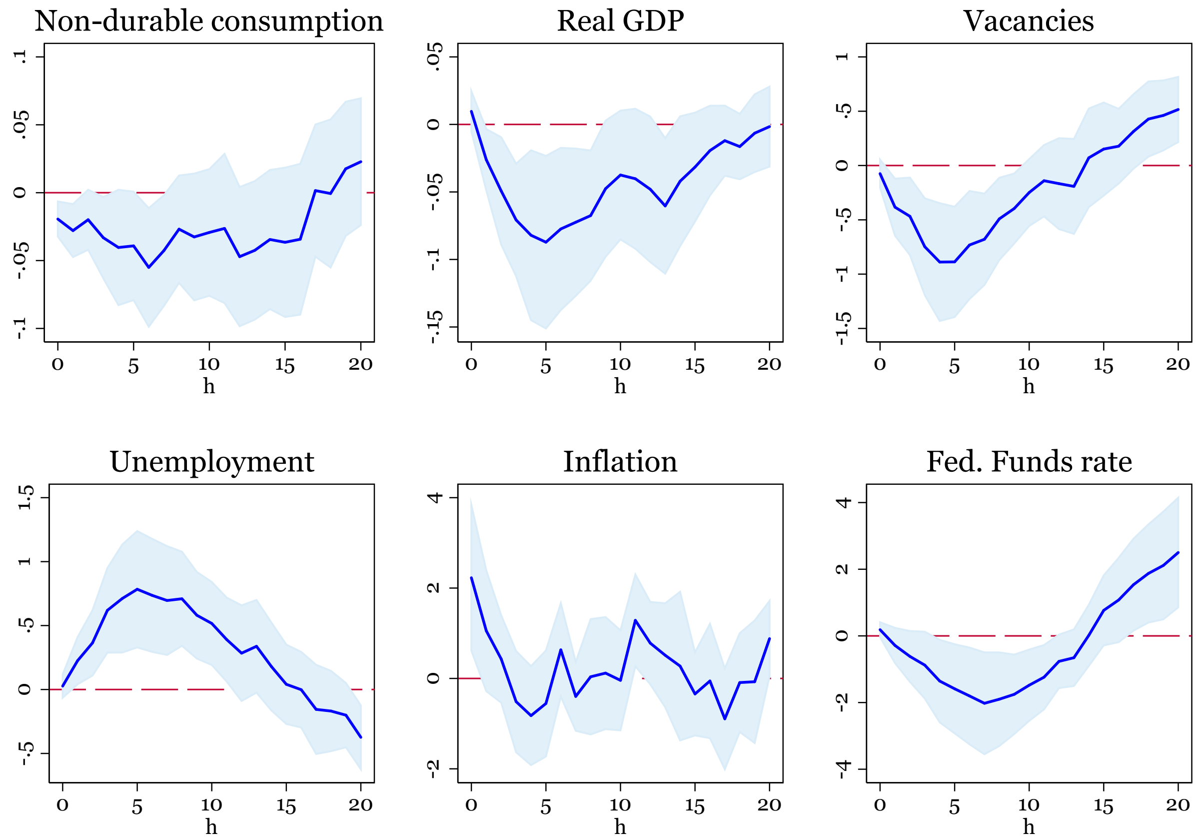
Note: The light red bands denote the 95% confidence intervals computed from a bootstrap procedure.

Robustness tests for the local projection results and confidence shocks

Shorter sample

Barakchian and Crowe (2013) highlight the sensitivity of estimates of the effect of monetary shocks to the chosen sample period across a range of identification schemes. This issue is investigated here in the context of news shocks, as I re-estimate the Beaudry-Portier shocks for a shortened, more recent sample. The baseline sample period is 1954:I - 2015:II, which includes the period prior to the Volcker monetary regime when monetary policy is largely viewed as being a source of instability which could perhaps skew the results for the estimated effects of news shocks. The sample also includes the Great Recession, when interest rates were at the zero lower bound an unconventional monetary policy was used to a large degree, which could also have the same distortionary effect. Taking both of these into account, the shocks are re-estimated for the period 1980:I - 2007:III. Besides the wider confidence intervals, which one would expect given the abbreviated sample, the estimated IRFs and FEV decompositions remain substantively unchanged. Hence, the results are not driven by the choice of the sample period.

Figure A2: Estimated IRFs from a local projection with the shortened sample 1980-2007.



Note: The light blue shaded area denotes the 90% confidence intervals.

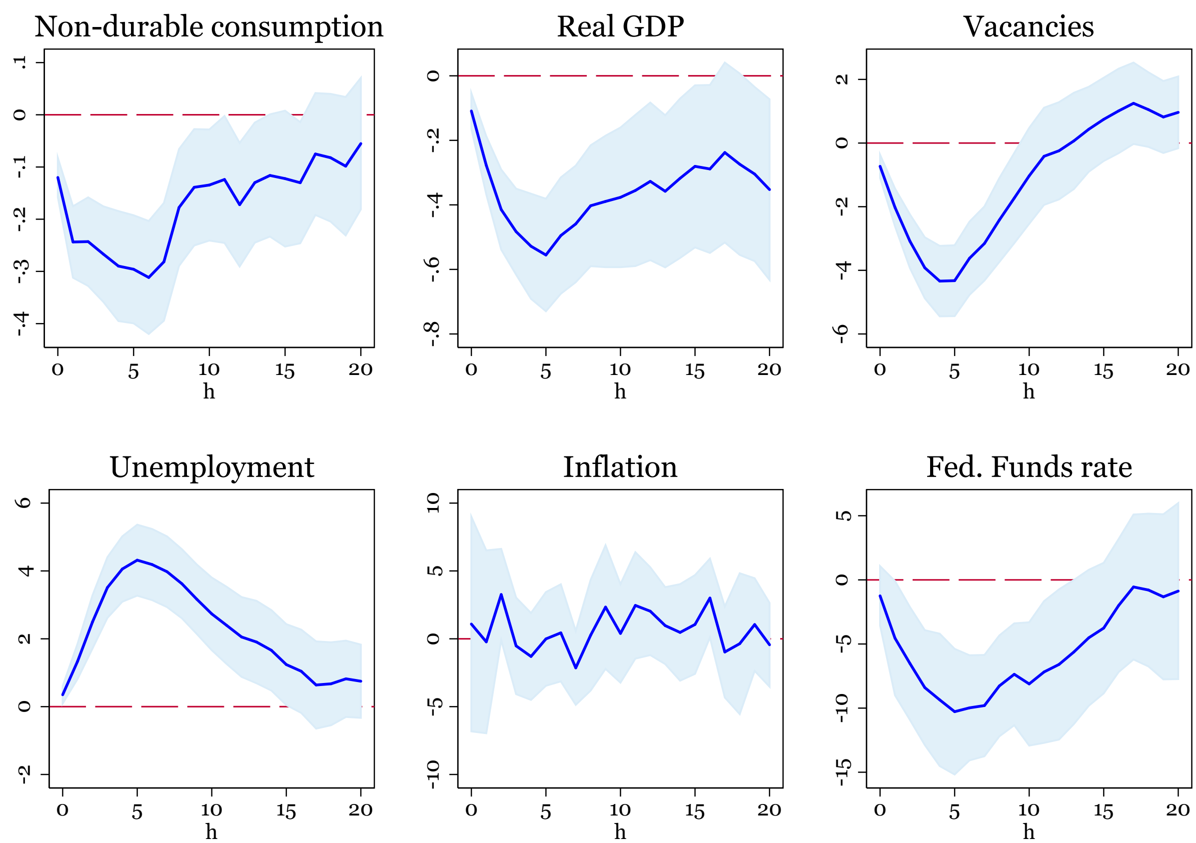
Figure A3: Variance decompositions for the shortened sample 1980-2007.

Note: The light red bands denote the 95% confidence intervals computed from a bootstrap procedure.

News shocks identified with long-run restictions on a SVAR

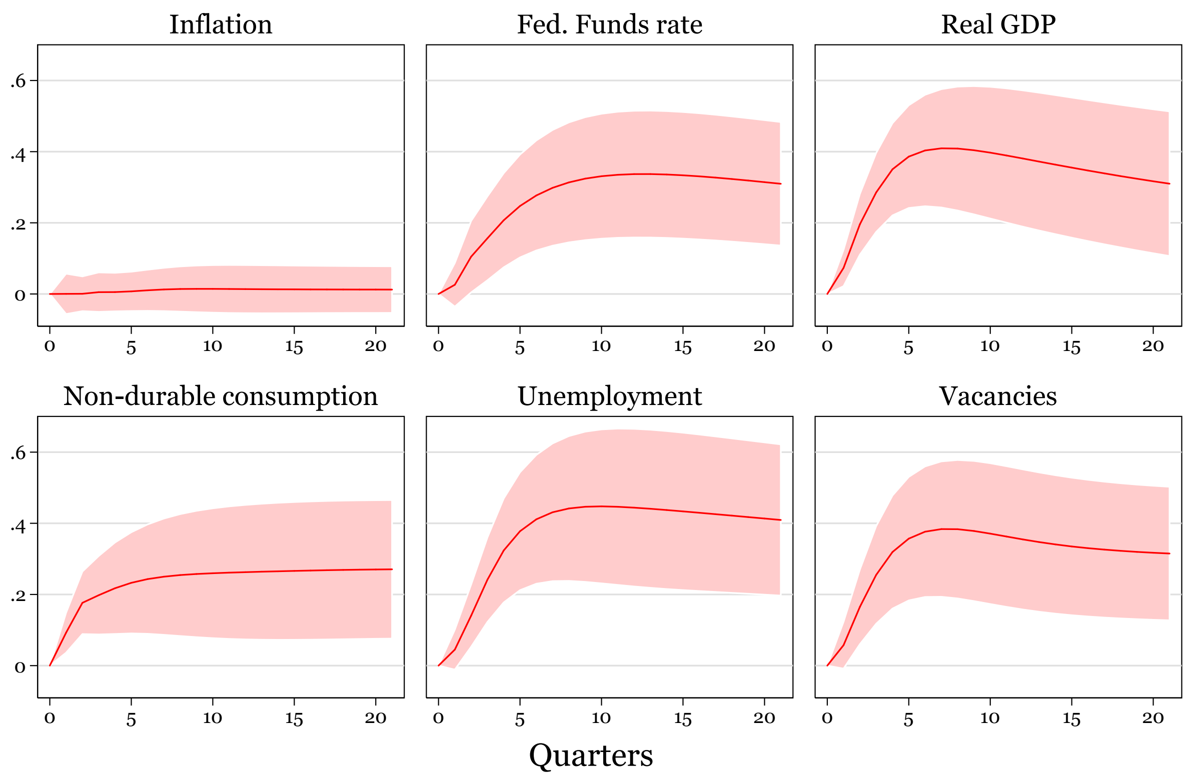
Beaudry and Portier (2006) also identify news shocks by imposing the restriction that a news shock has no long-run effect on TFP, and show that this shock is almost perfectly correlated with the shock identified via an impact restriction. This shock is included in the local projections and VAR for the FEV decompositions as an additional robustness test. Ultimately, the shock illicits a stronger response in many of the endogeneous variables, including vacancies, non-durable consumption and output. Relevant to the precautionary savings channel, consumption also responds strongly and immediately upon the shock's impact. The FEV decompositions show that the news shock identified with long run restrictions can explain an even greater portion of fluctuations in all of the endogeneous variables (apart from inflation) over business cycle frequencies.

Figure A4: Estimated IRFs from a local projection with the Beaudry-Portier shocks identified with long-run restrictions.



Note: The light blue shaded area denotes the 90% confidence intervals.

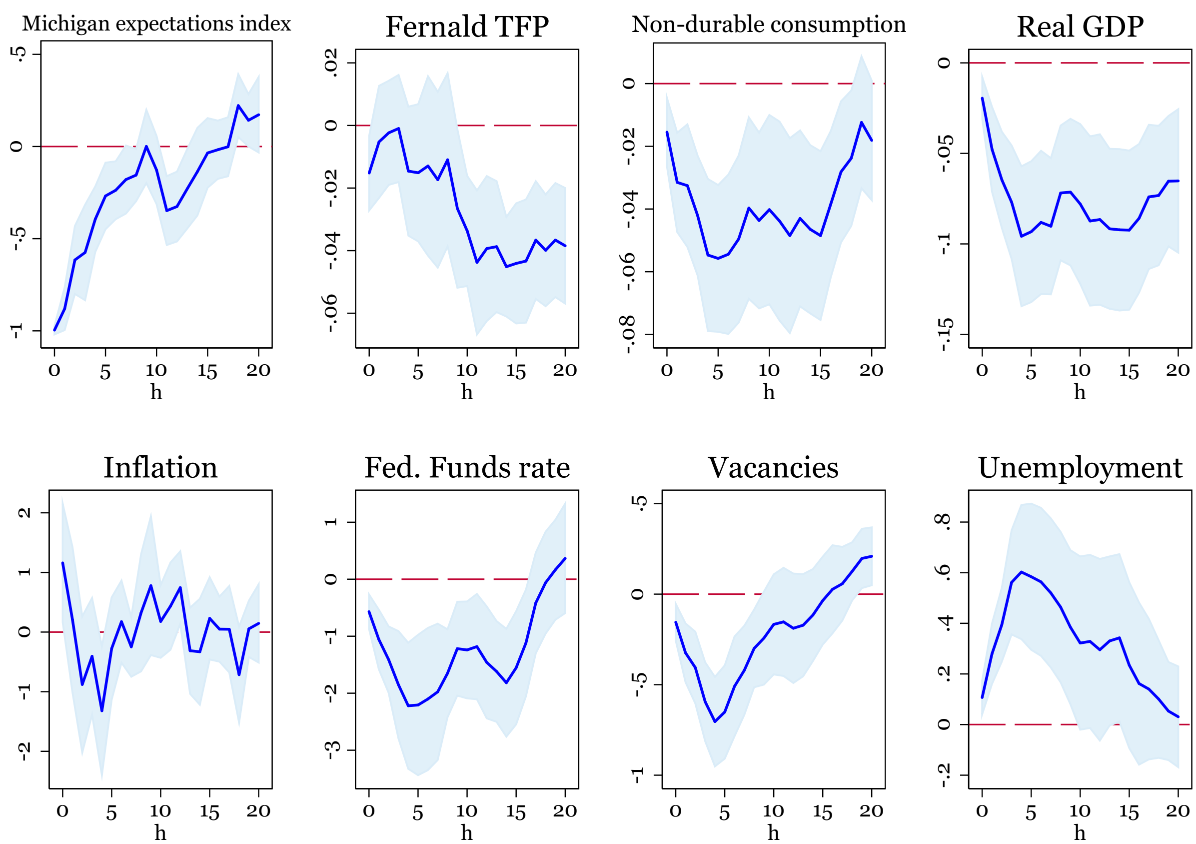
Figure A5: Variance decompositions for the Beaudry-Portier shock identified with long-run restrictions.



Confidence shocks

Beaudry et al. (2011) and Angeletos et al. (2018) propose the idea that business cycles may be driven by confidence shocks, of which news shocks are a subset. To investigate the effect of these confidence shocks on the labour market variables, I estimate a two variable structural VAR with the Michigan index of consumer expectations and Fernald-adjusted TFP. The structural expectation shock is obtained by performing a Cholesky decomposition on the variance-covariance matrix of the reduced form residuals, with the identifying assumption that TFP does not respond contemporaneously to an expectation shock. The expectations shock is, therefore, the part of the expectations index which is orthogonal to TFP. Four lags are used in the SVAR. The identified shock is then included in the standard local projection and VAR frameworks to estimate the IRFs and FEV decompositions respectively. The sample period is 1978:I-2015:II. The IRFs for this shock look remarkably similar to those in the baseline results, despite the shocks only being mildly correlated[14]. A point of note is that the response of real GDP, vacancies and unemployment all respond immediately upon the shock's impact. Non-durable consumption again exhibits a significantly negative response on the shock's realisation. The expectations shock explains a lower fraction of business cycle volatility in the six endogenous variables than the news shock does, however, with much wider confidence intervals.

Figure A6: Estimated IRFs from a local projection with the confidence shock.



[14]The correlation between the expectations shock and the Beaudry-Portier news shock os 0.36

Figure A7: Variance decompositions for the confidence shock.

Appendix B

Hypothesis test results for the smooth transition local projections

The tables below report results of the hypothesis test $(\beta_i^{h,HW} - \beta_i^{h,LW}) = 0$ for $i =$ (non-durable consumption, real GDP, vacancies, unemployment, Fed. Funds rate), $h = (0, 2, 4, 6, 8, 10)$.

Table A1: Results of hypothesis tests for non-durable consumption in the STLP framework.

h	$\beta^{h,HW}$	$\beta^{h,LW}$	$p((\beta^{h,HW} - \beta^{h,LW}) = 0)$
0	0.005	-0.026	0.1487
2	0.011	-0.071	0.0272
4	-0.022	-0.055	0.4973
6	-0.047	-0.046	0.9928
8	-0.018	-0.011	0.9053
10	-0.011	0.026	0.5240

Table A2: Results of hypothesis tests for real GDP in the STLP framework.

h	$\beta^{h,HW}$	$\beta^{h,LW}$	$p((\beta^{h,HW} - \beta^{h,LW}) = 0)$
0	0.053	-0.022	0.0086
2	0.034	-0.133	0.0002
4	-0.012	-0.149	0.0215
6	-0.026	-0.135	0.1258
8	-0.020	-0.111	0.2235
10	0.011	-0.130	0.1148

Table A3: Results of hypothesis tests for vacancies in the STLP framework.

h	$\beta^{h,HW}$	$\beta^{h,LW}$	$p((\beta^{h,HW} - \beta^{h,LW}) = 0)$
0	0.244	-0.016	0.2827
2	0.304	-0.719	0.0152
4	-0.011	-0.835	0.1012
6	-0.300	-0.324	0.9665
8	-0.065	-0.400	0.5847
10	0.164	-0.379	0.3815

Table A4: Results of hypothesis tests for unemployment in the STLP framework.

h	$\beta^{h,HW}$	$\beta^{h,LW}$	$p((\beta^{h,HW} - \beta^{h,LW}) = 0)$
0	-0.193	-0.232	0.8622
2	-0.228	0.310	0.1945
4	0.270	0.572	0.4906
6	0.717	0.467	0.6362
8	0.672	0.439	0.6416
10	0.542	0.393	0.7502

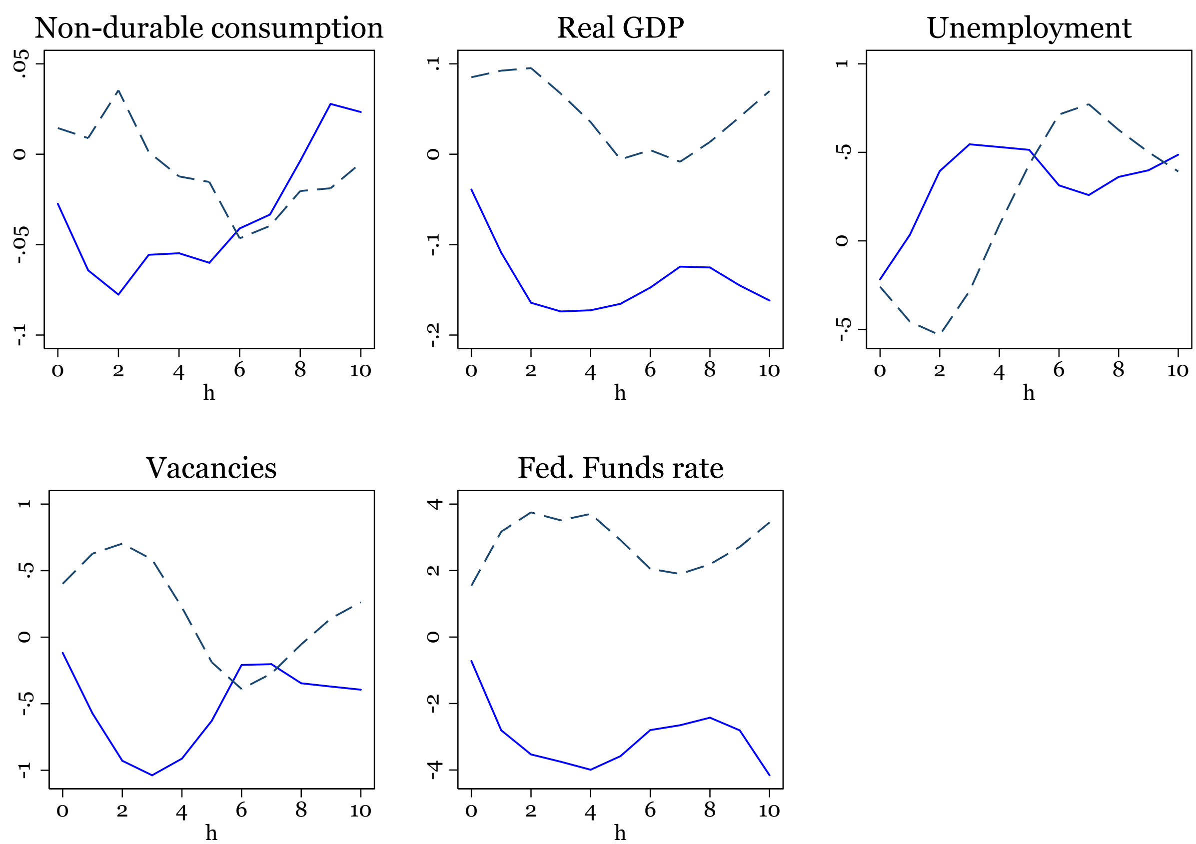
Table A5: Results of hypothesis tests for the Fed. Funds rate in the STLP framework.

h	$\beta^{h,HW}$	$\beta^{h,LW}$	$p((\beta^{h,HW} - \beta^{h,LW}) = 0)$
0	0.711	-0.194	0.5347
2	1.682	-2.547	0.0451
4	1.581	-3.123	0.0530
6	0.659	-2.411	0.1032
8	0.903	-2.060	0.1062
10	1.304	-3.077	0.0750

Robustness tests for the smooth transition local projections

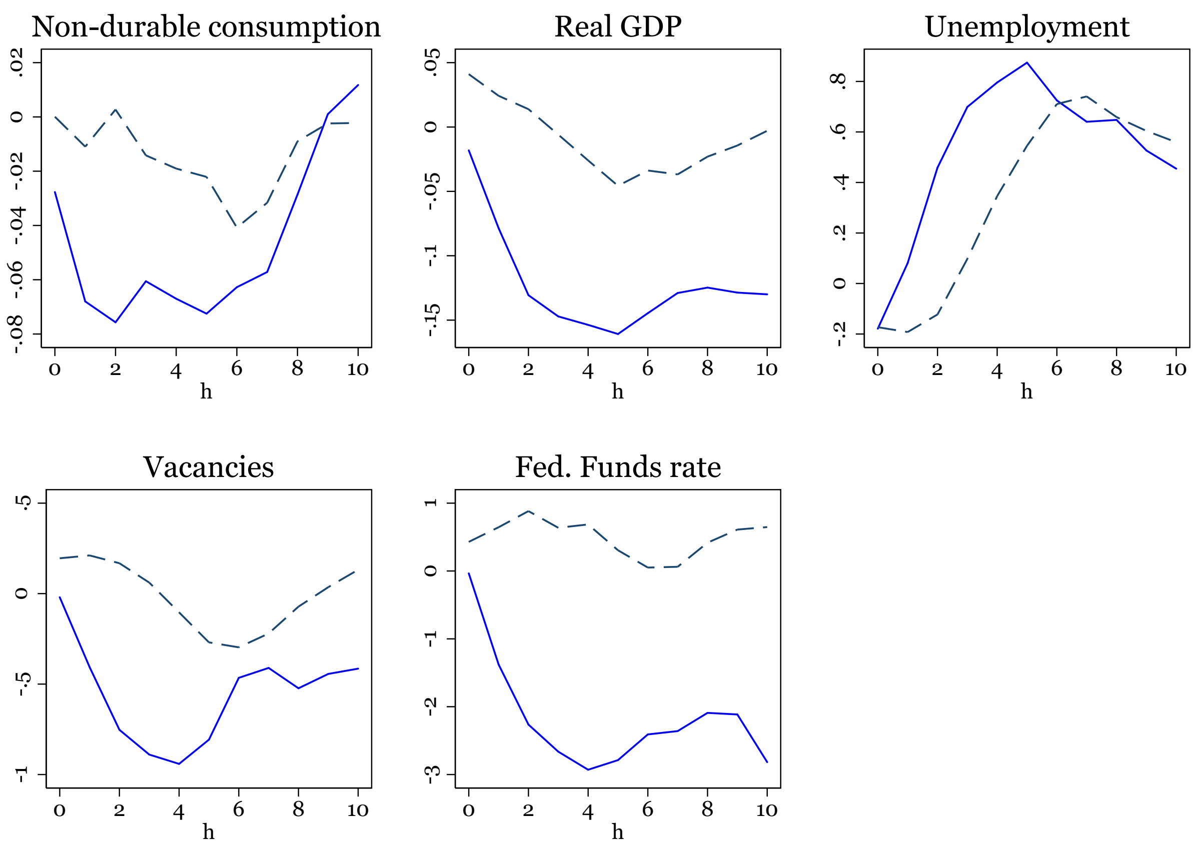
Alternative values of Ω. The figure below displays the IRFs for non-durable consumption, real GDP, unemployment, vacancies and the Fed. Funds rate in the STLP framework with the smoothness parameter, Ω, set to 1. This results in a smoother transition between the states relative to the baseline results.

Figure A8: The IRFs of real GDP, non-durable consumption, vacancies, unemployment and the Federal Funds rate to a negative Beuadry-Portier news shock in a low-wealth state (light blue solid line) and in a high-wealth state (dark blue dashed line), with Ω=1.



The figure below displays the IRFs for non-durable consumption, real GDP, unemployment, vacancies and the Fed. Funds rate in the STLP framework with the smoothness parameter, Ω, set to 10. This results in a transition between the states which is closer to a discrete regime-switching environment.

Figure A9: The IRFs of real GDP, non-durable consumption, vacancies, unemployment and the Federal Funds rate to a negative Beuadry-Portier news shock in a low-wealth state (light blue solid line) and in a high-wealth state (dark blue dashed line), with Ω=10.



Different proportion of low-wealth state periods. While in the baseline specification, the parameter Γ is set such as to ensure that 20% of periods are classified as low-wealth states, I now investigate different criteria for this. Specifically I look at setting Γ such that 10%, then 50% of periods are categorised as being low-wealth states. The two figures below display the IRFs of real GDP, non-durable consumption, vacancies, unemployment and the Federal Funds rate for each of these calibrations.

Figure A10: The IRFs of real GDP, non-durable consumption, vacancies, unemployment and the Federal Funds rate to a negative Beuadry-Portier news shock in a low-wealth state (light blue solid line) and in a high-wealth state (dark blue dashed line), with 10% of periods classed as low-wealth state.

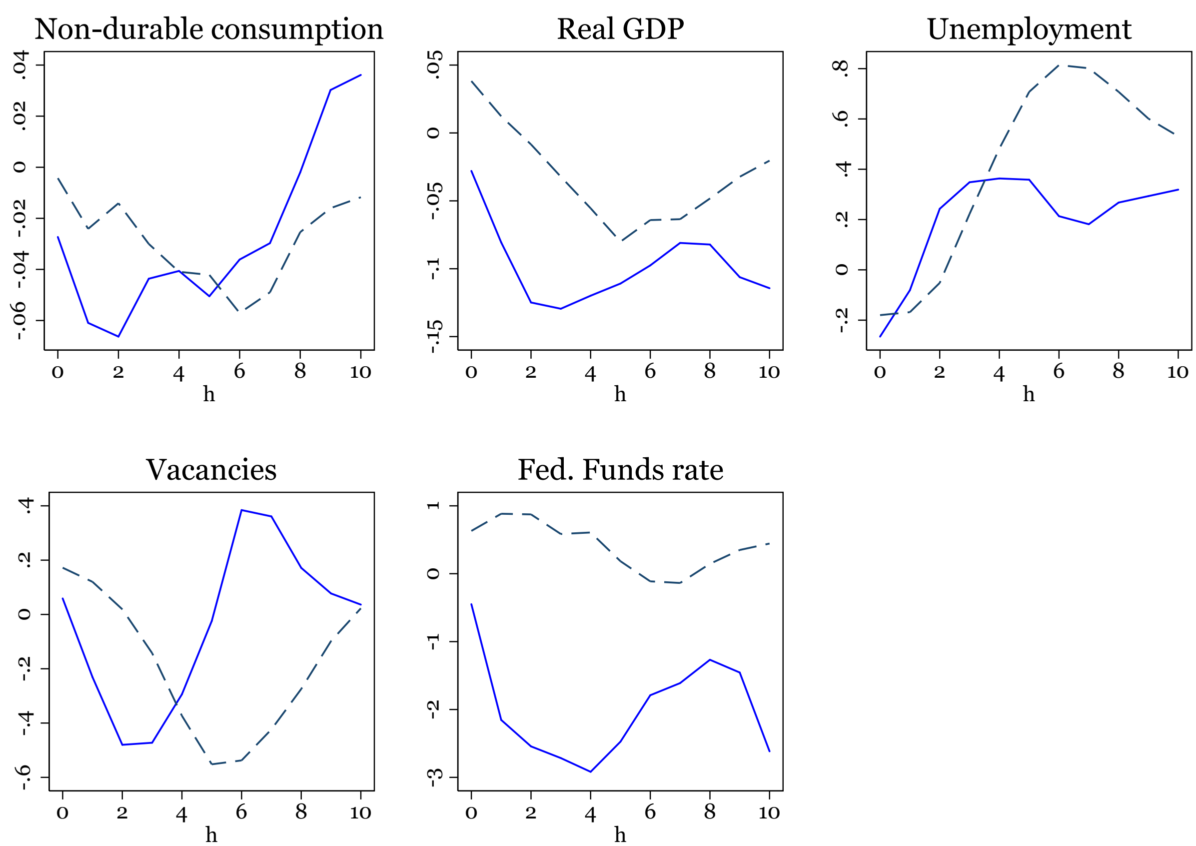
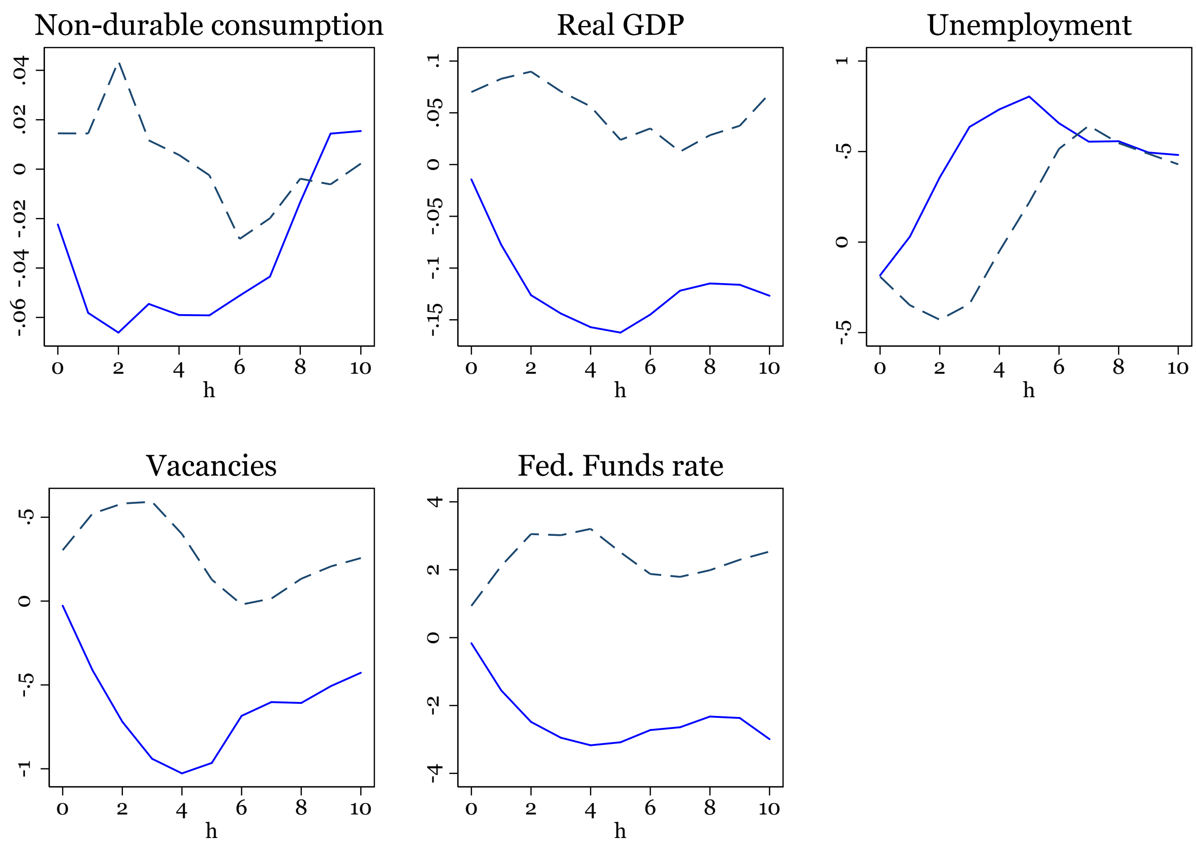


Figure A11: The IRFs of real GDP, non-durable consumption, vacancies, unemployment and the Federal Funds rate to a negative Beuadry-Portier news shock in a low-wealth state (light blue solid line) and in a high-wealth state (dark blue dashed line), with 50% of periods classed as low-wealth state.



Alternative state variables. Two different state variables are considered. The first is a twenty quarter lagging moving average of the real net worth growth rate, while the second is the log of real net worth detrended with a Hodrick-Prescott (HP) filter. The smoothing parameter for the HP filter in the is set to the standard value of 1600 typically used for quarterly data. Figures A12 and A13 illustrate that both of these state variables yield the same key result that, following a bad news shock, contractionary movements following a bad news shock are larger in magnitude during low-wealth states.

Figure A12: The IRFs of real GDP, non-durable consumption, vacancies, unemployment and the Federal Funds rate to a negative Beuadry-Portier news shock in a low-wealth state (light blue solid line) and in a high-wealth state (dark blue dashed line), with a twenty quarter lagging moving average of the real net worth growth rate used as the state variable.

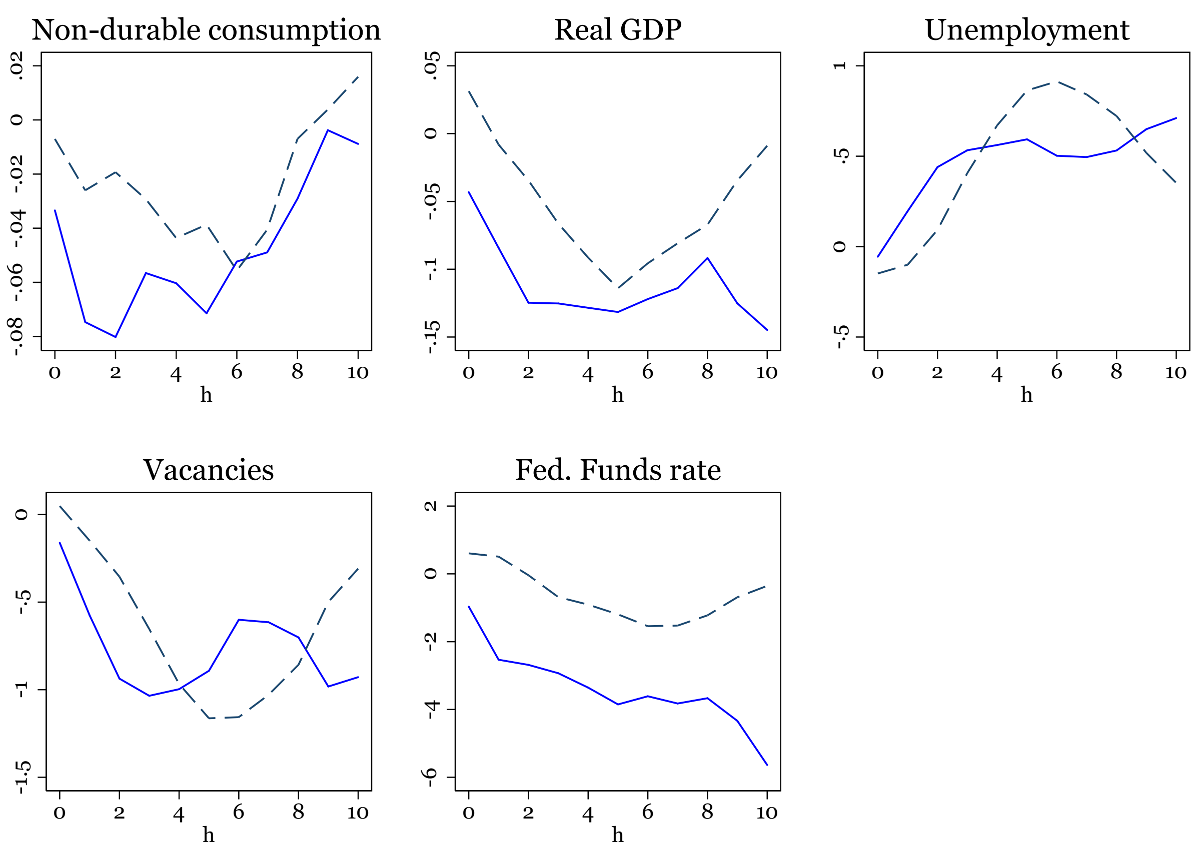
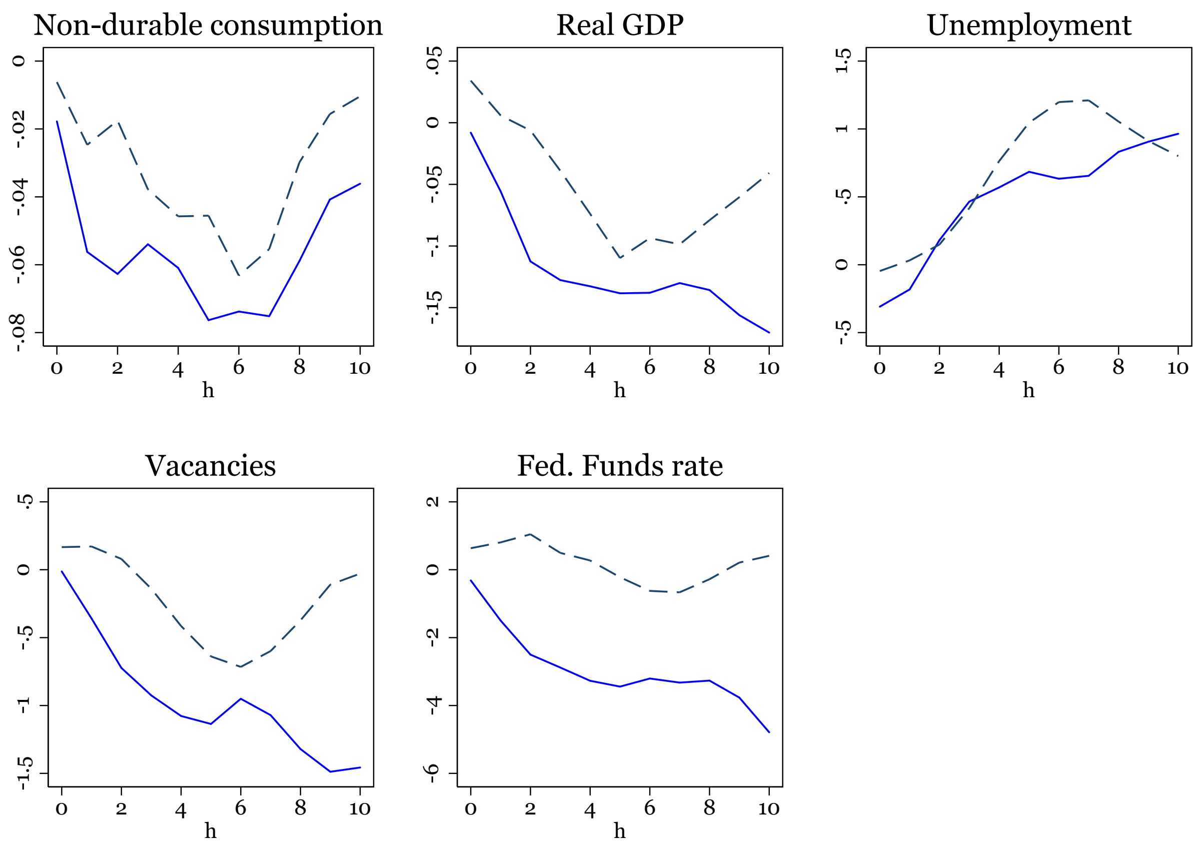
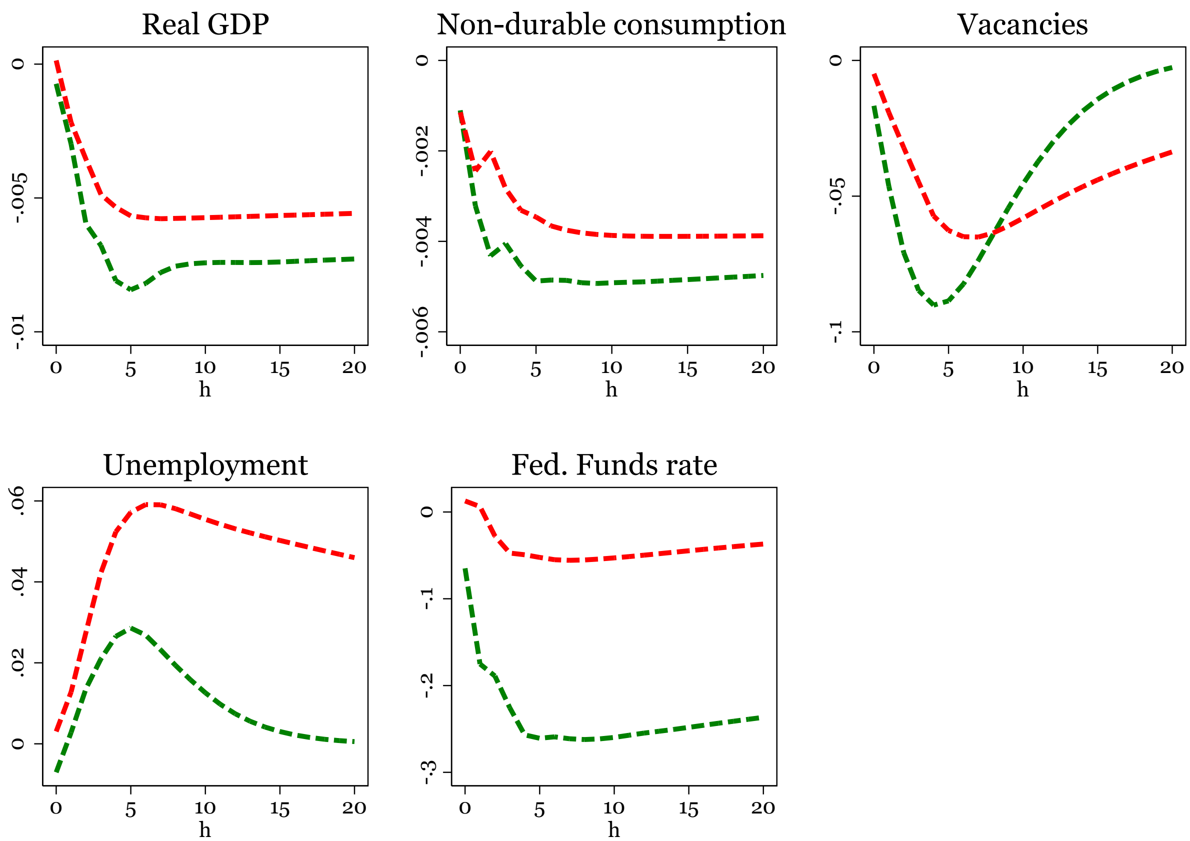


Figure A13: The IRFs of real GDP, non-durable consumption, vacancies, unemployment and the Federal Funds rate to a negative Beuadry-Portier news shock in a low-wealth state (light blue solid line) and in a high-wealth state (dark blue dashed line), with the log of real net worth detrended with a HP filter used as the state variable.



Threshold VAR

Figure A14: The IRFs of real GDP, non-durable consumption, vacancies, unemployment and the Federal Funds rate to a negative Beuadry-Portier news shock in a low-wealth state (green dashed line) and in a high-wealth state (red dashed line) from the TVAR specification.



Cubic shock in the local projection

The tables below present the estimated coefficients on the cubic shocks, η_i^h for $h \in (0, 10)$, i = (Non-durable consumption, Real GDP, Vacancies, Unemployment, Inflation, Fed. Funds rate). P-values for tests of the hypothesis: $\eta_i^h = 0$ are displayed in brackets.

h	Real GDP	Non-durable consumption	Vacancies
0	0.79 (0.18)	0.20 (0.40)	3.50 (0.23)
1	0.81 (0.34)	-0.41 (0.26)	4.18 (0.40)
2	0.61 (0.59)	-0.13 (0.82)	3.00 (0.70)
3	0.23 (0.85)	-0.65 (0.32)	-1.61 (0.86)
4	-0.63 (0.61)	-1.18 (0.14)	-8.66 (0.38)
5	-1.01 (0.46)	-1.21 (0.11)	-12.77 (0.17)
6	-0.87 (0.53)	-1.50 (0.04)	-14.65 (0.10)
7	-0.63 (0.65)	-1.41 (0.08)	-10.48 (0.26)
8	-0.04 (0.98)	-1.12 (0.15)	-6.66 (0.51)
9	0.29 (0.85)	-0.57 (0.41)	-1.60 (0.87)
10	0.51 (0.73)	-0.09 (0.90)	3.07 (0.76)

h	Unemployment	Inflation	Fed. Funds rate
0	-2.20 (0.16)	121.20 (0.08)	37.14 (0.10)
1	-3.96 (0.36)	64.05 (0.05)	60.67 (0.12)
2	-2.31 (0.75)	51.90 (0.01)	50.48 (0.17)
3	2.66 (0.73)	23.79 (0.34)	36.94 (0.34)
4	8.90 (0.28)	12.91 (0.50)	29.22 (0.48)
5	14.46 (0.08)	42.57 (0.06)	9.39 (0.81)
6	16.32 (0.04)	30.35 (0.3)	-6.83 (0.84)
7	15.52 (0.05)	43.64 (0.05)	-2.90 (0.93)
8	11.50 (0.15)	21.85 (0.43)	4.09 (0.89)
9	10.88(0.15)	-4.67 (0.86)	13.36 (0.65)
10	8.41 (0.29)	1.81 (0.95)	25.99 (0.49)

Appendix C

Equilibrium conditions for the model

1) Euler equation

$$W_t^{-\sigma} = \beta E_t \frac{R_t}{1+\pi_t} \left\{ (1-\rho(1-\eta_{t+1}))W_{t+1}^{-\sigma} + \rho(1-\eta_{t+1})\zeta^{-\sigma} \right\}$$

2) Marginal cost

$$MC_t = (\frac{1}{A_t})(W_t + \frac{\kappa}{\eta_t^v} - \beta E_t \left[(1-\rho)\frac{\kappa}{\eta_{t+1}^v} \right])$$

3) Optimal price setting condition

$$1 - \gamma + \gamma MC_t = \theta\pi_t(1+\pi_t) - \theta\beta E_t \left[\pi_{t+1}(1+\pi_{t+1})\frac{Y_{t+1}}{Y_t} \right]$$

4) Matching function

$$M_t = u_t^{\alpha} v_t^{1-\alpha}$$

5) Job finding rate

$$\eta_t = (\frac{v_t}{u_t})^{(1-\alpha)}$$

6) Vacancy filling rate

$$\eta_t^v = (\frac{v_t}{u_t})^{-\alpha}$$

7) Employment law of motion

$$N_t = (1-\rho)N_{t-1} + M_t$$

8) Unemployment

$$u_t = 1 - N_t$$

9) Production function

$$Y_t = A_t N_t$$

10) Taylor rule

$$R_t = \overline{R}\left(\frac{1+\pi_t}{1+\overline{\pi}}\right)^{\delta}$$

11) Employed worker value function

$$V_t^e = \frac{W_t^{1-\sigma}}{1-\sigma} + \beta E_t \rho(1-\eta_{t+1})V_{t+1}^u + \beta E_t[1-\rho(1-\eta_{t+1})]V_{t+1}^e$$

12) Unemployed worker value function

$$V_t^u = \frac{\zeta^{1-\sigma}}{1-\sigma} + \beta E_t(1-\eta_{t+1})V_{t+1}^u + \beta E_t(1-\eta_{t+1})V_{t+1}^e$$

13) Bargaining solution

$$(1-\chi)[V_t^e - V_t^u] = \chi\left(\frac{\kappa}{\eta_t^v}\right)$$

14) Stochastic process for TFP

$$log(A_t) = \phi_A log(A_{t-1}) + \varepsilon_t + \varepsilon_{t-4} + \varepsilon_{t-8}$$

15) Household consumption

$$C_t^H = N_t W_t + u_t \zeta$$

Appendix D

Model with complete markets

Households are organised as large families, meaning they are insured against idiosyncratic unemployment risk and labour market conditions do not directly influence the consumption-saving decision. They maximise expected discounted lifetime utility subject to budget and borrowing constraints:

$$\max E_t \sum_{t=0}^{\infty} \beta^t [\frac{C_t^{1-\sigma}}{1-\sigma} - \vartheta N_t]$$

s.t

$$C_t + B_t \leq N_t W_t + (1 - N_t)\zeta + \frac{R_{t-1}}{\pi_t} B_{t-1}$$

$$B_t \geq B^{limit}$$

where N_t is the fraction of the household who are employed. The first order conditions for C_t and B_t yield the standard complete markets Euler equation:

$$C_t^{-\sigma} = \beta E_t \frac{R_t}{1 + \pi_{t+1}} C_{t+1}^{-\sigma}$$

The absence of the job finding and job loss rates from the right hand side of this equation illustrate the lack of idisyncratic risk in the economy, which causes the precautionary savings motive of household to dissappear. Labour market frictions remain present, however. The remainder of the model is the same as the baseline, and equilibrium is therefore characterised by the above condition, equations 2 - 14 in Appendix C as well as the following goods market clearing condition:

$$C_t + \kappa v_t + \frac{\theta}{2}\pi_t^2 Y_t = Y_t$$

All calibrated parameters remain the same as in Table 1, with a zero-borrowing limit imposed which generates a degenerate wealth distribution. The model is again solved with a first-order perturbation method around the deterministic steady state.

Model with frictionless labour markets

Households are single-membered and can be either employed or unemployed in each period. Employed households face an exogenous probability of becoming unemployed each period (p^{EU}), meaning there is idiosyncratic risk which they face. This labout market risk is exogenous due to there being a spot labour market, with no search-and-matching frictions. The households maximise expected discounted lifetime utility subject to a budget and a borrowing constraint:

$$\max E_t \textstyle\sum_{t=0}^{\infty} \beta^t [\frac{C_t(i)^{1-\sigma}}{1-\sigma} - \vartheta_0 \frac{N_t(i)^{1+\vartheta_1}}{1+\vartheta_1}]$$

s.t

$$C_t(i) + B_t(i) \leq N_t(i)W_t + (1 - N_t(i))\zeta + \frac{R_{t-1}}{\pi_t}B_{t-1}(i)$$

$$B_t(i) \geq B^{limit}$$

setting $N_t(i) = 1$ if the household is employed and $N_t(i) = 1$ if they are unemployed. The employed household Bellman equation is:

$$V^e(B(i), \Gamma) = \max_{C(i),N(i),B^{'}(i)} \Big\{ U(C(i), N(i)) + \beta E(1 - p^{EU})V^e(B^{'}(i), \Gamma') + \beta E p^{EU} V^u(B^{'}(i), \Gamma^{'}) \Big\}$$

This leads to the following Euler equation in equilibrium given $B^{limit} = 0$ and the subsequent implication of households consuming their income each period:

$$W_t^{-\sigma} = \beta E_t \frac{R_t}{1+\pi_t} \left\{(1-p^{eu}))W_{t+1}^{-\sigma} + p^{eu}\zeta^{-\sigma}\right\}$$

The condition for household labour supply pins down the real wage:

$$W_t^{1-\sigma} = \vartheta_0 W_t^{\vartheta_1}$$

Firms produce a good with the production function:

$$Y_t(j) = A_t N_t(j)$$

where A_t follows the same stochastic process as in the baseline model:

$$log(A_t) = \phi_A log(A_{t-1}) + \varepsilon_t^A + \varepsilon_{t-4}^A + \varepsilon_{t-8}^A$$

Real marginal costs for firm j are given by:

$$MC_t = (\frac{1}{A_t})(W_t)$$

Each firms face Rotemberg price adjustment costs. Prices are set such as to maximise:

$$\max E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{P_t(j)}{P_t} Y_t(j) - W_t N_t(j) - \frac{\theta}{2}\left(\frac{P_t(j) - P_{t-1}(j)}{P_{t-1}(j)}\right)^2 Y_t\right]$$

s.t

$$Y_t(j) = A_t N_t(j)$$

$$Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\gamma} Y_t$$

The first order condition for this problem is:

$$1 - \gamma + \gamma MC_t = \theta\pi_t(1 + \pi_t) - \theta\beta E_t \left[\pi_{t+1}(1 + \pi_{t+1})\frac{Y_{t+1}}{Y_t}\right]$$

Monetary policy follows the same inflation-targetting framework:

$$R_t = \overline{R}\left(\frac{1 + \pi_t}{1 + \overline{\pi}}\right)^{\delta}$$

Aggregate output in symmetric equilibrium is given by:

$$Y_t = A_t N_t$$

The parameters β, σ, δ, γ, ζ and θ are kept the same is in Table 1. The parameter ϑ_1, the inverse Frisch elastcity, is set to one following much of the literature, while ϑ_0 is set to 1.155 to target a 6% steady state unemployment rate as in the baseline calibration. The parameter p^{EU} is set to 0.044, again following the baseline parameter value. Equilibrium is characterised by seven equations in seven unknowns. These are the household Euler equation, the labour supply condition, the real marginal cost equation, the first order condition for price setting, the aggregate production function, the interest rate rule and finally the stochastic process for TFP. The model is solved with a first-order perturbation method around the deterministic steady state.