NEWS SHOCKS AND THE LABOUR MARKET

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Abstract

There is a wealth of evidence which suggests that anticipated shocks are an important source of macroeconomic fluctuations, but many standard models cannot reproduce the response of economic activity found in much of this empirical work. First, I show by using a local projection method that there are also significant responses of labour market aggregates to identified news shocks and that they can explain a substantial proportion of the fluctuations present in these variables. Next, I embed anticipated shocks into a search and matching model with capital and ascertain that the calibrated model can generate responses which are extremely similar to those from the estimated impulse response functions, primarily via the forward-looking vacancy posting Euler equation. The presence of TFP news shocks can also increase the persistence in vacancies, which is too low in standard search and matching models. I find that both the empirical and theoretical results are robust to a number of extensions and modifications, although alternative calibrations of the model lead to the disappearance of any news shock dynamics. Ultimately, anticipated shocks seem to be of high importance to the labour market.

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 (1927) and Keynes (1936). From the former originates the concept of Pigovian cycles, where good news about the future can create an increase in economic activity today as forward-looking agents modify their current behaviour in response. This news-induced expansion is distinctly absent from the Real Business Cycle (RBC) model of Kydland and Prescott (1982), which explains aggregate fluctuations through unanticipated innovations to productivity.

This paper makes two specific contributions. First, I show using the local projection method of Jordá (2005) that key labour market variables such as the aggregate number of vacancies posted, the job finding rate and a measure of labour market tightness all respond positively to news that future total factor productivity (TFP) will be higher. Results of variance decompositions in a vector autoregression (VAR) framework suggest that TFP news shocks can explain a high fraction of volatility in labour market variables over a medium horizon. I also investigate the response of these variables to an investment-specific technology (IST) news shock. These results are subjected to a range of robustness checks which ultimately do not change the overall findings. Second, I find that when TFP news shocks are embedded in a calibrated macroeconomic model which features search and matching (SAM) frictions, the response of the aforementioned variables closely follows that found in the data. I investigate this in an RBC model with frictions in the labour market and investment adjustment costs. The benefits of using such a model that features capital investment explicitly are that it nests the work within the business cycle literature and allows me to also investigate the effect of IST news shocks. I find that the calibrated model can generate expansionary movements in the labour market which are remarkably similar to those in the empirical results.

As demonstrated by Beaudry and Portier (2007), the one-sector frictionless RBC model cannot produce positive co-movement between output and anticipated shocks to future TFP when news arrives. In this model, when agents receive news of higher future productivity, this renders the current period a relatively disadvantageous and inefficient time in which to work, resulting in a contemporaneous drop in labour supply which subsequently reduces output from the production function. It is shown that under modifications to the standard model[1], positive TFP news shocks can stimulate consumption, investment and employment upon impact and hence their effects are not purely dependent on market imperfections. Jaimovich and Rebelo (2009) also present a model without market imperfections which can generate these positive co-movements. Their model features variable capital utilization, investment costs and a novel functional form for preferences which allows for parameterization of the strength of the short-run wealth effect on labour supply. The weaker the wealth effect is, the less labour supply falls in response to news about future productivity and they demonstrate that when it is sufficiently weak, news shocks can be expansionary.

The seminal work of Beaudry and Portier (2006) marks a natural starting point when looking at modern empirical studies on the macroeconomic effects of TFP 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. They 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 cointe-

[1] Beaudry and Portier find that when the model includes multiple sectors and economies of scope, positive co-movement between real activity and news shocks are possible.

gration. 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.

Other work has, however, cast a more sceptical view on the importance of TFP news shocks in the macroeconomy. These can be dichotomised into methodological critiques of the Beaudry-Portier results and alternative identification strategies which yield different results. Forni et al's (2014) work falls into the former category, as they highlight problematic properties which the small-scale VECMs used in the previous two papers exhibit. Specifically, they argue that these suffer from the non-fundamentalness problem where the variables selected in the model do not contain sufficient information. Consequently, the structural moving average representation becomes non-invertible and shocks cannot be identified with a VECM. Their proposed solution to this issue is to estimate a Factor-Augmented VAR, which alleviates the problem by incorporating more information into the system, and ultimately they generate contrasting results to Beaudry and Portier. They find that the responses of real variables are much more closely in line with the predictions of a neoclassical model as hours worked, investment and output all fall on the impact of a TFP news shock and then increase when productivity actually begins to rise. Beaudry et al (2015) argue that the non-fundamentalness problem is quantitatively unimportant for TFP news shocks. Barsky and Sims (2011) also find evidence that variables respond in line with the predictions of the neoclassical model. They use an alternative identification scheme which utilises the maximum forecast error variance approach and find a contractionary response of hours, investment and output to a TFP news shock. They also conclude that a much lower proportion of output variance can be accounted for by these shocks and that the majority of the documented US recessions since 1961 cannot be explained by them. Structural DSGE models, such as that estimated by Schmitt-Grohe and Uribe (2012), also typically find that less than ten percent of fluctuations in real

GDP can be attributed to TFP-specific news shocks.

More recent research by Ben Zeev and Khan (2015) looks at investment-specific technology (IST) news shocks rather than anticipated TFP specific shocks. They use a similar methodology to Barsky and Sims, with their findings implying a substantial role for these types of shocks[2] in business cycles. Their results show that 73% of output variance can be explained by IST news shocks at the 8 quarter horizon in their model. Ramey (2016) further emphasizes the importance of the Ben Zeev-Khan shocks relative to several other types of shocks as she estimates a VAR containing a plethora of shocks and several important macroeconomic variables. The results of this exercise suggest that approximately 40 percent of the forecast error variance of output and hours worked can be explained by the identified IST shocks at the 8 quarter horizon, which is a far greater fraction than any of the other shocks included in the system. Whilst the literature ultimately remains divided on the degree of empirical importance of news shocks, the majority of work suggests they play a non-negligible role in business cycles. Beaudry and Portier (2014) summarise the literature relating to news and business cycles in a comprehensive manner.

The empirical work on TFP and the labour market presented here is closely linked to Fujita and Ramey (2007), who estimate a VAR for productivity, labour market tightness and employment with US data and find that a productivity shock induces a hump-shaped response in the latter two variables. This pattern is not replicated in the impulse responses from a benchmark SAM environment, as the response of both variables peaks on the shock's impact. This effectively serves as a critique of these models. Implicitly, all productivity shocks are assumed to be entirely unanticipated in this framework - a potential shortcoming - and I find that the empirical impulse responses estimated for TFP-specific news shocks exhibit a similar hump-shaped response. The model presented in Section 3 is able to replicate this closely.

The models of search frictions in the labour market originate from the counterfac-

[2] Ramey also considers shocks to government spending, taxes, medium horizon TFP and the marginal efficiency of investment alongside the Ben Zeev-Khan IST shock.

tual lack of any non-cyclical unemployment in the RBC model. The Mortensen-Pissarides model (Mortensen and Pissarides (1994)) represents the standard SAM model and, whilst I do not provide a complete review of the equilibrium unemployment literature and instead describe the work I directly build upon, such can be found in Rogerson and Shimer (2011). Pigovian cycles in models with labour market search frictions have been considered previously by Den Haan and Kaltenbrunner (2009), who show that in a model with entrepreneurs and projects, TFP specific news shocks can be expansionary. I embed TFP-specific news shocks in a model that closely follows that of Petrosky-Nadeau et al (2018), where labour search is integrated into a DSGE model of the economy. This gives rise to strong disaster mechanics via the combination of labour market frictions, low profits that plummet in recessions and wage rigidity which can cause an endogenous and very significant drop in aggregate employment. In the original model, all TFP shocks are unanticipated and I extend the stochastic process to include anticipated shocks also.

2 Empirical approach

This section presents an empirical investigation of the effect of TFP-specific news shocks on labour market variables. While Beaudry and Portier (2006, BP) examine the response of hours worked to their two TFP news shocks, identified by long-run and short-run restrictions on a VECM respectively, the response of additional labour market variables is not considered. 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. This is in line with their general findings that TFP news shocks are expansionary and suggests that the labour market responds in a similarly positive manner. However, 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. For example, an increase in hours worked may be due to incumbent employees working more hours (the intensive margin), or may be due to an increase in the total number of workers employed (the extensive margin).

Variation in the extensive margin can also be decomposed into changes in the number of searching workers and changes in the number of searching firms, which is reflected in the number of vacancies posted[3]. Hence, investigating the response of vacancies and employment can shed light on the transmission mechanism of TFP news shocks to the labour market.

The Mortensen-Pissarides model can be summarized in terms of its key endogenous variable, labour market tightness, which is the ratio of vacancies to unemployment. I investigate the response of labour market tightness, as well as vacancies, unemployment and the job finding rate, to identified TFP and IST news shocks. Subsection 2.1 presents the general methodology used for estimation as well as the data used. In subsection 2.2 results are presented, subsection 2.3 presents robustness tests and a summary is provided in subsection 2.4.

2.1 Methodology and data

Methodology. I seek to answer two key questions regarding news shocks and the labour market. Firstly, how do labour market variables respond to a news shock? Second, how important are news shocks in explaining fluctuations in labour market variables? To answer both of these, a measure of identified TFP news shocks is, of course, required. I focus primarily on the Beaudry-Portier shock identified with short-run restrictions (denoted BPSR henceforth). This identification scheme captures TFP-specific news shocks and is obtained by imposing an impact restriction on a VECM with TFP and stock prices. Long run restrictions are also used as an alternative means of identification and the correlation between the short-run and long-run shocks is extremely close to unity, so each identification strategy essentially obtains an identical measure of news shocks. As Ramey (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. Other identified news shocks, such as the IST news shocks identified

[3]This is evident from the typical matching function used in a SAM model, which states that the number of matches formed is increasing in both the aggregate number of job searchers and vacancies posted.

Table 1: Correlation coefficients between the four estimated news shocks.

	BPSR	**BPLR**	**BS**	**BZK**
BPSR	1.00			
BPLR	0.97	1.00		
BS	0.25	0.26	1.00	
BZK	0.08	0.10	0.07	1.00

Abbreviations: BPSR, Beaudry and Portier shock with short-run restrictions; BPLR, Beaudry and Portier shock with long run restrictions; BS, Barsky and Sims shock; BZK, Ben-Zeev and Khan shock

by Ben-Zeev and Khan (2015, BZK), do not satisfy this latter property. I estimate IRFs for this alternative shock series, as well as the Barsky-Sims (2011, BS) TFP-specific news shocks. Table 1 displays the correlation coefficients between each shock.

The first of the preceding questions can be answered by producing an impulse response function (IRF) for each relevant variable for the chosen shock. 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 technique of Jordá (2005) offers a means of doing this for pre-identified shocks. 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 Jordá projection, as 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 - X_i the relevant labour market variable and h the horizon length. The Jordá projection is then:

$$X_{i,t+h} = \alpha_{i,h} \cdot \varepsilon_t + controls + \upsilon_{i,t+h}$$

$\alpha_{i,h}$ then gives the estimated impulse response of X_i, h periods after a shock to ε_t. A separate regression is estimated for each h up to the designated limit, and 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 and necessitates the use of Newey-West standard errors. For the control variables, I follow Ramey and choose a quadratic trend term and two lags of the following variables: log real GDP per capita, log real stock prices per capita, log labour productivity and the dependent labour market variable. The labour market variables I choose to investigate are the log of vacancies per capita, log unemployment per capita, labour market tightness and the job finding rate. I consider the job separation rate separately. I set 20 quarters as the upper bound on h in the projections.

In order to answer the second question, I use a forecast error variance decomposition procedure. Again following Ramey, I perform this in a VAR with the shock, real output, real stock prices, real consumption, real investment, total hours worked and the labour market variable, all in log per capita terms. A quadratic trend is included, four lags are used and the shock is ordered first. This technique gives insight into just how much of the fluctuations in labour market variables can be attributed to TFP and IST news shocks.

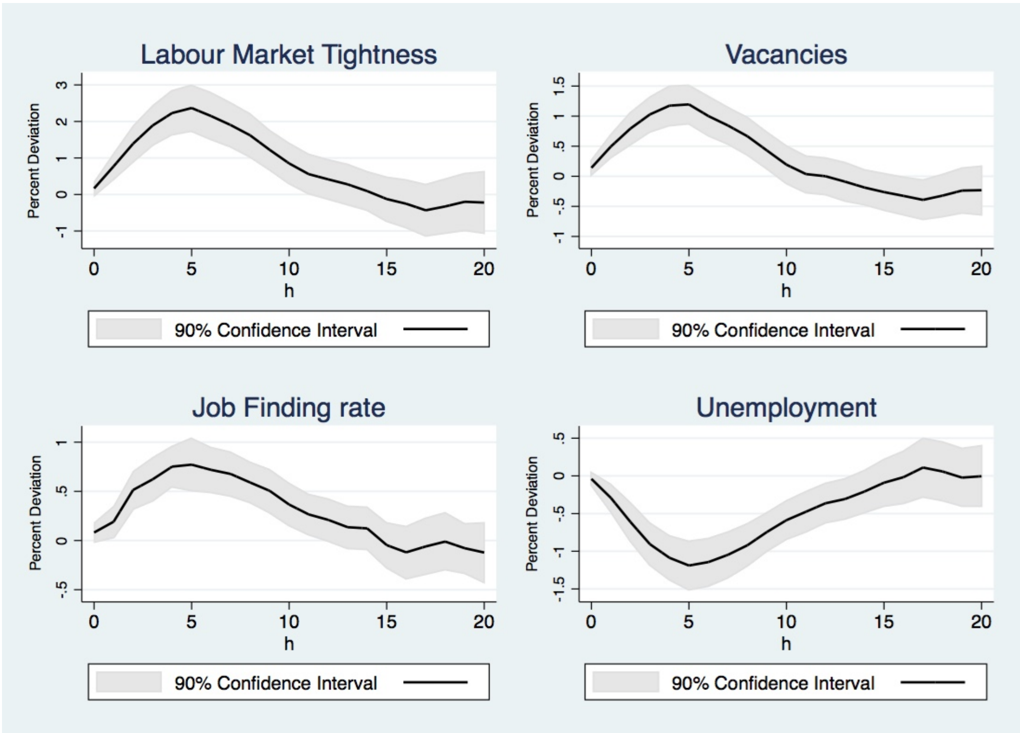
Data. I use quarterly US data throughout, and use a sample period of 1951Q1-2015Q3. The data for the control variables used in the Jordá projection and the VAR are taken from the Federal Reserve Bank of St Louis (FRED). Labour market data is taken from a combination of the Current Population Survey (CPS), the Job Openings and Labour Turnover Survey (JOLTS) and external sources. Monthly data on vacancies is available from JOLTS in the form of job openings, but this series only dates back to 2000. In order to extend this to the beginning of my sample, I utilize the composite help-wanted index produced by Barnichon (2010). Unemployment data is taken from the CPS and the labour market tightness rate is obtained by dividing the vacancy rate by the unemployment rate. The measure of the job finding rate I select is a duration based metric proposed by Shimer (2005), who infers the job finding rate from the month-to-month dynamics of the unemployment level and short-term unemployment level. The separation rate also comes from Shimer's measure, which again exploits data on short-term unemployment and the hiring rate. The time series of the BPSR shocks, as well as the BZK and BS shocks, are taken from Ramey (2016), who updates the data through 2015. All monthly data is transformed to the quarterly frequency by simply taking 3-month averages.

2.2 Findings

Jordá projections. I now evaluate the response of the four labour market variables to the BPSR shock which are displayed in Figure 1. It is evident that the BPSR shock causes a significant expansionary response in all four of the labour market variables, with labour market tightness being the most responsive of all. This is clearly a product of the shock raising the numerator (vacancies) and lowering the denominator (unemployment), combining to produce a large rise in the number of vacancies posted per unemployed worker. The TFP news shock seems to operate through the vacancy posting channel, as firms increase their job openings gradually after positive news about future TFP arrives. The higher number of vacancies makes it easier for a given worker to find a job, which is reflected in a corresponding increase in the job finding rate and a fall in unemployment. The hump-shaped response of the four variables is akin to the response of hours worked which BP find. The timing is also very similar here as the peak of the shock's effect occurs after roughly 5 quarters, which is the point where BP find the response of TFP reaches its maximum, while the hump shape lasts for 10-13 quarters. After this point, the response of all variables is not significantly different from zero.

Interestingly, as Figure 2 illustrates, the estimates suggest that a TFP news shock generates a fall in the job separation rate lasting a similar duration as the response

Figure 1: Estimated IRFs from a Jordá projection for labour market tightness, vacancies, the job finding rate and unemployment to a Beaudry-Portier TFP news shock identified with short-run restrictions.

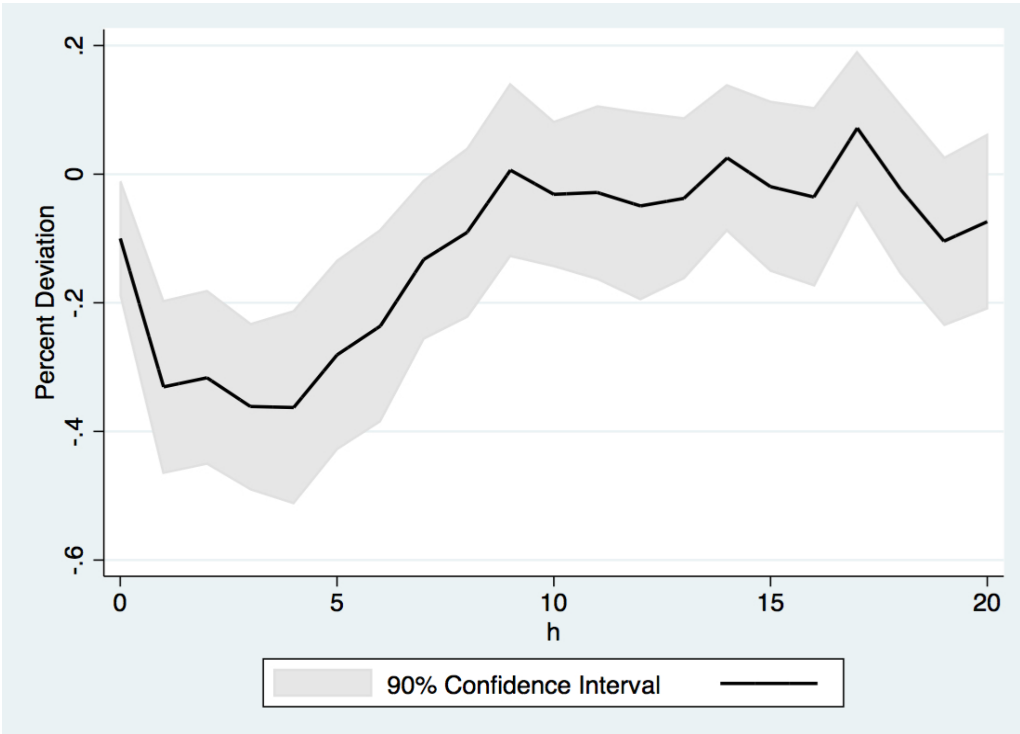


Notes: the grey shaded area denotes the 90% confidence interval.

of the other variables. Typically in theoretical work, the job separation rate is assumed to follow an exogenous stochastic process with an AR(1) often being used. However, Barnichon (2012) shows that the job separation rate Granger-causes the job finding rate thus suggesting that the separation rate is endogenous. The result here adds further credence to this view.

The appendix reports the IRFs for the BZK and BS shocks. The BZK IST news shocks result in a similar expansionary response for the labour market variables and its IRFs also exhibit the same hump shape. The magnitude of the response is significantly smaller, however. Interestingly these results suggest that vacancy posting by firms rises in response to both good news about both IST and TFP. The correlation between the BPSR and BZK shocks is not significantly different from zero, suggesting that each does indeed reflect news about different variables. As would most likely be expected given Barsky and Sims' (2011) finding that

Figure 2: Estimated IRF from a Jordá projection for the job separation rate to a Beaudry-Portier TFP news shock identified with short-run restrictions.



Notes: the grey shaded area denotes the 90% confidence interval.

their identified TFP news shocks are contractionary upon impact, labour market tightness, vacancies and the job finding rate experience a slight decrease initially after a BS shock, although the response is not significantly different from zero for any of the variables.

Variance decompositions. Table 2 displays the forecast error variance decompositions of vacancies and labour market tightness for a BPSR shock. The shock can explain approximately one-third of the variance of both of these variables, although it explains a very small part of variance on impact. It thus appears that TFP news shocks are crucial in explaining fluctuations in these key labour market variables over the business cycle. (See the appendix for the forecast error variance decompositions for the job finding rate, unemployment and also when the BS and BZK shocks are used in the VAR instead.) Well over one-third of the variance in unemployment and the job finding rate is explained by the shock. The results for

Table 2: Forecast error variance decomposition of vacancies and labour market tightness for the BPSR shock

Horizon (Quarters)	**Vacancies**	**Labour Market Tightness**
0	2.8	1.5
4	29.5	26.2
8	34.3	33.4
12	34.1	34.0
16	33.7	33.7
20	33.4	33.3

the BZK shock look very similar to those for the BPSR shock, implying that IST news shocks are also an important driver of variability in labour market tightness and vacancy posting. Puzzlingly, the BS shock actually explains the highest proportion of the variance of vacancies and labour market tightness on impact out of all the shocks, despite contributing an extremely small portion of the variance of each over longer horizons.

Labour force participation and search intensity. Solely looking at unemployment and vacancies may give a somewhat incomplete picture of the labour market, as it ignores entrants and exits by individuals from the labour market, and also neglects the fact that unemployed workers can vary the effort they make in searching for a job. As Leduc and Liu (2017) note, the vacancy filling rate and job finding rate implied by a standard SAM model fits the US data well prior to the Great Recession, but in the post-2009 period the predicted rates are higher than their counterparts in the data. They primarily attribute this to a reduction in both recruiting and search intensity. Using their measure of search intensity and the labour force participation rate[4] as measured by the BLS in the Jordá projection framework, the IRFs displayed in the appendix show that there are small but significant increases in both in response to a BPSR shock. This implies that workers, as well as firms, are responsive to TFP news shocks, varying both their

[4]Labour force participation rate data are available for the full sample period, while search intensity data are available from 1967 onwards.

probability of labour force entry and search intensity[5].

2.3 Robustness tests

In order to evaluate the sensitivity of these results, I conduct a number of robustness tests solely focusing on the BPSR shock in these exercises unless stated otherwise. I look at an alternate sample period, the use of a Hodrick-Prescott filter to detrend the variables, and a different measure of the job finding rate.

Different sample. I abbreviate the sample to 1990-2015 in order to check whether data points from the first four decades of the original sample are crucial in producing the results. The appendix displays the IRFs for the shortened sample period, which look remarkably similar to those for the full sample although the magnitude of the responses is slightly reduced. The negative response of the labour market variables in the estimates roughly 12 quarters after the shock is admittedly curious. The forecast error variance decomposition attributes a slightly higher proportion of the variance of the labour market variables to the BPSR shock over the first 10 quarters of the horizon and slightly less over the second 10 quarters compared to the full sample. These results ultimately suggest that the estimated relationship between news shocks and the labour market is maintained throughout the full sample.

Detrended variables. Following Shimer (2005), I use a Hodrick-Prescott filter with an extremely high value for the smoothing parameter of 10^5 to detrend all variables used in the Jordá projections and in the VAR. This removes low-frequency fluctuations which are not a consequence of business cycles, e.g the 1960s Equal Employment Opportunity legislation encouraging more vacancy posting that Shimer points out. (See the appendix for the IRFs and forecast error variance decomposition tables). Results remain extremely similar to those in the baseline specification.

[5] Davis et al (2013) and Gavazza et al (2018) both construct a measure of recruiting intensity using JOLTS data and find that there was a significant reduction in this during the Great Recession. However, their measure is only available from 2001 which prevents the inclusion of this metric in the Jordá projection due to a small sample size.

Alternative measure of the job finding rate. From 1990, data on the job finding rate can be obtained by looking at the number of unemployment-to-employment transitions from CPS survey data. The coefficient of correlation between this measure and the duration-based measure over the 25 years for which both are available is extremely high at 0.97 and, therefore, it is hardly surprising that the IRF displayed in the appendix which uses the CPS measure looks very similar to that produced in the baseline model. The variance decomposition shows that roughly a third of the variance of this measure of the job finding rate is explained by the news shock after 8 quarters which is again almost identical to when the duration-based measure is used. Interestingly, and somewhat inexplicably, the BS shock explains over 20% of the forecast error variance of the CPS job finding rate at the same horizon which is far more than the duration based metric, while the BZK shock explains practically no part of the variance over any part of the horizon.

2.4 Summary

The results presented in this section suggest that a TFP-specific news shock leads to a rise in vacancies, labour market tightness and the job finding rate which all gradually increase after impact and peak after roughly 5 quarters. It also seems that IST-specific news shock produces a similar hump-shaped increase in these variables, and forecast error variance decompositions suggest that each of the two types of shock are important in explaining a sizeable portion of fluctuations in labour market variables. This result for TFP-specific news shocks is sensitive to the identification strategy, as the positive response of labour market variables does not occur when the BS shocks are used instead. The results are robust to a shorter sample period, a detrending method being applied to the variables and when a different method of measuring the job finding rate is utilised.

3 News shocks in a search and matching model

The empirical results of the preceding section suggest that TFP and IST news shocks generate expansionary responses in labour market variables. In this section, I investigate whether these results can be produced in a macroeconomic model featuring SAM frictions and TFP-specific news shocks. I present an RBC model augmented with frictions in the labour market and investment adjustment costs, similar to that of Petrosky-Nadeau, Zhang and Kuehn (2018, PZK).

Environment. Time is discrete in the model, and following much of the literature the model period length is set to one month. There is a unit measure of homogeneous single-member households who populate the economy. Households can be either employed or unemployed, and gains utility from consumption, C_t, with log utility used as a functional form meaning that agents are risk averse:

$$U(C_t) = log(C_t) \tag{1}$$

Households have a stochastic discount factor given by:

$$M_{t+1} = \beta(C_t/C_{t+1}) \tag{2}$$

with $\beta \in (0, 1)$. There is also a unit measure of firms, and so we again work with a representative firm who uses labour, N_t, and capital, K_t, to produce output, Y_t. The production process is described by a constant returns to scale production function:

$$Y_t = A_t K_t^\alpha N_t^{1-\alpha} \tag{3}$$

with $\alpha \in (0, 1)$. A_t is total factor productivity, the log of which, a_t, follows the stochastic process:

$$a_t = (1-\rho_a)\overline{a} + \rho_a a_{t-1} + \epsilon_t^0 + \epsilon_{t-6}^6 + \epsilon_{t-12}^{12} \tag{4}$$

which is similar to that used in Schmitt-Grohe and Uribe (2012) with $\overline{a}$ denoting the unconditional mean of log TFP. The process features surprise shocks, six-period anticipated shocks and twelve-period anticipated shocks to TFP i.e firms either learn about a shock to TFP six months or one year in advance. For example, a six-period anticipated shock is realized in period t but agents learn about the innovation to TFP in period $t-6$. Each of the shocks, ϵ_{t-j}^j, has mean zero and variance σ_j^2 for $j = 0, 6, 12$, is serially uncorrelated and is uncorrelated with shocks of different anticipation lengths: $E(\epsilon_t^j \epsilon_{t-m}^k) = 0$ for $j, k = 0, 6, 12$ and all $m > 0$, and $E(\epsilon_t \epsilon_{t-m}) = 0$ for all $m > 0$. Past values of the shocks provide no information with regards to forecasting future values of the shock, i.e for all $m > 0$, $E(\epsilon_{t+m} \mid \varepsilon_t) = 0$ where ε_t is the set of shocks observed at and prior to period t, $\varepsilon_t = \{\epsilon_t, \epsilon_{t-1}, \epsilon_{t-2} ...\}$.

In order to obtain workers to produce output, firms post vacancies, V_t, which allows them to recruit unemployed workers, U_t, according to a constant returns-to-scale, CES matching function with time-invariant parameter $\iota > 0$:

$$G(U_t, V_t) = \frac{U_t V_t}{(U_t^{\iota} + V_t^{\iota})^{\frac{1}{\iota}}} \tag{5}$$

This functional form ensures that the matching probability is constrained to be between 0 and 1. The job finding rate, f_t, and vacancy filling rate, q_t, can both be expressed as functions of labour market tightness, $\theta_t = \frac{V_t}{U_t}$:

$$f_t = \frac{G(U_t, V_t)}{U_t} = \frac{1}{(1 + \theta_t^{-\iota})^{\frac{1}{\iota}}} \tag{6}$$

$$q_t = \frac{G(U_t, V_t)}{V_t} = \frac{1}{(1 + \theta_t^{\iota})^{\frac{1}{\iota}}} \tag{7}$$

The firm incurs a cost of κ per vacancy posted. Vacancy posting is subject to a non-negativity constraint:

$$V_t \geq 0 \tag{8}$$

The firm makes two forward-looking investment decisions: investment via vacancy posting and through capital accumulation. Capital follows the law of motion:

$$K_{t+1} = (1-\delta)K_t + \psi(I_t, K_t) \tag{9}$$

where $\psi(I_t, K_t)$ is the installation function:

$$\psi(I_t, K_t) = \left[\vartheta_1 + \frac{\vartheta_2}{1-\frac{1}{\nu}}(\frac{I_t}{K_t})^{1-\frac{1}{\nu}}\right] K_t \tag{10}$$

where $\nu > 0$ and captures the elasticity of capital supply[6]. Firms receive profits $\Pi_t = Y_t - W_t N_t - \kappa V_t - I_t$. Employment follows the law of motion:

$$N_{t+1} = (1-s)N_t + q_t\theta_t \tag{11}$$

where s is the exogenous job separation rate and $q_t\theta_t$ is the number of hires made in period t.

Taking q_t and W_t as given, the representative firm's problem is to maximize the present value of future profits by choosing an optimal level of vacancy posting and investment, subject to the laws of motion for capital and employment and the non-negativity constraint on vacancies:

[6]To set adjustment costs to zero in steady state, following Jermann (1998), I choose the values $\vartheta_1 = \delta/(1-\nu)$ and $\vartheta_2 = \delta^{\frac{1}{\nu}}$.

$$\max_{\{V_{t+T},I_{t+T},N_{t+T+1}\}_{T=0}^{\infty}} E_t \sum_{T=0}^{\infty} \left[M_{t+T}(Y_{t+T} - W_{t+T}N_{t+T} - \kappa V_{t+T} - I_{t+T})\right]$$

$$s.t \quad K_{t+1} = (1-\delta)K_t + \left[\vartheta_1 + \frac{\vartheta_2}{1-\frac{1}{\nu}}\left(\frac{I_t}{K_t}\right)^{1-\frac{1}{\nu}}\right] K_t$$

$$N_{t+1} = (1-s)N_t + q_t\theta_t$$

$$V_t \geq 0$$

Equilibrium. Equilibrium wages are endogenously determined through a generalized Nash bargaining process between workers and firms, with $\gamma \in (0,1)$ parameterizing the worker's relative bargaining power:

$$W_t = \gamma \left[(1-\alpha)\frac{Y_t}{N_t} + \kappa\theta_t\right] + (1-\gamma)b \tag{12}$$

where b is the worker's value of unemployment[7], and $(1-\alpha)\frac{Y_t}{N_t}$ is the marginal product of labour. The model can be summarized by this expression for wages, and the following optimality conditions[8]:

$$C_t + I_t + \kappa V_t = Y_t \tag{13}$$

$$\frac{\kappa}{q_t} - \lambda_t = E_t\left[M_{t+1}\left((1-\alpha)\frac{Y_{t+1}}{N_{t+1}} - W_{t+1} + (1-s)\left(\frac{\kappa}{q_{t+1}} - \lambda_{t+1}\right)\right)\right] \tag{14}$$

$$\frac{1}{\vartheta_2}\left(\frac{I_t}{K_t}\right)^{\frac{1}{\nu}} = E_t\left[M_{t+1}\left(\alpha\frac{Y_{t+1}}{K_{t+1}} + \frac{1}{\vartheta_2}\left(\frac{I_{t+1}}{K_{t+1}}\right)^{\frac{1}{\nu}}(1-\delta+\vartheta_1) + \frac{1}{\nu-1}\frac{I_{t+1}}{K_{t+1}}\right)\right] \tag{15}$$

$$q_t\theta_t \geq 0 \tag{16}$$

[7] As Hagedorn and Manovskii (2008) note, this is best interpreted as incorporating unemployment benefits, the value of additional leisure and home production possible when a worker is not employed, and the stigma of unemployment.

[8] See the online appendix of Petrosky-Nadeau et al (2018) for full derivations of all of these equilibrium conditions.

$$\lambda_t \geq 0 \tag{17}$$

$$\lambda_t q_t \theta_t = 0 \tag{18}$$

where λ_t is the Lagrange multiplier on the constraint $q_t\theta_t \geq 0$. The first of these is the goods market clearing condition, the second is the vacancy posting Euler equation, the third is the investment Euler equation and the last three are Kuhn-Tucker conditions.

Solving the model. I use a log-linearization method to solve the model. While Petrosky-Nadeau and Zhang (2017) use a global projection algorithm to solve their model, this becomes extremely burdensome computationally when TFP news shocks are added, to the point where it is not feasible. They show that log-linearization is less accurate than their projection method but is more accurate than using second-order perturbation, which is particularly inaccurate for the vacancy Euler equation. While the tendency of the log-linearized model to misstate the volatilities of labour market variables in lengthy simulations is duly noted, since the response of these variables to TFP news shocks is the primary interest, the solution method remains valid. Also, as I am not primarily interested in shocks which are large in magnitude (such as the disasters PZK focus on), the choice of solution method becomes less of a concern.

The model solution is characterised by policy functions for V_t and I_t as a function of the model's three state variables: employment, capital and log productivity. The vacancy non-negativity constraint is assumed to never bind and hence we set $\lambda_t = 0$ in every period as is standard in the literature for occasionally binding constraints. The model is reduced to six equations for six endogenous variables. The variables used are employment, capital, log productivity, consumption, investment, and labour market tightness. The equations used are the laws of motion for capital, TFP and employment, the vacancy posting Euler equation, the investment Euler equation and the identity for labour market tightness.

Calibration. Table 3 provides a comprehensive summary of chosen parameter values and the rationale behind them. The calibration of the worker's relative bargaining weight, γ, follows Hagedorn and Manovskii (2008) while the choice of b is very close to the value of 0.83 chosen by Schaal and Taschereau-Dumouchel (2016) and is between the value of 0.71 chosen by Hall and Milgrom (2008) and the value of 0.955 chosen by Hagedorn and Manovskii (2008). I choose the unit vacancy cost, κ, to target a steady state vacancy filling rate of 0.7 following Ravenna and Walsh (2008). The chosen value of $\overline{a}$ ensures that the average marginal product of labour is equal to one in simulations. The only parameters I have to choose are the standard deviations of the shocks, σ_0, σ_6 and σ_{12}, although these are, of course, not important for the IRFs presented for the model which all depict responses to a one percent shock. I choose values such that the simulated standard deviation of TFP remains the same as in the PZK model to facilitate direct comparison with their results, and I assume that TFP news shocks have the same standard deviation regardless of the anticipation horizon, setting $\sigma_6 = \sigma_{12}$. I follow Sims (2012) and target an 80/20 ratio of the unconditional variance of TFP explained by surprise shocks and news shocks respectively. The parameters of the installation function are chosen following Petrosky-Nadeau and Zhang (2017).

Table 3: Choice of parameter values

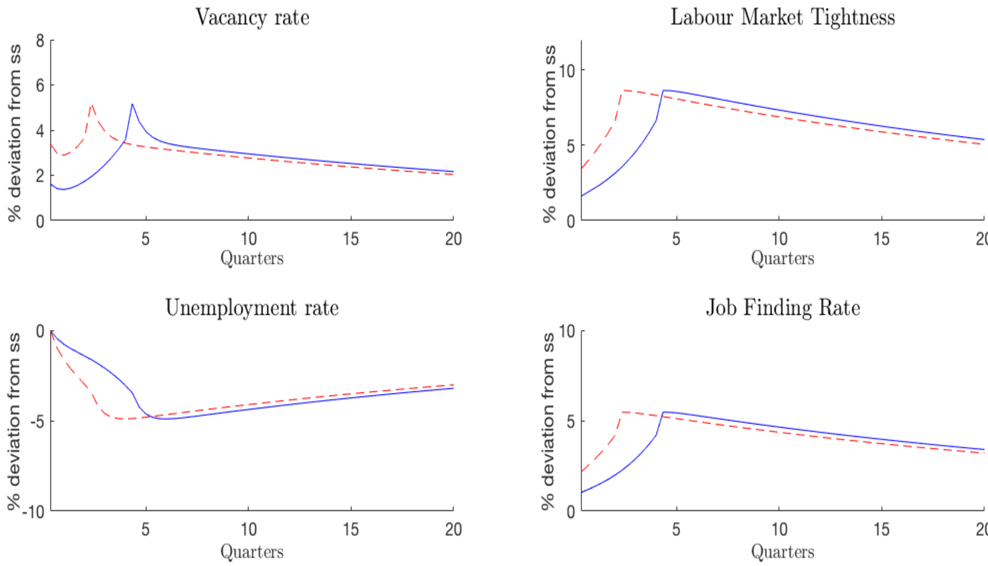
Parameter	Definition	Value	Reference/Target
α	Capital share	0.33	Standard value in business cycle literature
β	Discount rate	$0.99^{\frac{1}{3}}$	Standard value in business cycle literature, adjusted to monthly frequency
δ	Depreciation rate	0.01	Standard value in business cycle literature
s	Separation rate	0.038	Average monthly separation rate from JOLTS
b	Flow value of unemployment	0.85	See text
γ	Worker's relative bargaining weight	0.052	Hagedorn and Manovskii (2008)
ι	Matching curvature	1.27	Den Haan, Ramey and Watson (2000)
ν	Elasticity of installation function	2	Petrosky-Nadeau and Zhang (2017) (PZ)
κ	Unit vacancy cost	1.53	Steady state vacancy filling rate target
$\bar{a}$	Unconditional mean of log TFP	-0.802	PZ (2017)
ρ_a	Persistence of log TFP	$0.95^{\frac{1}{3}}$	PZ (2017)
σ_0	Standard deviation of surprise TFP shocks	0.0059	Sims (2012)
σ_6	Standard deviation of 6-month anticipated TFP shocks	0.0020	Sims (2012)
σ_{12}	Standard deviation of 12-month anticipated TFP shocks	0.0020	Sims (2012)

Results. Figure 3 shows the impulse response functions for vacancies, unemployment, labour market tightness and the job finding rate after a one-percent increase in TFP anticipated 6 months and 12 months in advance respectively. The left-hand side of the vacancy Euler equation represents the expected vacancy cost of hiring a worker and the right-hand side captures the expected present value of future profits that the worker produces. At the optimum, the two are equal and firms make zero expected net profits when posting a vacancy. News that future TFP will be higher increases the right-hand side of the equation, and in order for the equality to continue to hold, the vacancy filling rate must adjust downwards which requires an increase in the number of vacancies posted. This, in turn, causes market tightness and the job finding rate to rise well above their steady state levels. The shorter the horizon of the TFP news shock, the larger the immediate response generated. Intuitively, firms wish to take advantage of higher productivity in the future by hiring workers prior to the realization of the TFP increase. As figure 4 illustrates, unemployment remains at its steady state level in the period in which news arrives and gradually falls as it becomes easier for workers to find a job, meaning that vacancies and unemployment have a lead-lag relationship consistent with the empirical result that the vacancy rate Granger-causes the unemployment rate.[9] Much like the IRFs plotted from the Jordá projections for the US data, the response functions exhibit a hump-shaped pattern, with vacancies gradually increasing between the period at which the TFP news arrives and the period when the shock is realized, and then decreasing gradually afterwards.

The IRFs for two other variables of interest in the model are presented in figure 4. The increase in employment causes output to rise from the production function. This is not the case in the standard RBC model which does not satisfy the conditions outlined by Beaudry and Portier (2007). In this model, news that future TFP will be higher causes output to fall contemporaneously as workers reduce the amount of hours they work due to the present being a relatively inefficient time to supply labour compared to the future. An RBC model with search frictions added

[9] In a regression of the unemployment rate on eight lags of itself and eight lags of the vacancy rate using monthly data, the null hypothesis that all coefficients on the vacancy rate lags are zero can be rejected with a p-value of 0.0001

Figure 3: Model IRFs for key labour market variables

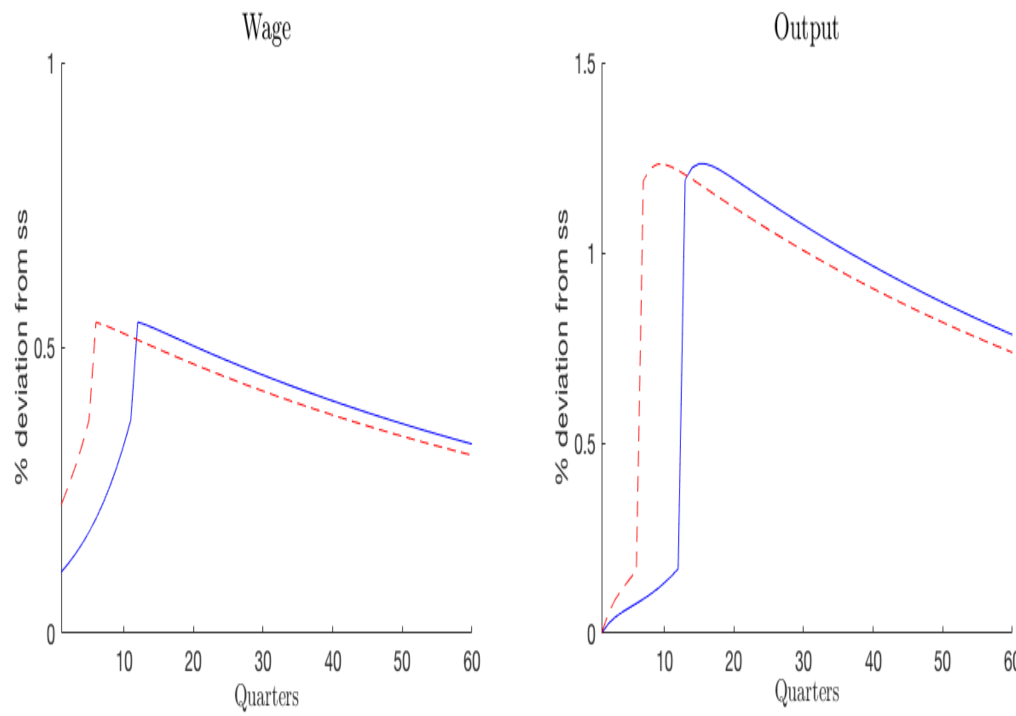


Notes: the red dotted line denotes the IRF for a one percent positive shock to TFP anticipated six months in advance. The blue solid line denotes the IRF for a one percent positive shock to TFP anticipated twelve months in advance.

is thus able to reverse this prediction which is at odds with the empirical evidence. This can partially be attributed to the inherent presence of spare capacity in the form of unemployed workers - a feature of models with search frictions - which can then be utilised upon the arrival of TFP news. Also, in the RBC model, employment only varies at the intensive margin whilst in SAM models these fluctuations occur at the extensive margin, and an increase in vacancy posting makes it easier for unemployed individuals to find a job. This then induces a subsequent increase in employment and output. The equilibrium wage increases upon the shock's arrival and evolves in the familiar hump-shaped pattern over time. The appendix presents the responses of consumption and investment. Due to the presence of adjustment costs, neither move by a large amount in the period between when news arrives and when TFP changes.

Whilst it is the response of labour market variables to TFP news shocks and not matching moments of US business cycles that is of primary interest, it is worth exploring this element with the presence of anticipated shocks nonetheless. I sim-

Figure 4: Model IRFs for wages and output.



Notes: the red dotted line denotes the IRF for a one percent positive shock to TFP anticipated six months in advance. The blue solid line denotes the IRF for a one percent positive shock to TFP anticipated twelve months in advance.

ulate the model for one million months and then, using a Hodrick-Prescott filter with a smoothing parameter of 129,600[10], I report standard deviations, correlations and first-order autocorrelations of each simulated, filtered variable in Table 4 relative to US data. The mean unemployment rate in the model is 7.7%, which is close to 7.2% in the 1929-2015 sample for the US. Also of note is the realistic average profit-output ratio, which is 8.9% in the model and averaged 9.1% in the US data from 1929-2015, implying that the calibration of b and γ generates a realistic profit share, adding to its plausibility. The model matches the volatility of vacancies in the data but produces a lower amount of volatility in unemployment and labour market tightness relative to their empirical counterparts. There is also insufficient negative correlation between unemployment and vacancies relative to the data, as the model's predicted Beveridge curve is slightly too flat.

[10]Following Ravn and Uhlig (2002) who suggest this value for monthly data.

Table 4: Moments of US monthly data compared to simulated data from the model

DATA	U	V	θ	
Standard deviation	0.007	0.004	0.15	
Autocorrelation	0.97	0.95	0.97	
Correlation matrix	1	-0.87	-0.84	U
	–	1	0.93	V
	–	–	1	θ
MODEL	U	V	θ	
Standard deviation	0.005	0.004	0.09	
Autocorrelation	0.97	0.73	0.92	
Correlation matrix	1	-0.76	-0.89	U
	–	1	0.89	V
	–	–	1	θ

Notes: The US monthly data is from the period 1929-2015. The model data is constructed from a simulation of 1000000 months. All variables are expressed in HP-filtered deviations from trend with a smoothing parameter of 129600.

Autocorrelation of vacancies. As table 4 shows, when the majority of variation in TFP is unanticipated there is a lack of persistence in aggregate vacancies relative to that present in the data. This has been highlighted previously as one of the shortcomings of the standard SAM model by Shimer (2005). However, the hump-shaped response of vacancies induced by the presence of TFP news shocks can help to remedy this issue and, to illustrate this, I perform an experiment within the model. Keeping the standard deviation of TFP constant, I first simulate the model with all variation in TFP coming from unanticipated shocks and then repeat this with all variation coming from news shocks anticipated 12 periods in advance. I then simulate each for one million periods and use a HP filter to detrend all variables as previously. In the economy with no anticipated shocks, vacancies have a monthly autocorrelation of 0.71 while in the economy where all shocks are anticipated vacancies are extremely persistent with a monthly autocorrelation of 0.94, which is very close to the level of persistence exhibited in the data. The autocorrelations of unemployment and labour market tightness remain at plausible levels. This suggests that the inclusion of TFP news shocks into SAM models may be a simple and realistic way of addressing this particular problem which tends to be present in standard Mortensen-Pissarides style models.

Alternative calibrations of the model. TFP news shock dynamics in two alternative 'extreme' calibrations are presented. The first is the Shimer (2005) calibration, which calibrates b according to the replacement ratio of unemployed workers in the US, and satisfies the Hosios (1990) condition by setting γ equal to the matching function elasticity with respect to unemployment[11]. The second is the Hagedorn and Manovskii (2008) calibration, which sets a higher parameter for the flow value of unemployment by accounting for the additional leisure and home production possible when an agent is unemployed and sets a much lower value for the worker's bargaining power. For both calibrations, I keep all parameters the same as in Table 3 apart from the flow value of employment b, the worker's relative bargaining weight γ and the vacancy posting cost κ which is chosen to ensure a steady state value of $q = 0.7$ as previously. In the first calibration, I set $b = 0.4$ and $\gamma = 0.72$, while in the second I set $b = 0.955$ and $\gamma = 0.052$.

The impulse responses for labour market tightness following a positive shock to ϵ_{t-12}^{12} for each of the calibrations, alongside the baseline results, are displayed in Figure 5. Interestingly, while in the first calibration there is a moderate rise in tightness when the TFP change actually realizes, there is no increase in θ_t when the news arrives or in the periods prior to the realization and hence in the traditional calibration of a SAM model, Pigovian cycles do not occur. This lack of any TFP news shock dynamics adds to the well established Shimer puzzle, which alludes to the insufficient amount of volatility in labour market variables that is a feature of calibrations that result in a fairly flexible real wage. The second calibration leads to labour market variable responses to TFP news shocks which are implausibly large on the other hand, as an anticipated 1% increase in TFP leads to roughly a 4% increase in tightness upon arrival which builds up to 22% when the increase actually occurs. Table 5 reports statistics of interest from each calibration and demonstrates this excessive volatility of vacancies in the Hagedorn and Manovskii calibration, as they are twice as volatile relative to the data. The Shimer calibration results in a volatility that is only one-quarter of that found in the data, while the baseline calibration gives a realistic value. The baseline calibration results in an elasticity of wages with respect to labour productivity of

[11]The Hosios condition is not satisfied in this model due to the functional form for the matching function, which produces a time varying elasticity of matching with respect to job seekers

Table 5: Statistics of interest from each of the three calibrations

Calibration	$Corr(V_t, V_{t-1})$	$Std(V_t)$	$Wage$ $elasticity$	$100 * \frac{\partial log(V_t)}{\partial \epsilon_t^{12}}$
Baseline	0.73	0.004	0.68	1.6
Hagedorn and Manovskii (2008)	0.68	0.009	0.51	4.0
Shimer (2005)	0.64	0.001	1.17	0.0

Notes: Results are from a simulation of each calibration for 1000000 periods. Vacancies are detrended using a HP filter with a smoothing parameter of 129600. The final column refers to the response of vacancies to a 12 period anticipated TFP shock upon impact of the news.

0.68, which is the closest of all to the recommended target of 0.8 by Haefke et al (2013), and suggests that implausible rigidity in wages is not necessary to produce news-induced fluctuations in the model.

4 Extensions of the model

I show that the expansionary, hump-shaped response of labour market variables in response to positive TFP-specific news shocks is robust to fixed costs in vacancy posting and real wage rigidity. The addition of anticipated investment-specific technology shocks is also considered.

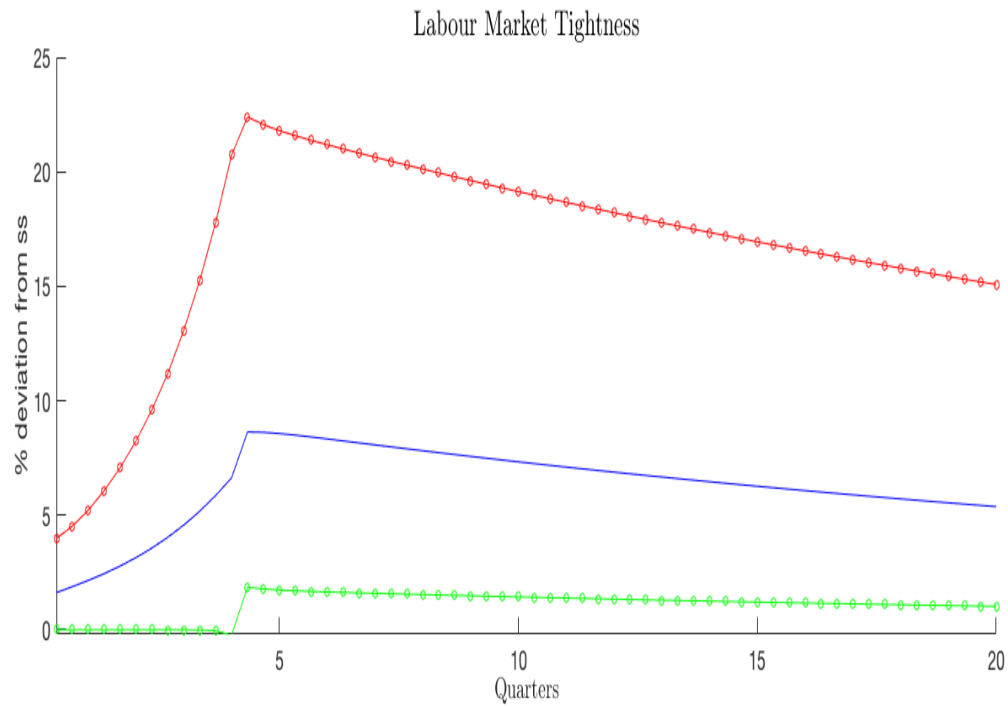
Fixed costs in vacancy posting. As Pissarides (2009) posits, in reality, the vacancy posting process exhibits a fixed component and a component which is increasing in the number of vacancies posted. The former consists of initial negotiation, administrative and training costs for example, while the latter is primarily justified by the cost of advertising vacancies which varies proportionally with the number of job openings posted. As such, unit vacancy posting costs become:

$$\kappa_t = \kappa_0 + \kappa_1 q_t \tag{19}$$

with κ_0, $\kappa_1 > 0$. The costs of hiring can now be expressed as:

$$\frac{\kappa_t}{q_t} = \frac{\kappa_0}{q_t} + \kappa_1 \tag{20}$$

Figure 5: Model IRFs for two alternative calibrations.



Notes: All IRFs are for a one percent positive shock to TFP anticipated 12 periods in advance. The red line is for the Hagedorn and Manovskii (2008) calibration and the green line is for the Shimer (2005) calibration, while the blue line is for the model's baseline calibration.

This clearly shows that κ_0 captures the proportional component of hiring costs while κ_1 captures the fixed cost part. During periods of high economic activity, labour market tightness is high and since the probability of filling a vacancy depends negatively on θ_t, hiring costs are increasing in θ_t. As such, marginal hiring costs are pro-cyclical while unit vacancy costs are countercyclical. The vacancy posting Euler equation becomes:

$$\frac{\kappa_0}{q_t} + \kappa_1 - \lambda_t = E_t\left[M_{t+1}\left((1-\alpha)\frac{Y_{t+1}}{N_{t+1}} - W_{t+1} + (1-s)\left(\frac{\kappa_0}{q_{t+1}} + \kappa_1 - \lambda_{t+1}\right)\right)\right] \tag{21}$$

In order to calibrate the two parameters in equation (19), I set $\kappa_0 = \kappa_1$ and target the average $\overline{\kappa} = \frac{1}{T}\sum_{t=1}^{T}\kappa_t$ to be 1.53 which allows direct comparison with the baseline model. This results in a calibration of $\kappa_0 = \kappa_1 = 0.9$, with all other parameters kept the same as in section 3, and the mean unemployment and vacancy rates remaining unchanged. The average marginal cost of hiring in terms of output per worker is 1.58, which compares to the estimate of 1.48 by Merz and Yashiv (2007), suggesting this calibration of hiring costs is empirically plausible. The presence of these fixed costs introduces a source of additional volatility in labour market tightness. Intuitively, when news of higher future TFP arrives the firm posts more vacancies as the marginal benefits of hiring a worker in period $t+1$ increase. The higher vacancy posting pushes up market tightness which brings down q_t and reduces unit vacancy costs, prompting a further boost to vacancy posting. This increase in vacancies then transfers through to other labour market variables and output. The IRF in the appendix shows a comparison between the response of θ_t to a shock to ϵ_{t-12}^{12} with and without fixed costs in vacancy posting. This demonstrates how initially the increase in labour market tightness is lower in the presence of fixed vacancy costs but as q_t rises and unit costs fall consequently, labour market tightness rises sharply and peaks at a higher level comparatively. Hence, fixed costs in vacancies slightly amplify the effects of TFP news shocks in the model.

Wage rigidity. As Hall (2005) argues, wage rigidity is of high importance in order to generate realistic fluctuations and, in the original calibration of the model, there is already a substantial degree of wage inertia. I go one step further by assuming that the real wage is completely rigid and is determined as $w_t = b$ in all t, meaning that effectively the workers are entirely devoid of bargaining power. I re-calibrate the cost of vacancy posting, κ, such that the steady state vacancy filling rate is equal to 0.7 as in the baseline model. The IRF in the appendix demonstrates that an entirely rigid wage causes an amplification in the immediate impact of a positive, anticipated TFP shock on the labour market variables. From the vacancy Euler equation, the lack of a wage increase means that the expected present value of future profits that the worker produces is higher than when wages are more flexible, and consequently, firms post more vacancies upon the arrival of news.

Investment-specific technology news shocks. The model is clearly able to reproduce some of the results seen in the empirical work for labour market variables when the news shock is TFP-specific, but can it also produce the large responses for IST-specific news shocks which also seem to be evident? To examine this, the model is augmented with stochastic, stationary shocks to the efficiency by which investment goods are transformed to capital following Fisher (2006)[12]. I abstract from adjustment costs and equation (10) becomes:

$$K_{t+1} = (1-\delta)K_t + Z_t I_t \tag{22}$$

where Z_t captures the marginal efficiency of investment, the log of which $z_t = log(Z_t)$ follows the stochastic process:

$$z_t = \rho_z z_{t-1} + \epsilon^0_{z,t} + \epsilon^6_{z,t-6} + \epsilon^{12}_{z,t-12} \tag{23}$$

This results in the investment Euler equation:

$$1 = E_t \left[M_{t+1} \left(\frac{Z_t}{Z_{t+1}} \left(Z_{t+1} \left[\alpha \frac{Y_{t+1}}{K_{t+1}} \right] + (1-\delta) \right) \right) \right] \tag{24}$$

The process again features surprise shocks and shocks which are anticipated 6 months and one year in advance. All shocks satisfy the same properties that the TFP specific shocks do, and $\epsilon^j_{z,t-j}$ has variance $\sigma^2_{z,j}$ for $j = 0, 6, 12$. To calibrate the persistence parameter, ρ_z, I use the median value from the posterior distribution of the parameter estimated by Schmitt-Grohe and Uribe (2012) of 0.47 and adjust this from the quarterly to the monthly frequency, yielding 0.78. All other parameters are held fixed at their baseline values.

Figure 6 reports the IRFs for labour market tightness to a one percent shock to $\epsilon^{12}_{z,t-12}$. Upon the arrival of IST news, both variables increase moderately and continue to rise in the periods before the efficiency of investment actually changes, peaking at a deviation of roughly 1% from their steady state levels. Then, when

[12] It is this type of shock which Schmitt-Grohe and Uribe (2012) find to be an important source of business cycle fluctuations in a DSGE model estimated with Bayesian methods, with anticipated shocks playing a particularly important role quantitatively.

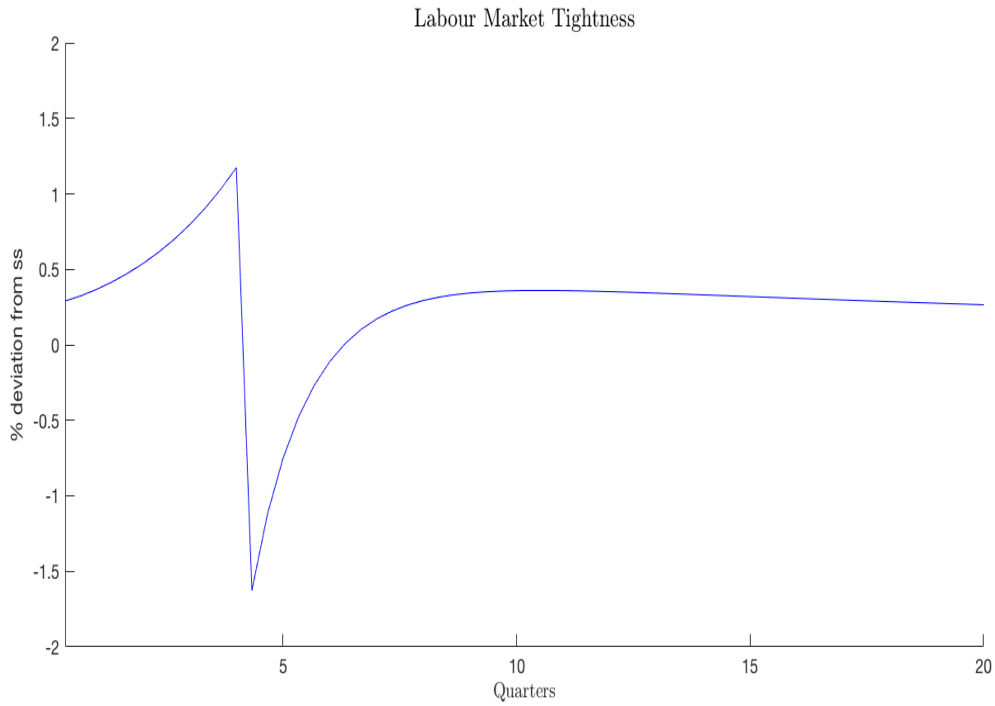
investment technology improves in period $t+12$, tightness falls significantly before rising back towards its steady state level in the following periods. The mechanism for this stems from firms having two investment decisions which they have to weight against each other. When firms learn that Z_t will be higher in the future, they also anticipate that this will eventually result in a higher marginal product of labour.[13] The marginal benefits of hiring a worker are now higher, and firms are induced to invest more in labour through greater vacancy posting to restore equality in the vacancy posting Euler equation. When the shock realises in period $t+12$, it becomes a relatively efficient time to invest in capital and so for equation (24) to continue to hold there must be a fall in the stochastic discount factor via a decrease in consumption. From the vacancy posting Euler equation, this necessitates a rise in q which occurs through a decline in vacancies and tightness consequently. As the shock dies out, all variables return towards their steady state level. These responses seem different to those in the IRFs for the BZK IST shocks estimated in Section 2 as, while both feature positive responses in vacancies when the news shock occurs, the empirical IRFs do not exhibit the contraction in labour market variables when investment technology changes. Ultimately, anticipated investment shocks can produce positive innovations in the labour market in the model, albeit in a way not entirely in line with the results of the Jordá projection.

5 Concluding remarks

The importance of anticipated shocks to both total factor productivity and investment-specific technology in explaining business cycle fluctuations has been a well-documented part of modern empirical macroeconomic literature. Equally well established is the inability of standard frictionless models to produce the expansionary movements evident in the data. I have presented results which suggest that the transmission mechanism of TFP-specific news shocks occurs, at least in some part, through the labour market. This operates through the vacancy posting channel primarily, although there is evidence that the number of job separations and search intensity

[13] The marginal product of labour is increasing in the level of capital, which will be produced more efficiently in the future as firms anticipate.

Figure 6: Model IRF for an IST shock



Notes: the IRF is for a one percent positive shock to Z_t anticipated 12 periods in advance.

also adjust when TFP news arrives. These findings are robust to a number of alternative metrics and a shorter sample but are sensitive to the strategy used to identify the TFP news shocks. Anticipated IST shocks seem to generate similar responses. A reasonably simple SAM model can reproduce this positive co-movement between vacancies and TFP-specific news shocks due to the forward-looking vacancy posting Euler equation, as firms respond to news of a future productivity innovation by altering the number of vacancies they post in the preceding periods. This key result remains intact when fixed costs to vacancies are included and when there is an entirely rigid real wage but the news shocks dynamics disappear when the model is calibrated to give workers a much greater share of the match surplus and a lower flow value of unemployment. This feature adds to the already extensive benefits of SAM models in capturing realistic elements of business cycles seen in the data. There is also evidence that adding anticipated shocks can help to address the lack of persistence in vacancy posting which is a flaw present in most benchmark models. Future research could incorporate TFP news shocks into Heterogeneous Agent New Keynesian models with SAM frictions, such as that of Ravn and Sterk (2018), in order to investigate the effects on the endogenous idiosyncratic income risk present in the model, as well as the implications for monetary policy.

Bibliography

Barnichon, R. (2010): "Building a composite Help-Wanted Index," *Economics Letters*, 109, 175–178.

——— (2012): "Vacancy posting, job separation and unemployment fluctuations," *Journal of Economic Dynamics and Control*, 36, 315 – 330.

Barsky, R. B. and E. R. Sims (2011): "News shocks and business cycles," *Journal of Monetary Economics*, 58, 273–289.

Beaudry, P., P. Feve, A. Guay, and F. Portier (2015): "When is Nonfundamentalness in VARs a Real Problem? An Application to News Shocks," Working Paper 21466, National Bureau of Economic Research.

Beaudry, P. and B. Lucke (2009): "Letting Different Views about Business Cycles Compete," in *NBER Macroeconomics Annual 2009, Volume 24*, National Bureau of Economic Research, Inc, 413–455.

Beaudry, P. and F. Portier (2006): "Stock Prices, News, and Economic Fluctuations," *American Economic Review*, 96, 1293–1307.

——— (2007): "When can changes in expectations cause business cycle fluctuations in neo-classical settings?" *Journal of Economic Theory*, 135, 458–477.

——— (2014): "News-Driven Business Cycles: Insights and Challenges," *Journal of Economic Literature*, 52, 993–1074.

Ben Zeev, N. and H. Khan (2015): "Investment-Specific News Shocks and U.S. Business Cycles," *Journal of Money, Credit and Banking*, 47, 1443–1464.

Davis, S. J., R. J. Faberman, and J. C. Haltiwanger (2013): "The Establishment-Level Behavior of Vacancies and Hiring," *The Quarterly Journal of Economics*, 128, 581–622.

den Haan, W. J. and G. Kaltenbrunner (2009): "Anticipated growth and business cycles in matching models," *Journal of Monetary Economics*, 56, 309–327.

den Haan, W. J., G. Ramey, and J. Watson (2000): "Job Destruction and Propagation of Shocks," *American Economic Review*, 90, 482–498.

Fisher, J. D. M. (2006): "The Dynamic Effects of Neutral and Investment-Specific Technology Shocks," *Journal of Political Economy*, 114, 413–451.

Forni, M., L. Gambetti, and L. Sala (2014): "No News in Business Cycles," *The Economic Journal*, 124, 1168–1191.

Fujita, S. and G. Ramey (2007): "Job matching and propagation," *Journal of Economic Dynamics and Control*, 31, 3671 – 3698.

Gavazza, A., S. Mongey, and G. L. Violante (2018): "Aggregate Recruiting Intensity," *American Economic Review*, 108, 2088–2127.

Haefke, C., M. Sonntag, and T. van Rens (2013): "Wage rigidity and job creation," *Journal of Monetary Economics*, 60, 887–899.

Hagedorn, M. and I. Manovskii (2008): "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited," *American Economic Review*, 98, 1692–1706.

Hall, R. E. (2005): "Employment Fluctuations with Equilibrium Wage Stickiness," *American Economic Review*, 95, 50–65.

Hall, R. E. and P. R. Milgrom (2008): "The Limited Influence of Unemployment on the Wage Bargain," *American Economic Review*, 98, 1653–74.

Hosios, A. (1990): "On The Efficiency of Matching and Related Models of Search and Unemployment," *Review of Economic Studies*, 57, 279–298.

Jaimovich, N. and S. Rebelo (2009): "Can News about the Future Drive the Business Cycle?" *American Economic Review*, 99, 1097–1118.

Jermann, U. J. (1998): "Asset pricing in production economies," *Journal of Monetary Economics*, 41, 257–275.

Jorda, O. (2005): "Estimation and Inference of Impulse Responses by Local Projections," *American Economic Review*, 95, 161–182.

Keynes, J. M. (1936): *The general theory of employment, interest, and money*, Springer.

Kydland, F. E. and E. C. Prescott (1982): "Time to Build and Aggregate Fluctuations," *Econometrica*, 50, 1345–1370.

Leduc, S. and Z. Liu (2017): "The slow job recovery in a macro model of search and recruiting intensity," *Working paper*.

Merz, M. and E. Yashiv (2007): "Labor and the Market Value of the Firm," *American Economic Review*, 97, 1419–1431.

Mortensen, D. and C. A. Pissarides (1994): "Job Creation and Job Destruction in the Theory of Unemployment," *Review of Economic Studies*, 61, 397–415.

Petrosky-Nadeau, N. and L. Zhang (2017): "Solving the Diamond-Mortensen-Pissarides Model Accurately," *Quantitative Economics*, 8, 611–650.

Petrosky-Nadeau, N., L. Zhang, and L.-A. Kuehn (2018): "Endogenous Disasters," *American Economic Review*, 108, 2212–45.

Pigou, A. C. (1927): *Industrial fluctuations*, Routledge.

Pissarides, C. A. (2009): "The Unemployment Volatility Puzzle: Is Wage Stickiness the Answer?" *Econometrica*, 77, 1339–1369.

Ramey, V. (2016): *Macroeconomic Shocks and Their Propagation*, Elsevier, vol. 2 of *Handbook of Macroeconomics*, chap. 0, 71–162.

Ravenna, F. and C. E. Walsh (2008): "Vacancies, unemployment, and the Phillips curve," *European Economic Review*, 52, 1494–1521.

Ravn, M. O. and V. Sterk (2018): "Macroeconomic Fluctuations with HANK & SAM: An Analytical Approach," *Working Paper*.

Ravn, M. O. and H. Uhlig (2002): "On adjusting the Hodrick-Prescott filter for the frequency of observations," *The Review of Economics and Statistics*, 84, 371–375.

Rogerson, R. and R. Shimer (2011): *Search in Macroeconomic Models of the Labor Market*, Elsevier, vol. 4 of *Handbook of Labor Economics*, chap. 7, Pages: 61.

Schaal, E. and M. Taschereau-Dumouchel (2016): "Aggregate Demand and the Dynamics of Unemployment," *Working paper*.

Schmitt-Grohe, S. and M. Uribe (2012): "What's News in Business Cycles," *Econometrica*, 80, 2733–2764.

Shimer, R. (2005): "The Cyclical Behavior of Equilibrium Unemployment and Vacancies," *American Economic Review*, 95, 25–49.

Sims, E. R. (2012): *News, Non-Invertibility, and Structural VARs*, chap. Advances in Econometrics, 81–135.

Appendix

A. Jordá projections and VARs

A1. Additional Impulse Response Functions

Figure A1: Estimated IRFs from a Jordá projection for labour market tightness, vacancies, the job finding rate and unemployment to a Barsky-Sims news shock.

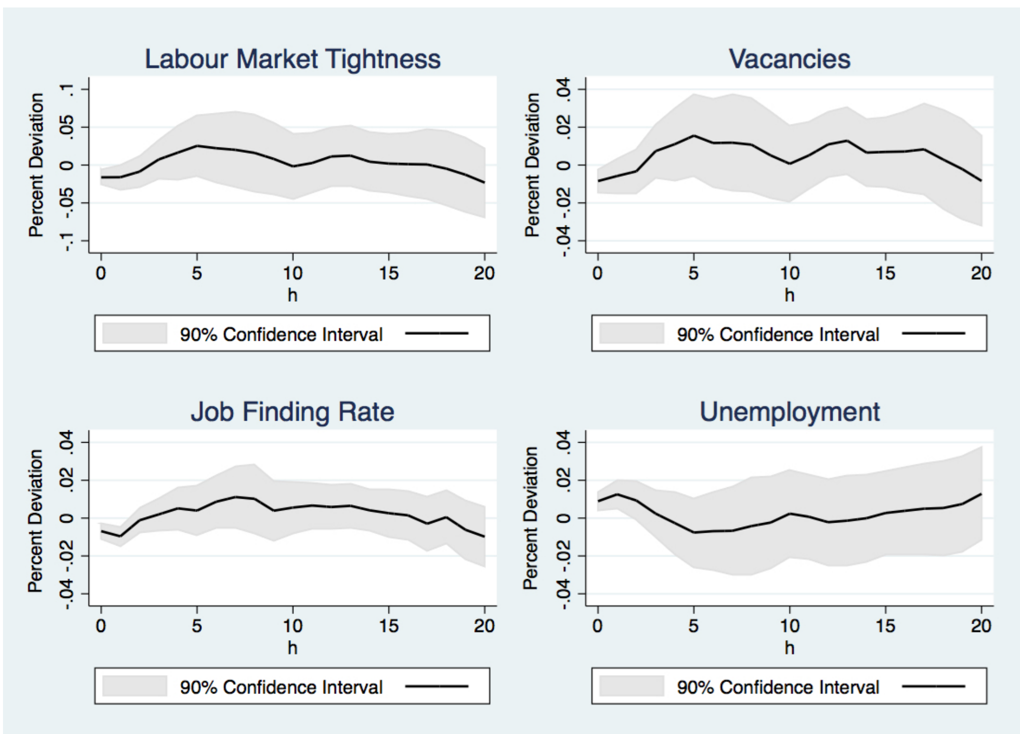


Figure A2: Estimated IRFs from a Jordá projection for labour market tightness, vacancies, the job finding rate and unemployment to a Ben-Zeev-Khan IST news shock.

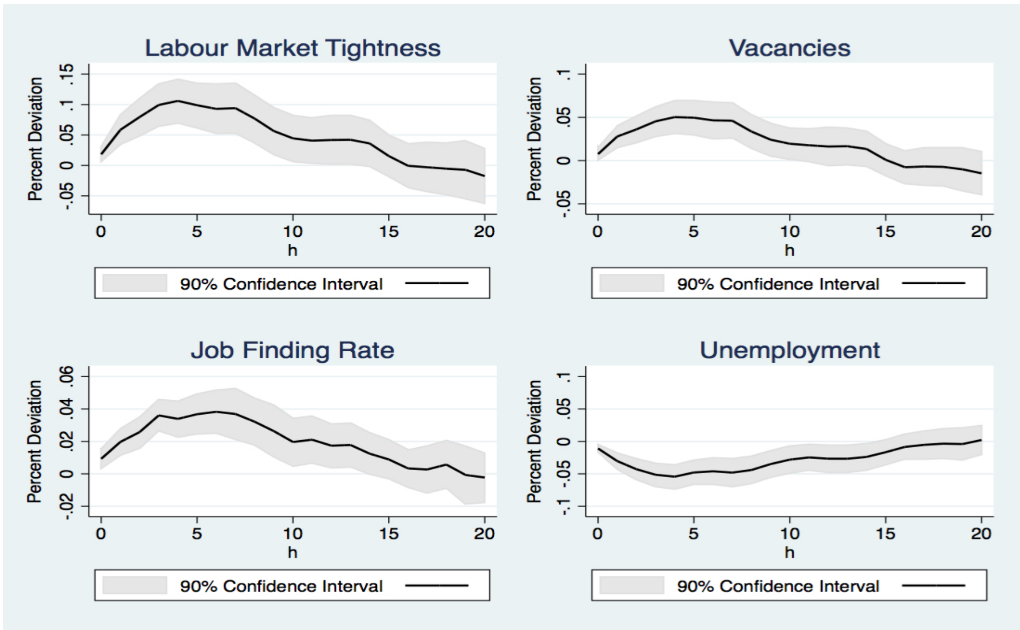


Figure A3: Estimated IRFs from a Jordá projection for search intensity and the labour force participation rate to a Beaudry-Portier news shock identified with short-run restrictions.

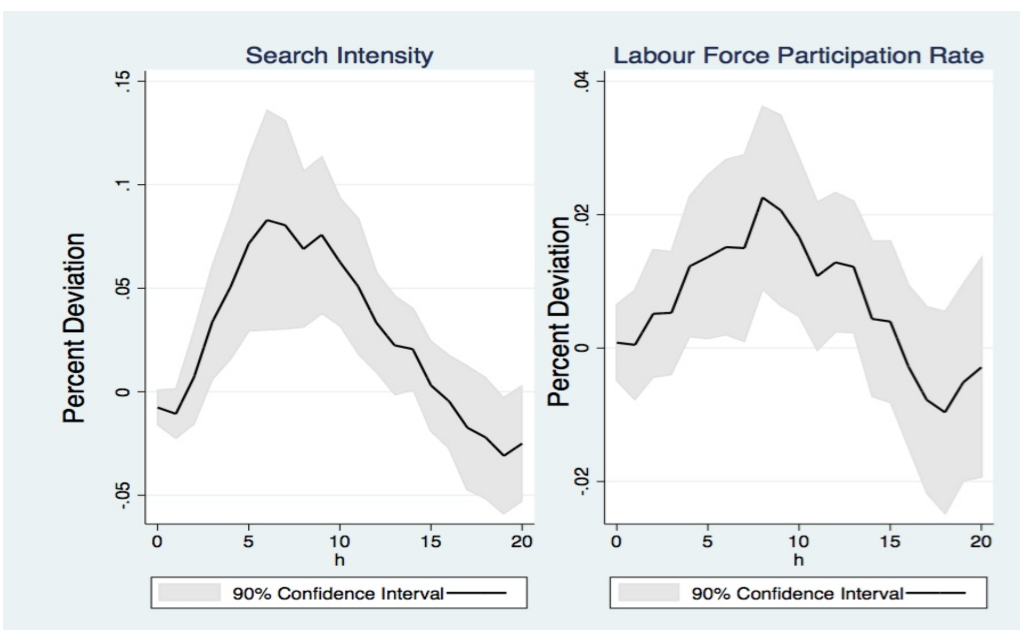


Figure A4: Estimated IRFs from a Jordá projection for the shorter sample period 1990-2015.

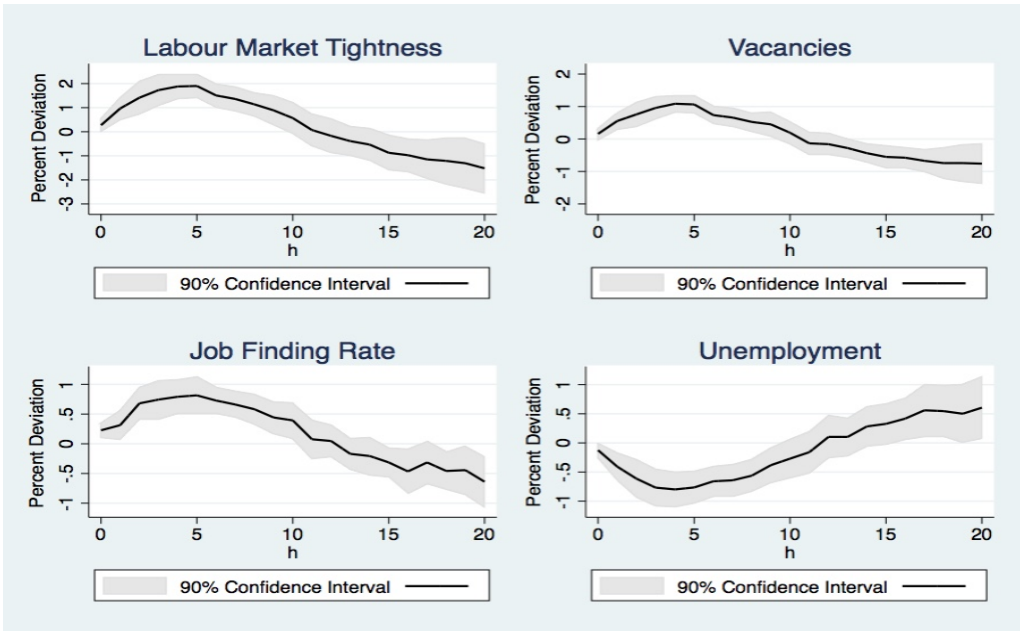


Figure A5: Estimated IRFs from a Jordá projection for the variables detrended with a Hodrick-Prescott filter.

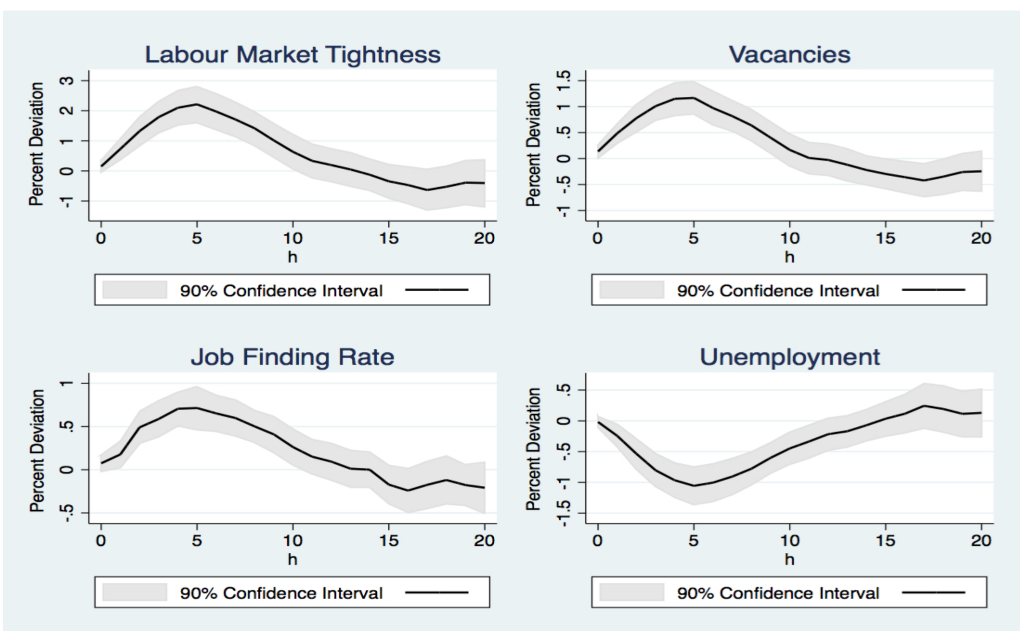
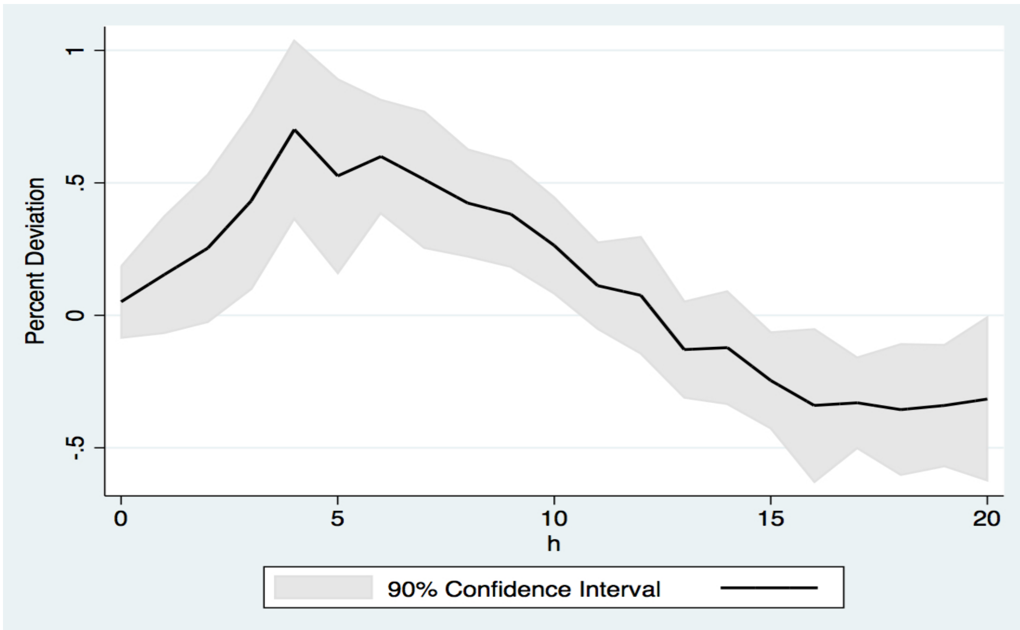


Figure A6: Estimated IRFs from a Jordá projection for the alternative measure of the job finding rate.



A2. Additional Variance Decompositions

Table A1: Variance decomposition for the Beaudry-Portier shock identified with short-run restrictions

Horizon (Quarters)	**Job Finding Rate**	**Unemployment**
0	0.1	0.1
4	25.7	20.6
8	34.5	28.3
12	36.1	34.6
16	36.1	35.0
20	35.7	34.8

Table A2: Variance decomposition for the Barsky-Sims TFP news shock

Horizon (Quarters)	**Vacancies**	**Labour Market Tightness**
0	5.5	2.5
4	2.5	2.7
8	5.2	5.4
12	5.9	5.9
16	5.5	5.9
20	5.4	6.2

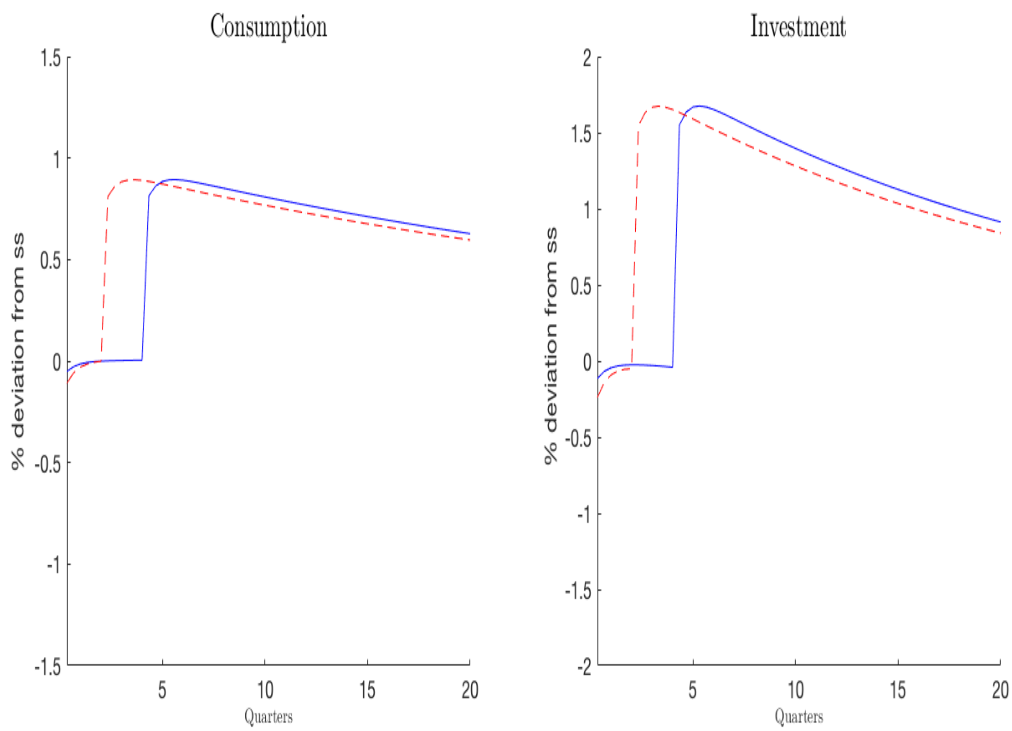
Table A3: Variance decomposition for the Ben-Zeev-Khan IST news shock

Horizon (Quarters)	**Vacancies**	**Labour Market Tightness**
0	2.9	4.7
4	24.0	27.2
8	29.6	31.3
12	29.5	30.1
16	29.1	29.2
20	28.9	28.4

B. Search and matching model

B1. Consumption and investment IRFs

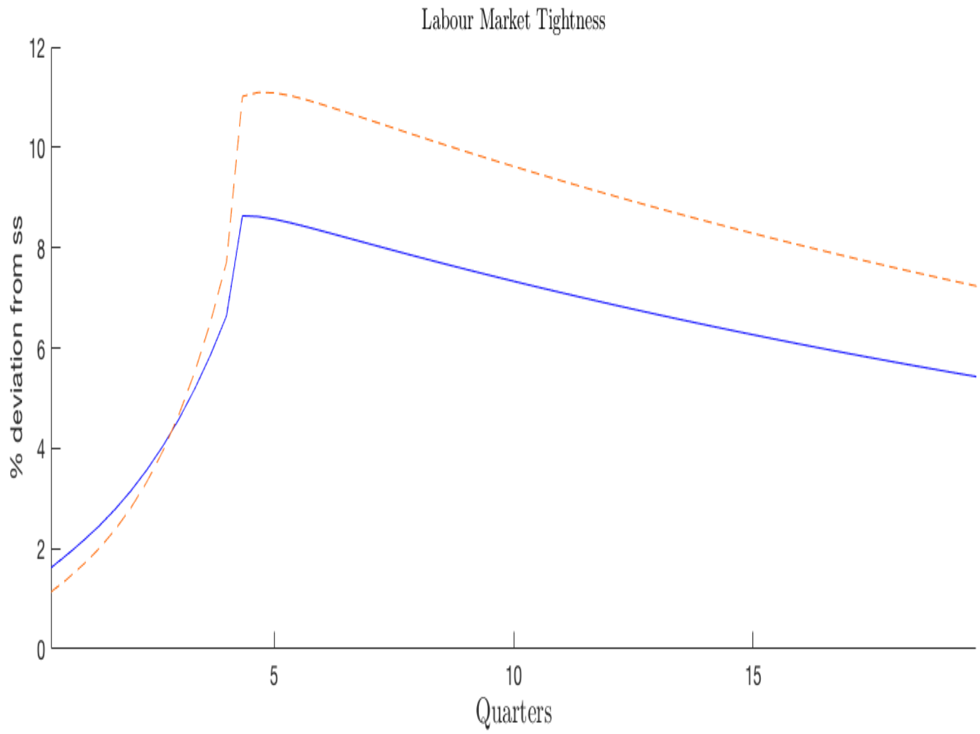
Figure B1: Model IRFs for consumption and investment



Notes: the red dotted line denotes the IRF for a one percent positive shock to TFP anticipated six months in advance. The blue solid line denotes the IRF for a one percent positive shock to TFP anticipated twelve months in advance.

B2. Fixed costs in vacancy posting

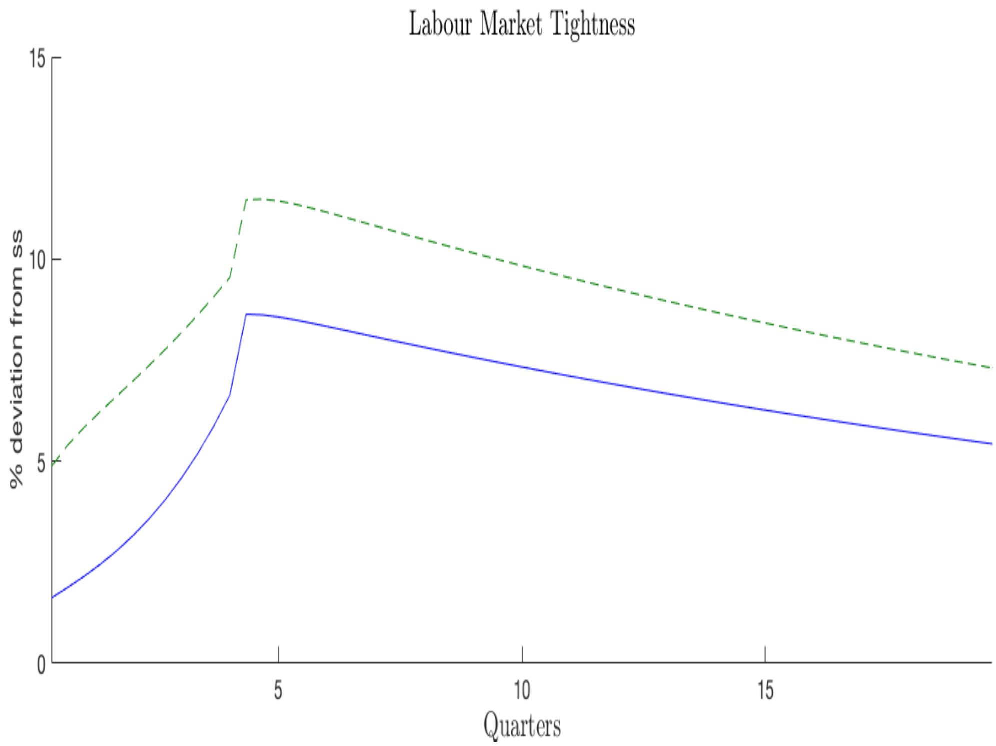
Figure B2: Model IRF for labour market tightness when there are fixed costs in vacancy posting



Notes: the orange dotted line denotes the IRF for a one percent positive shock to TFP anticipated twelve periods in advance with fixed costs in vacancy posting. The blue solid line denotes the IRF for a one percent positive shock to TFP anticipated twelve periods in advance for the baseline model.

B3. Wage rigidity

Figure B3: Model IRF for labour market tightness with complete wage rigidity.



Notes: the green dotted line denotes the IRF for a one percent positive shock to TFP anticipated twelve periods in advance with a rigid real wage. The blue solid line denotes the IRF for a one percent positive shock to TFP anticipated twelve periods in advance for the baseline model.