ESSAYS ON MONETARY POLICY

by

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Abstract

The thesis has three self-contained chapters on monetary policy. Each chapter is an empirical study of state dependence of monetary policy impacts and covers over the period until the COVID-19 pandemic. The goal is to investigate whether and how states of household debt, the economic cycle, and sentiment influence the transmission and the effectiveness of monetary policy.

The first chapter studies whether the level of household debt affects the transmission of monetary policy in Australia for the period 1994–2019. Using a state-dependent local projection model, we find that monetary policy is less effective when household debt is high than household debt is low, especially with respect to aggregate output, consumption, and investment. Durables expenditure and residential investment play an important role in driving the differences in aggregate output between the high and low states of household debt.

The second chapter looks at Australian monetary policy again. But this time, it explores how the state of the economic cycle affects monetary policy. We identify the strong growth and weak growth states of the economy for the period 1994–2018 and estimate a smooth transition local projection model with this data. We find that the effects of monetary policy are less powerful during weak growth periods of the economy.

The third chapter analyzes the effects of monetary policy during high and low periods of sentiment in the US. I estimate a self-exciting interacted vector autoregression model with data from 1960–2009. I find that the impacts of US monetary policy are weaker when sentiment is low. Especially, the responses of durables expenditure and investment to monetary policy shocks are much weaker in low sentiment periods.

Our findings question the common wisdom that cuts in policy rates can stimulate the economy, calling for the study of alternative policy measures during the periods of slow economic growth, high household debt, and low sentiment.

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Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

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Dedication

This is for my parents, Batsukh and Tuya, who gave up on many things so that I could obtain the best possible education, and for my wife, Tamiraa, who created atmosphere of love and care in which difficult work became easy.

Introduction

Understanding the macroeconomic effects of monetary policy shocks is a key part of monetary policy analysis. The literature traditionally studies the effects of monetary policy shocks in linear frameworks and pays less attention to nonlinear frameworks and their policy implications.[1] However, in light of the slow recovery of the global economy after the Global Financial Crisis of 2008 (GFC), nonlinear frameworks for analyzing the effects of monetary policy shocks have received more attention from policymakers and in the academic literature. The slow recovery that was experienced by many advanced economies after the GFC has cast more doubt on the effectiveness of monetary policy. A growing number of empirical works suggests that the effects of monetary policy could be state dependent. Initially, this literature (Thoma (1994), Weise (1999), Tenreyro and Thwaites (2016)) has focused on whether the effects of monetary policy are more or less powerful depending on the state of the business cycle (e.g., during recessions or expansions). More recently, the literature has moved on to explore other sources of state dependency. Namely, if investor confidence (Kurov, 2010), uncertainty (Pellegrino, 2021), household debt (Alpanda and Zubairy, 2019), and interest rate (Alpanda et al., 2021) cycles alter the effects of monetary policy. In spite of growing interest on this topic, the existing works have not converged towards any consensus on state dependencies of monetary policy. Furthermore, a majority of the works have concentrated on US data. This thesis seeks to contribute to the literature by applying recently developed nonlinear timeseries models and providing new evidence that includes non-US sources.

The first chapter investigates whether the level of household debt affects monetary policy transmission in Australia. The GFC highlighted that high household debt im-

[1] See, for example, Sims (1980), Eichenbaum and Evans (1995), Leeper et al. (1996), and Christiano et al. (1999).

poses a big risk to financial markets and the overall economy's stability. After the GFC, the relationship between household debt and monetary policy gained more attention from central banks. Globally, household debt and house prices declined. However, in Australia, household debt and house prices have continued to rise and have reached new heights. This evolution has been a continual topic of policy debate over the past two decades in Australia. Historically, mortgage loan rates have moved almost one-for-one with the cash rate, suggesting that monetary policy may have a strong impact on house prices and housing demand in Australia. The above reasons make Australia an interesting case for monetary analysis among other advanced economies. We estimate a state-dependent local projection model with Australian data for the period 1994–2019. Monetary shocks used in this method are the Australian version of Romer and Romer monetary shocks (Beckers, 2020; Bishop and Tulip, 2017). In the model, we use key global variables to account for the fact that Australia is a small open economy. We find that the impacts of monetary policy shocks on the Australian economy are weaker in periods of high household debt. We examine how subcomponents of consumption and investment respond to a monetary shock in high and low periods of household debt. The results show that the responses of durables expenditure and residential investment are substantially weaker in periods of high household debt. Durables expenditure and residential investment play a major role in driving the differences in the response of GDP between the two states. The chapter provides a theoretical discussion on why the effects of monetary policy may be reduced when households debt is high. The findings suggest that in Australia households with high and low debt do not equally benefit from a policy rate cut. It appears that households with low debt benefit more from a policy rate cut given that adjustable-rate mortgage loans dominate in Australia. One possible explanation is that the Australian households with high debt face constraints preventing them to increase their borrowing (through home equity withdrawals) following a decline in mortgage loan rates.

The second chapter considers Australia again, but this time the chapter studies whether the state of the economic cycle affects monetary policy transmission. Keynes (1936) suggests that when the economy is weak, the effectiveness of monetary policy may be reduced. A growing number of works examine if there is empirical support for this view. A majority of these studies use US data.[2] Similar studies for other advanced countries, including Australia, are fairly limited or do not exist. To the best of our knowledge, this chapter is the first to study this question for Australia. There exists a large body of literature on Australian monetary policy. However, the state dependence of monetary policy has not been analyzed for the Australian economy. According to the traditional approach (Cashin and Ouliaris, 2004), which identifies the business cycle by fluctuations in real output growth rate, the Australian economy has not had a single recession since 1992. In contrast, an alternative approach, which identifies the business cycle by fluctuations from the trend of real output, suggests that Australia has gone through a series of strong and weak growth episodes of the economy since 1992. We then estimate a smooth-transition local projection model with the Romer and Romer monetary shock data for Australia for the period 1994–2018. Our results show that Australian monetary policy is less powerful in periods of weak economic growth than strong economic growth. Among the variables we considered, the responses of real GDP, inflation, and the unemployment rate are considerably weaker during weak growth periods. Our finding is relevant for the use of monetary policy as a way to stabilize the Australian economy. If a change in the cash rate has limited power during weak growth periods, then the Reserve Bank of Australia may need to consider unconventional monetary policy tools, namely public communication, quantitative easing, or bond rate targeting.

The third chapter studies the impacts of high and low sentiment in the effective-

[2]These include Weise (1999), Mumtaz and Surico (2015), and Tenreyro and Thwaites (2016).

ness of monetary policy in the US. Since Pigou and Keynes, economists have argued that sentiment or beliefs matter for macroeconomic activities. The goal of this chapter is to empirically explore the interaction between sentiment and monetary policy in the US by using a nonlinear model. I estimate a recently developed self-exciting interacted vector autoregression (SEIVAR) model (Pellegrino, 2021) with US data for the period 1960–2009. The key feature of the SEIVAR over other competing state-dependent models is that it allows the state variable, sentiment, to endogenously move after a monetary policy shock hits, so the impulse responses become fully nonlinear with respect to high and low levels of sentiment. As the two baseline measures for sentiment, I use the Michigan consumer sentiment and the Conference board consumer confidence indices. I find that monetary policy is more powerful when sentiment is high, in particular for GDP, durables expenditure with investment, and nondurables expenditure with services. In contrast, the responses are much weaker in periods of low sentiment. From a policy standpoint, the finding suggests that if monetary policy is less powerful in periods of low sentiment, central banks may need more aggressive and unconventional policy measures (in case the policy rate reaches the zero lower bound). In addition, policymakers may need to coordinate fiscal and monetary policies to stabilize the economy more effectively. For the modelling side, this chapter shows that sentiment alters the effects of monetary policy. Hence, models for monetary policy analysis should take into account sentiment.

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By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Nicolas Groshenny		
Contribution to the Paper	Designing the research question, checked all results, contributed to results interpretation, contributed to writing of the paper		
Signature		Date	16 January 2023

Please cut and paste additional co-author panels here as required.

Chapter 1

State-dependent effects of monetary policy in Australia: The role of household debt

Khuderchuluun Batsukh* and Nicolas Groshenny†

Abstract

We study the influence of household indebtedness on the transmission and effectiveness of monetary policy in Australia. We estimate a state-dependent local projection model over the period 1994Q1–2019Q3, and find that the effects of monetary policy shocks on real economic activity are more powerful in a low-debt state than a high-debt state. Monetary policy loses traction as household debt increases: the responses of GDP, consumption and house prices to a surprise cut in the cash rate become more muted. We examine the responses of sub-components of consumption and investment to a monetary policy shock in the two debt states, and observe that durable-goods consumption and residential investment drive the differences in the response of GDP across the two states. Our results point towards a home-equity channel, that amplifies the effects of monetary policy and is more powerful when household indebtedness is moderate, as having played a major role in Australia over that period.

Keywords: Monetary policy, household debt, state dependence, local projections.

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1 Introduction

Does the effectiveness of monetary policy depend on the level of household debt? The aftermath of the 2008 Global Financial Crisis (GFC) highlighted that high household debt imposes a substantial risk to financial stability and the overall economy. Yet, in some countries, most notably Australia, household debt has continued to increase after the GFC. Recently, the role of household indebtedness in the propagation of monetary policy shocks has received attention from researchers in academia and central banks, e.g. Alpanda and Zubairy (2019) and Alpanda et al. (2021). However, this question has not been investigated specifically within the Australian context, where rising household debt has been a concern to policymakers for the past two decades (Debelle, 2004; Kearns et al., 2021).

In this paper, we study the influence of household indebtedness on the transmission of monetary policy shocks in Australia. We use Australian quarterly data over the period 1994–2019 to estimate a state-dependent local projection model, similar to the one estimated by Alpanda and Zubairy (2019) for the United States. We employ the series of monetary policy shocks for Australia constructed by Beckers (2020) using the methodology of Romer and Romer (2004).[1] We examine the dynamic responses of a range of macroeconomic variables to a surprise cut in the cash rate, i.e. the overnight interest rate targeted by the Reserve Bank of Australia (RBA). Our main result is the following: Monetary disturbances have more powerful effects in periods of low household debt than high household debt. In other words, monetary policy loses traction as household debt increases: the responses of GDP, consumption and house prices to monetary shocks become more muted. We then inspect the responses of sub-

[1] Bishop and Tulip (2017) were the first to apply the methodology of Romer and Romer (2004) to identify monetary policy shocks for Australia. Motivated by Caldara and Herbst (2019), Beckers (2020) extends the approach of Bishop and Tulip (2017) to account for the systematic response of the RBA to credit spreads. La Cava and He (2021) update the series of shocks constructed by Beckers (2020) up to the end of 2019. Nguyen and La Cava (2020) also use these shocks.

components of consumption and investment to a monetary policy shock in the two debt states. We observe that durable-goods consumption and residential investment drive the differences in the response of GDP across the two states. Our results are robust to using alternative measures of household indebtedness, employing a different filtering approach to identify the high- and low-debt states, and controlling for key global variables.

Our findings point towards the home-equity transmission channel of monetary policy. This channel, which amplifies the effects of monetary disturbances, hinges on two connected elements: i) the sensitivity of house prices to monetary policy; ii) the ability of moderately-indebted home-owners to increase their borrowing through home-equity withdrawals after a policy-rate cut. This mechanism is more powerful when household debt is low because the access to equity-withdrawal facilities tends to disappear for highly-indebted borrowers. Our empirical results suggest that the equity channel played an important role in Australia over the period 1994–2019. We draw the following policy recommendation: To achieve its macroeconomic stabilization goals in times of high household debt, the RBA should be ready to deploy macro-prudential policies and unconventional monetary policy tools.

For the purpose of analysing the role of household debt in the transmission of monetary policy, the Australian context is peculiar and interesting for at least two reasons: First, since the GFC, household debt and house prices have increased significantly, whereas globally these variables have either decreased or stabilized (see Figures 1 and 2). From an international historical perspective, Schularick and Taylor (2012) and Jordà et al. (2013) argue that vigorous increases in household debt help predict the occurrence of financial crises. Thus, the dynamics of household debt in Australia is perceived by some observers as a threat to financial stability (Dumitrescu et al., 2022; Kearns et al., 2021). Second, adjustable-rate mortgages account for the lion's share of home-loans in Australia (Debelle, 2004). Moreover, mortgage loan rates move almost

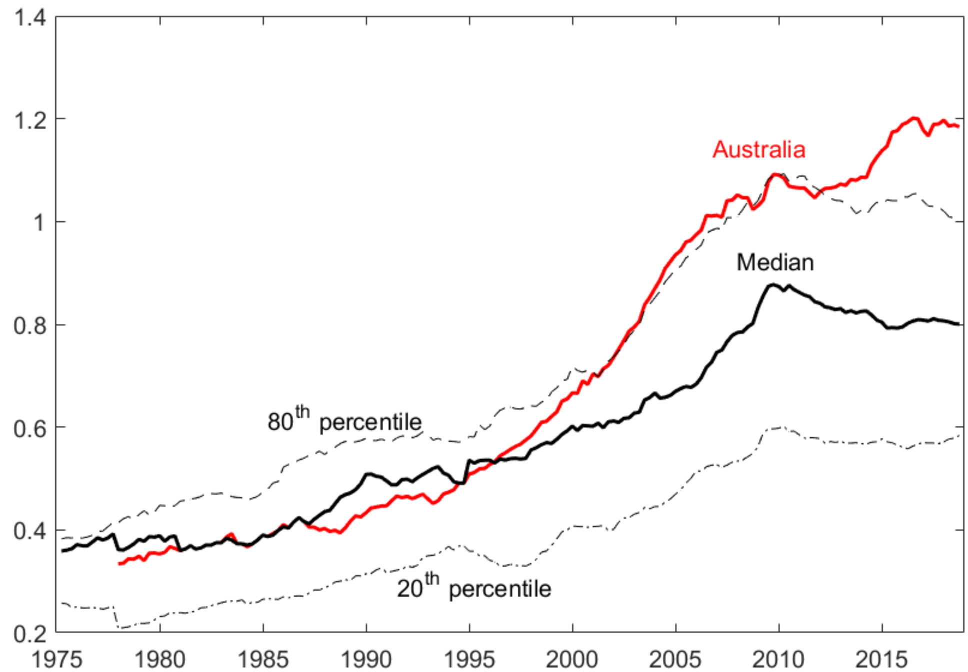

Figure 1: Household debt-to-GDP ratios in advanced economies. Sample: 1975Q1–2018Q4. Source: Alpanda et al. (2021) and authors' calculations.

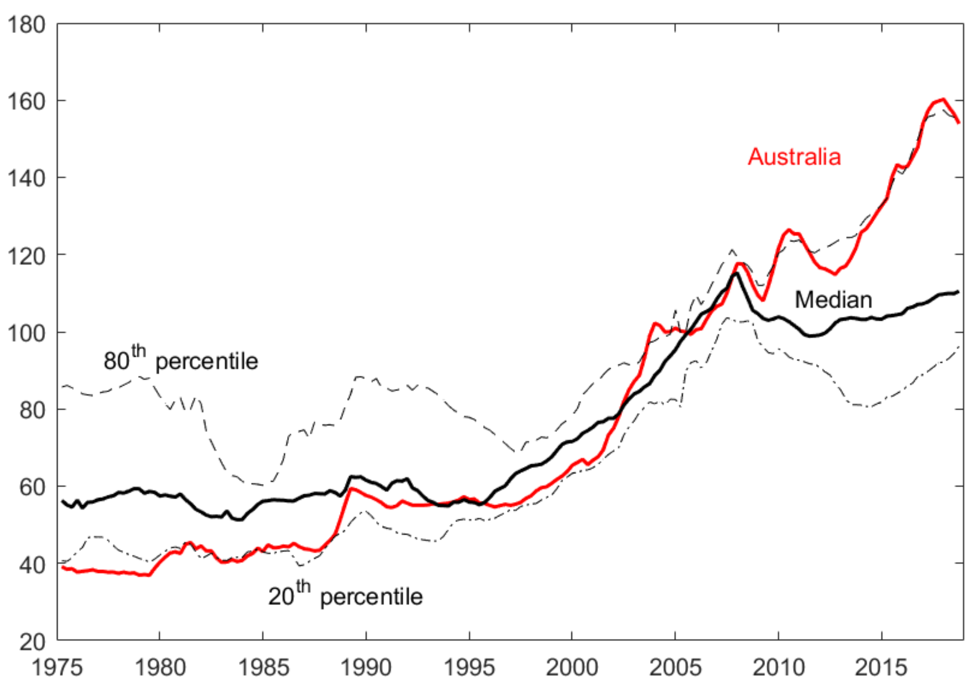

Figure 2: House prices indices in advanced economies. Sample: 1975Q1–2018Q4. Source: Alpanda et al. (2021) and authors' calculations.

one-for-one with the cash rate (see Figure 3). These features suggest that monetary policy may have a strong and rapid impact on housing demand and house prices. Altogether, these characteristics make Australia a special case-study among OECD countries for an investigation of the influence of household debt on the effectiveness of monetary policy.

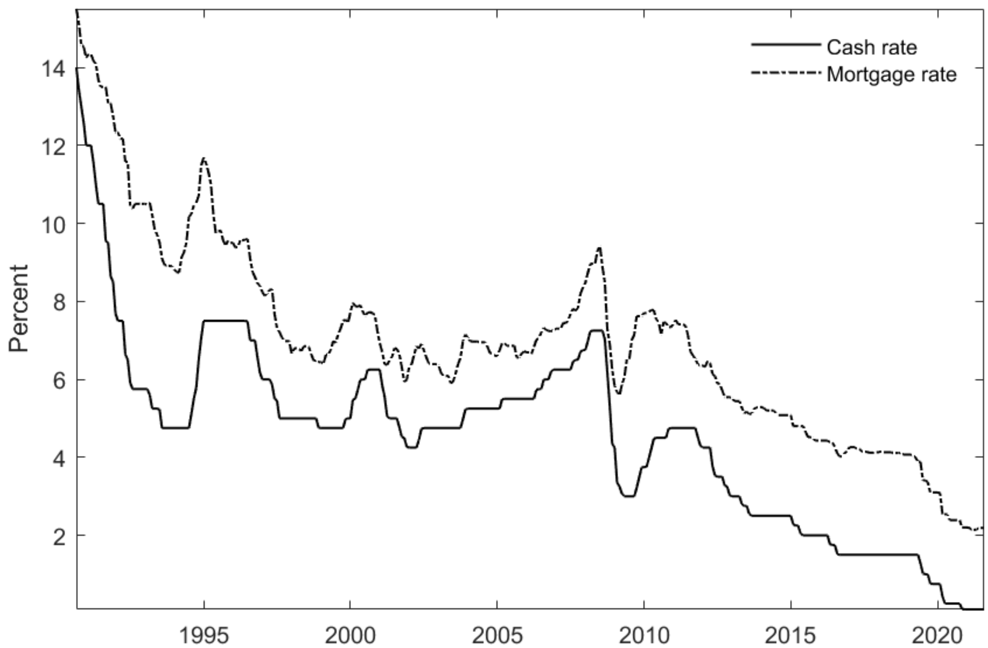

Figure 3: Cash rate and mortgage loan rate for Australia. Sample: 1990M9–2021M8.

2 Literature review

Our paper connects with three strands of literature. A first strand, that is most closely related to our work, studies the role of household debt in the transmission of monetary policy shocks (Alpanda and Zubairy, 2019; Alpanda et al., 2021).[2] Our econometric strategy follows Alpanda and Zubairy (2019). They estimate a state-dependent

[2]Another branch of the literature investigates the opposite causal link, i.e. how monetary policy affects household-debt dynamics. See Duygan-Bump et al. (2015), Fagereng et al. (2021) and Canakci (2021).

local projection model to study the effects of household debt on the propagation of monetary disturbances in the United States. They find that monetary policy is less powerful when household debt is high.[3] We obtain a similar result for Australia. This convergence of findings is remarkable given the institutional disparities between the U.S. and the Australian household mortgage markets. The bulk of home-loans in Australia are variable-rate mortgages, whereas long-maturity fixed-rate mortgages are predominant in the United States.[4] Compared to Alpanda and Zubairy (2019), we adapt our analysis to the Australian situation by including the unemployment rate and the real exchange rate into the model. These two variables are of particular interest to Australian monetary policymakers. In a robustness check, we also control for three key global variables to better account for small-open-economy features peculiar to Australia.

Alpanda et al. (2021) investigate whether the effectiveness of monetary policy may jointly depend on the business cycle, the state of household debt and the average level of interest rates. They use a panel-dataset made of 18 OECD countries to estimate a panel state-dependent local projection model. They find that monetary policy is least effective during recessions that coincide with both moderate levels of household debt and high interest rates.[5] Focusing on the state-dependence of monetary policy with respect to household debt only, the findings of Alpanda et al. (2021) contrast with our own results for Australia, and with the ones of Alpanda and Zubairy (2019) for the United States. This contrast may be due to the fact that Alpanda et al. (2021) consider a panel of 18 countries: their average findings need not apply to an individual country. Indeed, in terms of household-debt dynamics, Australia stands somewhat as

[3]Iacoviello (2005), Sufi (2015), Beraja et al. (2017), and De Luigi and Huber (2018) also find that U.S. monetary policy may be less effective when households are highly indebted.

[4]For Australia, Debelle (2004) argues instead that household consumption may be more responsive to interest-rate changes when households are highly indebted.

[5]Hofmann and Peersman (2017), Gelos et al. (2019) and Kim and Lim (2020) also find that the effects of monetary policy are weaker when household debt is low.

an outlier among OECD countries, as we have discussed above. Moreover, Alpanda et al. (2021) and Alpanda and Zubairy (2019) identify monetary policy shocks through different methods. Alpanda et al. (2021) employ sign-restrictions, whereas Alpanda and Zubairy (2019) adopt a standard recursive (Cholesky) identification scheme. We, instead, borrow the series of Australian monetary policy shocks directly from Beckers (2020) whose identification strategy is similar in spirit to Romer and Romer (2004).

A second strand of literature, to which our paper is related, analyses the implications of household debt for business-cycle fluctuations and macroeconomic stability more broadly. Mian et al. (2013), Jordà et al. (2016) and Mian and Sufi (2018) find that a buoyant household-debt dynamics is associated with more severe recessions and financial crises. Dumitrescu et al. (2022) stress that high household debt magnifies default risk, especially during periods of economic slack. Moreover, lending institutions are less likely to extend new loans to highly indebted households, preventing them to smooth their consumption, and thereby further exacerbating the slump. Finally, defaults have more severe consequences when preceded by a simultaneous boom in household debt and real estate prices, as happened in the run-up to the U.S. subprime crisis of 2007–2008. Policymakers should therefore monitor the evolution of household indebtedness and be ready to deploy micro- and macro-prudential policies to promote macroeconomic stability.[6]

Finally, our paper adds to the empirical literature on the state-dependence of monetary policy. A growing number of papers find evidence of non-linearity in the transmission of monetary impulses.[7] Several contributions explore the extent to which the effectiveness of monetary policy depends on the state of the business cycle and com-

[6]See Benito et al. (2009) and Hunt et al. (2015) for further discussions of the macroeconomic implications of elevated household debt. For related discussions focusing on the Australian context, see Wilkins and Wooden (2009), Loukoianova et al. (2019), Kolios (2020) and Kearns et al. (2021).

[7]For Australia, this literature is scant. The only papers studying the non-linear effects of monetary policy in Australia that we are aware of are Bodman (2006) and Leu and Sheen (2006). Both papers investigate the asymmetry of positive versus negative monetary shocks.

pare the transmission of expansionary versus contractionary monetary shocks (Cover, 1992; Thoma, 1994; Weise, 1999; Angrist et al., 2018). From a methodological point of view, the closest paper to ours, in that branch of literature, is Tenreyro and Thwaites (2016). They estimate a smooth-transition local projection model on U.S. data and find that the efficacy of monetary policy is subdued in recessions. Besides the state of the business cycle, some papers investigate other sources of non-linearity in the transmission of monetary policy. Employing nonlinear interacted VAR models, Aastveit et al. (2017) and Pellegrino (2021) find that monetary policy is less effective when uncertainty is high. Kurov (2010), Lien et al. (2021), and Dahmene et al. (2021) examine the influence of investor sentiment on the propagation of monetary disturbances. They find that monetary shocks have a greater impact on stock returns when investor sentiment is high. Debes et al. (2014) and Guo et al. (2016) consider the role of consumer sentiment and obtain similar results.

3 Econometric strategy

Our goal is to investigate the extent to which the effects of monetary policy in Australia depend on the level of household debt. Following Alpanda and Zubairy (2019), we specify a state-dependent local projection model which we estimate on Australian data.

3.1 State-dependent local projections

The local projection method of Jordà (2005) consists in estimating a series of regressions:

$$y_{t+h} = \alpha_h + \theta_h(L)x_t + \beta_h\varepsilon_t + u_{t+h}, \tag{1}$$

for $h = 0, 1, 2, ..., H$. Here, y denotes the variable of interest, x is a set of control variables, $\theta_h(L)$ is a polynomial in the lag operator, α_h is a constant, and ε is the identified structural shock of interest, in our case a monetary policy shock. The coefficient β_h measures the response of y at time $t+h$ to the shock ε at time t. One constructs the impulse response function as a sequence of β_h, $h = 0, 1, 2, ..., N$, estimated in a series of separate regressions for each horizon.

We extend the linear model of equation (1) to a state-dependent model by adding the indicator variable I_{t-1}:

$$y_{t+h} = (I_{t-1})\left[\alpha_h^H + \theta_h^H(L)x_t + \beta_h^H\varepsilon_t\right] + \left(1 - I_{t-1}\right)\left[\alpha_h^L + \theta_h^L(L)x_t + \beta_h^L\varepsilon_t\right] + u_{t+h}, \quad (2)$$

$I_{t-1} \in \{0, 1\}$ is a dummy variable that represents the state of household debt in period $t-1$. It is equal to 1 in the high-debt state and to 0 in the low-debt state. Superscripts H and L denote the high-debt and low-debt state respectively.[8] The nonlinear model of equation (2) allows parameters to change according to the binary state variable. y describes the variable for which we wish to compute the dynamic response to a monetary shock. In our case, y corresponds in turn to the cash rate, GDP, the inflation rate, the unemployment rate, the real exchange rate, consumption, investment, the household debt-to-GDP ratio and house prices. Except the cash rate, inflation and the unemployment rate, all variables are expressed in log. We include three lags of GDP, inflation, the cash rate and the variable of interest to the set of control variables. We set the maximum horizon $N = 15$. When computing standard errors, we apply the Newey-West correction to account for serial correlation in the residuals.

Non-linear local projection methods have become highly popular thanks to their appealing features in comparison to other non-linear approaches, such as smooth-transition VAR, threshold-VAR and Markov-switching models.[9] Auerbach and Gorod-

[8]Below, we explain how we construct the state variable.

[9]See Ramey and Zubairy (2018) discuss the advantages of non-linear local projections.

nichenko (2013) were the first to apply nonlinear local projections to study the state-dependence of fiscal policy in the United States. Since then, several studies have adopted similar approaches to investigate the state-dependence of monetary policy (Tenreyro and Thwaites, 2016; Alpanda and Zubairy, 2019; Auer et al., 2021; Alpanda et al., 2021). State-dependent local projections offer a convenient approach to compute impulse responses that allow for transitions between states. The coefficients β_h^H and β_h^L measure the average impact of a monetary shock conditional on the initial state, allowing for changes in the state variable over the projection horizon h. Instead, non-linear VAR models typically impose stronger assumptions on the evolution of the state variable following a shock. For example, Auerbach and Gorodnichenko (2013) estimate a regime-switching VAR and compute impulse responses in both business-cycle states under the assumption that a contraction lasts for at least twenty quarters. Ramey and Zubairy (2018) argue that such an assumption is unrealistic - the average duration of a contraction in the U.S. is less than 4 quarters - and problematic as it leads to very different impulse responses. As an alternative to state-dependent local projections, the generalized impulse response functions (GIRFs) of Koop et al. (1996) also allow for the state variable to evolve after the shock. However, the approach based on GIRF is computationally much more intensive.[10]

3.2 Data

We use quarterly data for Australia for the period 1994Q1–2019Q3. The availability of data for the Augmented RR shocks dictates our sample. The start of the sample is the mid-1990s. During this time, a structural break in Australia's monetary policy regime occurred as the RBA adopted Inflation Targeting. Thus, it is common to start

[10] For example, Pellegrino (2021) computes GIRFs from an interacted-VAR to analyze the effect of uncertainty on the transmission of monetary policy shocks.

the sample period in the mid-1990s. Our sample ends just before the COVID-2019 pandemic began. We chose to end our sample in 2019 to avoid the extreme observations recorded during the COVID-2019 pandemic. The choice is motivated by a recent study by Lenza and Primiceri (2022) who show that dropping the extreme observations from a sample is acceptable for parameter estimation in a VAR model and does not significantly affect the results.

The variable of interest, y, in equation (2) consists, in turn, of the cash rate, real GDP, core inflation, the unemployment rate, the real exchange rate, real consumption, real investment, household debt-to-GDP ratio, and real house prices. We use the quarter-to-quarter core CPI inflation, which excludes volatile items. The aggregate variables are deflated by using the GDP deflator. For real investment, we employ the private fixed capital formation from Australian national accounts. The real residential property prices index is used to measure real house prices. Following Alpanda and Zubairy (2019), we consider the subcomponents of real consumption and real investment as additional variables of interest. We break consumption into durables, nondurables, and services.[11] We split investment into residential and nonresidential. We use dwelling and non-dwelling private capital formation to measure residential and non-residential investment, respectively. Section A1 in the Appendix provides more details.

3.3 The state variable

Following Alpanda and Zubairy (2019) and Alpanda et al. (2021), we use the household debt-to-GDP ratio as the state variable. This ratio is a common measure of the household indebtedness of a country. It refers to the number of quarters it would take to pay back the debt if GDP were used for repayment. The higher the

[11] See classifications of consumer spending categories from Table A1 in Black and Cusbert (2010).

household debt-to-GDP ratio, the higher the risk of default. Alternative measures to the household debt-to-GDP ratio are the household debt-to-income and the household debt-to-asset ratios. For robustness, we estimate equation (2) with these two measures. To identify a high-debt state and a low debt state, we construct a household debt gap measure. A positive debt gap then corresponds to the high-debt state, whereas a negative debt gap refers to the low-debt state. To do so, we apply the HP filter with a large smoothing parameter $\lambda = 10^4$ to estimate the trend component in the household debt-to-GDP ratio. We thus obtain a debt gap measure, expressed in percent deviation from a smoothed trend.[12] The large value for λ captures the long duration and the large amplitude of the debt cycle. The value we use for λ is in line with Alpanda and Zubairy (2019), Bauer and Granziera (2016), and Aikman et al. (2017).

Figure 4 plots the household debt-to-GDP ratio with its HP trend. The two vertical lines indicate the subsample that we use in the model estimation. The household debt-to-GDP ratio has an upward trend throughout the sample, besides some drops around the GFC and early 2016. Since the middle of the 1990s, the trend has increased over time in a context marked by rising household income, falling mortgage rates, easy access to credit (Kearns et al., 2021; Claus and Nguyen, 2020), and robust household optimism about the overall economy (Lim and Bone, 2022; Claus and Nguyen, 2020; Drachal, 2020).

[12]To compute the debt trend, we filter the household debt-to-GDP series for the period 1977Q1–2020Q4. We then disregard observations before 1994Q1 and after 2019Q3 to estimate the model. In other words, equation (2) is estimated for the period 1994Q1–2019Q3.

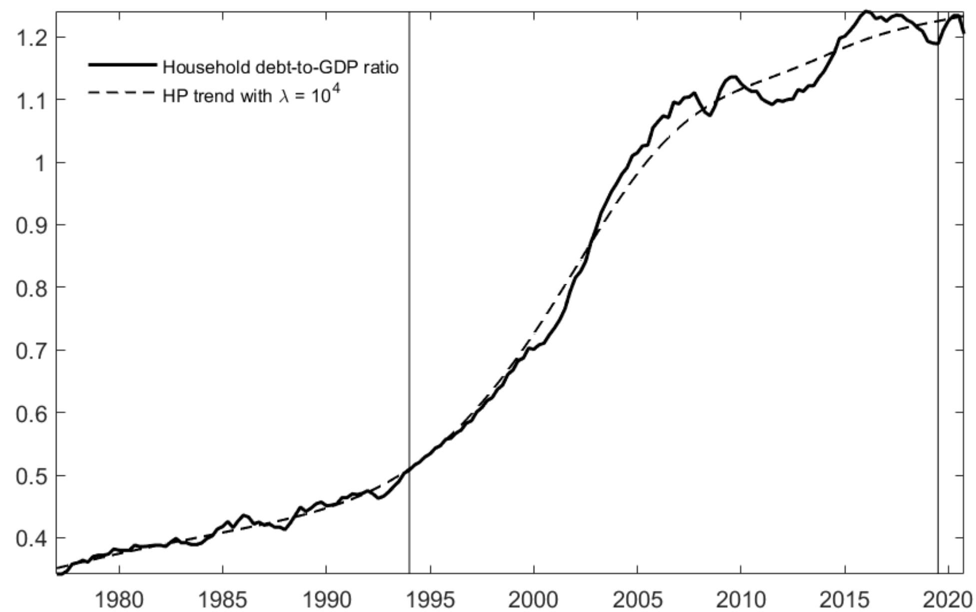

Figure 4: The household debt-to-GDP ratio. Sample: 1977Q1–2020Q4. Solid line: the household debt-to-GDP ratio. Dashed line: a HP trend with $\lambda = 10^4$. Two vertical lines: subsample for the model estimation, 1994Q1–2019Q3.

Figure 5 displays the household debt gap constructed from the household debt-to-GDP ratio. The household debt gap provides additional insights about the evolution of household debt in Australia. The fast accumulation of household debt in Australia may to a large extent have been driven by easy access to credit resulting from financial deregulation in the 1990s and low interest rates post-GFC (Loukoianova et al., 2019). The Australian mining boom from 2000 and 2015 may also have contributed to this fast accumulation. The mining boom drove up both residential investment and household income. These factors led to the buildup of high household debt. Figure 5 shows that the positive debt gap reached its highest level and lasted for the longest period between 2002Q2 and 2010Q4, which coincided with the boom period of the mining sector and housing market. Household sentiment may also have a stimulating effect on the rising household indebtedness in Australia, especially for the period from 2003 and 2011, which coincide with periods of sentiment (See Figures A1 and A2 in the Appendix).

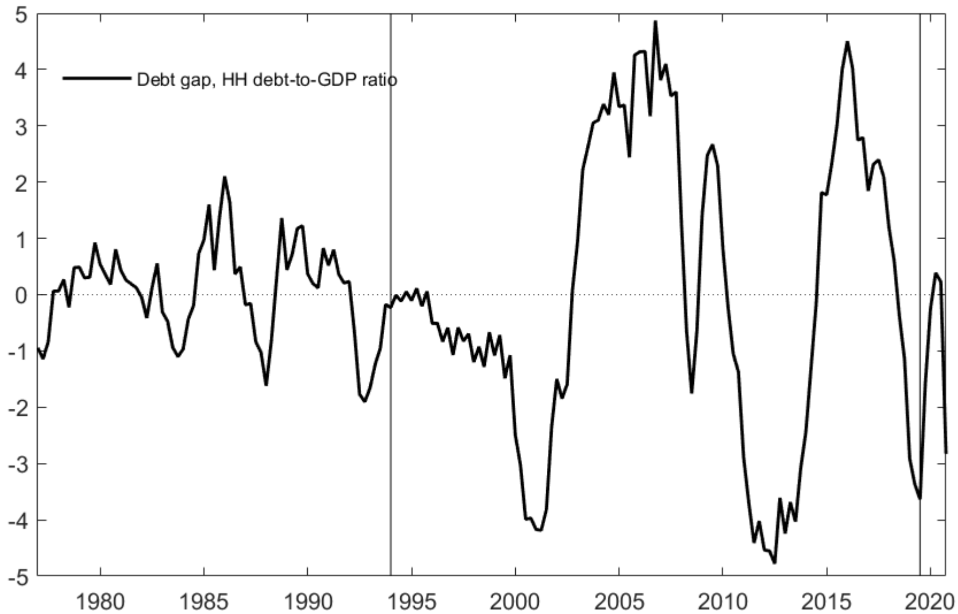

Figure 5: Household debt gap. Percentage deviation from HP trend with $\lambda = 10^4$. Sample: 1977Q1–2020Q4. Two vertical lines: subsample for the model estimation, 1994Q1–2019Q3.

This is consistent with Gric et al. (2022), Lim and Bone (2022), and Claus and Nguyen (2020) who find that household debt is positively associated with household sentiment. From Figure 4, we observe that the household debt-to-GDP ratio continues to grow over time. One might conjecture that the household debt gap could be largely correlated with the GDP gap. A high correlation between the two gap measures indicates that they are similar concepts empirically. To confirm whether this is the case, we conduct a correlation analysis between the household debt gap and the GDP gap (see Table A2 in the Appendix). We consider the GDP gap series computed from HP and linear trending methods for different sample periods. The results show that the correlation coefficient between the two measures is overall weak, ranging from 0.01 to 0.15 in absolute numbers. Thus, the weak coefficients suggest that the two gap measures are different concepts empirically.

3.4 Romer and Romer monetary shocks for Australia

We use the Augmented RR shocks constructed by Beckers (2020) as the measure of monetary policy shocks. The methodology proposed by Beckers (2020) to identify monetary policy shocks in Australia is inspired by Romer and Romer (2004) and Bishop and Tulip (2017). Beckers (2020) specifies a forward-looking Taylor-type rule which he estimates using the RBA's forecasts of output, unemployment, and inflation. Motivated by Caldara and Herbst (2019), Beckers (2020) also includes different measures of credit spreads for Australia as additional explanatory variables in his regression, in order to account for the systematic response of the cash rate to changes in credit market conditions.[13] The residuals from this regression are dubbed the 'the Augmented Romer and Romer shocks'. These residuals capture the non-systematic changes in the cash rate, conditional on the RBA's information set, including credit spreads, at the time of each monetary policy decision.[14] Section A4 in the Appendix provides the specification of the Taylor-type regression used by Beckers (2020).

Figure 6 plots the Augmented RR shocks. The figure displays two episodes marked by highly volatile monetary policy shocks, one at the very beginning of the sample period, the other around 2008. The first episode corresponds to the adoption of Inflation Targeting by the RBA. The second episode relates to the GFC of 2007–2009.

[13]Caldara and Herbst (2019) show that credit spreads are a key determinant of monetary policy in the US. Credit spreads are essential to correctly characterize the systematic component of US monetary policy and its transmission.

[14]Interestingly, Beckers (2020) shows that adding the credit spread to the RBA's interest-rate rule helps to remove the price puzzle in the inflation response to monetary shocks. The price puzzle was an issue with the Romer and Romer shocks constructed first by Bishop and Tulip (2017).

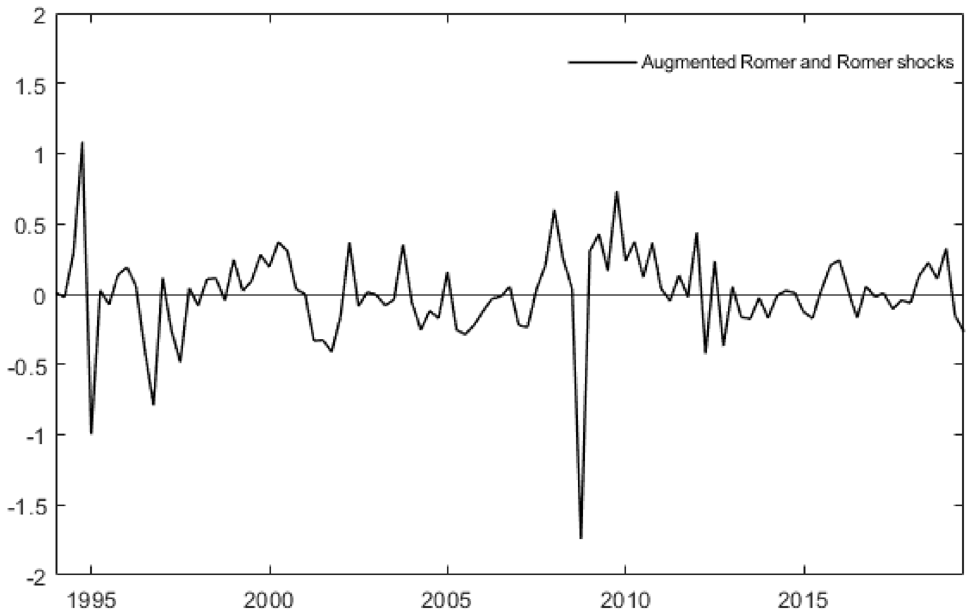

Figure 6: The Augmented Romer and Romer monetary shocks. Sample: 1994Q1–2019Q3. Sources: Beckers (2020) and Nguyen and La Cava (2020) who extended the shock series from 2018Q4 until 2019Q3.

4 Results

Figure 7 reports the impulse responses of real GDP, core inflation, the unemployment rate, the real exchange rate, real investment, real consumption, the state variable, and real house price to an expansionary monetary policy shock, i.e. a one percentage point cut in the cash rate. The horizon h is on the x-axis, and the coefficient β_h is on the y-axis. Blue and red lines represent the impulse responses in a high-debt and low-debt state, respectively. Following an expansionary monetary shock that hits the Australian economy in the low-debt state, we document a large hump-shaped increase in GDP, investment, consumption, household debt-to-GDP, and houses prices. These variables reach their peak between 4 and 12 quarters after the shock hits. In contrast, when the expansionary monetary disturbance occurs in the high-debt state, we find that the responses of these variables are much more muted.

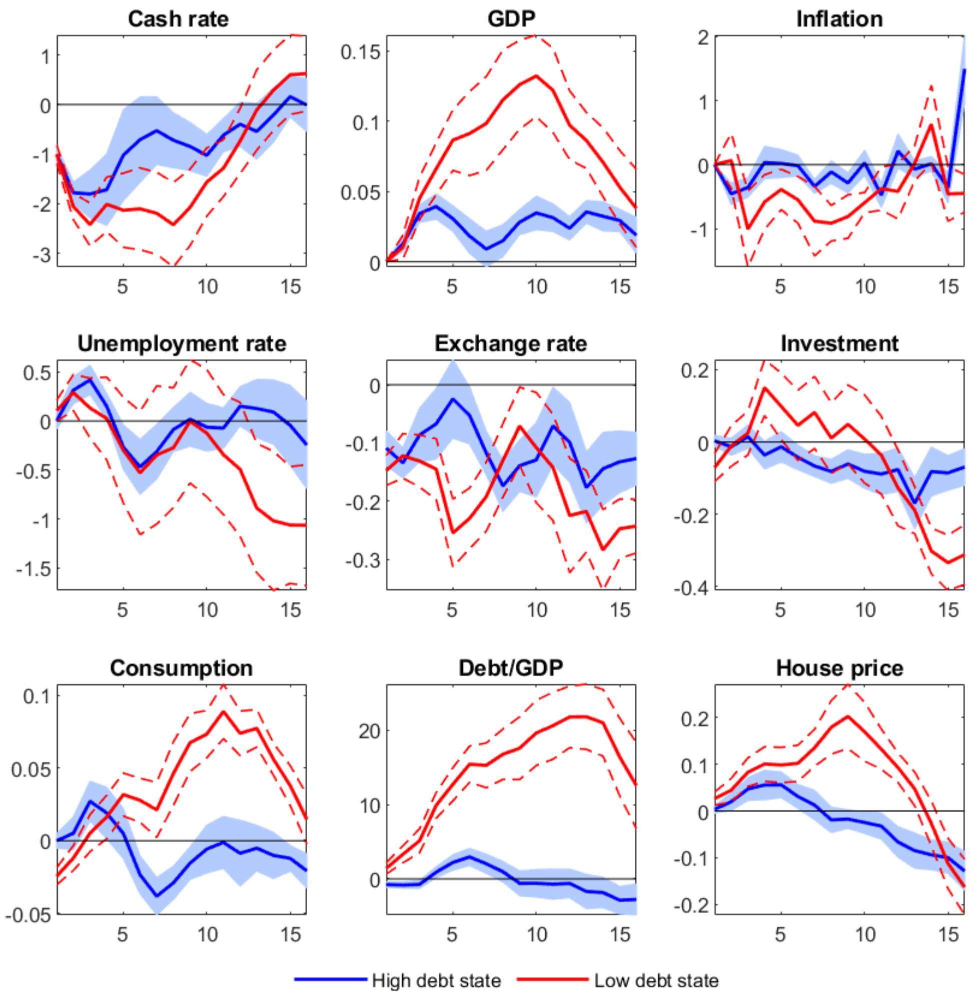

Figure 7: Impulse responses to a monetary policy shock that reduces the cash rate by 1 percentage point. Blue (red) lines show median impulse responses following a shock that occurs in the high-debt (the low-debt) state. Dashed lines (shaded bands) represent 96% point-wise confidence intervals.

The response of inflation to a monetary shock occuring in the high-debt state is barely significant. If the shock hits in the low-debt state, we observe a mild but persistent price puzzle. Manifestations of the price puzzle are often documented in the empirical literature on monetary policy in the Australian context.[15] The response

[15]The negative response of inflation to an expansionary monetary shock is commonly found for Australia. Most empirical studies on Australian monetary policy document a large price-puzzle. Notable exceptions are Beckers (2020), Hartigan et al. (2018), and Dungey and Pagan (2000). In the hope of attenuating the price puzzle, we added in turn the US federal funds rate, the real effective exchange rate, commodity prices, oil prices, and inflation expectations, as control variables. While

of the unemployment rate to a monetary shock occuring during the high-debt state is essentially insignificant at all horizons. If the shock hits in the low-debt state, we observe a gradual fall in the unemployment rate that becomes significant roughly three years after the shock. The real effective exchange rate depreciates (i.e. the Australian dollar weakens), no matter whether the expansionary monetary shock hits in the low- or high-debt state. The depreciation is more pronounced in the low-debt state.

Overall, the responses in the low-debt state are significantly different from those in the high-debt state. This is especially true for GDP, consumption, and the household debt-to-GDP ratio. The differences that we observe in the response of GDP across the two states appear to be primarily driven by state-dependent reaction of consumption to a monetary policy shock.

Figure 8 shows the impulse responses of subcomponents of consumption and investment. In response to an unexpected decrease in the cash rate, we report significant hump-shaped responses for durable consumption, non-durable consumption, and services consumption in the low-debt state. As expected, durable consumption is more sensitive to monetary shock than non-durable and services consumption. When the shock hits in the high-debt state, the responses of the three subcomponents of consumption are more subdued. Turning to the subcomponents of investment, residential investment displays a large positive hump-shaped response in the low-debt state, whereas the response in the high-debt state is much weaker. Nonresidential investment reacts negatively in both states, suggesting that non-residential investment may be crowded out, in particular by durable consumption and residential investment.

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we do not report these results here, adding these variables helped to mitigate the negative response of inflation, but did not produce a positive response to any large extent.

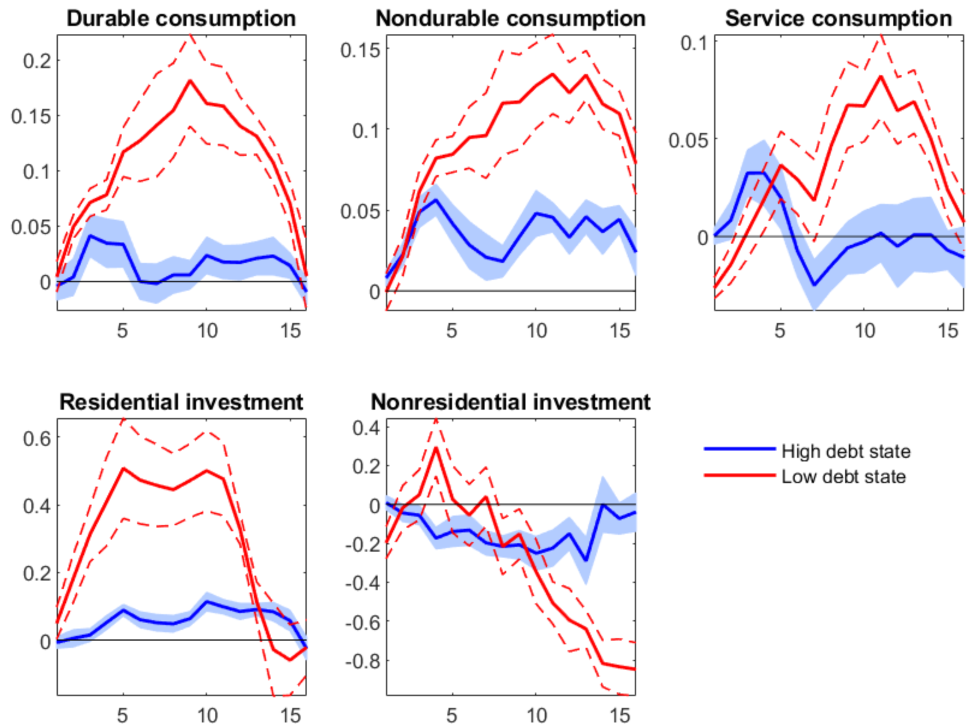

Figure 8: Impulse responses of subcomponents of consumption and investment to a monetary policy shock that reduces the cash rate by 1 percentage point. Blue (red) lines show median impulse responses following a shock that occurs in the high-debt (the low-debt) state. Dashed lines (shaded bands) represent 96% point-wise confidence intervals.

In summary, Figures 7 and 8 show that the degree of household indebtedness materially alters the transmission of monetary policy in Australia. When households are highly indebted, expansionary monetary policy shocks are less effective at stimulating the economy. Durable goods consumption and residential investment appear to be the main drivers of the different responses across the two household debt states.

4.1 Asymmetric effects of monetary policy shocks

We investigate whether the sign of monetary policy shocks is important in explaining the reduced effectiveness of monetary policy during phases of high household indebtedness. If, for example, positive shocks are more powerful than negative shocks, and if they occur more commonly during phases of low household indebtedness, then we would mistakenly conclude that the high phases of household indebtedness are the only source of the reduced effectiveness of monetary policy.

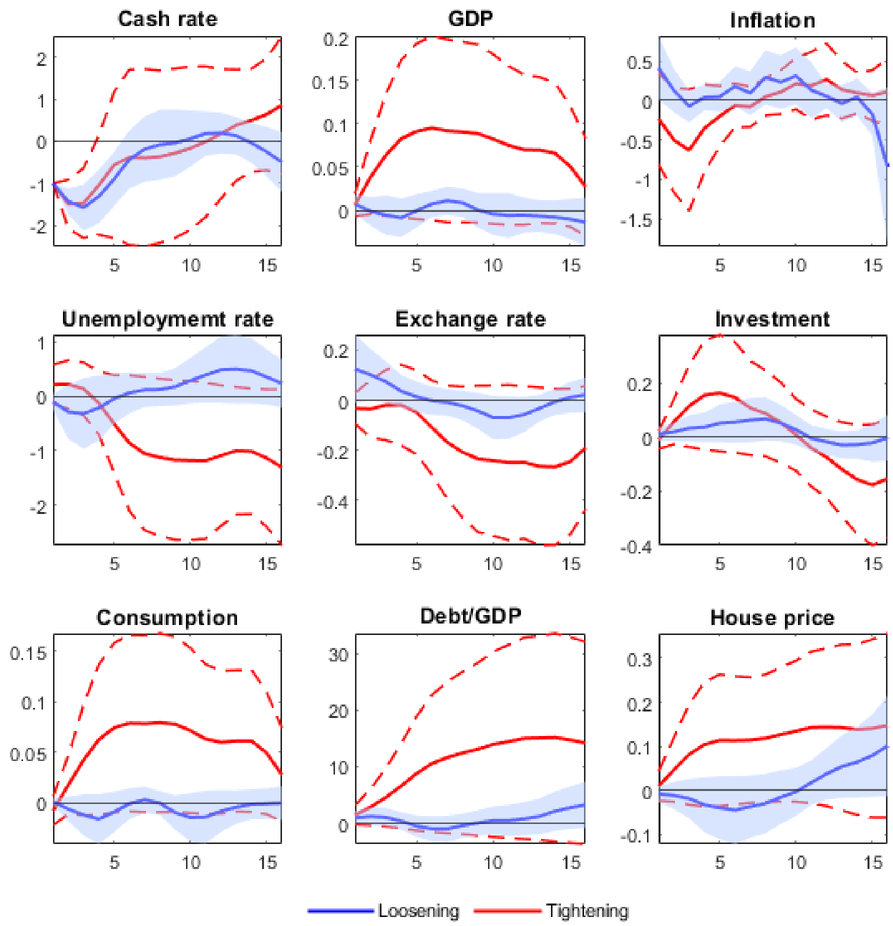

Figure 9: Impulse responses to positive and negative monetary policy shocks. Blue (red) lines depict median responses to a negative (a positive) monetary policy shock. Dashed lines and shaded bands represent 96% point-wise confidence intervals. Impulse responses to a positive monetary policy shock (a monetary tightening) are inverted for easier comparisons.

Figure 9 shows the impulse responses for the state-dependent local projection model, which is modified such that positive and negative monetary shocks are enabled to have different effects. By following the methodology used by Tenreyro and Thwaites (2016), we estimate β_h^+ and β_h^- for $h = 0, 1, 2, ..., 15$ from the following equation:

$$y_{t+h} = \tau t + \alpha_h + \beta_h^+ max[0, \epsilon_t] + \beta_h^- min[0, \epsilon_t] + \boldsymbol{\gamma}' \boldsymbol{x_t} + u_t, \tag{3}$$

The results in Figure 9 suggest that positive monetary shocks (monetary tightenings) are more powerful than negative monetary shocks (monetary loosenings), especially for GDP and consumption. This finding is in line with those in Barnichon et al. (2017) and Debortoli et al. (2020). The effects of monetary tightenings and loosenings on inflation and investment are, however, not so distinguishable between the two states.

We next investigate the distributions of monetary shocks. Previously, we have found that positive monetary shocks are more powerful than negative shocks. To dig deeper into this investigation, we study which phases of household indebtedness occur more commonly with positive shocks. Figure 10 shows that positive shocks are common during neither of the states. However, negative shocks appear to be more common during high household indebtedness as the mean of these shocks slides more to the negative side.

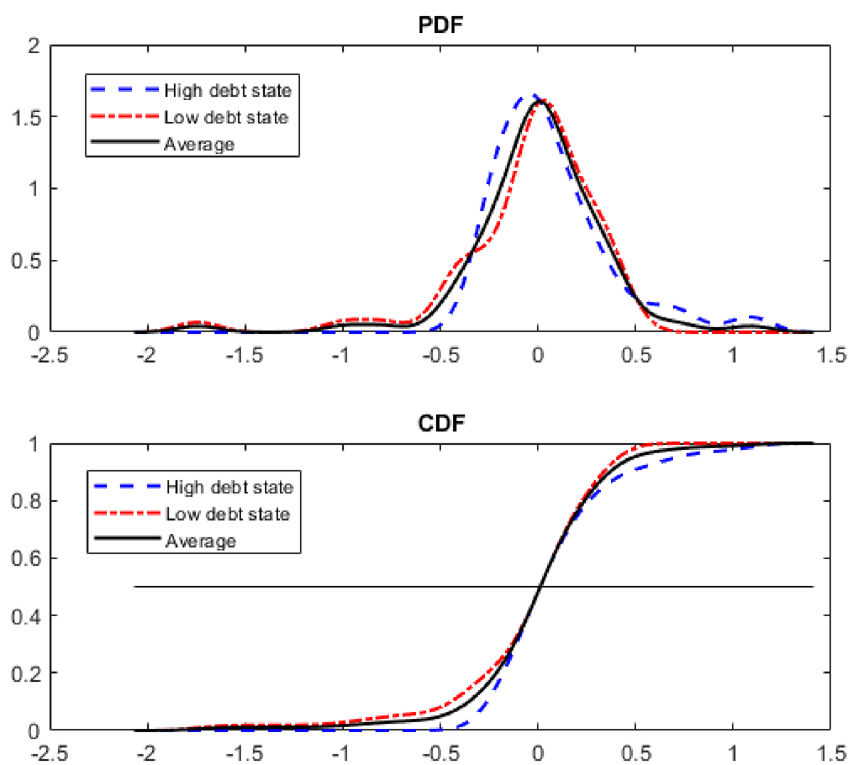

Figure 10: PDFs and CDFs of monetary policy shocks in the different regimes. Blue dashed lines show the distribution during the high-debt state. Red dash-dotted lines show the distribution during the low-debt state. Black solid lines are the average of the two debt states.

In summary, positive shocks are more powerful than negative shocks. But, this result does not explain our main finding since we find no evidence that positive shocks dominate at certain phases of household indebtedness. Instead, negative shocks appear to be more common during phases of high household indebtedness. This suggests that the frequency of the shocks during the two debt states may be more important than the sign of the shocks for explaining the reduced effectiveness of monetary policy during high household indebtedness.

4.2 Discussion

Our paper is an empirical investigation of the influence of household indebtedness on the transmission of monetary policy in Australia. We discuss our findings in light of the following questions. What does economic theory predict regarding the role of household debt in the propagation of monetary shocks? How do our empirical findings relate to these theoretical predictions?

Alpanda and Zubairy (2019) use a partial equilibrium model to analyse how a policy rate cut stimulates the spending decisions of households with high and low debt. Their model features two transmission channels of monetary policy: the debt-service channel, i.e. how a change in the policy rate affects the burden of interest payments borne by households; and the home-equity loan channel, which refers to the ability for home owners to withdraw home equity when house prices increase. The paper evaluates these two channels under fixed-rate and adjustable-rate mortgages.

For clarity, let us first abstract from the home-equity loan channel and focus exclusively on the debt-service channel. Under purely adjustable mortgage rates, a policy rate cut immediately reduces mortgage rates, and both households with high and low debt can switch to mortgage loans with cheaper rates. The effects of a cut in the policy rate on households with high and low debt are then proportional. In other words, the more indebted a household is, the more it benefits from the interest rate cut. The debt-service channel thus makes monetary policy more effective when household debt is high. Moreover, this channel gets stronger as adjustable-rate mortgage dominates.

The home-equity loan channel, instead, dampens the efficacy of monetary policy as household indebtedness rises. The reason is the following: Despite the fact that a policy rate cut lowers mortgage rates and increases house prices, highly indebted households are unable to access home-equity loans due to their existing high debt. Put differently, the home-equity channel amplifies the stimulative effects of a policy rate cut only for households with low levels of debt. This channel vanishes at high aggregate levels of household indebtedness. Moreover, the strength of this channel does not hinge on whether mortgage rates are fixed or adjustable. Rather, it depends positively on the widespread availability of home-equity withdrawal facilities, and on the sensitivity of house prices to monetary policy.

Whether household indebtedness amplifies or dampens the effectiveness of monetary policy would thus depend on which of these two channels dominates. If the debt-service channel prevails, monetary policy would become more effective as household debt increases. If instead, the home-equity channel predominates, monetary policy would be more powerful when household debt is low.

Alpanda and Zubairy (2019) calibrate their partial-equilibrium model to the US context, where long-maturity fixed-rate mortgages are prevalent and equity-withdrawal facilities are widely diffused. Their model simulations show that a policy rate cut has a greater stimulative effect on households with low debt than on more highly indebted households. In other words, their calibrated model predicts that the home-equity channel is stronger than the debt-service channel in the US. As a result, monetary policy is more effective when household debt is low. This theoretical prediction is consistent with their empirical findings, based on a state-dependent local projection model, for the US.[16]

Our empirical findings suggest that the effects of monetary policy in Australia are reduced when households are highly indebted. Our results are consistent with the empirical findings of Alpanda and Zubairy (2019) for the US. In Australia, however, most mortgage loans have variable rates. Historically, adjustable-rate mortgages have accounted for around 85% of all mortgage loans in Australia. Under adjustable-rate mortgages, the theoretical model of Alpanda and Zubairy (2019) reveals that the debt-service channel will be strong. However, our empirical results indicate that households with low debt benefit the most from a policy rate cut, suggesting that the home-equity channel actually prevails over the debt-service channel. Presumably, Australian households with high debt experience substantial difficulties to access home-equity loans or cheaper funding sources after a mortgage-rate decline. This view is in line with Schwartz et al. (2010) who find that Australian households with high debt, measured by the loan to value ratio (LVR), face constraints against further borrowing or home equity withdrawals.

5 Robustness tests

We examine the robustness of our findings with respect to: 1) alternative measures of household debt; 2) a different value of the HP filter's smoothing parameter to construct the debt-gap state variable; 3) including additional controls in the state-dependent local projection model, especially foreign variables to account for the small-open-economy nature of the Australian context.

[16] Alpanda et al. (2021) consider a simpler version of the partial-equilibrium model which only features the debt-service channel. They use data from 18 OECD countries to calibrate their model. They find that monetary policy is more effective when household debt is high.

5.1 Alternative measures of household indebtedness

In our baseline specification, we have employed the household debt-to-GDP ratio to measure household indebtedness. Here, we want to assess whether our key result, i.e. Australian monetary policy is less effective when households are highly indebted, is robust to using alternative measures of household indebtedness. We consider the following two measures that have been proposed in the literature: i) the household-debt-to-household-disposable-income ratio, and ii) the household-debt-to-household-asset ratio.[17] We repeat the same econometric procedure as in the baseline: We apply the HP filter (with $\lambda = 10^4$) to each measure of indebtedness to construct the debt-gap and its associated binary state variable. We then re-estimate the non-linear local projection model for each measure of the state variable. In the Appendix, Figures A3 and A4 show the two ratios along with their trends, and Figures A5 and A6 display the corresponding debt-gaps.

Figure 11 displays the impulse responses of key macroeconomic indicators to a monetary shock, in the high- and low-debt states, obtained with the two indebtedness measures. Figure 12 reports the responses of sub-components of consumption and investment. In both figures, the first column shows the findings based on the debt-to-income ratio, while the second column reports the results for the debt-to-asset ratio.

The results based on the debt-to-income ratio are nearly identical to our baseline results. In particular, the responses of GDP, consumption (especially of durable goods), residential investment, and house prices to a monetary shock are significantly larger in the low-debt state than in the high-debt state.

[17]Kearns et al. (2021) and Debelle (2004) assess the riskiness of household indebtedness in Australia. Kearns et al. (2021) focus on the household debt-to-income ratio, while Debelle (2004) favors the household debt-to-asset ratio, which compares two stock variables and provides a balance-sheet perspective. In both cases, the higher the ratio, the higher the risk of default.

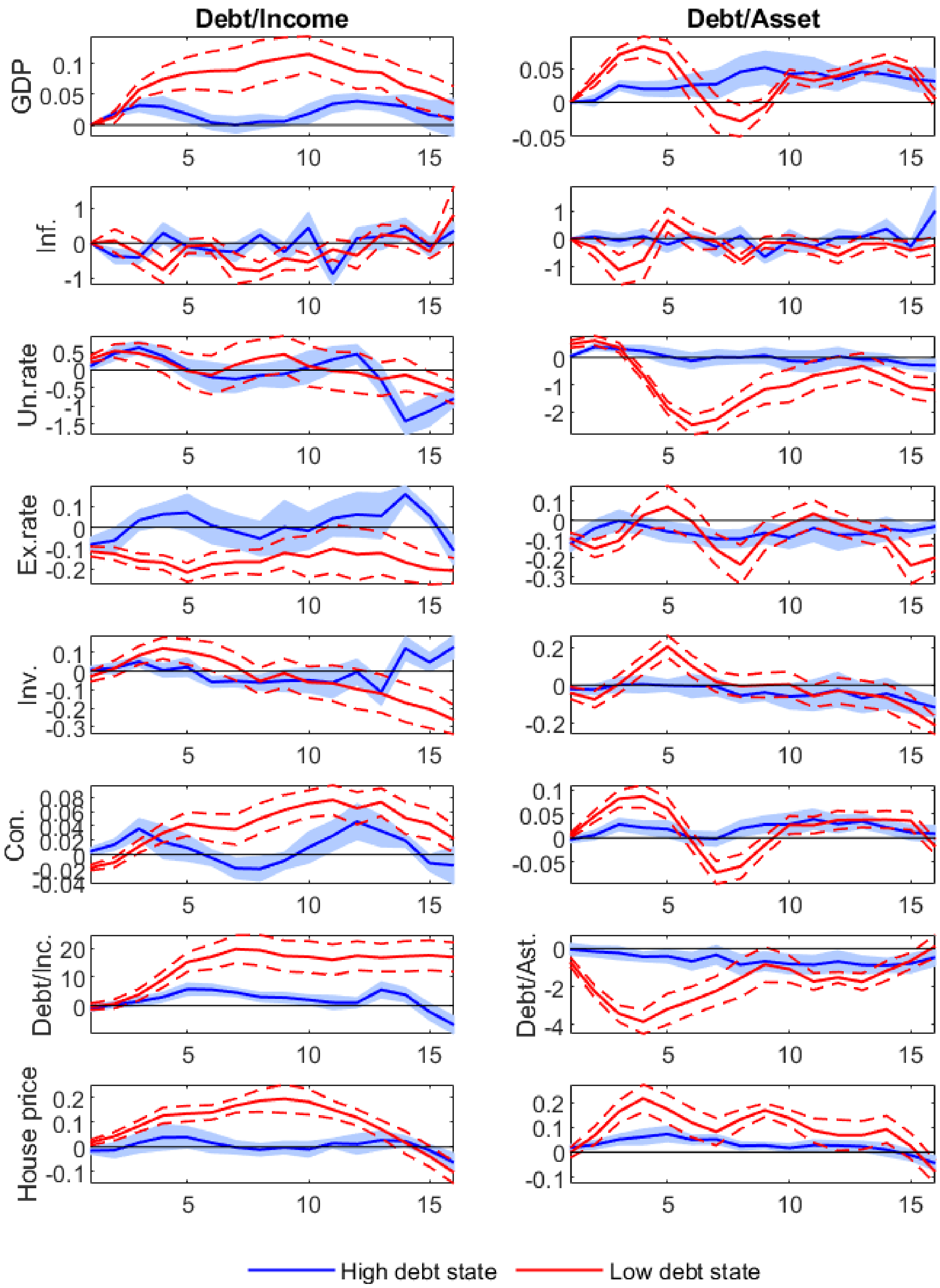

Figure 11: Impulse responses of key macroeconomic indicators to a monetary shock that decreases the cash rate by 1 percentage point. In the first column, the state variable is based on the debt-to-income ratio; In the second column, it is based on the debt-to-asset ratio. Blue lines (red lines) depict median responses to a shock in the high-debt (the low-debt) state. Dashed lines and shaded bands represent 96% point-wise confidence intervals.

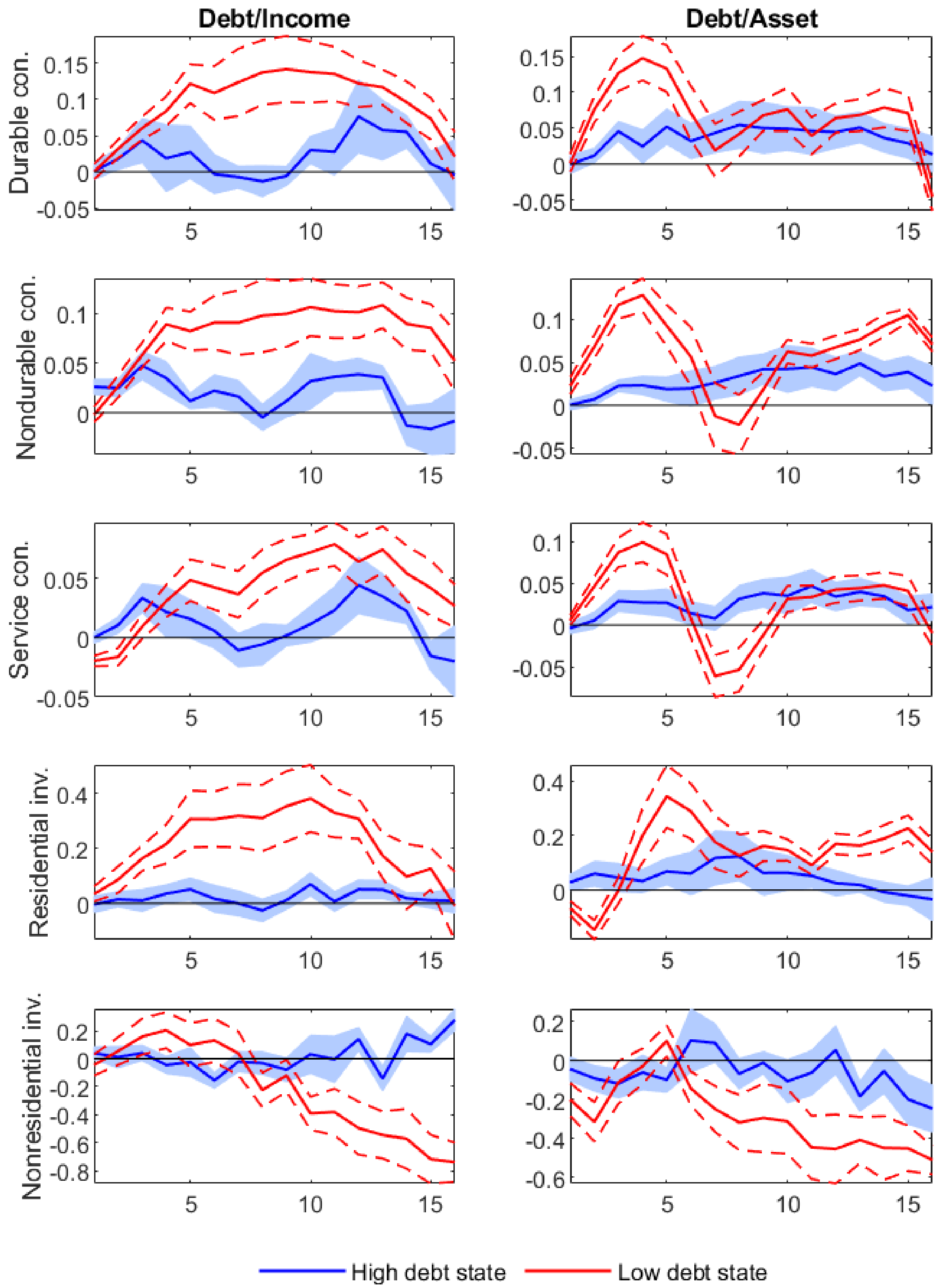

Figure 12: Impulse responses of subcomponents of consumption and investment to a monetary policy shock that decreases the cash rate by 1 percentage point. In the first column, the state variable is based on the debt-to-income ratio. In the second column, it is based on the debt-to-asset ratio. Blue (red) lines depict median responses to a shock in the high-debt (the low-debt) state. Dashed lines and shaded bands represent 96% point-wise confidence intervals.

The results obtained with the debt-to-asset ratio are, qualitatively, broadly similar to our baseline results. We still find significantly different dynamic responses across the low- and the high-debt states, with low-debt responses displaying greater magnitude than their high-debt counterparts. Even though low-debt responses are less persistent than in the baseline, we still observe that the stimulative effects on GDP, consumption and house prices of a cash rate cut are more powerful at low levels of indebtedness. Though, in contrast to our baseline findings, a policy-rate cut now generates a reduction in indebtedness, as measured by the debt-to-asset ratio. This fall is most remarkable in the low-debt state, as house prices are then more responsive to the monetary easing.

5.2 Alternative value of the HP filter's parameter

We now check the robustness of our results to changing the value of λ, the HP filter's parameter, when constructing the debt-gap. In the baseline case, we obtained the debt-gap by HP-detrending the debt-to-GDP ratio using $\lambda = 10^4$. We now set $\lambda = 1600$. Figure A7 and A8 in the Appendix show the effects of varying λ on the trend and debt-gap respectively. For completeness, we also HP-detrend the debt-to-income and debt-to-asset ratios (introduced in the previous robustness check) with $\lambda = 1600$. Figure 13 displays the impulse responses obtained with $\lambda = 1600$. The first column shows the responses for the debt-to-GDP ratio, the second and third columns report the results for the debt-to-income and debt-to-asset ratios respectively. For all cases, we find that GDP, consumption, and house prices react more to monetary policy in the low-debt state. The responses of the unemployment rate and investment are not robust to setting $\lambda = 1600$ when the state variable is based on the debt-to-income ratio. Other than this, the responses are in line with the baseline case.

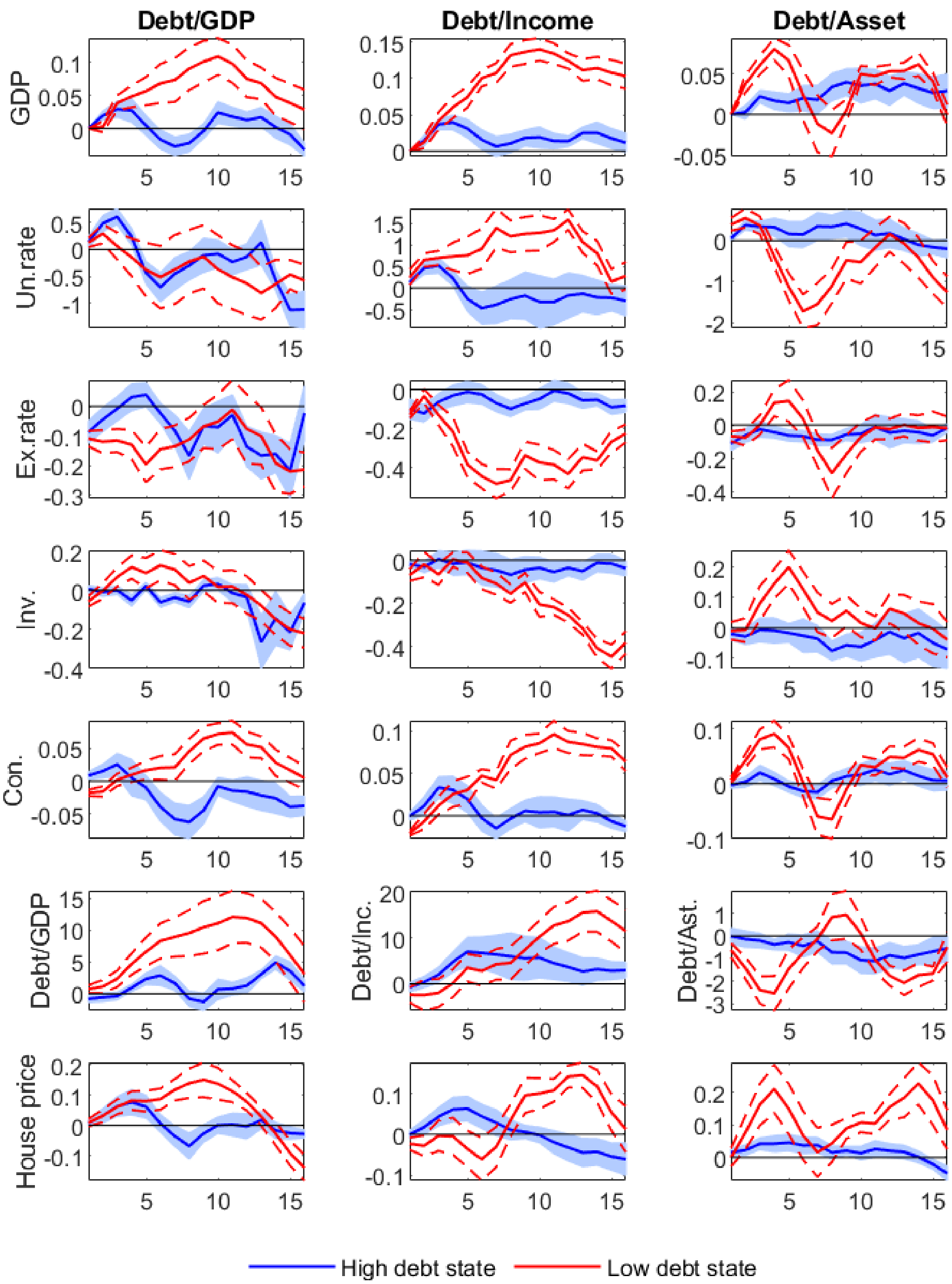

Figure 13: Impulse responses of key macroeconomic indicators to a monetary policy shock that decreases the cash rate by 1 percentage point. The debt-gap is constructed using $\lambda = 1600$ in the HP filter. In the first column, the state variable is based on the debt-to-GDP ratio; In the second and third column, it is based on the debt-to-income and debt-to-asset ratios, respectively. Blue (red) lines depict median responses to a shock in the high-debt (the low-debt) state. Dashed lines and shaded bands represent 96% point-wise confidence intervals.

5.3 Controlling for key global variables

We now assess the sensitivity of our baseline results to the inclusion of additional control variables into our state-dependent local projection model. Motivated by arguments put forth by Brischetto and Voss (1999) and Dungey and Pagan (2000) among others, we select three key global variables to account for small-open-economy aspects that are crucial to the Australian context. We simultaneously add the following explanatory variables to our model: oil prices (measured by the West Texas Crude Oil index), the World Industrial Production index constructed by Baumeister and Hamilton (2019) to proxy for global economic activity, and the Global Financial Cycle estimated by Miranda-Agrippino and Rey (2020) to capture the influence of US monetary policy on global funding costs.[18] Figure 14 presents the impulse responses when we control for these three global variables.[19] The differences between impulse responses across the two debt-states are less striking than in the baseline. However, we still observe that the responses of GDP, consumption, house prices and the debt-to-GDP ratio are larger in the low-debt state than in the high-debt state.

[18]Dungey and Pagan (2000) and Brischetto and Voss (1999) estimate small-open-economy SVAR models to quantify the aggregate effects of monetary policy in Australia. Miranda-Agrippino and Rey (2020) exploit a world-wide cross section of risky asset prices to estimate a global common factor dubbed the Global Financial Cycle. They show that US monetary policy is the main determinant of the Global Financial Cycle.

[19]With these additional controls, we cut the lag-order of the local projection model down to $L = 2$, instead of $L = 3$ in the baseline specification.

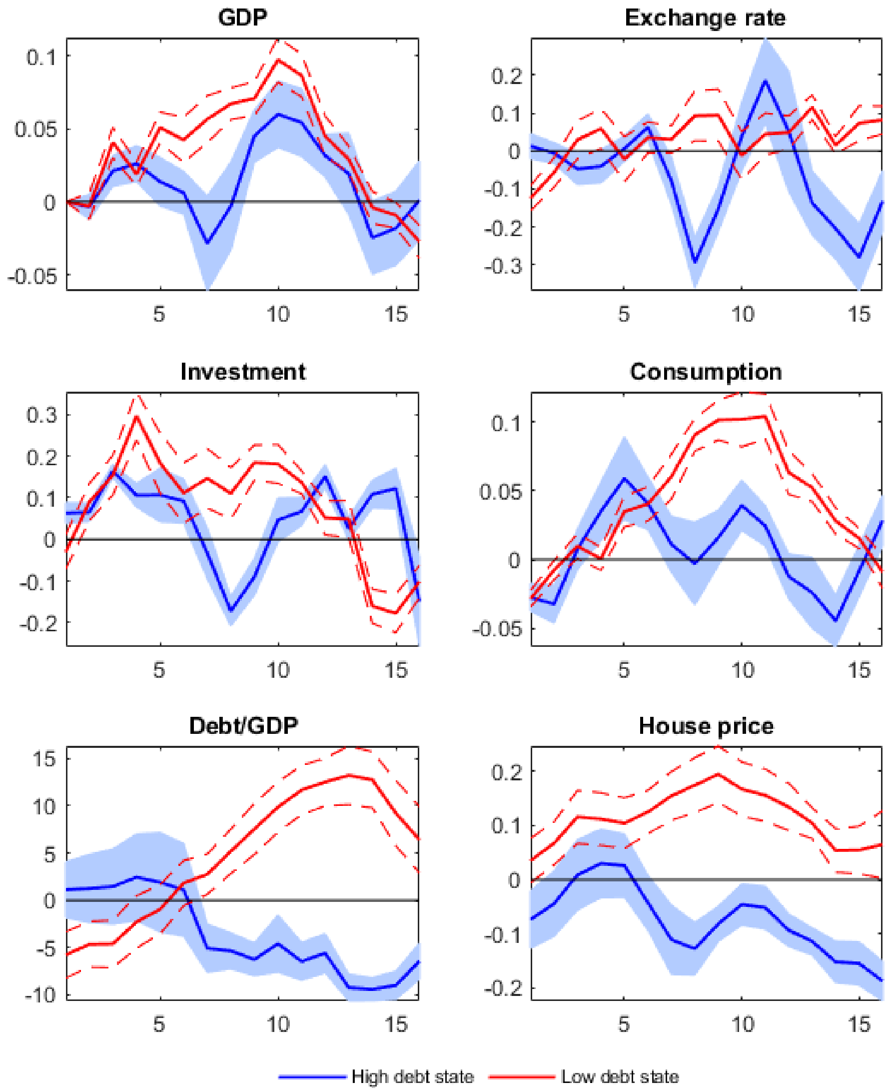

Figure 14: Impulse responses of Australian macroeconomic indicators to a monetary policy shock that decreases the cash rate by 1 percentage point. The model features three global variables as additional controls. The state variable is based on the debt-to-GDP ratio, as in the baseline. Blue (red) lines depict median responses to a shock in the high-debt (the low-debt) state. Dashed lines and shaded bands represent 96% point-wise confidence intervals.

6 Conclusion

Over the last two decades, the evolution of household indebtedness has captured the attention of Australian policymakers as a major risk to financial stability, e.g. Debelle (2004) and Kearns et al. (2021). In this paper, we contribute to the discussion of the stakes for the Australian economy of rising household debt. We estimate a state-dependent local projection model over the period 1994 to 2019 to uncover the influence of household debt on the transmission channels of monetary policy in Australia. Our study provides new empirical evidence showing that monetary policy loses some of its effectiveness when household indebtedness is elevated: In particular, the responses of GDP, consumption and house prices to monetary shocks become more muted. Our findings suggest that households with low debt benefit more from a surprise cut in the cash rate than highly-indebted households do. While an expansionary monetary shock reduces the interest burden for all borrowers, highly-indebted households may be unable to obtain home-equity loans. This view is consistent with Schwartz et al. (2010) who find that Australian households with high debt face constraints against further borrowing or home equity withdrawals. Thus, from 1994 to 2019 in Australia, the home-equity channel of monetary policy seems to have prevailed over the debt-service channel.

Our findings provide novel insights into the role of household debt in the transmission of monetary policy. During periods of elevated household indebtedness, as conventional monetary policy loses traction, the Reserve Bank of Australia should be ready to resort to unconventional monetary policy tools and macro-prudential policies to achieve its goals.

Appendix

A1 Data sources

Variable	Source and code
Augmented Romer and Romer shock	Beckers (2020), Nguyen and La Cava (2020)
Cash rate	RBA
Consumption	ABS, A2304081W
Durable consumption	ABS, author's calculation
Non-durable consumption	ABS, author's calculation
Service consumption	ABS, author's calculation
GDP	ABS, A2304402X
GDP price deflator (2015=100)	FRED
Global financial cycle	Miranda-Agrippino and Rey (2020)
Household debt-to-gdp ratio	Trading economics
Household debt-to-income ratio	RBA, BHFDDIT
Household debt-to-asset ratio	RBA, BHFDA
House prices (Real residential prop. price index for AU)	FRED
Inflation (CPI inflation, q-to-q, exl. volatile items)	ABS, A2330845W
Investment (Private, fixed capital formation)	ABS, A2304100T
Residential investment	ABS, author's calculation
Non-residential investment	ABS, author's calculation
Oil price (WTI spot price)	FRED
Trade-weighted index (in real terms)	RBA, FRERTWI
Unemployment rate (Aged 15-64)	FRED
World industrial production index	Baumeister and Hamilton (2019)

Table A1: Data sources

A2 The correlation analysis between the household debt gap and the GDP gap

	Household debt gap	
	$1977Q1 - 2020Q4^*$	$1994Q1 - 2019Q3^\dagger$
GDP gap, HP trend with $\boldsymbol{\lambda = 10^4}$	0.06	−0.01
GDP gap, HP trend with $\boldsymbol{\lambda = 1600}$	0.01	−0.09
GDP gap, Linear trend	0.14	0.15

* Entire sample period

† Sample period for model estimation

Table A2: The correlation between the household debt gap and the GDP gap. The household debt gap is displayed in Figure 5. The GDP gap is obtained from different trends for the comparison purpose.

A3 Sentiment measures for Australia

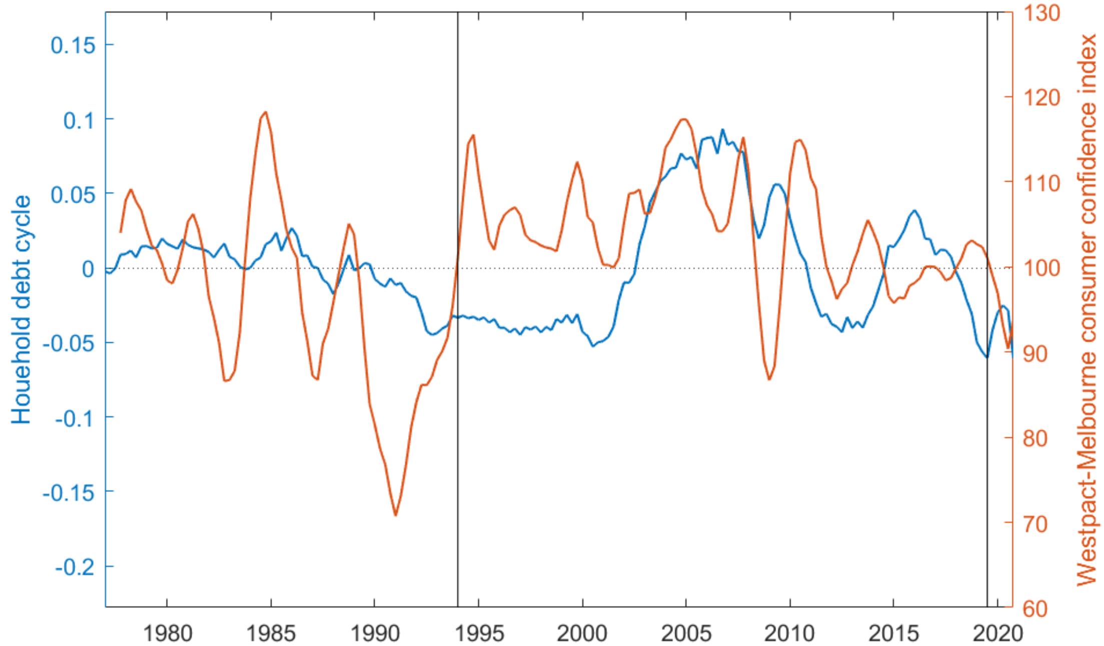

Figure A1: Household debt cycle and Westpac-Melbourne consumer confidence index. Blue line: household debt cycle. Orange line: Westpac-Melbourne consumer confidence index (4-quarter moving average). Sample: 1977Q1–2020Q4. Two vertical lines: sample for model estimation, 1994Q1–2019Q3.

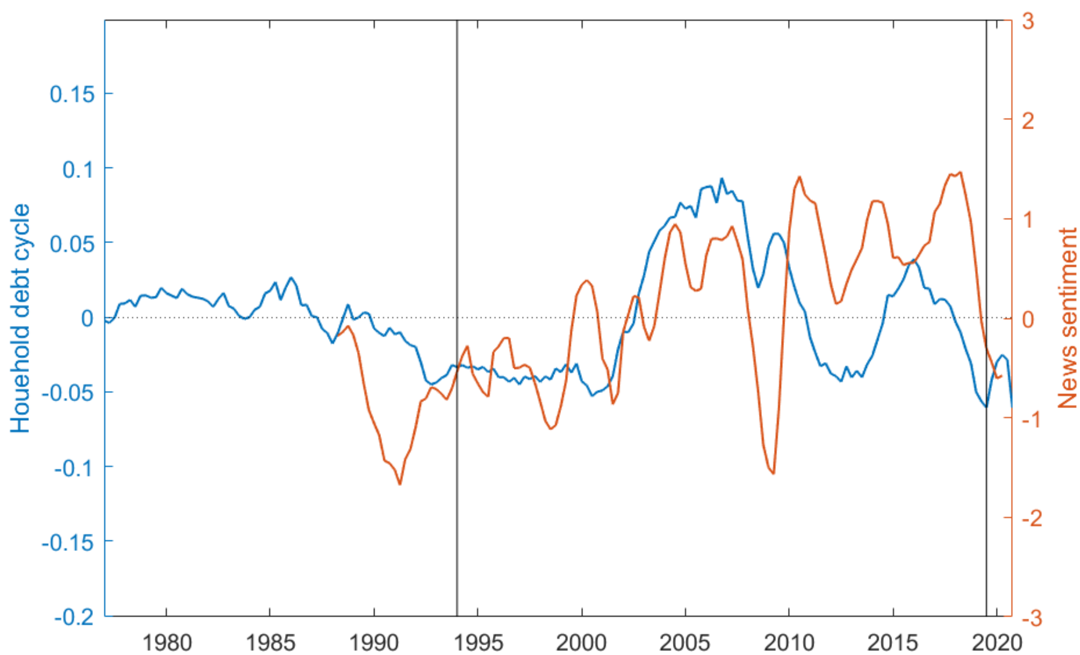

Figure A2: Household debt cycle and News sentiment index for Australia. Blue line: household debt cycle. Orange line: news sentiment index (4-quarter moving average)(Nguyen and La Cava, 2020). Sample: 1977Q1–2020Q4. Two vertical lines: sample for model estimation, 1994Q1–2019Q3.

A4 Romer and Romer regression for Australia

The Taylor-type regression is directly from Beckers (2020). The regression follows the methodology used by Romer and Romer (2004) and estimates the Australian version of Romer and Romer monetary policy shocks.

$$\Delta cr_t = \alpha + \rho_1 cr_{t-1} + \mathbf{Y}^{fc}_{t+h|t}\boldsymbol{\beta} + \mathbf{CS}_t\boldsymbol{\gamma} + m_t$$

where Δcr is the change in the cash rate at the RBA Board meeting in month t, cr_{t-1} is the cash rate prior to the meeting, $\mathbf{Y}^{fc}_{t+h|t}$ is a vector of variables that contains the RBA's h-quarters ahead macroeconomic forecast, and $\mathbf{CS}_t$ is credit market spread (the spread between large business lending rate and 3-month BAB rate) at the time of the meeting. The residual, $\hat{m}_t$, from equation (3) is the augmented RR shock. The residual, $\hat{m}_t$, is a monthly series. Following Coibion et al. (2017) and Romer and Romer (2004), we sum the estimated residual, $\hat{m}_t$, within each quarter to convert it to a quarterly series. Figure 6 in the main text shows the quarterly Augmented Romer and Romer monetary shocks.

A5 Figures for Section 5.1

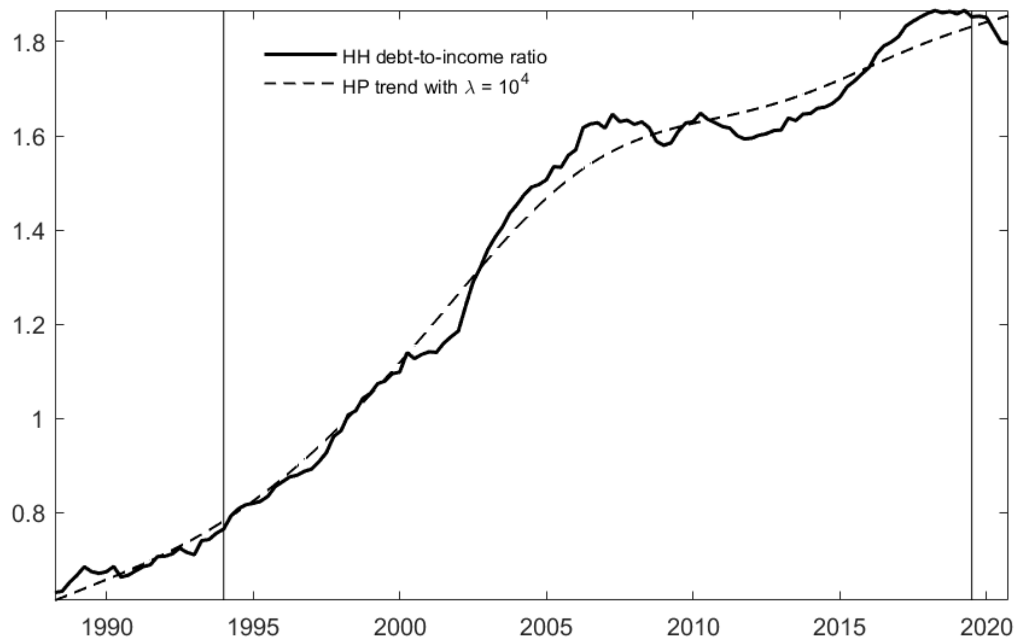

Figure A3: The household debt-to-income ratio. Sample: 1988Q1–2020Q4. Solid line: the household debt-to-income ratio. Dashed line: a HP trend with $\lambda = 10^4$. Two vertical lines: subsample for the model estimation, 1994Q1–2019Q3.

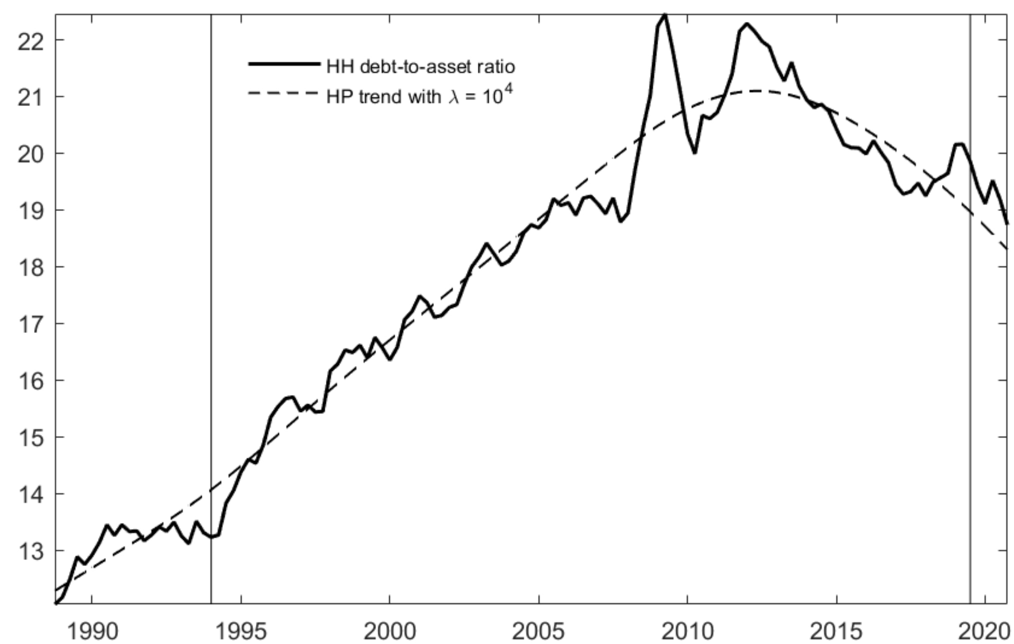

Figure A4: The household debt-to-asset ratio. Sample: 1988Q3–2020Q4. Solid line: the household debt-to-asset ratio. Dashed line: a HP trend with $\lambda = 10^4$. Two vertical lines: subsample for the model estimation, 1994Q1–2019Q3.

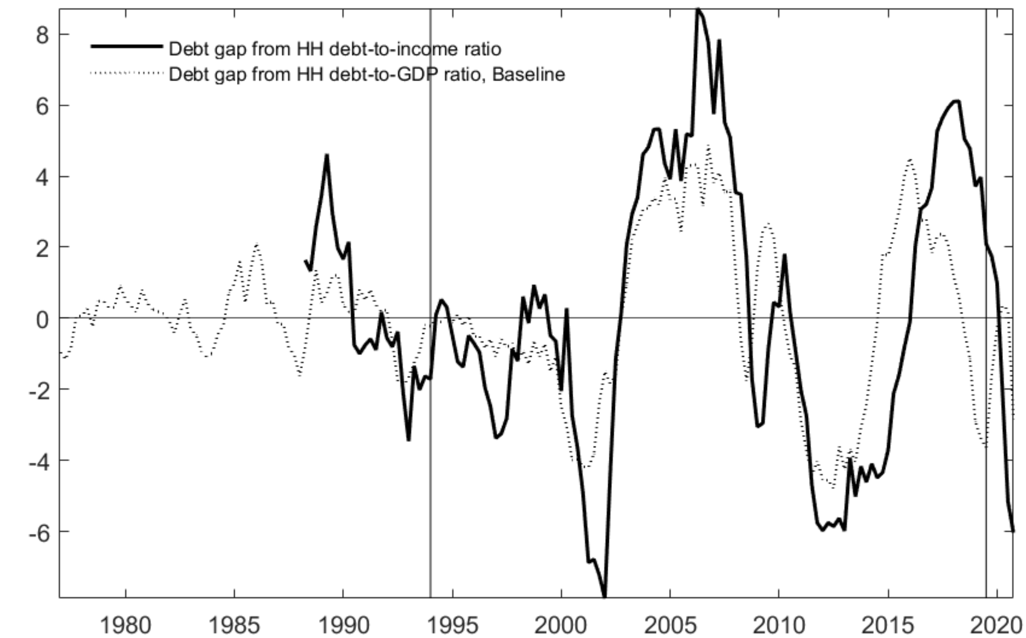

Figure A5: The debt gap from the household debt-to-income ratio when $\lambda = 10^4$. Solid line: the debt gap from the household debt-to-income ratio. Dotted line: the debt gap from the household debt-to-GDP ratio. Two vertical lines: subsample for the model estimation, 1994Q1–2019Q3.

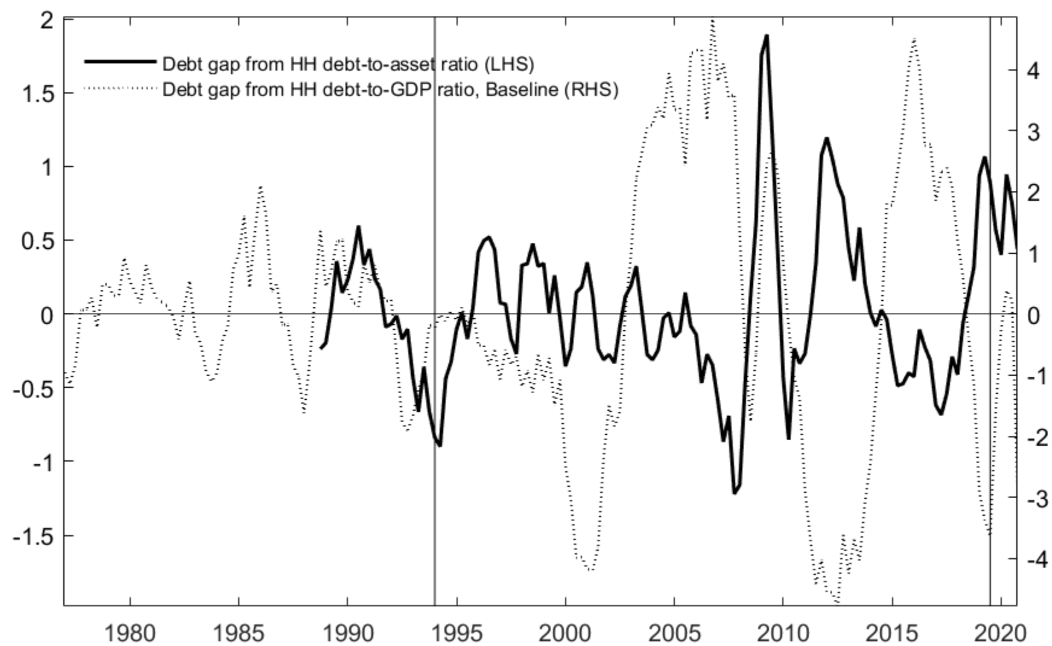

Figure A6: The debt gap from the household debt-to-asset ratio when $\lambda = 10^4$. Solid line: the debt gap from the household debt-to-asset ratio. Dotted line: the debt gap from the household debt-to-GDP ratio. Two vertical lines: subsample for the model estimation, 1994Q1–2019Q3.

A6 Figures for Section 5.2

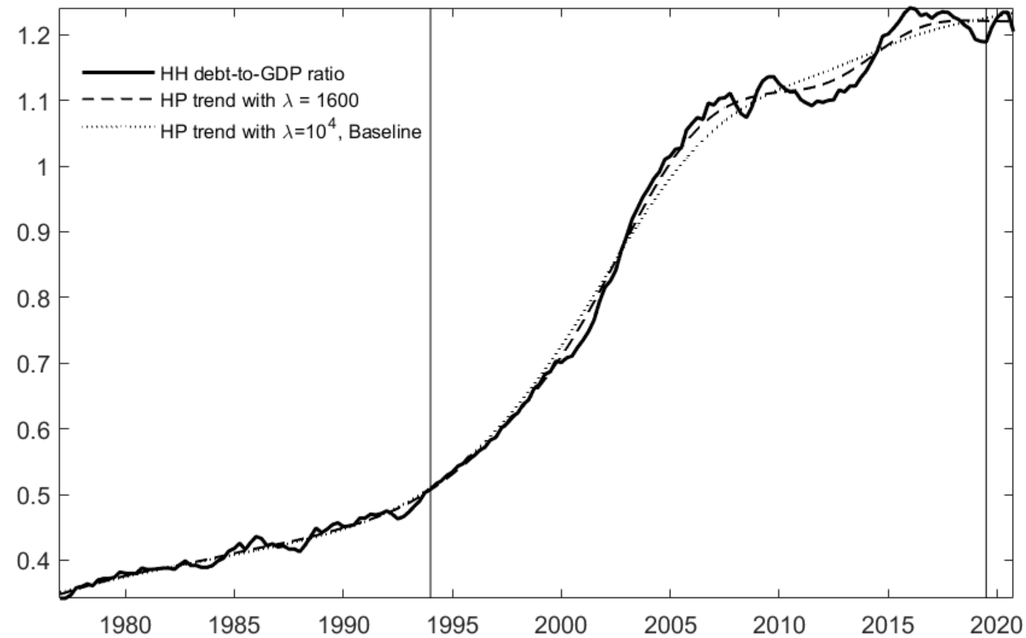

Figure A7: The household debt-to-GDP ratio and a HP trend with $\lambda = 1600$. Sample: 1977Q1–2020Q4. Solid line: the household debt-to-GDP ratio. Dashed line: a HP trend with $\lambda = 1600$. Dotted line: a HP trend with $\lambda = 10^4$. Two vertical lines: subsample for the model estimation.

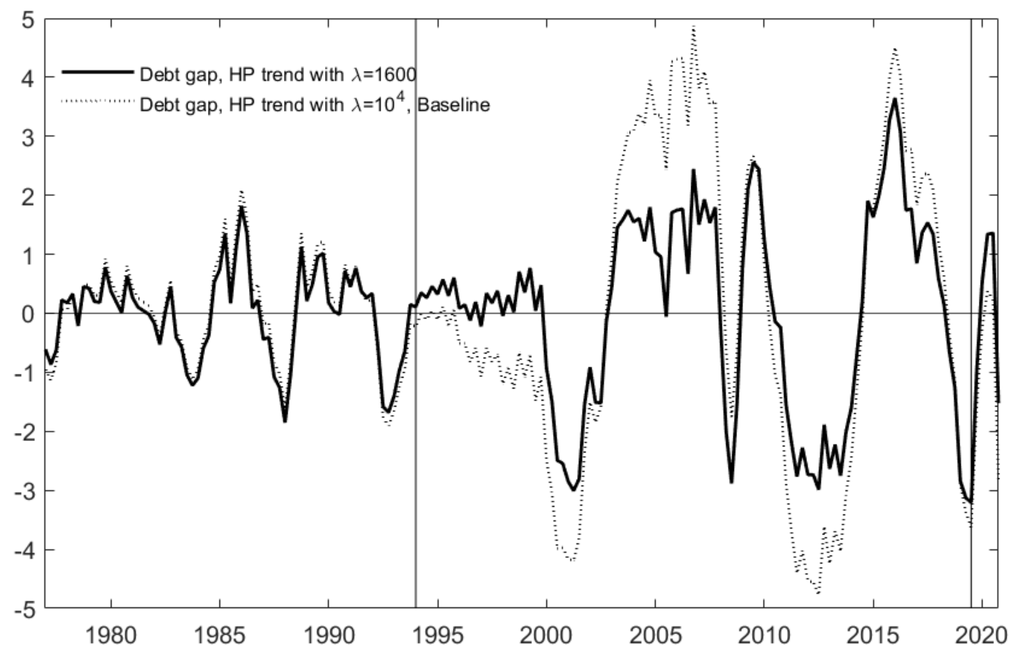

Figure A8: The debt gap from the household debt-to-GDP ratio. Solid line: the debt gap from the household debt-to-GDP ratio under a HP trend with $\lambda = 1600$. Dotted line: the debt gap from the same ratio under a HP trend with $\lambda = 10^4$. Sample: 1977Q1–2020Q4. Two vertical lines: subsample for the model estimation.

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Principal Author

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Contribution to the Paper	Matlab coding, data collection, model estimation, produced all results, review of literature, contributed to writing of the paper		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	10 January 2023

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Nicolas Groshenny		
Contribution to the Paper	Designing the research question, checked all results, contributed to results interpretation, contributed to writing of the paper		
Signature		Date	16 January 2023

Please cut and paste additional co-author panels here as required.

Chapter 2

Does the effectiveness of monetary policy in Australia depend on the pace of economic growth?

Khuderchuluun Batsukh* and Nicolas Groshenny†

Abstract

We investigate whether the pace of economic growth influences the transmission of monetary policy shocks in Australia. We first define two states of the Australian economy, strong-growth versus weak-growth phases, by identifying local peaks and troughs in the cyclical component of Australia's real GDP over the period 1990–2019. We then estimate a smooth-transition local projection model to measure the extent to which the effects of monetary policy shocks vary across the two growth-pace states. Our results show that monetary policy is less effective in slow-growth phases.

Keywords: Monetary policy, state dependence, local projections, Australian economy.

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1 Introduction

Does the pace of economic growth influence the effectiveness of monetary policy? We tackle this question for the case of Australia. We provide new empirical evidence on state-dependent effects of monetary policy.

Several studies, including Caggiano et al. (2014), Mumtaz and Surico (2015), Tenreyro and Thwaites (2016), Alpanda et al. (2021), document that the effectiveness of monetary policy to stimulate the economy is limited during recessions. The vast majority of existing research on the the state dependence of monetary policy concentrates on the United States. For other advanced economies, including Australia, similar studies are fairly limited or do not exist.

In this paper, we examine two issues: (1) identifying slow-growth and fast-growth states of the Australian economy; (2) assessing the dependency of the effects of monetary policy with respect to these two states.[1] Business-cycle states can be defined in many ways. Canova (1999) forcefully argues that one should not rely on a single approach. We identify strong-growth and weak-growth periods in Australia by following the approach proposed by Cashin and Ouliaris (2004). We then estimate a smooth-transition local projection model (STLP) to explore the state-dependent effects of monetary policy shocks in Australia over the period 1991–2019. STLP models combine the local projections of Jordà (2005) and the smooth-transition regression method of Granger and Terasvirta (1993). STLP models offer a convenient approach to estimate state-dependent impulse responses allowing for potential state-transition after the shock.[2] We find that monetary policy shocks have more powerful effects when the economy is in a strong-growth state. Our findings are relevant for designing monetary policy to stabilize the Australian economy. If a change in the cash rate has limited ef-

[1]We use the expressions "strong vs weak" and "fast vs slow" interchangeably.

[2]Tenreyro and Thwaites (2016) estimate a STLP model for the United States and find that the effects of monetary policy are less powerful in recessions.

fects during a weak-growth of the economy, then the Reserve Bank of Australia (RBA) may need to react more aggressively and be ready to deploy complementary monetary policy tools, such as quantitative easing, and longer-maturity bond rate targeting.

An increasing number of studies investigate the state-dependent effects of monetary policy shocks, employ various nonlinear methods such as causal inference (Angrist et al., 2018), nonlinear SVARs (Weise, 1999), Markov-switching models (Garcia and Schaller, 2002), smooth transition local projections (Tenreyro and Thwaites, 2016) and functional approximations (Barnichon and Matthes, 2018). These studies find that the effects of monetary policy depend on the state of the business cycle. Many of them document empirical evidence of lower effectiveness of monetary policy in bad times. Most of the evidence on the nonlinear effects of monetary policy is based on US data. For Australia, a study on the state dependent effects of monetary policy has not yet been conducted. Existing works assume that the effects of monetary policy do not depend on the state of the economy. Previous works mainly use linear SVAR models.[3]

2 The economic cycle in Australia

Before the COVID-19 pandemic, Australia had its last recession in 1991. The 1991 recession is a technical recession, which is defined as having negative rates of real GDP growth for two consecutive quarters.

In line with Cashin and Ouliaris (2004), we measure the Australian economic cycle as deviations of real GDP from its trend. We use the Hamilton (2018) filter to extract the secular component in Australia's real GDP. Then, we apply the BBQ algorithm (Bry and Boschan, 1971) to the cyclical component to determine strong and weak growth states of the economy by identifying local peaks and troughs.[4]

[3]For a survey of the Australian empirical literature on monetary policy shocks, see Beckers (2020).

[4]The algorithm automates the identification of economic cycle phases in various macroeconomic

Figure 1 shows the cyclical component of Australia's real GDP for the period 1990-2019. The shaded areas denote periods of weak economic growth, and the non-shaded areas denote periods of strong economic growth. The BBQ algorithm detects six weak growth periods between 1990 and 2019. They account for around 42 percent of the sample period. Major weak growth episodes occurred over the following periods 1994–1996, 1999–2001, 2008–2010, and 2012–2015. Natural resource prices and business investments in Australia declined significantly during these periods. Since the 1990s, resource prices and business investments have been major contributors to Australia's GDP. Their low performance is the possible driver of these weak growth episodes.[5]

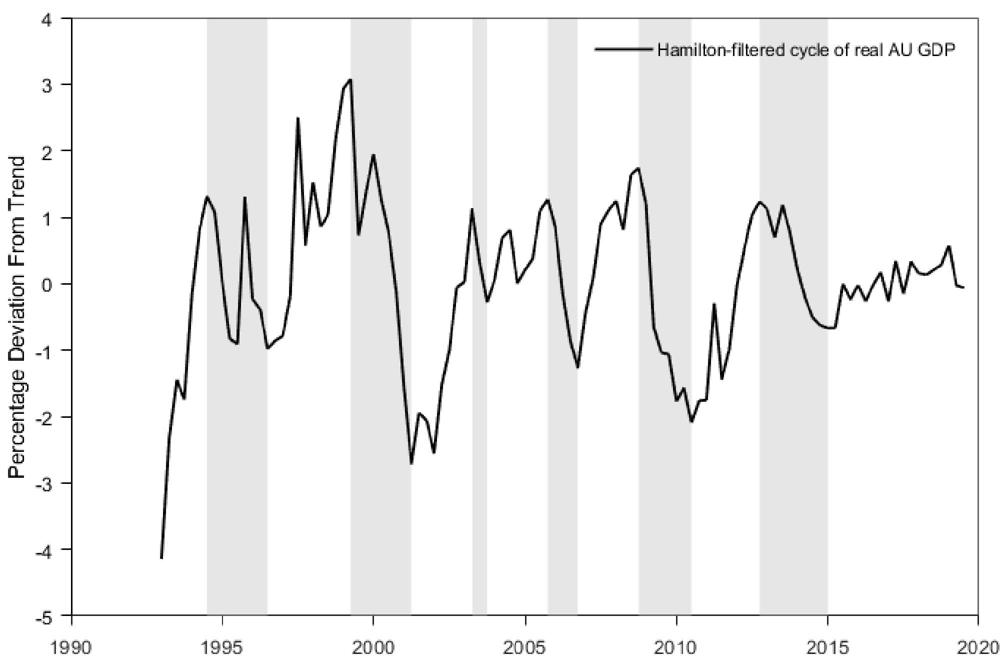

Figure 1: The cycle of real GDP in Australia. Shaded areas denote weak growth states (periods between a peak and a trough). Non-shaded areas denote strong growth states (periods between a trough and a peak). The cycle is extracted by using the Hamilton filter. Peaks and troughs are detected by the BBQ algorithm.

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series. See Harding and Pagan (2002), and Stock and Watson (2014). The algorithm is based on a pattern-recognition procedure. When applied to a noisy time series, it may mistakenly identify false turning points as peaks and troughs. To mitigate this, we use the Hamilton (2018) filter, as it produces a less noisy cycle compared to the Hodrick and Prescott (1997) filter.

[5]For the performance of resource prices and business investment and their contributions to the Australian GDP since 1990s, see Rees et al. (2016); Australian Data Chart Pack 2020 of the RBA.

3 Econometric methodology

We use the smooth transition local projection model (STLPM) of Tenreyro and Thwaites (2016) to analyse the state-dependent effects of monetary policy shocks in Australia. The model is specified as:

$$y_{t+h} = \tau t + F(z_t)(\alpha_h^e + \beta_h^e \epsilon_t + \boldsymbol{\gamma}^{\boldsymbol{e}'} \boldsymbol{x_t}) + (1 - F(z_t))(\alpha_h^c + \beta_h^c \epsilon_t + \boldsymbol{\gamma}^{\boldsymbol{c}'} \boldsymbol{x_t}) + u_t \tag{1}$$

where y_t is the variable of interest, $h \in \{0, H\}$ is the time horizon of impulse response, τ is a linear time trend, $F(z_t)$ is a smooth increasing function of the state variable z_t, α_h^j is a constant, $j \in \{e, c\}$ is the state of the economy (e denotes a strong growth, and c denotes a weak growth), β_h^j is the impulse response of y_t at horizon h in state j to a monetary policy shock ϵ_t. $\boldsymbol{\gamma}^{\boldsymbol{j}'}$ are coefficients and $\boldsymbol{x_t}$ is a vector of control variables containing one lag of the dependent variable and one lag of the cash rate (i.e. the policy rate in Australia). u_t is the error term. $F(z_t)$ is a logistic function that determines the probability that the economy is in the strong growth state in period t:

$$F(z_t) = \frac{exp(\theta \frac{z_t - c}{\sigma_z})}{1 + exp(\theta \frac{z_t - c}{\sigma_z})} \tag{2}$$

where c is a parameter that controls the proportion of the sample period during which the economy is in weak growth. σ_z is the standard deviation of the state variable z and θ is a parameter that determines how quickly the economy moves between strong growth and weak growth states when z_t changes. For each variable y_t, the impulse response β_h^j is estimated by seemingly unrelated regressions (SURE). Excluding $F(z_t)$ from equation (1), we specify a linear local projection model by as follows:

$$y_{t+h} = \tau t + \alpha_h + \beta_h \epsilon_t + \boldsymbol{\gamma} \boldsymbol{x_t} + u_t \tag{3}$$

We define z_t as the cyclical component of Australia's real GDP and set $\theta = 3$ and $c = 42$.[6] We chose $\theta = 3$ to have a moderate intensity in the switch between the two states. Higher values of θ imply that $F(z_t)$ becomes closer to a discrete regime-switching setup, $\{0, 1\}$. We set $c = 42$ to match the proportion of low growth states identified by the BBQ algorithm.[7] In the robustness check section, we assess the sensitivity of our empirical results to these choices. Figure 2 shows the function $F(z_t)$ with periods of weak growth states. $F(z_t)$ indicates the probability of a strong growth state. The figure shows that the probability of an a strong growth state decreases to zero when there is a weak growth state, while it increases during a strong growth state.

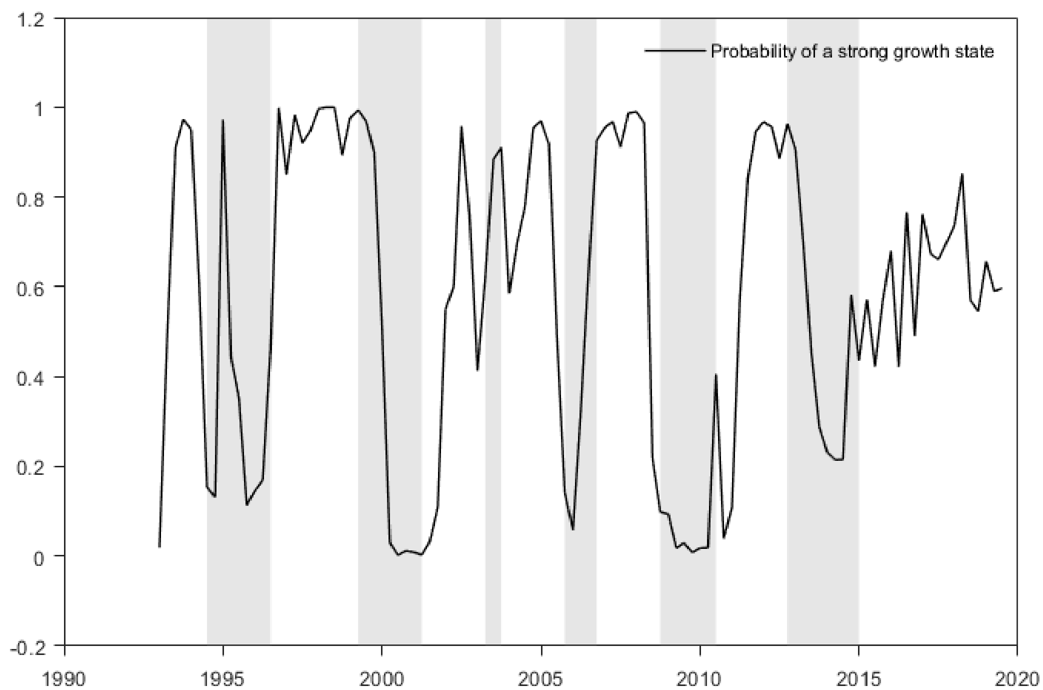


Figure 2: Probability of a strong growth state of the economy. The black line is the probability. Shaded areas denote weak growth states (periods from a peak to a trough) in the Hamilton-filtered cycle of real Australian GDP. Non-shaded areas denote strong growth states (periods from a trough to a peak). Peak and trough points are determined by the BBQ algorithm.

[6]Tenreyro and Thwaites (2016) define z_t as a seven quarter moving average of GDP growth.

[7]Auerbach and Gorodnichenko (2012) and Tenreyro and Thwaites (2016) set $c = 20$ for the US economy.

3.1 Romer and Romer monetary policy shocks for Australia

To measure monetary policy shocks, we use the series of shocks constructed by Beckers (2020) for Australia. Beckers (2020) applies the Romer and Romer (2004) approach to the Australian case.[8] Beckers (2020) estimates the following Romer and Romer regression with the Australian data:

$$\Delta CR_t = \boldsymbol{\beta}' \boldsymbol{X_t} + \epsilon_t \tag{4}$$

where ΔCR_t is the change in the cash rate at the RBA's board meeting in time t. $\boldsymbol{X_t}$ is a vector of control variables.[9] The estimated residuals $\hat{\epsilon}_t$ are the identified monetary policy shocks.

We also measure nonlinear Romer and Romer shocks for Australia. Following Tenreyro and Thwaites (2016), we extend a linear Romer and Romer regression, specified in equation (4), to a nonlinear Romer and Romer regression by adding $F(z_t)$.

$$\Delta \widetilde{CR}_t = F(z_t)\boldsymbol{\beta^{e\prime}} \boldsymbol{X_t} + (1 - F(z_t))\boldsymbol{\beta^{c\prime}} \boldsymbol{X_t} + \tilde{\epsilon}_t \tag{5}$$

where the residuals $\hat{\tilde{\epsilon}}_t$ are our nonlinearly identified Romer and Romer shocks. In our paper, we call the shock series identified from equations (4) and (5) as the linear and nonlinear Augmented Romer and Romer shocks, respectively.[10]

[8] Romer and Romer (2004) identify US monetary policy shocks as the residuals in an estimated Taylor-type reaction function. More precisely, they regress changes in the federal funds rate on the Greenbook's forecasts of inflation and output growth and nowcasts of the unemployment rate.

[9] Control variables include the cash rate prior to the meeting, the RBA's h-quarter-ahead forecasts for inflation and GDP, the revisions of the forecasts of inflation and GDP, the nowcast of the unemployment rate, and the credit spread variables (see Beckers (2020) for details).

[10] Beckers (2020) uses the credit spread variables as additional controls in his regression as motivated by Caldara and Herbst (2019) who show that credit spreads are a main determinant of US monetary policy. By adding credit spread variables into the regression, Beckers (2020) identifies monetary shocks that are more exogenous than monetary shocks from the original Romer and Romer (2004) regression. As Beckers (2020) augments credit spread variables in his regression, we call this shock as the Augmented Romer and Romer shocks in our analysis.

Figure 3 shows linear and nonlinear Augmented Romer and Romer shocks for Australia along with $F(z_t)$. The linear shocks (state independent) are the residuals from equation (4). The nonlinear shocks (state dependent) are the residuals from equation (5). The nonlinear shocks follow $F(z_t)$ with much higher correlation of around 0.12 compared to correlation between the linear shocks and $F(z_t)$, which is around 0.01. The higher correlation reflects that the nonlinear shocks are in accordance with the state of the economy.

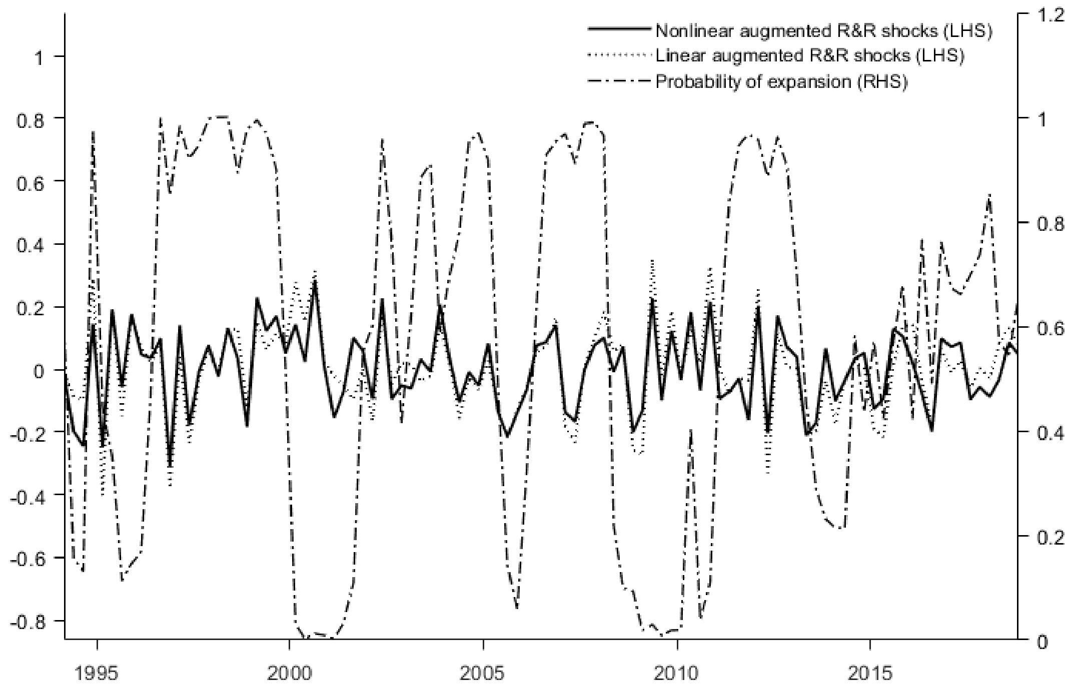


Figure 3: Linear and nonlinear Augmented Romer and Romer shocks for Australia. The linear shocks are state independent and the residuals from equation (4). The nonlinear shocks are state dependent and the residuals from equation (5). R&R shocks refers to Romer and Romer shocks.

3.2 Data

The variables for which we want to compute impulse responses consist of real GDP, the unemployment rate, CPI, durables expenditure, nondurables expenditure and services, private business investment, and the nominal exchange rate (Australian dollar trade-weighted index).[11] For model estimation, we use quarterly data for the period 1994Q1–2018Q3. The start date and the end date of our sample is determined by the availability of the Augmented Romer and Romer shocks constructed by Beckers (2020).

4 Results

Figure 4 shows the impulse responses of real GDP, underlying CPI, and the unemployment rate to a contractionary monetary policy shock that increases the cash rate by a 1 percentage point. We denote these variables as headline variables. The first column presents the impulse responses in a linear model along with the responses in strong growth and weak growth states. The impulse responses in a linear model are estimated from equation (3) with the linear Augmented Romer and Romer shocks. The second and third columns present the impulse responses in strong growth and weak growth states, respectively. The fourth column represents estimates of the $t-statistics$ testing for the difference of the impulse responses between the two states. The null hypothesis is ($\beta^{StrongGrowth} - \beta^{WeakGrowth} = 0$) with the area between ± 1.65. The interpretation of this statistical test is that, for example, if the green line for GDP in the fourth column falls below the lower bound of the shaded area at some point of horizon h, then we reject the null hypothesis that the difference of the impulse responses are equal and favor the alternative hypothesis that the impulse responses are more negative in the strong growth state at a 10 percent significance level.

[11] We construct durables expenditure, nondurables expenditure, and services from National Accounts data provided by the ABS. Private Business Investment is the difference between Gross Fixed Capital Formation and Total Private Business Investment. See Black et al. (2010).

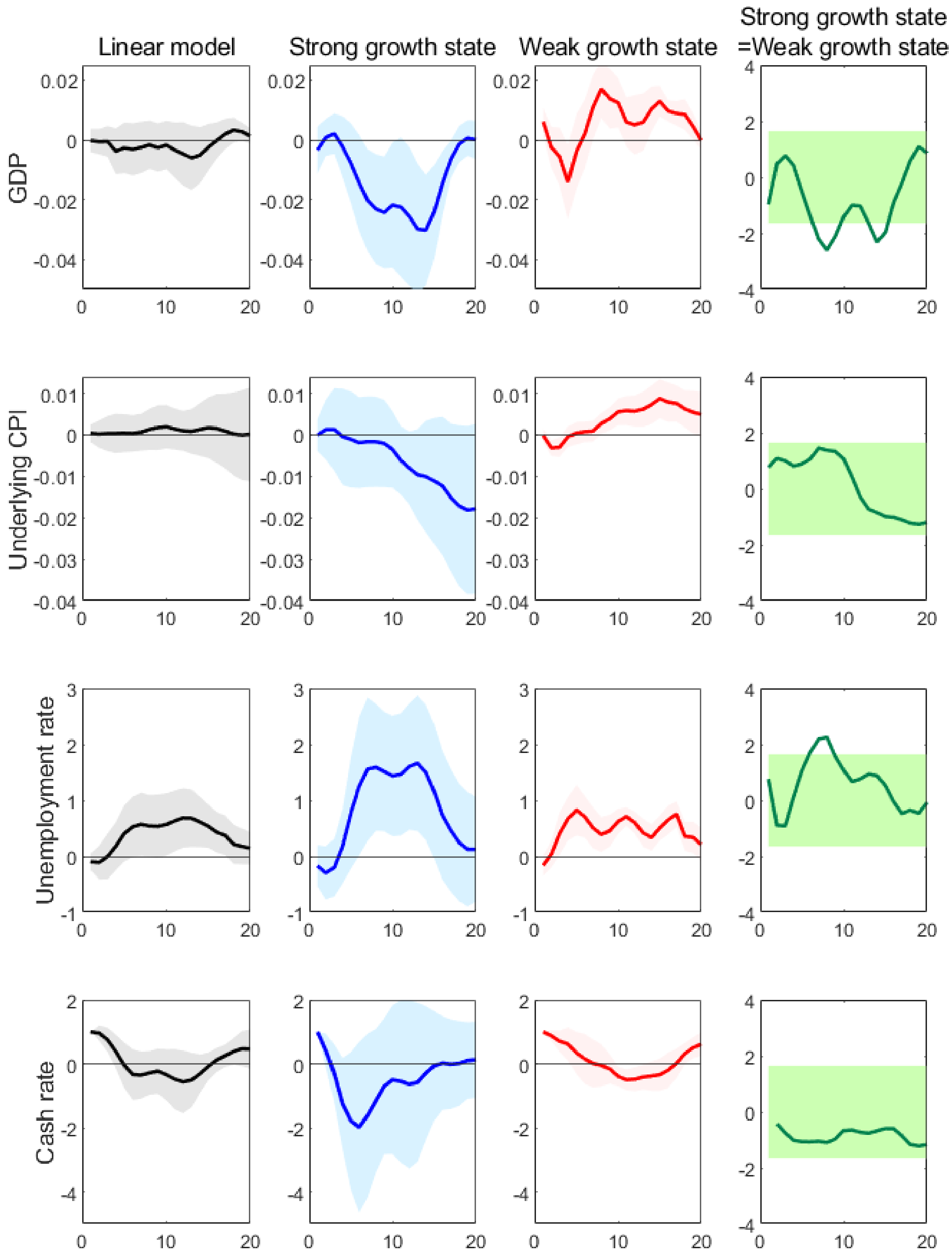


Figure 4: Impulse responses of headline variables to a monetary policy shock that increases the cash rate by one percentage point. Black lines in the first column denote median impulse responses in a linear model. Blue lines in the second column (red lines in the third column) denote median impulse responses following a monetary policy shock that occurs in the strong growth state (the weak growth state) of the economy. Shaded bands in columns 1 to 3 represent 90% point-wise confidence intervals. Green lines in the fourth column show the $t - statistics$ testing the hypothesis that the difference between the impulse responses in the two states is zero. The green line is calculated by the bootstrap method as in Tenreyro and Thwaites (2016). The shaded area is ± 1.65.

The figure shows that following a contractionary monetary policy shock, in a linear model real GDP and underlying CPI barely change and the unemployment rate rises. The responses of the three variables in a linear model are overall insignificant. In contrast to a linear model, we see a familiar picture of the impulse responses in a strong growth state (the second column). The second column shows that both real GDP and underlying CPI drop, yet the unemployment rate rises after a contractionary monetary policy shock, which standard macroeconomic theory predicts. The responses in a weal growth state (the third column) are much smaller than those in a strong growth state. In a weak growth state, we see the price puzzle. The difference between strong growth and weak growth states can be seen clearly in the first column of Figure 4. In the first column, real GDP, underlying CPI, and the unemployment rate respond more strongly in a strong growth state (blue lines) than in a weak growth state (red lines). In particular, real GDP and the unemployment rate respond more strongly in a strong growth state, with the maximum rate of responses about 3 and 2 percent, respectively. Underlying CPI is initially sticky but decreases sharply after the tenth quarter with the maximum of responses about 2 percent in a strong growth state (see Table A1(a) in the Appendix for details).

Figure 5 plots the impulse responses of durable goods expenditure, nondurable goods and services expenditure, investments, and the exchange rate to the same contractionary monetary shock as before. We denote these variables as expenditure variables in Figure 5. In line with the responses of real GDP and the unemployment rate, all four variables except nondurable goods and services expenditure respond much more in a strong growth state. After a contractionary monetary shock, both durable goods expenditure and investment decline, and the exchange rate depreciates in a strong growth state. The response of nondurable goods and services expenditure barely declines in a strong growth state and behaves similarly to the response in a linear model. The peak response of durable goods in a high growth state occurs in the eighth quarter

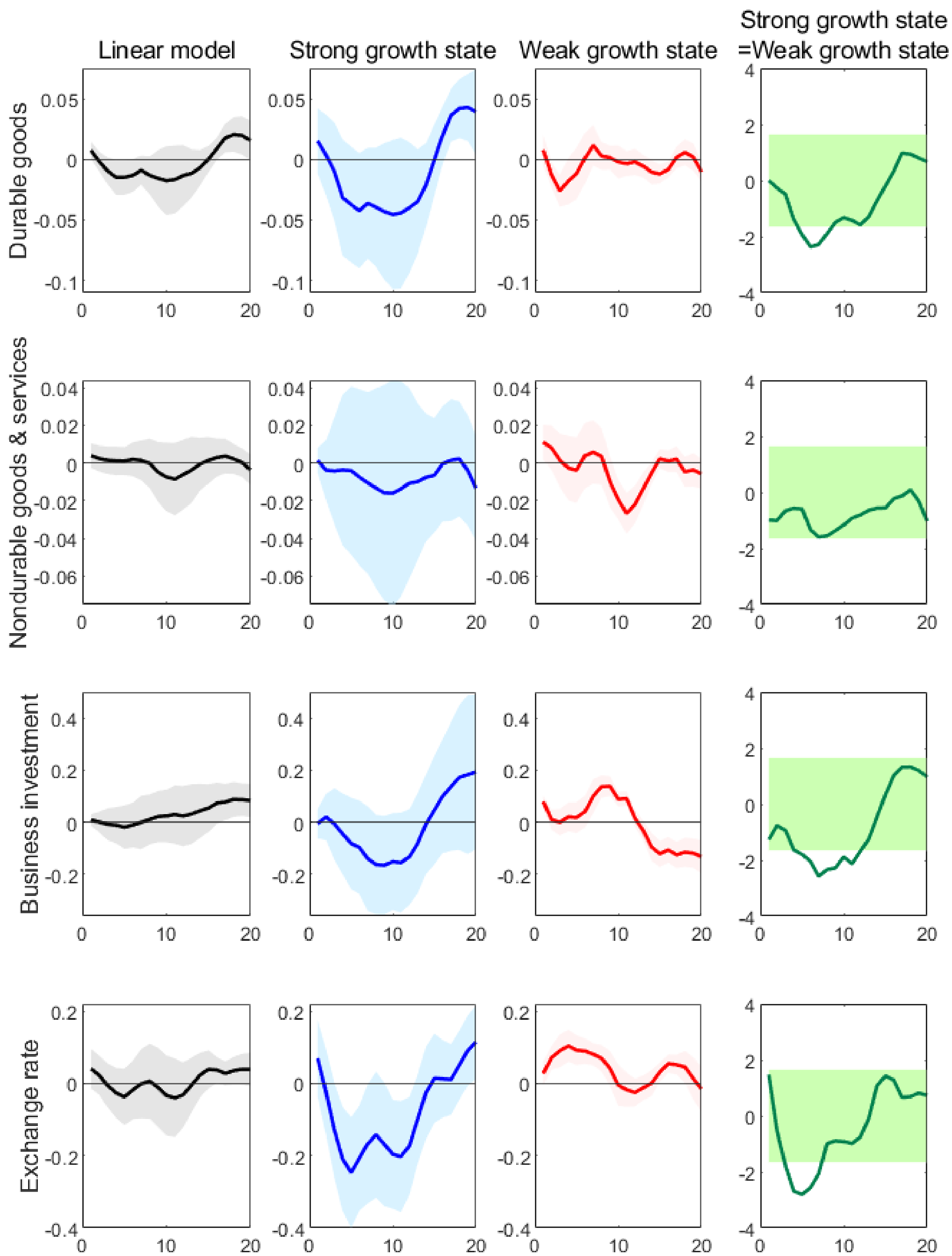


Figure 5: Impulse responses of expenditure variables to a monetary policy shock that increases the cash rate by one percentage point. Black lines in the first column denote median impulse responses in a linear model. Blue lines in the second column (red lines in the third column) denote median impulse responses following a monetary policy shock that occurs in the strong growth state (the weak growth state) of the economy. Shaded bands in columns 1 to 3 represent 90% point-wise confidence intervals. Green lines in the fourth column show the $t-statistics$ testing the hypothesis that the difference between the impulse responses in the two states is zero. The green line is calculated by the bootstrap method as in Tenreyro and Thwaites (2016). The shaded area is ± 1.65.

when it drops to about 4.3 percent, while the peak response in a weak growth state occurs in the third quarter when it drops to about 2.4 percent. The response of business investment in a strong growth state peaks around 16 percent in the quarter eight, yet in a weak growth state it has the peak response of around 12 percent in the sixteenth quarter. For the exchange rate, the maximum depreciation of about 25 percent occurs in the fifth quarter in a strong growth state, while it barely changes in a weak growth state (see Table A1(b) in the Appendix for details).

Overall, the impulse responses of the variables are in line with the findings of Tenreyro and Thwaites (2016), in particular for output, durable goods expenditure, and investment. The $t-statistics$ test suggests that the differences of impulse responses between the two states are significant for GDP, durable consumption, business investment, and the exchange rate. When the credit spreads channel of Australian monetary policy is controlled, it removes the price puzzle, which the existing Australian literature often does not resolve. This is also in line with the findings of Beckers (2020). In our analysis, the prize puzzle is removed in a strong growth state, while the response of underlying CPI is very weak both in a linear model and a weak growth state. Possible explanation behind this could be that the RBA began targeting Australian inflation from the early 1990s. Since the implementation of this target, the Australian price level has been stable at around 2–3 percent.

4.1 Asymmetric effects of monetary policy shocks

We investigate whether the sign of monetary policy shocks matters in explaining the reduced effectiveness of monetary policy shocks during slow-growth phases. Following Tenreyro and Thwaites (2016), we estimate β_h^+ and β_h^- for $h = 0, 1, 2, ..., 20$

from the following equation:

$$y_{t+h} = \tau t + \alpha_h + \beta_h^+ max[0, \epsilon_t] + \beta_h^- min[0, \epsilon_t] + \boldsymbol{\gamma}' \boldsymbol{x_t} + u_t, \tag{6}$$

Figure 6 shows that positive monetary shocks (monetary tightenings) appear to be more powerful than negative monetary shocks (monetary loosenings). The finding is in line with those in Angrist et al. (2018), Tenreyro and Thwaites (2016), Barnichon and Matthes (2018), and Davide et al. (2020). However, a formal statistical test does not seem to support this finding. The third column in Figure 6 reports estimates of the $t - statistics$ testing the null hypothesis that ($\beta^{Tightening} - \beta^{Loosening} = 0$) with the shaded area between ± 1.65. At a 10 percent significance level, we do not reject the null hypothesis as the green lines in the third column do not exceed the upper or the lower boundary of the shaded area.

We next compute the distributions of monetary policy shocks in strong-growth and weak-growth states. Figure 7 shows that negative monetary shocks seem to occur more frequently during strong-growth states. This is because the central tendency of the distributions of the shocks in strong-growth states slide more toward the negative side. This suggests that negative monetary policy shocks appear to preponderate when the economy is in a good state. It is possible that such negative shocks may explain an increase in the effectiveness of monetary policy when the economy is in strong-growth states.

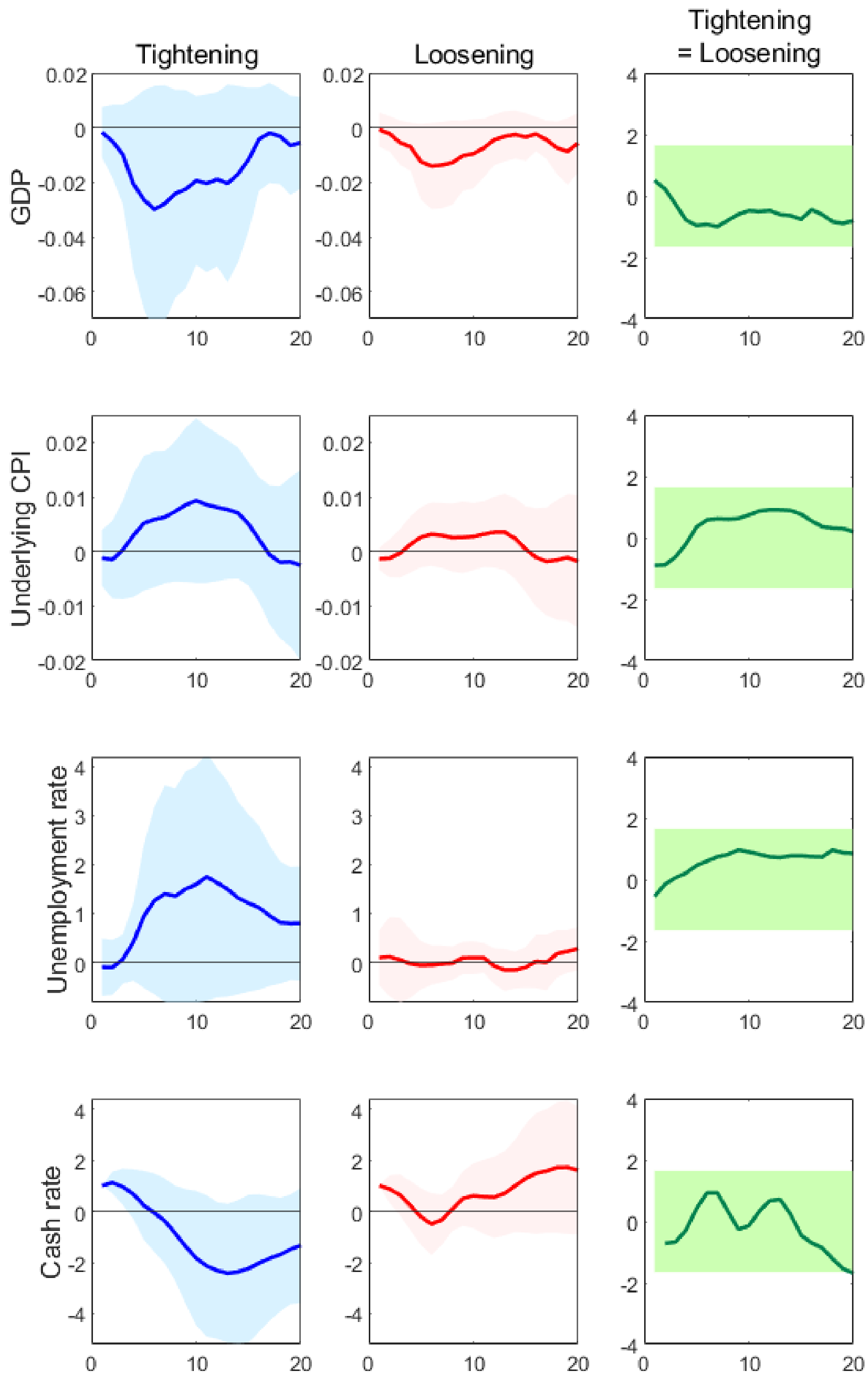


Figure 6: Impulse responses to positive and negative monetary policy shocks. Blue (red) lines depict median responses to a positive (a negative) monetary policy shock. Responses to a negative monetary policy shock (a monetary loosening) in the second column are inverted for easier comparisons. Shaded bands in columns 1 and 2 represent 90% point-wise confidence intervals. Green lines in the third column show the $t-statistics$ testing the hypothesis that the difference between the impulse responses in the two monetary regimes is zero. The green line is calculated by the bootstrap method as in Tenreyro and Thwaites (2016). The shaded area is ± 1.65.

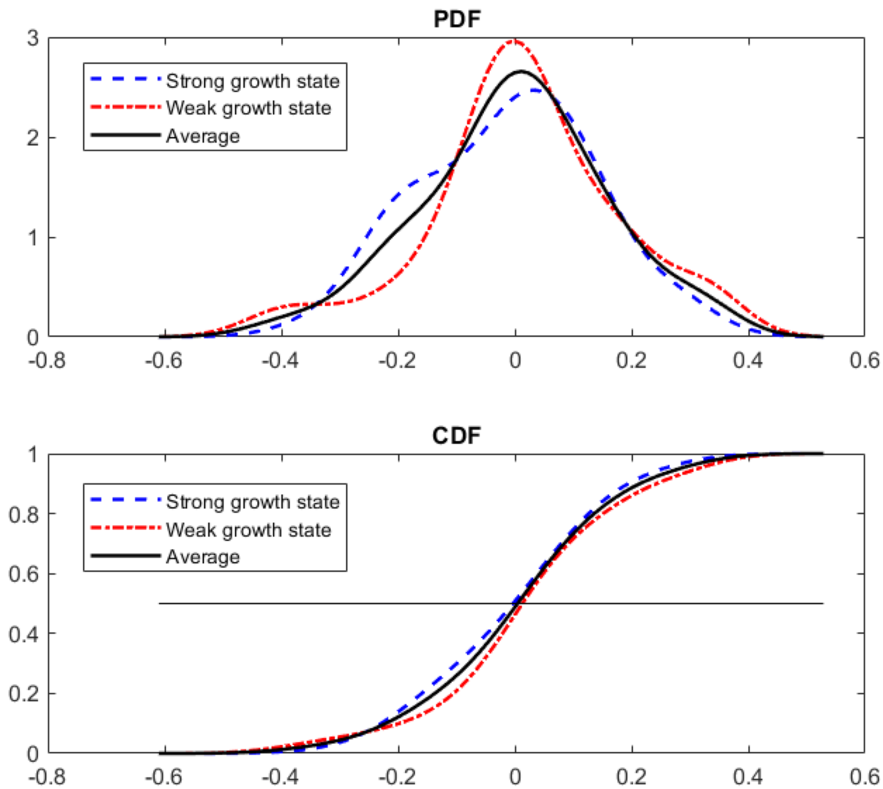


Figure 7: PDFs and CDFs of monetary policy shocks in the different regimes. Blue dashed lines show the distribution during the strong-growth state. Red dash-dotted lines show the distribution during the weak-growth state. Black solid lines are the average of the two states.

5 Robustness analysis

In this section, we check the robustness of our results with four cases. In the first robustness check, we reduce the proportion of the sample period where the economy stays in the weak growth state to $c = 20$. In the second check, we increase the intensity of the economy that switches between the two states to $\theta = 10$. In the third check, we use the seven quarter moving average of real GDP growth as the state variable z_t. Finally for the fourth test, we estimate equation (1) without the linear time trend. We report the results at the end of this section.

5.1 Different proportion of sample in weak growth states (c)

For the first robustness check, we change our baseline value for $c = 42$ to $c = 20$. As a reminder, c controls a portion of the sample period in a weak growth state. In the baseline case, we use $c = 42$, which is based on the Hamilton-filtered cycle of real GDP. In this exercise, we assume that $c = 20$, which means that the economy spends in a weak growth state around 20 percent of the sample period. $c = 20$ is the same setting that Tenreyro and Thwaites (2016) use for their valuation of c for the US. As shown in Figure 1, it is clear that weak growth states make around 42 percent of the sample period. Thus, it appears that setting $c = 20$ is not so appealing. But, we want to see how the baseline results are sensitive in an unrealistic case of $c = 20$. Figure A1 in the Appendix shows the probability of a strong growth state when $c = 20$ and along with the probability in the baseline case. As the figure displays, the probability declines significantly for the reduced value of c.

Figure 8 shows the impulse responses of the headline and the expenditure variables to a contractionary monetary policy shock. The figure confirms that the responses are similar to those at the baseline case. However, the magnitude of the responses in Figure 6 are overall smaller compared to the baseline case.

5.2 Different intensity of regime switching (θ)

For the second robustness test, we change the baseline value for $\theta = 3$ to $\theta = 10$. This change reflects that the intensity of regime switching becomes closer to a Markov regime switching, in which the economy changes its regime abruptly. In the baseline case, we use $\theta = 3$, which is an intermediate intensity level of regime switching. An intermediate intensity of regime switch makes the transition of the economy between the two states smoother. $\theta = 10$ means that the economy switches from one state to another at a much faster speed, indicating the economy switches abruptly between the two states. This makes $F(z_t)$ become less smooth, as the dash-dotted line in Figure A2 in the Appendix shows. Figure 9 displays the impulse responses of the headline and the expenditure variables. Like the first robustness test, we see no major change on the impulse responses and they appear similar to the baseline results. Again, our baseline results are not so sensitive to the higher degree of intensity to the regime switching.

5.3 Alternative state variable (z_t)

For the third robustness case, we replace the Hamilton-filtered cycle of real GDP by the seven-quarter centered moving average of real Australian GDP growth. We annualize the real GDP growth for the extended sample period 1990Q1–2019Q2, so that we obtain larger cycles. Then, by following Tenreyro and Thwaites (2016), we calculate a seven-quarter centered moving average from this annualized real GDP growth for the sample used in the baseline estimation, 1994Q1–2018Q3. Figure A3 in the Appendix shows the annualized real Australian GDP growth alongside its seven quarter moving average. Figure A4 compares the seven quarter moving average of annualized real Australian GDP growth with the Hamilton-filtered cycle of real Australian GDP. As the figure shows, patterns of the two cycles appear quite similarly. Also the figure shows that the major drops of the seven quarter moving average are in line with the weak growth phases of the Hamilton-filtered cycle. Figure A5 plots probability of a strong growth state of the seven quarter moving average of real Australia GDP growth.

Figure 10 presents the impulse responses of the two set variables. Like the other two cases, we see similar impulse responses. In particular, the impulse responses appear almost the same as those in the baseline case.

5.4 No time trend (τt)

For the final robustness check, we consider equation (1) without the time trend, τt. In the baseline case, we model equation (1) with the time trend, and this time trend is not strictly required given that z_t in $F(z_t)$ has already been detrended with the Hamiton filter. Thus, we want to see whether the exclusion of the time trend from equation (1) has any significant changes to our main finding. Figure 11 reports the results. We see that our main finding is also robust to this exercise.

Among the four robustness tests, the impulse responses, especially in a weak growth state, are most sensitive to when we reduce the parameter c. This suggests that the smaller c directly translates to restricting a weak growth state in the sample to the shorter period. The shorter period of a weak growth state means there are less observations for the impulse responses to a shock in a weak growth state and there are more observations in a strong growth state. The first robustness test shows that calculating the parameter c directly from the state variable is important to study the state dependency of monetary policy shock. This is because calculating c from the state variable makes it in line with actual weak growth states in the economic cycle.

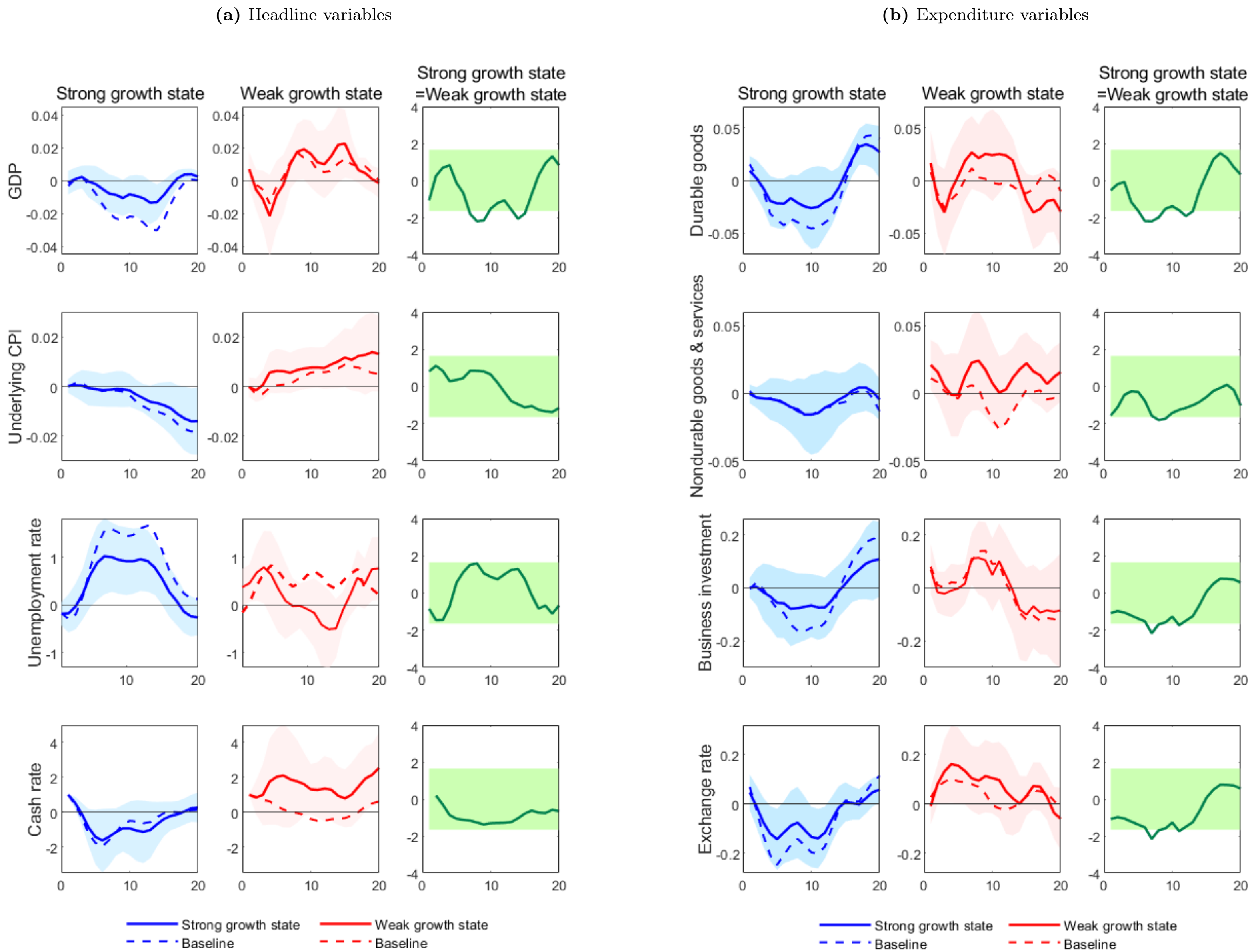


Figure 8: Results of the first robustness test. Impulse responses of headline and expenditure variables to a monetary policy shock that increases the cash rate by one percentage point. Subfigures (a) and (b) show median impulse responses in a strong growth state (blue lines) and a weak growth state (red lines) with their median impulse responses in the baseline case (dashed lines). Impulse responses are computed when $c = 20$, $\theta = 3$, and z_t as the Hamilton-filtered cycle of real AU GDP. Shaded bands represent 90% point-wise confidence intervals. Green lines in the third column of the two subfigures denote estimates of the $t - statistics$ testing for the difference between impulse responses in the two states. The shaded area is ± 1.65.

(a) Headline variables **(b)** Expenditure variables

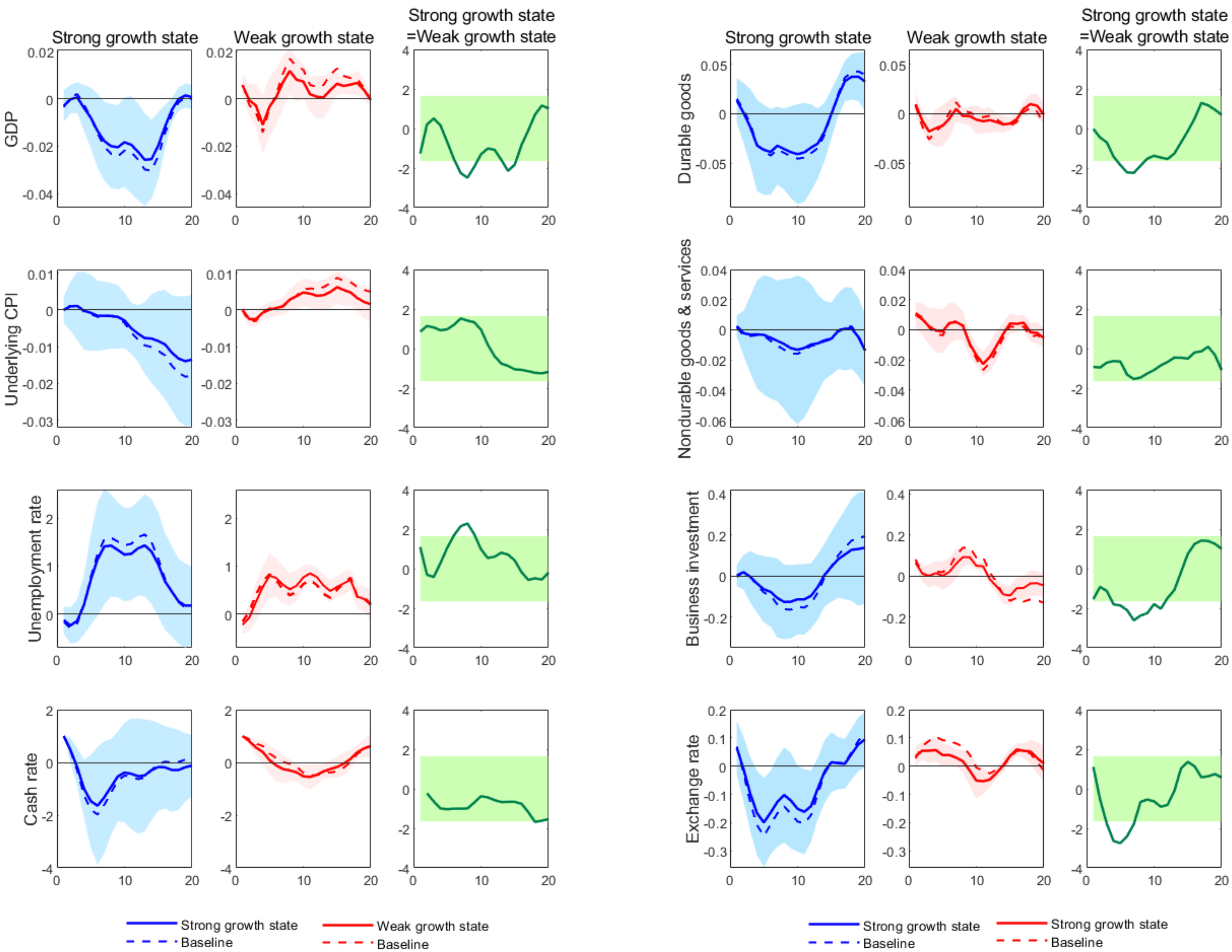


Figure 9: Results of the second robustness test. Impulse responses of headline and expenditure variables to a monetary policy shock that increases the cash rate by one percentage point. Subfigures (a) and (b) show median impulse responses in a strong growth state (blue lines) and a weak growth state (red lines) with their median impulse responses in the baseline case (dashed lines). Impulse responses are computed when $c = 42$, $\theta = 10$, and z_t as the Hamilton-filtered cycle of real AU GDP. Shaded bands represent 90% point-wise confidence intervals. Green lines in the third column of the two subfigures denote estimates of the $t - statistics$ testing for the difference between impulse responses in the two states. The shaded area is ± 1.65.

(a) Headline variables **(b)** Expenditure variables

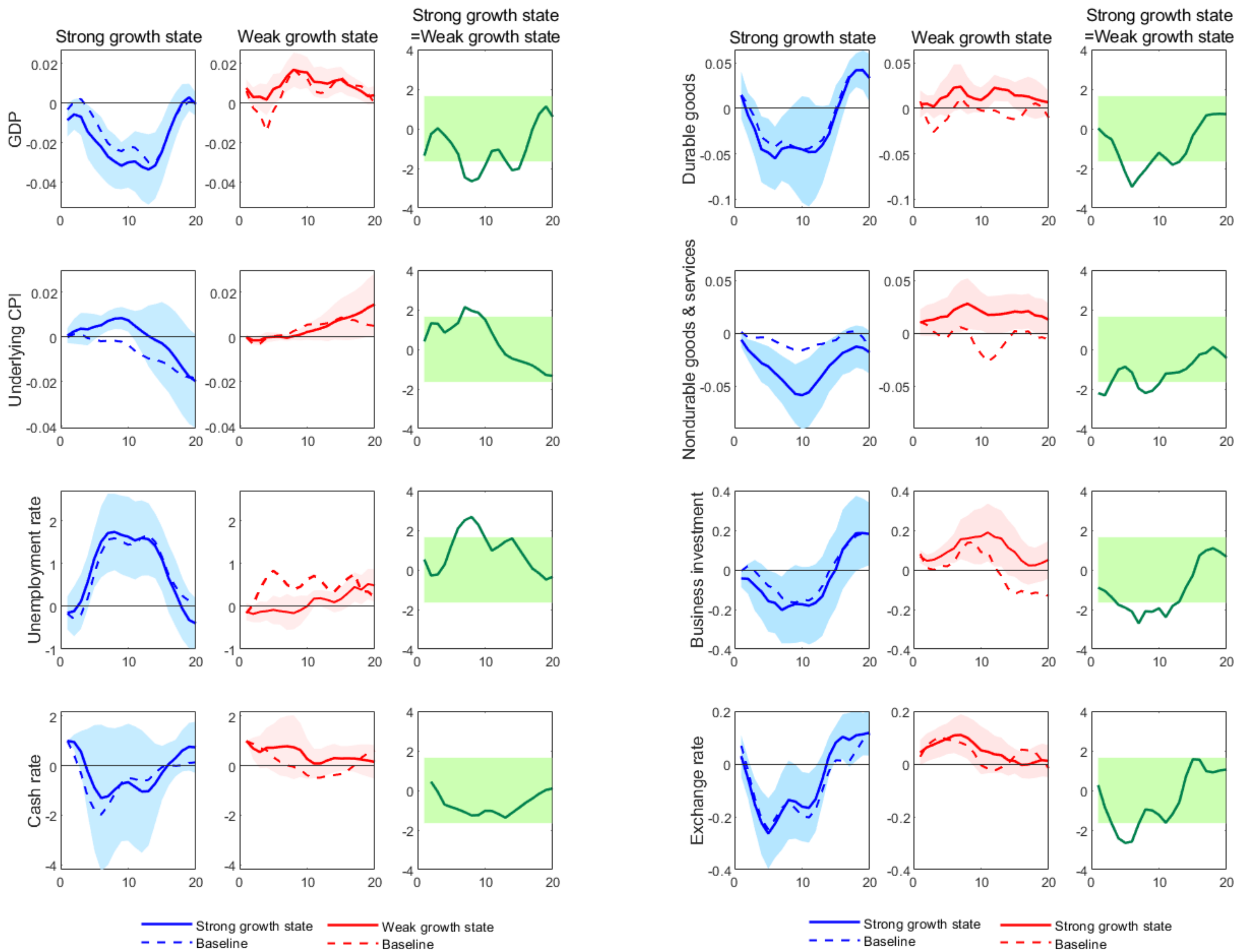
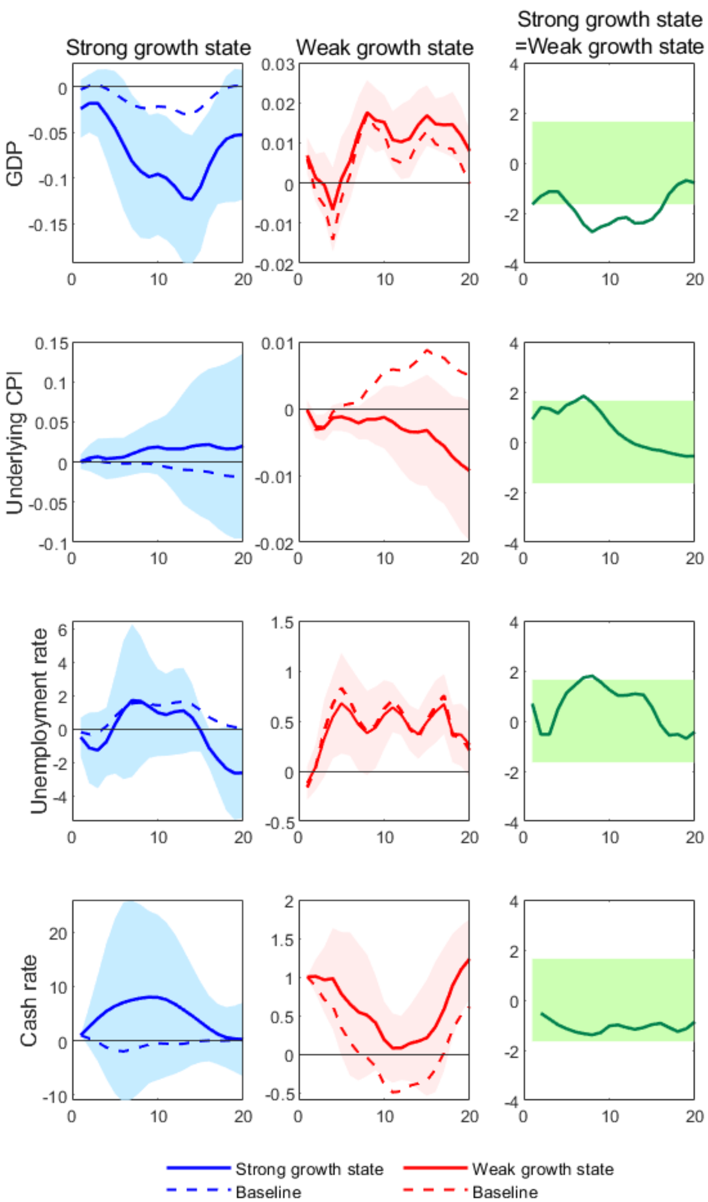


Figure 10: Results of the third robustness test. Impulse responses of headline and expenditure variables to a monetary policy shock that increases the cash rate by one percentage point. Subfigures (a) and (b) show median impulse responses in a strong growth state (blue lines) and a weak growth state (red lines) with their median impulse responses in the baseline case (dashed lines). Impulse responses are computed when $c = 42$, $\theta = 3$, and z_t as the seven quarter moving average of real AU GDP growth. Shaded bands represent 90% point-wise confidence intervals. Green lines in the third column of the two subfigures denote estimates of the $t - statistics$ testing for the difference between impulse responses in the two states. The shaded area is ± 1.65.

(a) Headline variables



(b) Expenditure variables

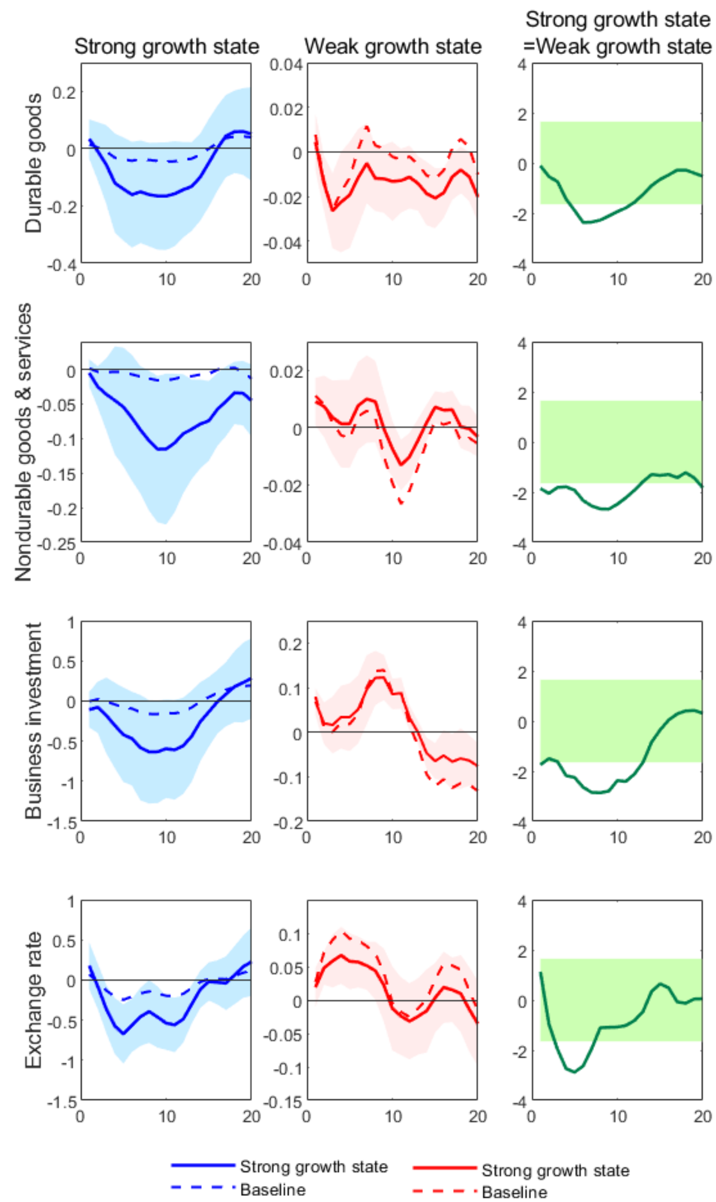


Figure 11: Results of the fourth robustness test. Impulse responses of headline and expenditure variables to a monetary policy shock that increases the cash rate by one percentage point. Subfigures (a) and (b) show median impulse responses in a strong growth state (blue lines) and a weak growth state (red lines) with their median impulse responses in the baseline case (dashed lines). Impulse responses are computed when equation (1) is estimated without the linear time trend, τt. Shaded bands represent 90% point-wise confidence intervals. Green lines in the third column of the two subfigures denote estimates of the $t - statistics$ testing for the difference between impulse responses in the two states. The shaded area is ± 1.65.

6 Conclusion

We explore the extent to which the pace of economic growth determines the effectiveness of monetary policy shocks in Australia over the period 1990–2019. We apply the methodology of Cashin and Ouliaris (2004) to characterize two states of the Australian economy: strong-growth phases and weak-growth phases. We then estimate a smooth-transition local projection model to assess whether the effects of a surprise cut in the cash rate vary across the two states. We find that monetary policy shocks are less effective in weak-growth phases. Our results suggest that the RBA should be ready to act promptly and aggressively during slow-growth episodes.

Appendix

Horizon h	GDP		Underlying CPI		Unemployment rate	
	Strong	Weak	Strong	Weak	Strong	Weak
1	0.001	-0.003	0.001	-0.003	-0.289	0.040
	(0.20)	(-0.61)	(0.29)	(-2.68)	(-1.03)	(0.28)
4	-0.014	0.002	-0.002	0.001	1.251	0.705
	(-1.47)	(0.28)	(-0.29)	(0.48)	(1.66)	(3.14)
8	-0.022	0.012	-0.004	-0.006	1.435	0.623
	(-1.72)	(2.48)	(-0.63)	(2.84)	(2.20)	(4.59)
12	-0.030	0.010	-0.010	0.007	1.499	0.336
	(-2.69)	(2.27)	(-1.23)	(2.60)	(2.05)	(2.35)
16	-0.001	0.008	-0.017	0.006	0.245	0.357
	(-0.38)	(2.68)	(-1.45)	(2.29)	(0.38)	(2.27)
20	-0.004	-0.002	-0.017	0.006	0.306	0.275
	(-0.74)	(-0.90)	(-1.47)	(1.94)	(0.60)	(1.84)

(a) Headline variables

Horizon h	Durable goods		Nondur. & serv.		Business invest.		Exchange rate	
	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak
1	0.004	-0.013	-0.04	0.008	0.020	0.010	-0.025	0.071
	(0.18)	(-2.05)	(-0.38)	(1.12)	(0.37)	(0.42)	(-0.34)	(3.56)
4	-0.037	-0.012	-0.004	-0.004	-0.081	0.018	-0.247	0.092
	(-1.29)	(-0.91)	(-0.14)	(-0.36)	(-0.76)	(0.50)	(-2.66)	(3.69)
8	-0.043	0.001	-0.016	-0.010	-0.164	0.139	-0.168	0.041
	(-1.26)	(0.23)	(-0.45)	(-1.21)	(-1.43)	(6.07)	(-1.62)	(1.40)
12	-0.035	-0.006	-0.010	-0.014	-0.081	-0.031	-0.099	-0.013
	(-1.33)	(-0.99)	(-0.39)	(-2.59)	(-0.69)	(-1.35)	(-1.32)	(-0.61)
16	0.036	0.002	0.002	0.002	0.138	-0.125	0.011	0.052
	(2.74)	(0.29)	(0.08)	(0.51)	(0.92)	(-4.08)	(0.18)	(3.12)
20	0.039	-0.034	-0.026	-0.005	0.199	-0.182	0.098	-0.053
	(1.37)	(-5.19)	(-1.42)	(1.14)	(1.18)	(-3.19)	(1.16)	(-1.29)

(b) Expenditure variables

Table A1: The impacts of a contractionary monetary policy shock on headline and expenditure variables in strong growth and weak growth states of the economy. The impacts are computed when $c = 42$, $\theta = 3$, and z_t as the Hamilton-filtered cycle of real AU GDP. The table reports the coefficient $\hat{\beta}_h$ (without parentheses) and its t-statistics (with parentheses). All responses are in logs.

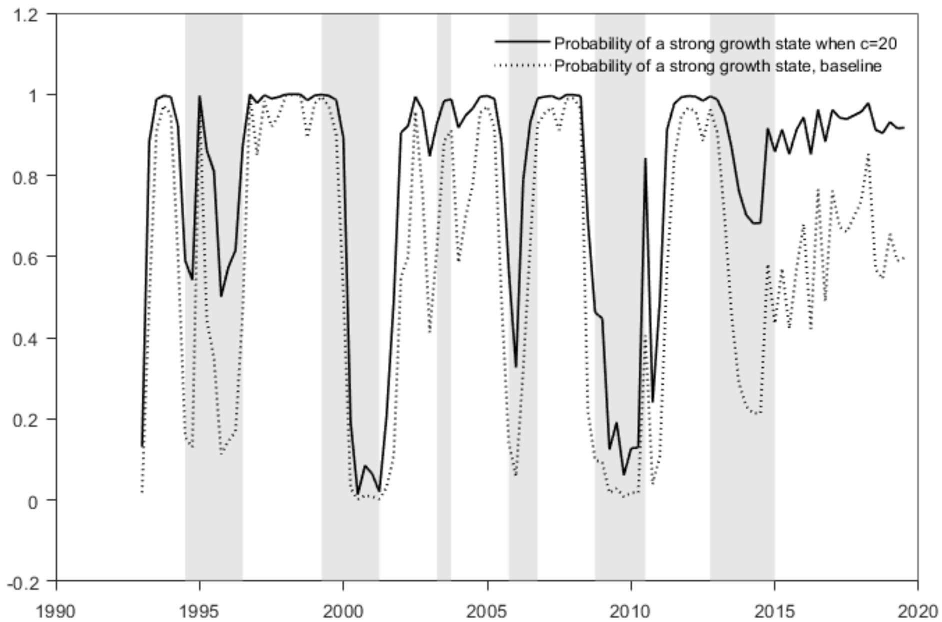


Figure A1: Probability of a strong growth state of the economy when $c = 20$. The dotted line is the probability in the baseline case. Shaded areas denote weak growth states (periods from a peak to a trough). Non-shaded areas denote strong growth states (periods from a trough to a peak). Peak and trough points are determined by the BBQ algorithm.

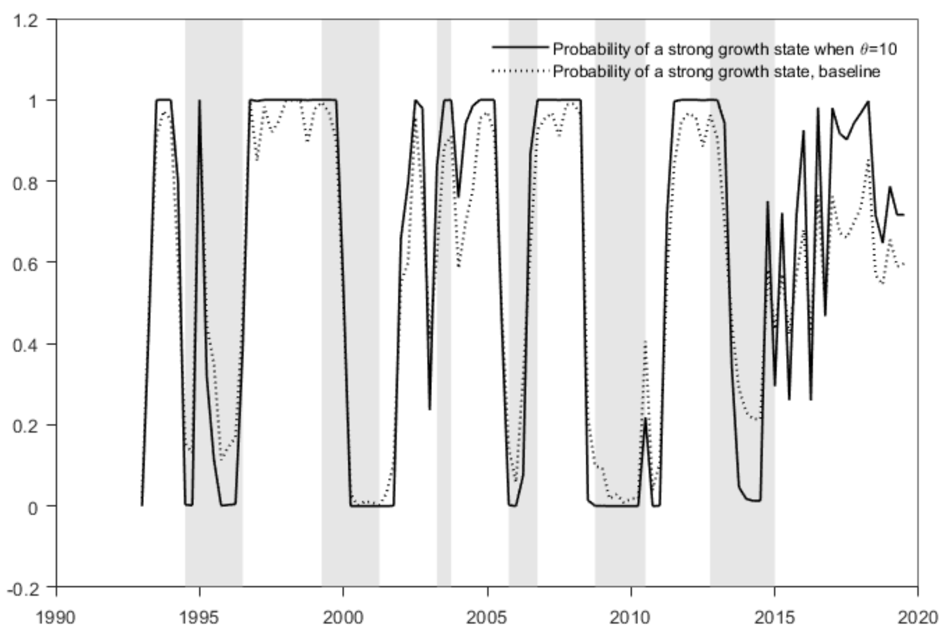


Figure A2: Probability of a strong growth state of the economy when $\theta = 10$. The dotted line is the probability in the baseline case. Shaded areas denotes weak growth states (periods from peaks to troughs). Non-shaded areas denote strong growth states (periods from a trough to a peak). Peak and trough points are determined by the BBQ algorithm.

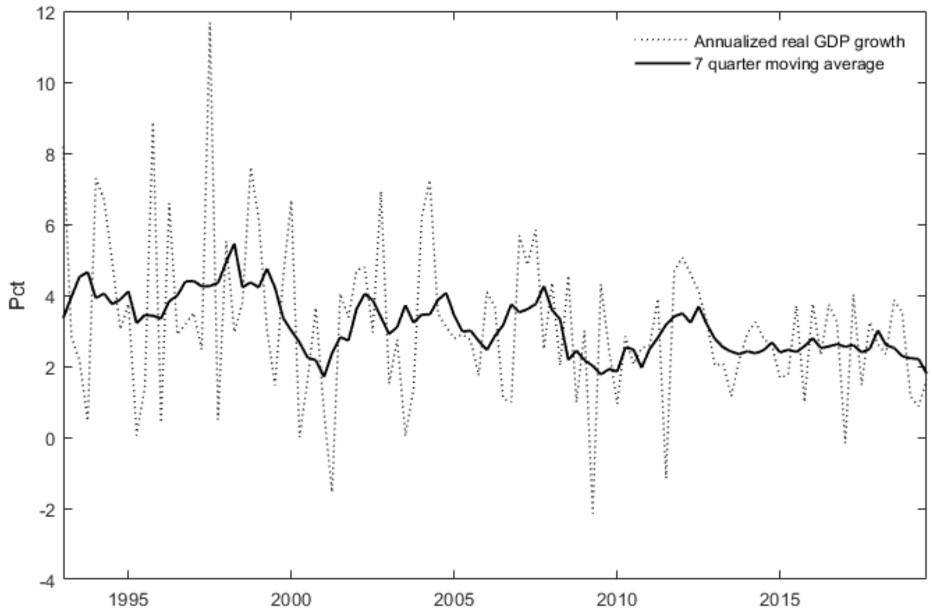


Figure A3: Real AU GDP growth. The dotted line is the annualized real GDP growth. The solid line is 7 quarter moving average.

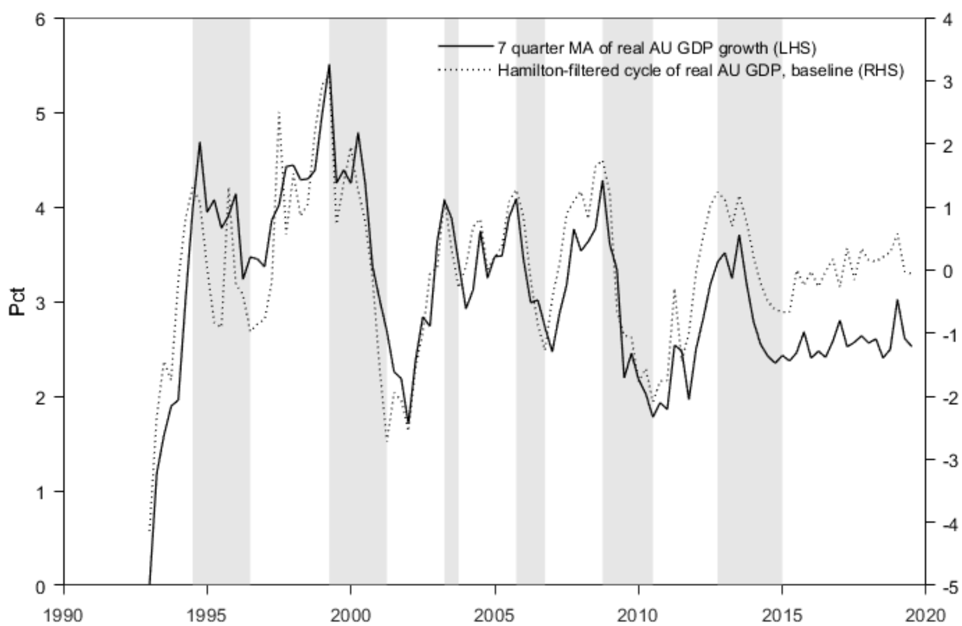


Figure A4: 7 quarter moving average of real AU GDP growth as the state variable. The solid line is 7 quarter moving average. The dotted line is the Hamilton-filtered cycle of real AU GDP. Shaded areas denotes weak growth states (periods from peaks to troughs) in the baseline case. Non-shaded areas denote strong growth states (periods from a trough to a peak) in the baseline case. Peak and trough points are determined by the BBQ algorithm.

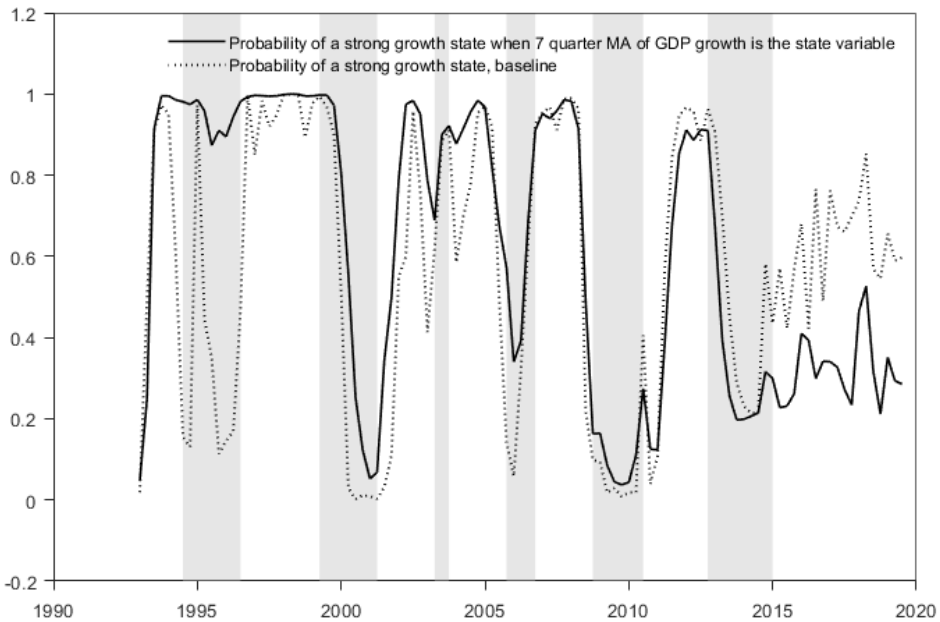


Figure A5: Probability of a strong growth state of the economy when z_t is 7 quarter moving average of real AU GDP growth. The dotted line is the probability in the baseline case. Shaded areas denotes weak growth states (periods from peaks to troughs). Non-shaded areas denote strong growth states (periods from a trough to a peak). Peak and trough points are determined by the BBQ algorithm.

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Chapter 3

Sentiment and the effectiveness of monetary policy in the US*

Khuderchuluun Batsukh†

Abstract

This paper explores whether sentiment changes the effectiveness of monetary policy in the US. I use consumer and market sentiment measures and estimate a self-exciting interacted vector autoregression model with data from 1960Q1 to 2009Q2. I find that the effects of US monetary policy shocks are less powerful when sentiment is low, especially for GDP, durables expenditure, and investment. Forecast error variance decomposition analysis shows that a monetary policy shock is less important when sentiment is low.

Keywords: Sentiment, monetary policy, an interacted VAR.

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*I thank Giovanni Pellegrino for kindly making his MATLAB code for modeling the SEIVAR available, which are modified in accordance with my research aims and needs. Any errors and omissions in this paper are my responsibility.

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"Animal spirits, sentiment, psychology, whatever you want to call it, was central to the economic and financial story..." (Bernanke, 2015).

1 Introduction

Sentiment has received much attention lately both by monetary policymakers and in the academic literature, as sentiment is a potential driver of business cycle fluctuations. The findings of Benhabib et al. (2015), Milani (2017), Angeletos and La'O (2013), and Angeletos et al. (2018) suggest that expectations may be a non-fundamental yet important driver of business cycle fluctuations.[1] In general, sentiment and uncertainty are the terms that are used to refer to expectations (Nowzohour and Stracca, 2020). Where sentiment is the first moment measure (the mean) and uncertainty is the second moment measure (the variance) of expectations (Haddow et al., 2013). Previous works on expectations and monetary policy mostly focus on the role of uncertainty in the transmission of monetary policy.[2] Yet, the literature that specifically looks at the role of sentiment is limited. My contribution to the literature is to directly study if and how strongly sentiment influences the effectiveness of monetary policy by using a recently developed nonlinear model.[3]

I investigate if the level of sentiment influences the effectiveness of conventional monetary policy in the US. I employ the self-exciting interacted vector autoregression (SEIVAR) model, proposed by Pellegrino (2021), with a sample from 1960Q1 to 2009Q2.[4] My sample ends in 2009Q2 to avoid the zero lower bound period in the US.

[1] See Pesaran and Weale (2006) and Coibion and Gorodnichenko (2015) for why and how agents form their expectations.

[2] For example, Pellegrino (2021), Aastveit et al. (2017), Castelnuovo and Pellegrino (2018) and Caggiano et al. (2017).

[3] Sentiment also refers to confidence. I use the two terms interchangeably in my paper to refer to the first movement of expectations.

[4] The term 'self-exciting' refers to 'fully nonlinear'. The term is borrowed from Teräsvirta et al. (2010), who review nonlinear time series models used in macroeconomic studies.

This nonlinear VAR has an interaction term between the policy rate and the state variable, which is sentiment in my analysis, and computes the state-dependent impulse responses (IRs) to a monetary policy shock. I use the Michigan consumer sentiment and the Conference board consumer confidence indices as the measures for sentiment. The advantage of the SEIVAR model compared to other competing nonlinear models is that the model allows the state variable to endogenously move after a monetary policy shock hits. This makes IRs fully dependent on sentiment levels. I use Cholesky decompositions to identify monetary policy shocks and Generalized Impulse Response Functions (GIRFs) by Koop et al. (1996) to compute state-dependent IRs. I examine the response of a range of variables to monetary policy shocks, including GDP, durables expenditure with investment, nondurables expenditure with services, the GDP price deflator, and sentiment.

I find that the effects of monetary policy shocks are more powerful in periods of high sentiment than in low sentiment. In periods of high sentiment, GDP, durables expenditure with investment, and nondurables expenditure with services all significantly rise in response to a negative monetary shock. Particularly, the responses of GDP and durables expenditure with investment are more sensitive to a monetary shock, a finding which is in line with Tenreyro and Thwaites (2016). In contrast, in periods of low sentiment, the responses are much smaller. I also find that an expansionary monetary policy shock leads to a large increase in sentiment. For the response of the GDP price deflator, I document a 'price puzzle'.[5] My findings are robust to alternative measure of sentiment, uncertainty as an additional control variable, and different high and low levels of sentiment.

[5] A price puzzle in this analysis is no surprise as VAR models for monetary analysis often find a price puzzle for the US economy. The literature proposes a number of methods to remove a price puzzle for the US economy, such as starting the sample from the post-Volcker period and adding control variables. I tried these methods, but they did not help to remove a price puzzle. Removing a price puzzle is beyond the scope of this paper, thus I did not try using additional methods.

The findings are relevant for stabilizing monetary policy and the models that examine it. From a policy standpoint, if the effectiveness of monetary policy is reduced in periods of low sentiment, then policymakers may need to implement aggressive monetary policy measures during the low sentiment periods. If indeed low sentiment periods happen to occur during the zero lower bound periods, then policymakers may need to implement unconventional monetary policy measures. The results also imply that policymakers need to coordinate fiscal and financial policies with monetary policy in order to stabilize the economy more effectively when sentiment is low. For the modeling side, my results show that the models that analyse the effects of monetary policy shocks need to take sentiment into account.

2 Literature review

I follow the econometric method used by Pellegrino (2021) and apply it to sentiment. Pellegrino (2021) uses an interacted VAR (IVAR) model to investigate if the high and low levels of uncertainty influence the effects of monetary policy in the US economy.[6] He finds that high uncertainty reduces the effects of monetary policy. In terms of modelling, Pellegrino (2021) proposes a novel approach. He models uncertainty endogenously in his IVAR model, which he names the SEIVAR model. His IVAR model allows uncertainty to move with respect to its level after a shock hits. As uncertainty is allowed to change after the shock hits, uncertainty has feedback effects on the dynamics of the VAR system. The IVAR model in Pellegrino (2021) captures

[6]Towbin and Weber (2013) and Sá et al. (2014) first used an IVAR model. Since then, a growing number of papers have used an IVAR model to study the state-dependent effects of macroeconomic shocks. These papers include Pellegrino (2021), Castelnuovo and Pellegrino (2018), Aastveit et al. (2017), Caggiano et al. (2017), Belke and Goemans (2021), and Di Serio et al. (2020). Notably, Pellegrino (2021) and Di Serio et al. (2020) have developed an IVAR model further. As stated before, Pellegrino (2021) models the state variable fully endogenously in the interaction term. Di Serio et al. (2020) propose a factor-augmented interacted vector autoregression (FAIVAR) model in which an interaction term is added to the factor-augmented VAR.

these feedback effects, which make his IRs fully dependent on uncertainty. In contrast, most other papers that use an IVAR model assume that the state variable is exogenous, which may lead to biased state-dependent IRs as the state variable tends to change after the shock hits. Pellegrino (2021) uses Cholesky decompositions to identify monetary policy shocks and GIRFs by Koop et al. (1996) to calculate uncertainty-dependent IRs.[7] From an application standpoint, my work differs from Pellegrino (2021) in that 1) my work specifically looks at sentiment as another source of the state dependence on monetary policy, 2) I use durables expenditure with investment and nondurables expenditure with services in my model, making it possible to document the effects of monetary shocks on durables and nondurables expenditure separately, and 3) my data covers a longer sample period, 1960Q1–2009Q2.

There is a growing literature that studies how the regimes of market sentiment influence the effects of monetary policy on stock returns. These include Kurov (2010), Guoz et al. (2016), Debes et al. (2014), Lien et al. (2019), Chen (2007), and Dahmene et al. (2021). These papers find that monetary policy has larger effects on stock returns when market sentiment is high. For instance, Kurov (2010) who uses a Markov-switching model studies if the effects of monetary policy on stock returns vary in bear and bull regimes of the S&P 500 index and the investor sentiment index by Baker and Wurgler (2007). He finds that monetary policy shocks have a stronger impact on investor sentiment in bear market periods. Guoz et al. (2016), on the other hand, uses a linear model, in which the coefficients are conditional on the high and low states of sentiment, and studies if the state of sentiment affects the impacts of monetary policy on stock returns. The paper uses the Michigan consumer sentiment and the Conference board consumer confidence indices as measures of sentiment and finds that

[7]GIRFs by Koop et al. (1996) are commonly applied to nonlinear VAR models and are capable of computing IRs that depend on the state, the sign, and the size of the shock. The local projection method proposed by Jordà (2005) is an alternative to GIRFs by Koop et al. (1996).

stock returns respond stronger to a monetary policy shock when sentiment is high. Debes et al. (2014) uses a linear VAR model to examine how monetary policy shocks affect the Michigan consumer sentiment. The paper finds that consumer confidence drops significantly after a contractionary monetary policy shock.

3 Econometric method

I use the SEIVAR model of Pellegrino (2021) to conduct my analysis. The SEIVAR model has the following expression:

$$\boldsymbol{Y}_t = \boldsymbol{c} + \boldsymbol{\tau} \cdot t + \sum_{k=1}^{L} \boldsymbol{b}_k \boldsymbol{Y}_{t-k} + \left[\sum_{k=1}^{L} \boldsymbol{d}_k R_{t-k} \cdot sent_{t-k} \right] + \boldsymbol{u}_t \tag{1}$$

$$sent_t = \epsilon'_{sent} \boldsymbol{Y}_t \tag{2}$$

$$R_t = \epsilon'_R \boldsymbol{Y}_t \tag{3}$$

$$E(\boldsymbol{u}_t \boldsymbol{u}'_t) = \boldsymbol{\Omega} \tag{4}$$

where $\boldsymbol{Y}_t$ is a (n x 1) vector of endogenous variables, $\boldsymbol{c}$ is a (n x 1) vector of constant terms, $\boldsymbol{\tau}$ is the (n x 1) vector of slope coefficients for the linear time trend, $\boldsymbol{b_k}$ is the (n x n) matrices of coefficients, and $\boldsymbol{u_t}$ is the (n x 1) vector of error terms, whose variance covariance matrix is $\boldsymbol{\Omega}$. The interaction term in the bracket has $\boldsymbol{d_k}$, a (n x 1) vector of coefficients, R_t, the federal funds rate (the policy rate that I applied the shock to), and $sent_t$, a sentiment measure (the state variable that defines the high and low states of sentiment). Without the interaction term, equation (1) is a linear VAR. ϵ_y is a selection vector for the endogenous variable y in $\boldsymbol{Y}$. Because ϵ_y is a selection vector for endogenous y, the federal funds rate (R) and a sentiment measure ($sent$) in the interaction term both are treated as endogenous variables. Section A1 in the Appendix provides a further description of equation (1).

I set $\boldsymbol{Y} = \left[P, GDP, DuInv, NduSer, R, Sent\right]'$. Where the variables denote, respectively, the GDP price deflator (P), the real GDP (GDP), real durables expenditure with real investment ($DuInv$), real nondurables expenditure with real services ($NdurSer$), the federal funds rate (R), and a sentiment measure ($Sent$). This ordering assumes that the policy rate is allowed to react contemporaneously to changes in the real variables and the price level, while these variables are not allowed to react contemporaneously to changes in the policy rate. I order $Sent$ last in $\boldsymbol{Y}$. This suggests that sentiment reacts instantaneously to policy rate changes. Responses to a monetary policy shock are expressed in percentages. I take the log of real variables in $\boldsymbol{Y}$ then multiply them by 100.

I use OLS to estimate equation (1). I impose $L = 3$ for both the nonlinear and the linear models as the Akaike information criterion suggests.[8] I conduct a linearity test whether there exists evidence for the interaction term, which is the nonlinear specification, in the SEIVAR model (see Section A2 in the Appendix for details on the linearity test). Since the linear VAR and the SEIVAR are nested models, I use a likelihood-ratio (LR) test for the exclusion of the interaction term in the SEIVAR model. The test shows evidence of the interaction term in the SEIVAR model. I identify the monetary policy shocks by using a Cholesky decomposition. I compute sentiment-dependent IRs to monetary policy shocks via GIRFs by Koop et al. (1996). The GIRFs account both for the endogenous response of sentiment and for the feedback effects of this endogenous response on the dynamics of the SEIVAR. For the SEIVAR, the policy rate and sentiment in the interaction term are both modeled endogenously. This allows sentiment to switch endogenously from one state to another. Section

[8]The nested linear model refers to a linear VAR, which is equation (1) without the interaction term. The SEIVAR model in equation (1) is nonlinear in terms of the state of the sentiment measure, but it is symmetric. Thus, the model is not designed to capture the asymmetric effects of positive and negative shocks. In this work, I only consider negative policy shocks (expansionary monetary policy shocks).

A3 in the Appendix provides the details on how the GIRFs compute the sentiment-dependent IRs. Another advantage of the SEIVAR model is that the model computes the state-dependent IRs more precisely. Comparing with threshold VARs, smooth-transition VARs, time-varying coefficients VARs, and Markov regime switching VARs, the SEIVAR model does not have a transition function, which approximates regimes and their transitions with some probability. In contrast, regimes in the SEIVAR are directly defined from the distribution of the state variable, making the computation of IRs more precise and quarter-specific (assuming the state variable is quarterly).

3.1 The high and low states of sentiment

I use the Michigan consumer sentiment (MCS) and the Conference board consumer confidence (CBC) indices as the baseline measures of sentiment.[9] The two indices are built monthly. I use quarterly averages of them in my analysis. I define the high and low states of sentiment as the ninth and the first deciles of the distribution of MCS and CBC with an eight percentile tolerance band around the two deciles.[10] The two states are defined as follows:

$$\textbf{\textit{High sentiment state}} : \{\varpi_{t-1} : 82^{th} perc. \leq sent_{t-1} \leq 98^{th} perc.\}$$
$$\textbf{\textit{Low sentiment state}} : \{\varpi_{t-1} : 2^{th} perc. \leq sent_{t-1} \leq 18^{th} perc.\}$$

I chose consumer sentiment for the following reasons.[11] First, US household con-

[9]See Kellstedt et al. (2015), Desroches and Gosselin (2002), and Throop et al. (1992) for detailed discussions on reliability and measurement of the two indices. The two measures are well known among economists and widely cited in theoretical (Angeletos et al. (2018); Milani (2017); Baker et al. (2016); Dräger et al. (2016)) and empirical papers (Coibion et al. (2020); Carvalho and Nechio (2014); Bachmann and Sims (2012)).

[10]This wide tolerance band makes it possible to include large enough quarters of the high and low states of sentiment.

[11]The literature proposes a variety of sentiment measures for the US economy. Commonly used sentiment measures for the US include investors sentiment (Baker and Wurgler, 2007), news sentiment (Shapiro et al., 2020), and US business confidence (OECD).

sumption alone accounts for more than 60 percent of GDP and the share has been increasing, making it important from a monetary policy perspective. Changes in consumer confidence are regarded as a major driver of consumer spending and, consequently, of fluctuations in the business cycle (Carroll et al., 1994; Ludvigson, 2004; Blanchard et al., 2013). Second, consumer sentiment, uncertainty, and recessions do not always coincide (Figure 1). This distinguishes consumer sentiment from uncertainty and allows me to explore consumer sentiment as another source of the state dependence on monetary policy. Third, the literature lacks in the role of sentiment on the transmissions of monetary policy, especially for consumer sentiment. Few studies specifically look at the role of consumer sentiment in the effects of monetary policy.[12] My paper, therefore, employs consumer sentiment in the SEIVAR model to fill this gap.

Figure 1 plots the two sentiment measures along with an uncertainty measure and NBER recessionary periods. Uncertainty is flipped upside-down for easier comparison with sentiment. For uncertainty, I use a measure of economic and financial uncertainty for the US for the period 1960Q3–2009Q2 from Ludvigson et al. (2021). I compare movements between this uncertainty and my sentiment measures. As the figure displays, the two consumer sentiments and uncertainty (flipped) do not coincide. The movements appear to be more correlated only during recessions but not during all of them. This shows that the two consumer sentiment measures are empirically distinguishable from uncertainty and recessions episodes. I conduct a correlation analysis between two consumer sentiment measures (MCS and CBC) and the uncertainty measure by Ludvigson et al. (2021) (see Table A1 in the Appendix). Table A1 displays that the correlation coefficient between MCS and the uncertainty measure is -0.34, and for

[12]See, for example, Debes et al. (2014) and Guoz et al. (2016) who study how monetary policy affects the Michigan consumer sentiment and the Conference Board consumer confidence indices. However, the two papers do not look at sentiment-dependent effects of monetary policy shocks.

CBS it is -0.09. The coefficients show that the association between consumer sentiment and uncertainty measures are not so strong, suggesting that they are different concepts empirically.

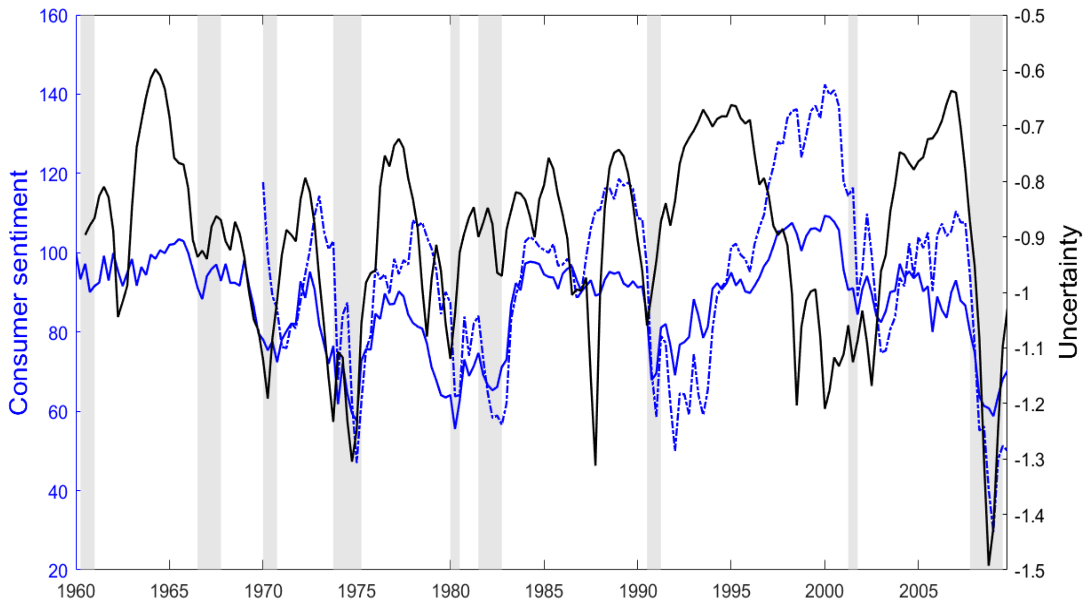


Figure 1: Consumer sentiment and uncertainty. Blue solid line denotes Michigan consumer sentiment index for the period 1960Q1–2009Q2. Blue dash-dotted line denotes Conference board consumer confidence index for the period 1970Q1–2009Q2. Black solid line displays Economic financial uncertainty index (flipped) of Ludvigson et al. (2021) for the period 1960Q3–2009Q2. Grey areas represent NBER recessionary periods.

Figure 2 shows the two sentiment measures and the periods corresponding to their high and low periods. The solid line is for MCS data, and the dashed line is for CBC data. The light blue bars correspond to the high state periods of sentiment, while the light red bars present the low state periods. The high and low states of each sentiment are in the 90^{th} and the 10^{th} percentiles of each sentiment with an 8 percentile tolerance level. MCS and CBC behave differently in each state, especially in the high state. The only common high state periods for them are in the early 2000s. But, the low states of the two measures occur in more periods. Namely, the low state periods of MCS and CBC coincide in the mid 1970s, the early 1980s, the mid 1990s, and the late 2000s.

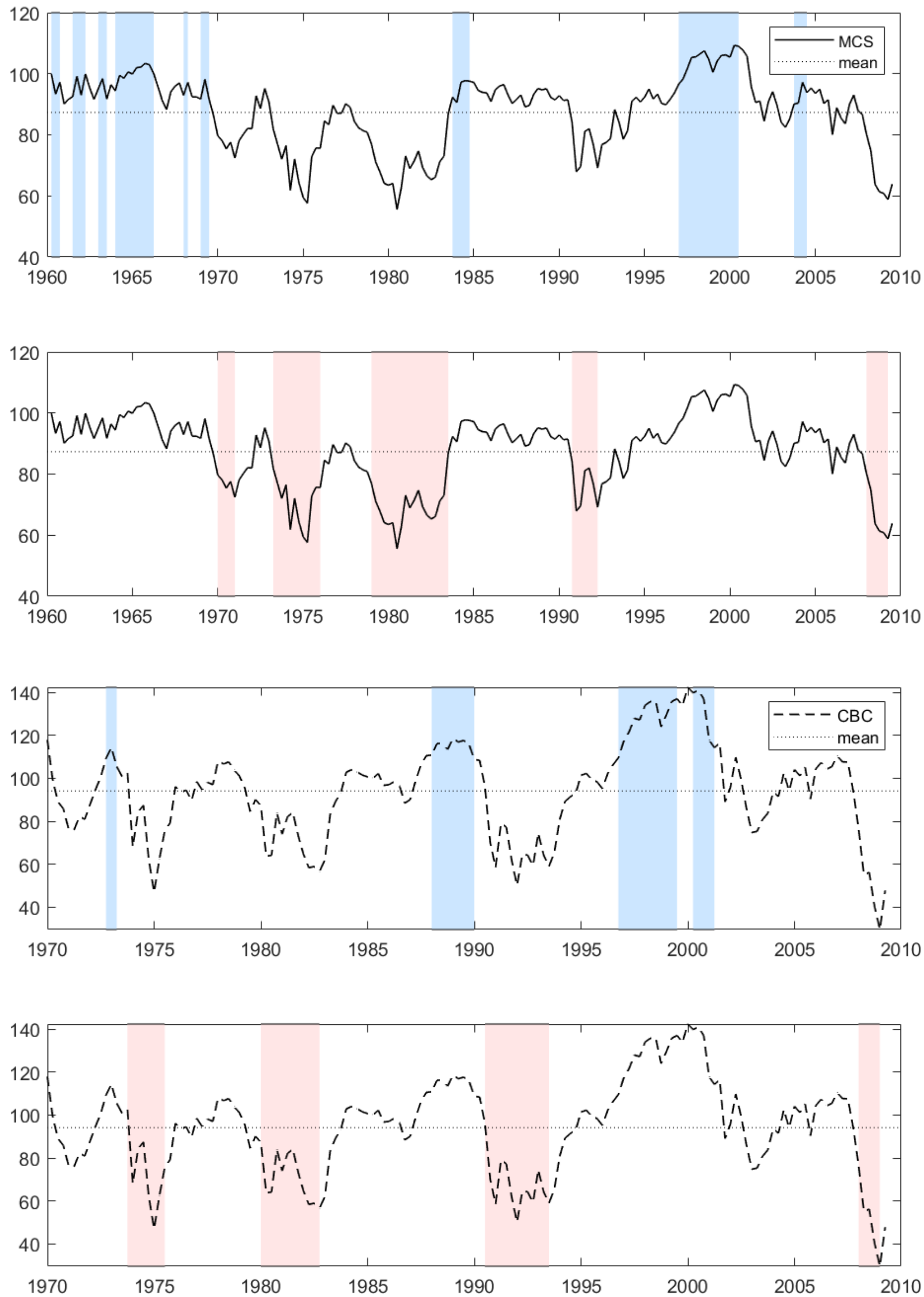


Figure 2: The high and low states of sentiment. The upper two panels for Michigan consumer sentiment (MCS) for the period 1960Q1–2009Q2. The lower two panels for Conference board consumer confidence (CBC) for the period 1970Q1–2009Q2. Light blue areas (light red areas) denote the high state (low state).

3.2 Data

I use quarterly the US data from 1960Q1–2009Q2 in the SEIVAR model. The starting time of the sample is dictated by the availability of MCS and CBC indices. I stop the sample in 2009Q2 due to the zero lower bound (ZLB) period 2009Q3–2015Q4, in which the federal funds rate (FFR) is near zero. The shadow rate of Wu and Xia (2016), which is the common interest rate used instead of the FFR in the ZLB period, is negative in the same period. Mixing the policy rate with the shadow rate in the ZLB period is problematic as the impulse responses to a monetary policy shock cannot represent true state-dependent responses (Bauer and Rudebusch, 2016).

Following Tenreyro and Thwaites (2016) and Berger and Vavra (2015), I break real personal consumption expenditure into durables, nondurables, and services. Then, I combine real durables expenditure with real investment and real nondurables expenditure with real services. My paper stresses the difference in the response between durables and nondurables expenditure in the high and low states of sentiment.[13] Details on the data sources are available in Section A5 of the Appendix.

4 Results

Figure 3 displays the sentiment-dependent IRs along with the linear IRs to a one-standard-deviation expansionary monetary shock. The top six panels show IRs when MSC is the state variable in the SEIVAR model. The bottom six panels are IRs when CBC is the state variable in the model. Overall, the responses suggest that monetary policy shocks are more powerful when sentiment is high. Evidence from a linear VAR shows that the responses are similar to the averages of the responses in high and low states.

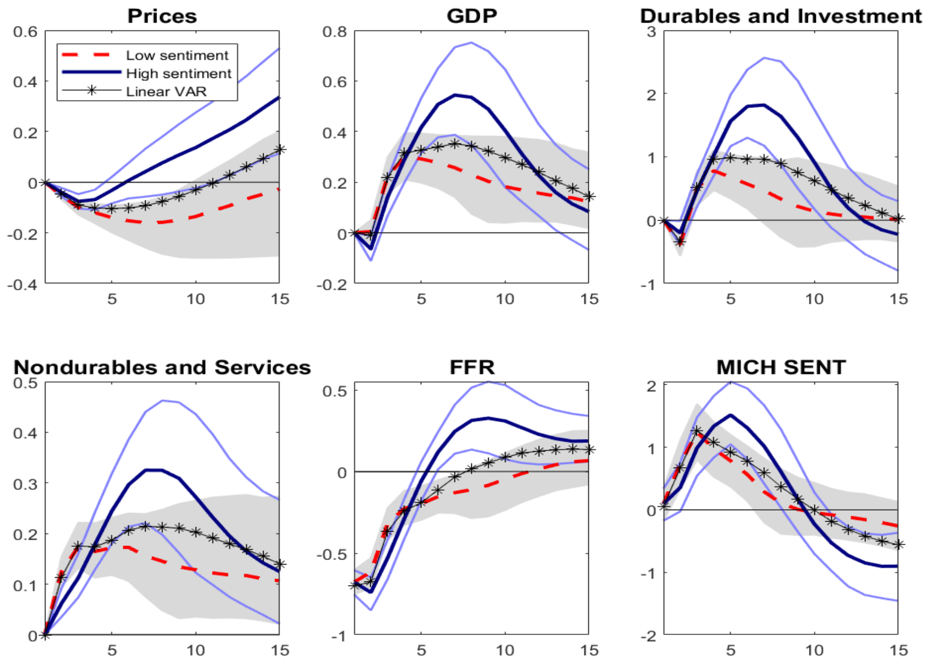
[13]These components of real consumption are important for monetary policy because in real options theory sentiment influences consumption and investment.

In periods of high sentiment, the responses of GDP, durables expenditure with investment, and nondurables expenditure with services are much stronger. In contrast, in periods of low sentiment, these variables respond far less. Notably, the response of durables expenditure with investment is substantially stronger than the response of nondurables expenditure with services. For the same variables, the bottom six panels display a similar pattern and also show quantitatively larger responses to the shock when sentiment is high. For the response of consumer confidence, both the top and bottom six panels in Figure 3 show a significant increase in MCS and CBC after an expansionary monetary shock. This result suggests that after an expansionary monetary shock, economic agents feel more optimistic and confident about the economy.

For the response of the GDP price deflator, I document a 'price puzzle'. A price puzzle is a common result of using a structural VAR with a Cholesky decomposition, which has recursive ordering for identifying monetary policy shocks.[14] Like the responses of the real variables, there is a large difference in the price responses in both the high and low states of each sentiment measure. The literature proposes that one way to resolve the price puzzle is to add more variables into the model as the model may suffer from omitted variables. I have explored 1) adding a variety of variables, such as commodity prices, oil prices, exchange rates, and money supplies, and 2) splitting my sample with and without the post-Volcker period to see if they resolve the price puzzle. But, they do not significantly reduce the price puzzle. I test if the responses are statistically different between the high and low states of sentiment for both the MCS and CBC cases. The results show that the responses are significantly different between the two states for the both cases (Figure A1 in the Appendix).

[14] See Sims (1980) and Christiano et al. (1999) for further discussion on the presence of a price puzzle in structural VAR models.

Michigan consumer sentiment as the state variable



Conference board consumer confidence as the state variable

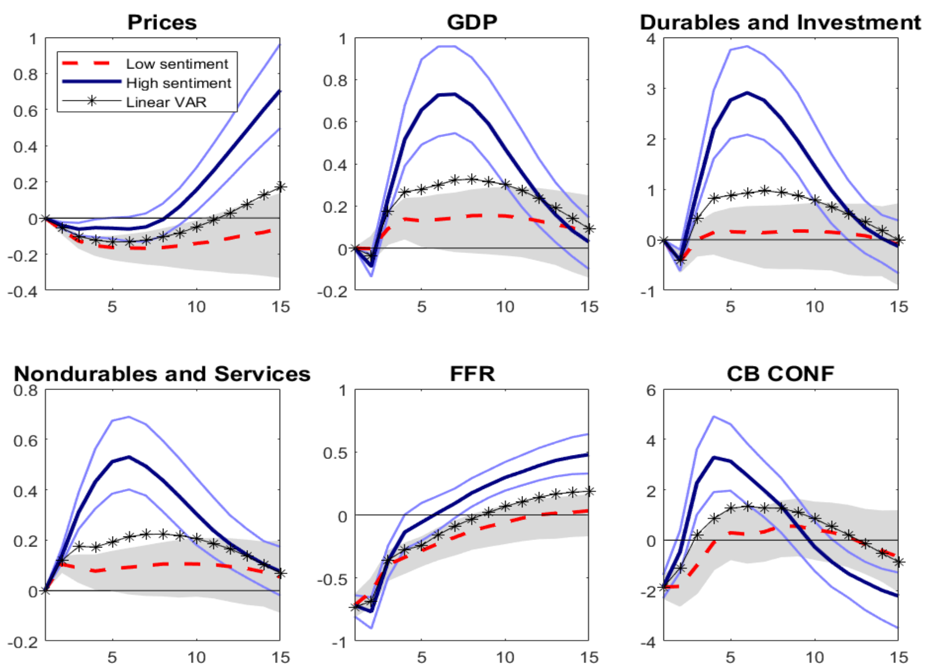


Figure 3: Impulse responses to a monetary policy shock that decreases the federal funds rate by a one-standard deviation. Dark-blue lines (red-dashed lines) show median impulse responses in the high state (the low state) of sentiment. Asterisk lines denote median impulse response in a linear VAR model. Light blue lines (shaded areas) represent 68% point-wise confidence intervals.

4.1 Contributions of monetary policy shocks

I study how important monetary policy shocks are in explaining the fluctuations of the response in the two states. I employ the algorithm used by Caggiano et al. (2017) to compute the state-dependent Generalized Forecast Error Variance Decomposition (GFEVD) for a forecast horizon of 15 quarters. The formula for computing the state-dependent GFEVD is:

$$GFEVD_{ij,\omega_{t-1}}(h) = \frac{\sum_{l=1}^{h} GIRF(h, \delta_j, \omega_{t-1})_i^2}{\sum_{j=1}^{n} \sum_{l=1}^{h} GIRF(h, \delta_j, \omega_{t-1})_i^2} \qquad i, j = 1, ..., n \tag{5}$$

where $GFEVD_{ij,\omega_{t-1}}$ lies between 0 and 1 and measures the relative contribution of a monetary policy shock in each state, i is a variable of interest, j is a monetary policy shock, $h = 0, 1, 2, ..., 15$ is the forecast horizon, n is the number of variables in the vector $\boldsymbol{Y}$, $GIRF(.)$ is a GIRF by Koop et al. (1996), δ_j is size of a monetary policy shock, and ω_{t-1} denotes the initial history of the state of sentiment.[15]

Table 1 shows the results of the GFEVD when the Michigan consumer sentiment is used as the state variable in the SEIVAR model. The table reports that the average contributions of monetary policy shocks for a forecast horizon of 15 quarters are 9%, 22%, 21%, and 24% for prices, GDP, durables expenditure with investment, and nondurables expenditure with services, respectively in the high sentiment state. In contrast, the contributions to the same variables are far less in the low sentiment state (5%, 12%, 6%, and 15%). A FEVD of monetary policy shock from a linear VAR lies in general between the results in the high and low sentiment states. Table 2 reports the results of the GFEVD when the Conference board consumer confidence is used as the state variable. From Table 2, I also document that the GFEVD is larger in the high sentiment state. Figure 4 shows the relative contributions of monetary policy shocks

[15]See the Appendix of Caggiano et al. (2017) for the steps for computing the state-dependent GFEVD.

in the two sentiment states at each point of a forecasting horizon of 15 quarters. From the figure, we see that the contributions in the high sentiment state are much larger than those in the low sentiment state.

Michigan consumer sentiment as the state variable

Variables	High sentiment state	Low sentiment state	Linear VAR
Prices	0.09	0.05	0.41
GDP	0.22	0.12	0.23
Durables and investment	0.21	0.06	0.01
Nondurables and services	0.24	0.15	0.06
Federal funds rate	0.60	0.44	0.25
Michigan consumer sentiment	0.13	0.08	0.06

Table 1: Average contribution of a monetary policy shock in the high and low states of Michigan consumer sentiment (MCS) for a forecasting horizon of 15 quarters. Contribution in the SEIVAR: The Generalized Forecast Error Variance Decomposition (FEVD) of the SEIVER, in which the federal funds rate and MCS are interacted. Contribution in a linear VAR: FEVD of a linear VAR. A monetary policy shock is a one-standard deviation decrease in the federal funds rate.

Conference board consumer confidence as the state variable

Variables	High sentiment state	Low sentiment state	Linear VAR
Prices	0.05	0.05	0.32
GDP	0.34	0.13	0.19
Durables and investment	0.32	0.07	0.03
Nondurables and services	0.48	0.22	0.06
Federal finds rate	0.60	0.52	0.33
Michigan consumer sentiment	0.12	0.06	0.07

Table 2: Average contribution of a monetary policy shock in the high and low states of Conference board consumer confidence (CBC) for a forecasting horizon of 15 quarters. Contribution in the SEIVAR: The Generalized Forecast Error Variance Decomposition (FEVD) of the SEIVER, in which the federal funds rate and CBC are interacted. Contribution in a linear VAR: FEVD of a linear VAR. A monetary policy shock is a one-standard deviation decrease in the federal funds rate.

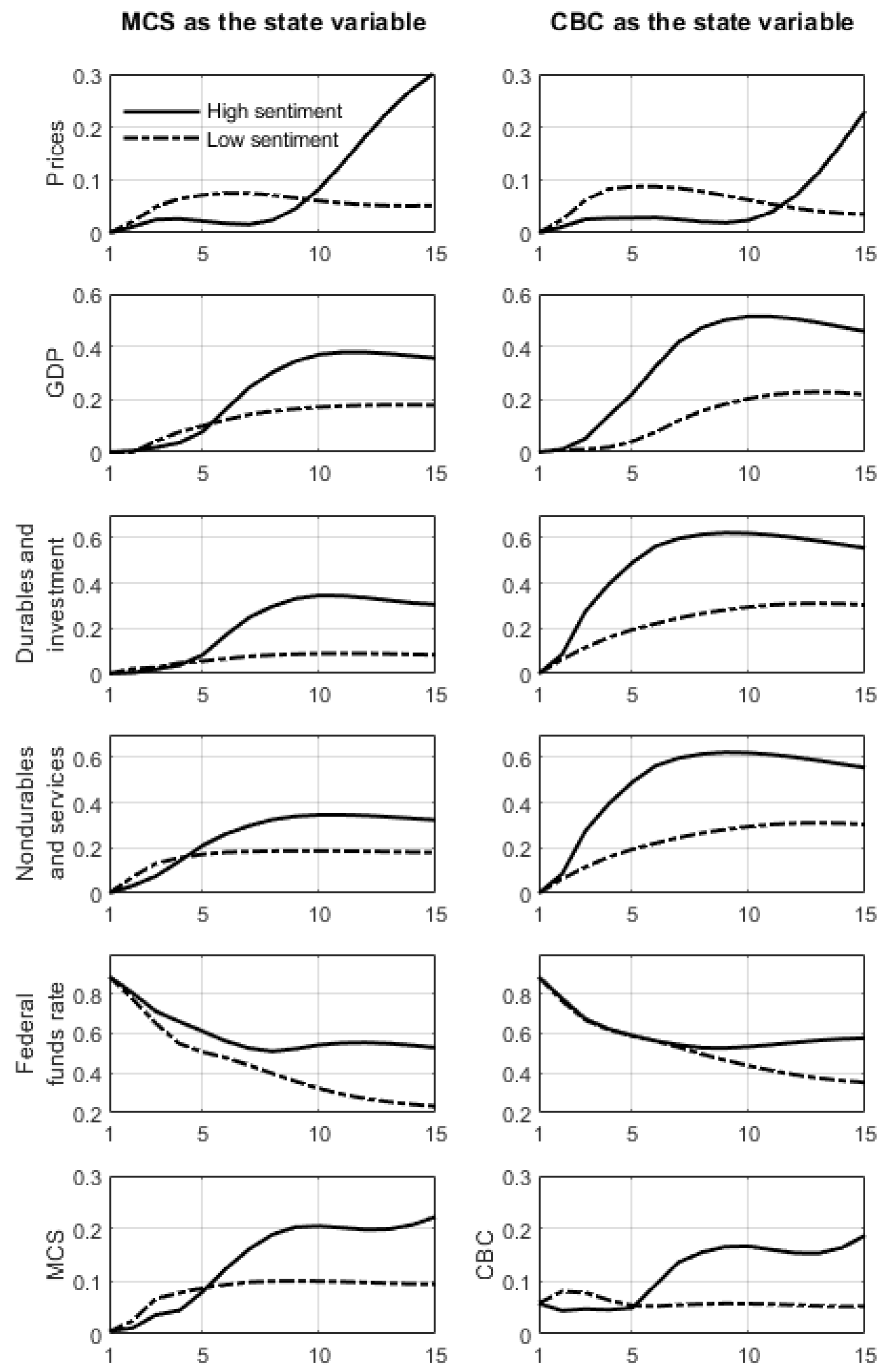


Figure 4: Relative contribution of a monetary policy shock in the high and low states of sentiment at each point of a forecasting horizon of 15 quarters. The first (the second) column shows the contributions in the two states when Michigan consumer sentiment (Conference board consumer sentiment) is the state variable in the SEIVAR. Solid (dash-dotted) lines display the contributions in the high (the low) sentiment state. Contribution in the SEIVAR: The Generalized Forecast Error Variance Decomposition (FEVD) of the SEIVER. A monetary policy shock is a one-standard deviation decrease in the federal funds rate.

4.2 Discussion

The main finding of my paper suggests that the high state of consumer sentiment increases the effectiveness of monetary policy shocks. I propose the following two points to explain possible reasons for this.

First, consumer sentiment could have the amplifying effects on the economy.[16] Findings of Barsky and Sims (2012), Blanchard et al. (2013), Angeletos and La'O (2013), and Angeletos and Lian (2022) suggest that sentiment is a non-fundamental driver of business cycle fluctuations. On the theoretical side, the role of consumer sentiment in economic fluctuations relates to the "sunspot" framework, which was popularized by Farmer (1999) and others. The framework describes that the economy has multiple aggregate equilibria, and a sudden change in economic agents' beliefs can cause the economy to shift from one equilibrium to another. The literature is still silent on the particular importance of consumers' optimism and pessimism for the monetary policy transmission.[17] The well-established view is that when consumers are optimistic, they are likely to increase their spending and borrowing. In turn, firms tend to have more confidence in consumer demand and the economy, which leads to an increase in investments and hirings. Therefore, higher spending and investment boost the economy.[18] Expansionary monetary surprises during such periods may thus have a stronger stimulating effect on the economy, which may, in turn, boost consumers and firms' confidence further. Conversely, pessimistic sentiment could lead to lower consumer spending and investment since consumers and firms become more anxious to

[16]The permanent income hypothesis by Hall (1978) supports that confidence drives consumption. See Ludvigson (2004) and Bachmann and Sims (2012) for empirical details on the role of consumer sentiment in changing consumption and economic activity.

[17]Existing works mostly focus on the role of market sentiment in the transmission of monetary policy. See Section 2.

[18]Gennaioli and Shleifer (2018) argue that high optimism of consumers and firms was a major contributor to the housing bubble and the economic expansion that occurred from the early 2000s to 2007 in the US.

spend and invest, which leads to slow down the economy and may result in a recession.[19] Pessimistic sentiment could also contribute to both consumers and firms' "wait and see" attitude in spending and investment (Bloom, 2009), which can be viewed as an obstacle for monetary policy. Thus, because of this increased cautious attitude, the impacts of expansionary monetary surprises are unlikely to be as effective as during optimistic periods.

Second, consumer sentiment may be a channel of monetary policy to boost the impacts of monetary policy on durable goods consumption and investment. Debes et al. (2014) finds that consumer sentiment increases significantly after a monetary loosening and this increased sentiment temporarily amplifies the impacts of monetary policy on consumption. The variables' ordering in $\boldsymbol{Y}$ of my SEIVAR model and my identification scheme are in line with their finding. I order the price index first and the real variables second, the policy rate third, and consumer sentiment last in $\boldsymbol{Y}$. The ordering allows for the price index and the real variables to respond to a monetary policy shock with a time lag, while consumer sentiment responds contemporaneously to a monetary policy shock. Thus, consumer sentiment responds to a monetary policy shock before the other variables respond. In my analysis, the timing of the peak responses of the variables suggests that after a monetary shock consumer sentiment increases first and next contributes to the impacts of a monetary policy shock on durable goods consumption and investment. Figure 3 shows that after an expansionary monetary shock consumer sentiment increases significantly and the peak response occurs around the fifth quarter after the shock. For durable goods consumption and investment, the responses are also significant, but the peak responses occur around the seventh quarter after the shock. Since consumption and investment account for the vast majority of GDP, we observe a similar response for GDP. It is interesting to point out that the quantitative differences

[19] Blanchard (1993) and Hall (1993) argue that a drop in consumer confidence was the main source of the 1990-1991 recession in the US.

in the responses of durable goods consumption with investment and nondurable goods consumption with services in the two sentiment states suggest that consumers prefer to spend more on durable goods during optimistic periods following a monetary policy loosening.

In summary, this section proposes and discusses a possible source for my paper's main finding. The amplifying effects of consumer sentiment on the economy seem to be the underlying source of the higher effectiveness of monetary policy shocks when consumer sentiment is lifted. For this amplification mechanism, durable goods consumption and investment appear to be the key channels through which consumer sentiment boosts the impacts of monetary policy. From a policy point of view, the implication of this section is that when consumer sentiment is low, the power of monetary policy in stimulating the economy is reduced. Although not discussed in this section, it is interesting to point out how consumer sentiment is formed. Understanding the formation of consumer sentiment is important for monetary policy to achieve its objectives. A recent work by Coibion et al. (2020) suggests that economic agents' inflation expectations can be used as a monetary policy tool for economic stabilization purposes. The authors stress that forward guidance and effective communication strategies play a crucial role to drive these expectations.

5 Robustness checks

This section examines the robustness of my findings with respect to: 1) alternative measure for sentiment; 2) uncertainty as an additional control variable; 3) alternative threshold of sentiment. Overall, my results are robust to these checks. I report the robustness results at the end of this section.

As the first robustness check, I replace sentiment with the principal component of the different sentiment measures for the US. As there exists no single perfect measure for sentiment (Lutz, 2015), I consider six different sentiment measures that the literature provides. Instead of estimating IRs for each of these measures, I compute the principal component of them. Figure A2 in the Appendix shows the principal component along with the different sentiment measures I considered. Figure 5 presents the impulse responses, and I document that the responses to an expansionary monetary shock are larger in high sentiment states than in low sentiment states.

Second, I add uncertainty as a control variable into my SEIVAR model. I use the economic financial uncertainty by Ludvigson et al. (2021) as an uncertainty measure. I control for uncertainty in the SEIVAR model as sentiment and uncertainty are inversely associated. By following Pellegrino (2021) and Caggiano et al. (2017), I order uncertainty first in a vector $\boldsymbol{Y}$ in the SEIVAR model. The ordering of the variables becomes: 1) uncertainty, 2) prices, 3) GDP, 4) durables expenditure and investment, 5) nondurables expenditure and services, 6) the federal funds rate, and 7) sentiment. Figure 6 reports the results, which appear similar to the baseline case.

Third, I set a wider tolerance band (ten percentile, which is the maximum level I could consider given the two deciles) around the ninth and first deciles of the distribution of sentiment to define the two states of sentiment. By doing so, samples for the two states contain more historical data of the state of sentiment. In the baseline case, I set an eight percentile tolerance band around the two deciles (Figure 2). When the tolerance band increases to 10 percentile, the high state covers ($80^{th}perc. \leq sent \leq 100^{th}perc.$) and the low state covers ($0^{th}perc. \leq sent \leq 20^{th}perc.$) of the distribution of sentiment. Figure A3 in the Appendix shows the high and low states of the two sentiment measures under this wider tolerance level. Compared to Figure 2, Figure A3 shows more observations for each state. Figure 7 presents the results. Again, the results are very similar to my baseline case shown in Figure 3.

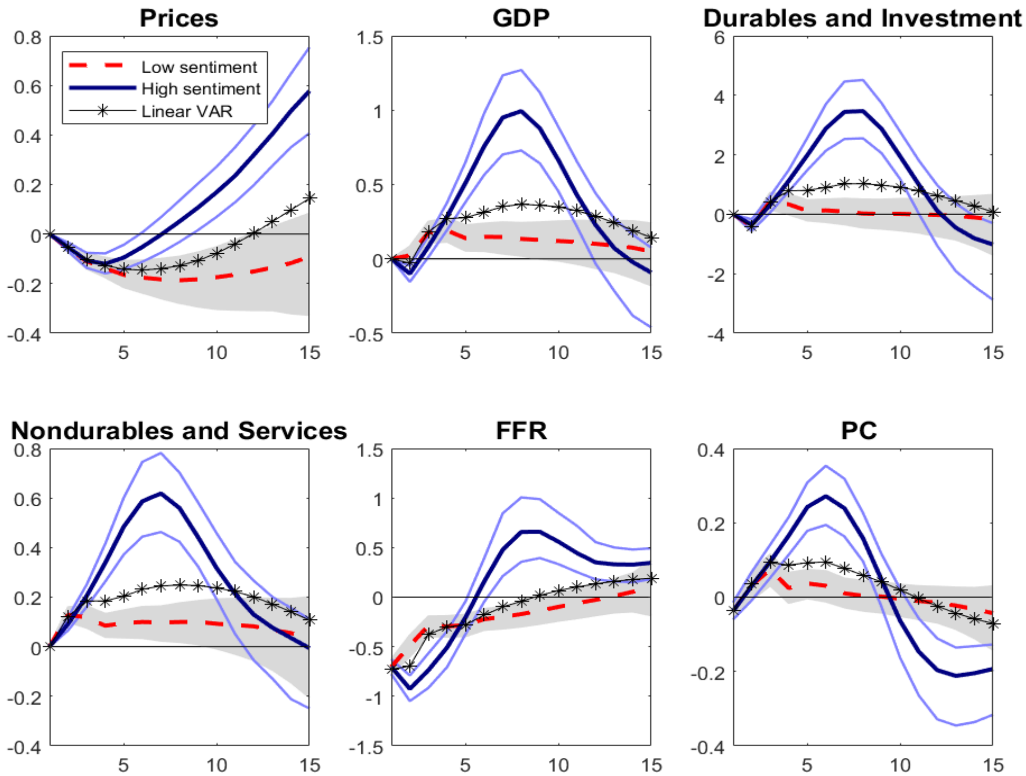
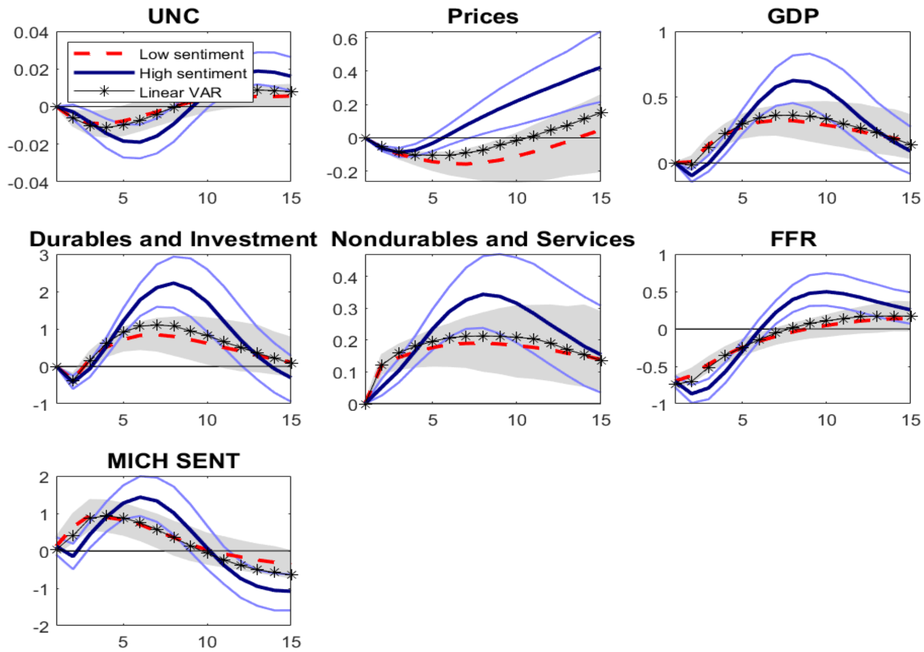


Figure 5: Impulse responses under the principal component (PC) of the different sentiment measures as the state variable. A monetary policy shock is a one-standard deviation decrease in the federal funds rate. Dark-blue lines (red-dashed lines) show median impulse responses in the high state (the low state) of sentiment. Asterisk lines denote median impulse responses in a linear VAR model. Light blue lines (shaded areas) represent 68% point-wise confidence intervals.

Michigan consumer sentiment as the state variable



Conference board consumer confidence as the state variable

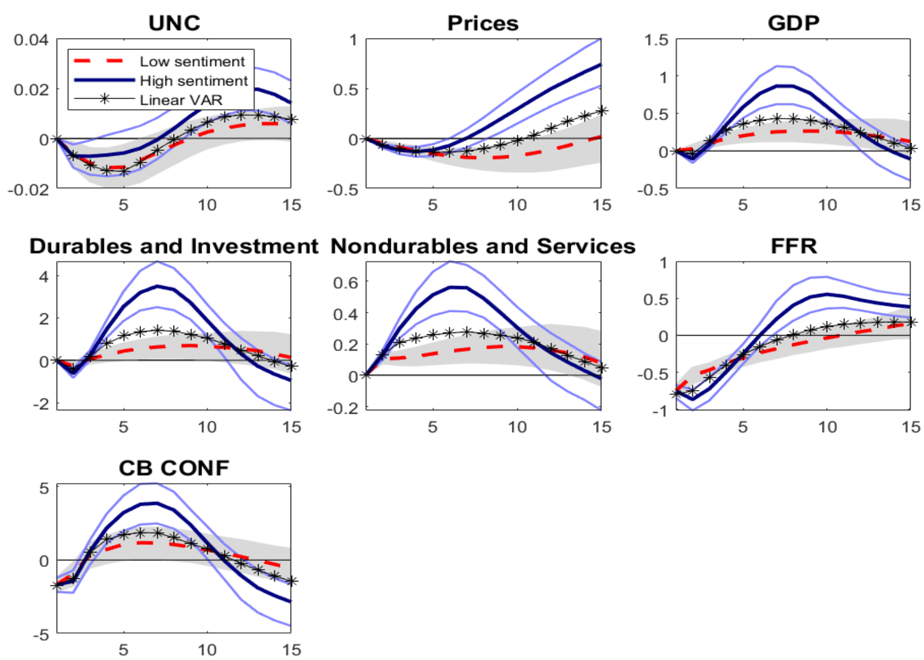
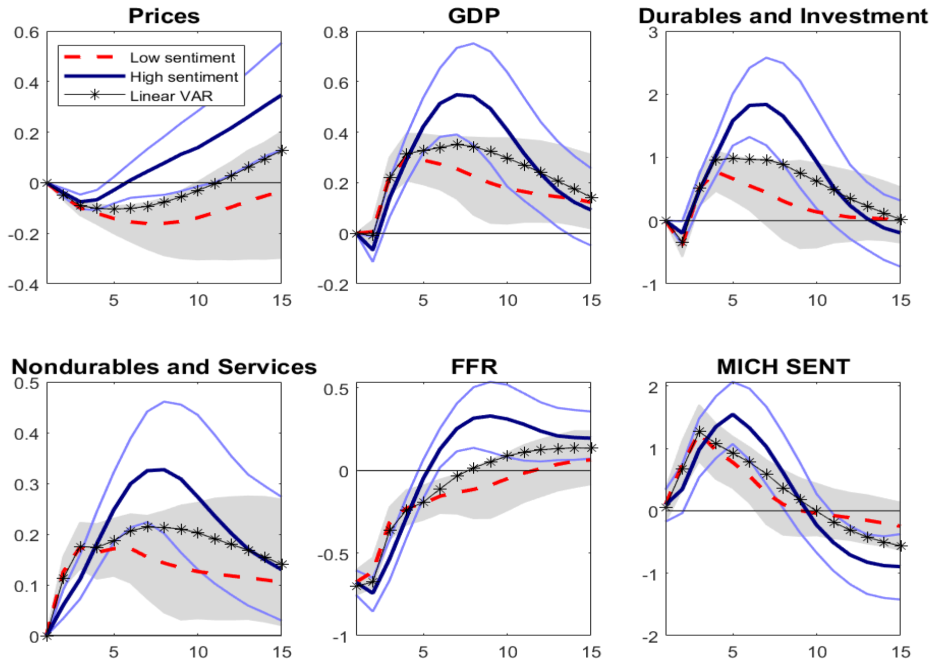


Figure 6: Impulse responses under uncertainty as an additional control variable. A monetary policy shock is a one-standard deviation decrease in the federal funds rate. Dark-blue lines (red-dashed lines) show median impulse responses in the high state (the low state) of sentiment. Asterisk lines denote median impulse responses in a linear VAR model. Light blue lines (shaded areas) represent 68% point-wise confidence intervals.

Michigan consumer sentiment as the state variable



Conference board consumer confidence as the state variable

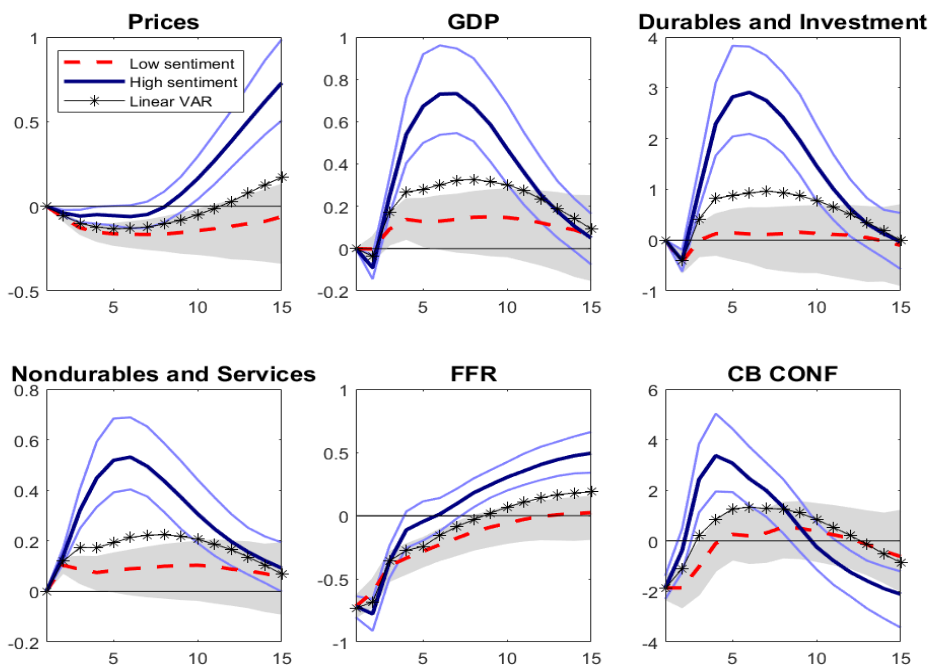


Figure 7: Impulse responses under the wider tolerance band of sentiment. A monetary policy shock is a one-standard deviation decrease in the federal funds rate. Dark-blue lines (red-dashed lines) show median impulse responses in the high state (the low state) of sentiment. Asterisk lines denote median impulse responses in a linear VAR model. Light blue lines (shaded areas) represent 68% point-wise confidence intervals.

6 Conclusion

The macroeconomic role of sentiment has received much attention lately, yet the empirical evidence on the role of sentiment in the effectiveness of monetary policy is limited. My study seeks to contribute to this literature by finding evidence of sentiment-dependent effects of monetary policy shocks for the US economy. I find that the effectiveness of monetary policy is reduced when sentiment is low.

My findings have important implications for monetary policy and the models that study its effects. My results imply that periods of low sentiment pose big challenges for monetary policymakers. Evidence I find in this paper calls for more aggressive monetary policy measures during low sentiment periods. On the modeling side, my results underline the importance of taking into account sentiment.

Appendix

A1 Specification of the SEIVAR model

To specify the SEIVAR that I use in this paper, I first start by illustrating a standard VAR in the following structural form:

$$\boldsymbol{B}_0 \boldsymbol{Y}_t = \boldsymbol{C} + \sum_{k=1}^{L} \boldsymbol{B}_k \boldsymbol{Y}_{t-k} + \boldsymbol{\varepsilon}_t \tag{1}$$

$$\boldsymbol{\varepsilon}_t \sim d(0, \boldsymbol{\Omega}) \tag{2}$$

where $\boldsymbol{B}_0$ is a lower triangular (n x n) matrix with ones on the main diagonal, $t = 1, ..., T$ is time, $\boldsymbol{Y}_t$ is a (n x 1) vector of endogenous variables, $\boldsymbol{C}$ is a (n x 1) vector of intercept, $k = 1, ..., L$ denotes lags, $\boldsymbol{B}_k$ is a (n x n) matrix of coefficients, $\boldsymbol{\varepsilon}_t$ is the (n x 1) vector of error terms whose variance-covariance matrix is $\boldsymbol{\Omega}$, and $d(\cdot)$ is the distribution of the residuals.

Then, the structural VAR is augmented with an interaction term between the federal funds rate and a sentiment measure. The structural VAR with the interaction term (IVAR), which is in brackets, is:

$$\boldsymbol{B}_0 \boldsymbol{Y}_t = \boldsymbol{C} + \sum_{k=1}^{L} \boldsymbol{B}_k \boldsymbol{Y}_{t-k} + \left[\sum_{k=1}^{L} \boldsymbol{D}_k R_{t-k} \cdot sent_{t-k} \right] + \boldsymbol{\varepsilon}_t \tag{3}$$

where $\boldsymbol{D}_k$ is a (n x 1) vector of coefficients, R_t is the federal funds rate (the policy rate that I applied the shock to), $sent_t$ is a sentiment measure (a conditioning variable that defines the high and low states), and the rest are defined as in equation (1).

Pre-multiplying the IVAR in equation (2) with $\boldsymbol{B}_0^{-1}$ yields the reduced-form of the model. Then, I add a linear time trend into the model by following Pellegrino (2021). Finally, the SEIVAR is expressed in the following reduced form, which is same as the model specified in equation (1) in the main text:

$$\boldsymbol{Y}_t = \boldsymbol{c} + \boldsymbol{\tau} \cdot t + \sum_{k=1}^{L} \boldsymbol{b}_k \boldsymbol{Y}_{t-k} + \left[\sum_{k=1}^{L} \boldsymbol{d}_k R_{t-k} \cdot sent_{t-k} \right] + \boldsymbol{u}_t \tag{4}$$

$$sent_t = \epsilon_{sent}^{'} \boldsymbol{Y}_t \tag{5}$$

$$R_t = \epsilon_R^{'} \boldsymbol{Y}_t \tag{6}$$

$$E(\boldsymbol{u}_t \boldsymbol{u}_t^{'}) = \boldsymbol{\Omega} \tag{7}$$

where $\boldsymbol{\tau}$ is the (n x 1) vector of slope coefficients for the linear time trend t, $\boldsymbol{c} = \boldsymbol{B}_0^{-1}\boldsymbol{C}$, $\boldsymbol{b}_k = \boldsymbol{B}_0^{-1}\boldsymbol{B}_k$, $\boldsymbol{d}_k = \boldsymbol{B}_0^{-1}\boldsymbol{D}_k$, $\boldsymbol{u}_t = \boldsymbol{B}_0^{-1}\boldsymbol{\varepsilon}_t$, and ϵ_y is a selection vector for the endogenous variable y in $\boldsymbol{Y}$. The rest is defined as in equation (1) in the main text.

A2 Linearity test in the SEIVAR model

I conduct a linearity test whether there exists evidence for the interaction term, nonlinear specification, in the SEIVAR model. Since the standard VAR and the SEIVAR are nested models, I use a likelihood-ratio (LR) test for the exclusion of the interaction term in the SEIVAR. The LR test tests the null hypothesis of a standard VAR model against the alternative hypothesis of the SEIVAR model, which resembles a VAR model with the interaction term. The test statistic of the LR test is:

$$LR = T\big(ln|\tilde{\boldsymbol{\Omega}}^r_{\boldsymbol{u}}| - ln|\tilde{\boldsymbol{\Omega}}_{\boldsymbol{u}}|\big) \tag{8}$$

where T is the sample size, $|\tilde{\boldsymbol{\Omega}}^r_{\boldsymbol{u}}|$ is the estimated variance-covariance matrix in the restricted model (the standard VAR), $|\tilde{\boldsymbol{\Omega}}_{\boldsymbol{u}}|$ is the estimated variance-covariance matrix in the unrestricted model (the SEIVAR), and ln denotes the natural logarithm. The LR test suggests that $\chi_{12} = 37.02$ with a p-value $= 0.00521$ when the Michigan consumer sentiment is used as a sentiment measure, while $\chi_{12} = 52.65$ with a p-value $= 0.00003$ when the Conference Board consumer confidence is used as a sentiment measure. Since the p-values are less than 1%, I strongly reject the null hypothesis of the standard linear VAR. This suggests that there exists statistically significant evidence for the interaction term in the SEIVAR model.

A3 Generalized Impulse Response Functions

I compute IRs to monetary policy shocks via GIRFs by Koop et al. (1996).[20] Following Koop et al. (1996) and Kilian and Vigfusson (2011), the GIRFs of the vector of endogenous variables in $\boldsymbol{Y}_t$ are computed as:

$$GIRF_{\mathbf{Y},t}\big(h, \delta, \boldsymbol{\varpi}_{t-1}\big) = E\big[\mathbf{Y}_{t+h}|\delta, \boldsymbol{\varpi}_{t-1}\big] - E\big[\mathbf{Y}_{t+h}|\boldsymbol{\varpi}_{t-1}\big] \tag{9}$$

where $h = 0, 1, ..., H$ is the horizons for which the GIRFs are computed, t is the time of the shock, and δ is the shock size, $\boldsymbol{\varpi}_{t-1} = \{\boldsymbol{Y}_{t-1}, ..., \boldsymbol{Y}_{t-k}\}$ is the initial condition for observed values of $\boldsymbol{Y}$, where k is the number of lags, and $E\big[\cdot\big]$ is the expectation. $\boldsymbol{\varpi}_{t-1}$ is from the ninth and the first deciles of the distribution of sentiment with an eight percentile tolerance band around the two deciles[21].

$$\textbf{\textit{High sentiment state}} : \{\varpi_{t-1} : 82^{th} perc. \leq sent_{t-1} \leq 98^{th} perc.\}$$
$$\textbf{\textit{Low sentiment state}} : \{\varpi_{t-1} : 2^{th} perc. \leq sent_{t-1} \leq 18^{th} perc.\}$$

Given equation (9), the formula for computing nonlinear GIRFs that are conditional on the high and low states of sentiment is:

$$GIRF_{\mathbf{Y},t}\big(h, \delta, \boldsymbol{\Omega}_{t-1}^{state\, i}\big) = \mathbb{E}\big[GIRF_{\mathbf{Y},t}\big(h, \delta_t, \{\boldsymbol{\varpi}_{t-1} \in \boldsymbol{\Omega}_{t-1}^{state\, i}\}\big)\big] \tag{10}$$

where $\boldsymbol{\Omega}_{t-1}^{state\, i}$ is histories of the state of sentiment $i = \{highsentiment, lowsentiment\}$[22].

[20] An alternative approach to GIRFs for computing nonlinear IRs is Local Projections by Jordà (2005). As argued by Owyang et al. (2013), GIRFs are preferred over Local Projections for two reasons. First, Local Projections are not informative as GIRFs since they compute average IRs in a given state, while GIRFs compute precise IRs in each quarter of a given state. Second, Local Projections require large degrees of freedom. This is often not suitable for computing nonlinear IRs because computation of nonlinear IRs is sensitive to historical samples for a given state.

[21] This wide tolerance band makes it possible to include large enough quarters of the high and low states of sentiment.

[22] See Appendix A1 of Pellegrino (2021) for the description of the algorithm that is used to compute the nonlinear GIRFs and their confidence intervals.

A4 Correlation between sentiment and uncertainty measures

Regime	*Michigan consumer sentiment*	*Conference board consumer confidence*
Linear	-0.34	-0.09
Recessions	-0.54	-0.30
Expansions	-0.10	0.13

Table A1: Correlation between sentiment and uncertainty measures. Sentiment measure: Michigan consumer sentiment (MCS); Conference board consumer confidence (CBC). Uncertainty measure: the economic financial uncertainty by Ludvigson et al. (2021). Sample: 1960Q1–2009Q2 for the correlation between MCS and uncertainty; 1970Q1–2009Q2 for the correlation between CBC and uncertainty. For example, -0.34 indicates the correlation between MCS and uncertainty for the period 1960Q1–2009Q2, and -0.54 indicates the correlation between the two series for only NBER defined recessions in the same period.

A5 Data sources

This section complements Section 3.2 of the paper and provides details on the source and construction of the data series used in my paper.

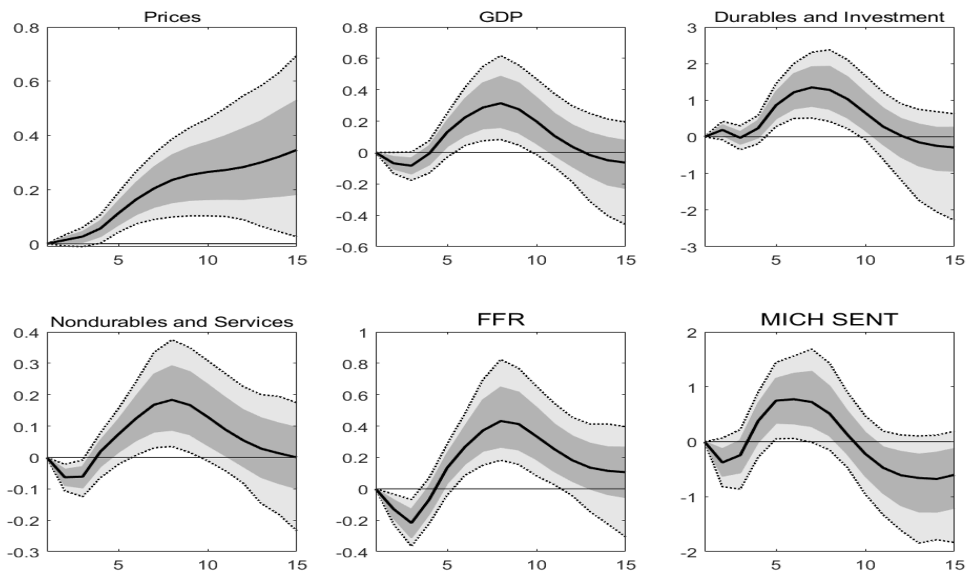
- **Sentiment measures for the US.** Source (data): the Survey of Consumers, the University of Michigan (Michigan Consumer Sentiment and Michigan Consumer Expectations); the Conference Board (Conference Board Consumer Confidence); the OECD database (US business Confidence, US Consumer Confidence, US Business Tendency); Baker and Wurgler (2007) (Investor Sentiment Index); Ludvigson et al. (2021) (Economic Financial Uncertainty Index). All the sentiment measures are monthly. For this analysis, I take the quarterly average of them.

- **GDP, investment, prices, and the FFR:** The source is the Federal Reserve Bank of St. Louis (FRED). The exact names of the variables: Real Gross Domestic Product, Billions of Chained Dollars, Quarterly, Seasonally Adjusted Annual Rate; Real Gross Private Domestic Investment, Billions of Chained Dollars, Quarterly, Seasonally Adjusted Annual Rate; Gross Domestic Product: Implicit Price Deflator; Effective Federal Funds Rate, Percent, Quarterly, Not Seasonally Adjusted.

- **Consumption expenditure variables:** The source is the Federal Reserve Bank of Philadelphia. The exact names of the variables: Real Personal Consumption Expenditure on Durable Goods, Nondurables goods, and Services, Billions of Dollars, Quarterly, Seasonally Adjusted.

A6 Supplementary figures

Michigan consumer sentiment as the state variable



Conference board consumer confidence as the state variable

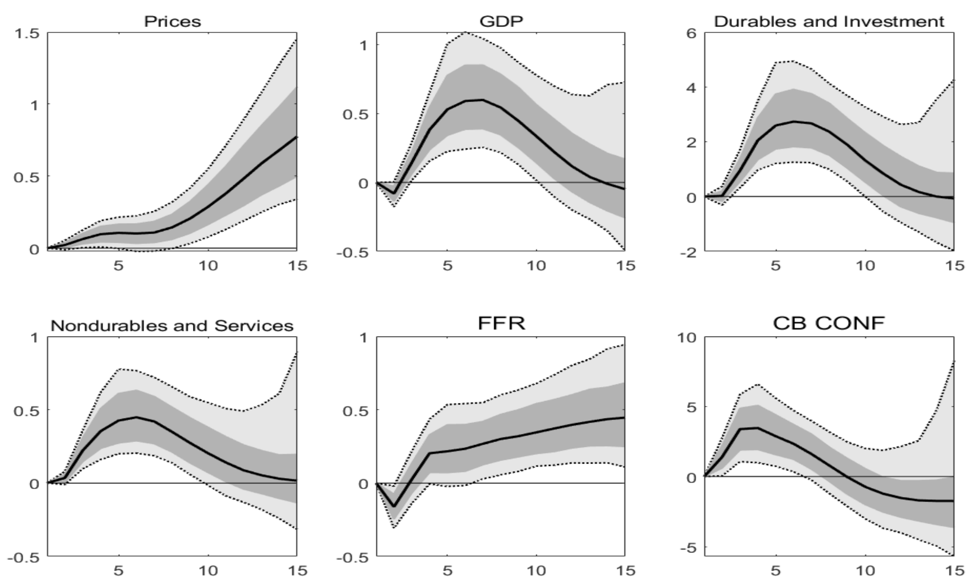


Figure A1: Difference between the impulse responses in the high and low states of sentiment. Black solid line denotes difference between median responses in the high and low states of sentiment (high state responses minus low state responses). Dark shaded areas (light shaded areas) denote 68% point-wise confidence intervals (90% point-wise confidence intervals).

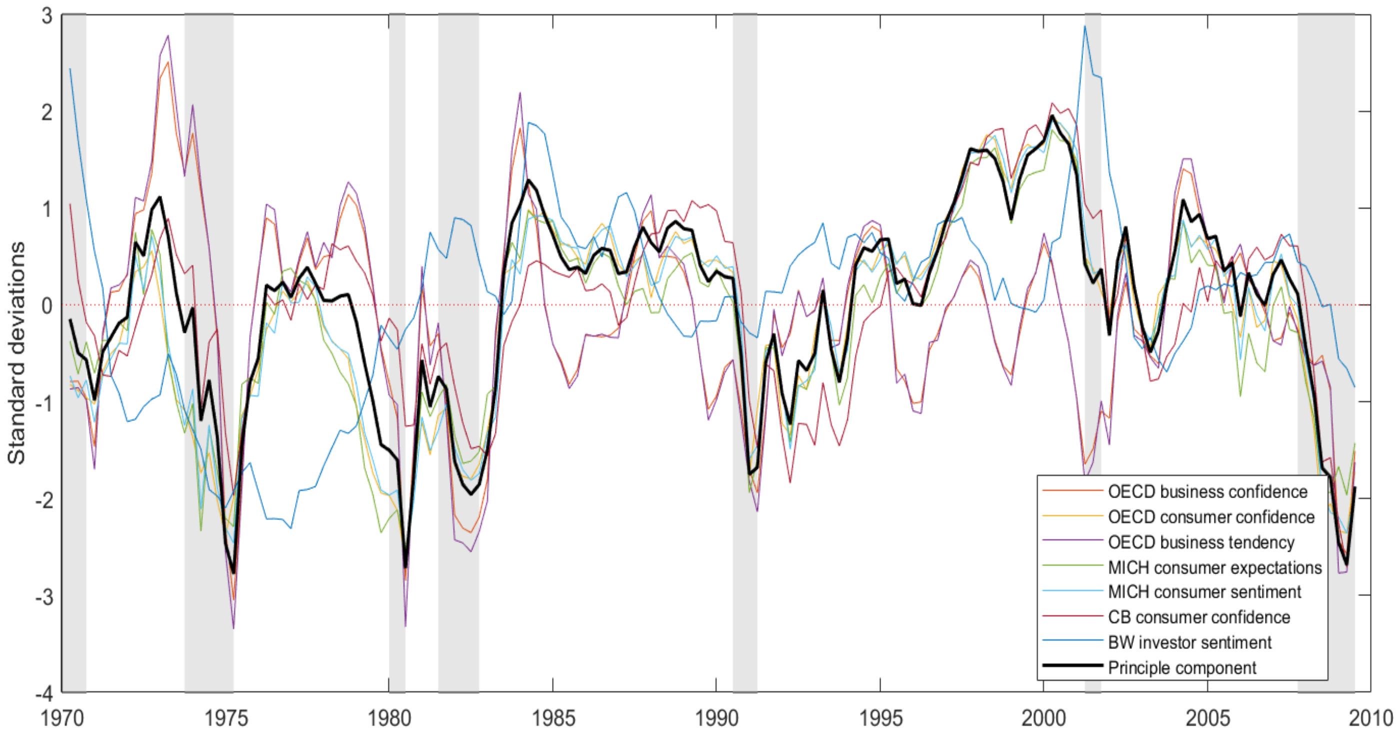


Figure A2: The principal component of the different sentiment measures for the US. Sample: 1970Q1–2009Q2. Black solid line: the principal component. Other colour lines: the selected sentiment series for the US. The selection of the sentiment measures is dictated by data availability. All the sentiment series are standardized as they are in different measures.

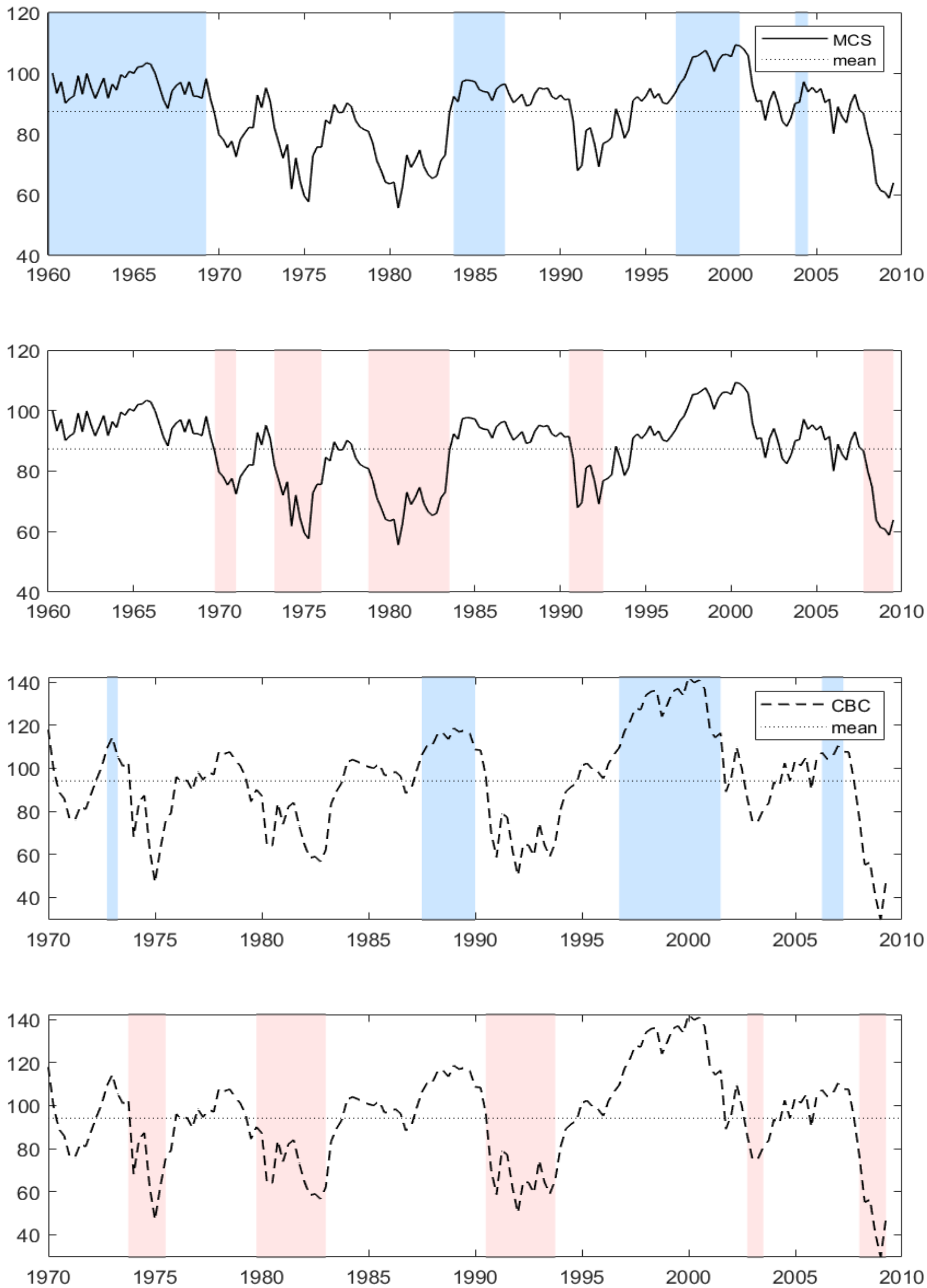


Figure A3: The high and low states of sentiment under the wider tolerance band. The upper two panels are for Michigan consumer sentiment (MCS). The lower two panels are for Conference board consumer confidence (CBC). Light blue areas (light red areas) denote the high state (low state). The states are defined by a 10 percentile tolerance band around the 9^{th} and 1^{th} deciles of the distribution of each sentiment.

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Conclusion

Inspecting empirically the effects of monetary policy shocks is essential to gain a better understanding of the transmission channels of monetary policy, and to help policymakers improve their conduct of monetary policy. The business cycle, household debt, and sentiment have received much attention lately, both by researchers and practitioners, as potential determinants of the propagation mechanisms of monetary policy disturbances. My thesis contributes to this recent body of research by providing new empirical evidence on the nature and importance of different types of non-linearity in the transmission of monetary impulses. My thesis estimates non-linear time-series models on US and Australian data to explore the extent to which the effects of monetary policy shocks are influenced by the business cycle, sentiment, and household debt. I find strong evidence that the effectiveness of monetary policy depends on the state of the business cycle, the level of sentiment, and the degree of household indebtedness.

The first chapter explores how the level of household debt affects monetary policy transmission in Australia. We estimate a state-dependent local projection model and find that the effects of monetary policy are less powerful during periods of high household debt. The second chapter focuses on the distinction between phases of strong versus weak economic growth in Australia. We investigate whether the effectiveness of monetary policy in Australia depends on the pace of economic growth by estimating a smooth-transition local projection model. Our results show that monetary policy is less effective in weak-growth phases than in strong-growth periods. In the third chapter, I estimate a self-exciting interacted vector autoregression model to assess the role of sentiment in the propagation of monetary policy shocks in the US. I find that the effects of monetary policy on the US economy are less powerful when sentiment is low.

Overall, the empirical findings reported in my thesis imply that periods of weak economic growth, low sentiment, and high household debt pose challenges for central banks, as monetary policy loses traction during these phases. Hence, a good strategy for central banks may be to pursue more aggressive and prompt monetary policies during these episodes.