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House Prices, Monetary Policy and Commodities: Evidence from Australia*

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Monetary policy and commodity prices are key drivers of Australian house prices, but endogeneity between these variables complicates empirical research. To address this, we use local projection methods and instrumental variables for estimation. We find that one standard deviation expansionary monetary and commodity shocks increase house prices at peak by 1.5 per cent and 1.4 per cent, respectively. Using geographically disaggregated panel data, we exploit the heterogeneity in house price responses to study the different channels through which these shocks affect housing markets. We find that both monetary policy and commodity price shocks have significant effects on housing markets through income channels.

I *Introduction*

As Australian house prices hit new highs, both the public and policy-makers have become increasingly concerned about housing affordability. To understand these changes, we first need to understand the economic drivers of house price movements. In this paper, we study the effects of two of the most important influences on the Australian macroeconomy: monetary policy and commodity prices.

As shown in Figure 1, real house prices increased by 230 per cent between 1991 and 2020 (*i.e*. the dates of Australia's two most recent recessions). Over this same period, the cash rate target set by the Reserve Bank of Australia (RBA) has fallen by 5.2 percentage points. In addition, the RBA's commodity price index reached record highs in 2021, having increased more than 200% per cent over the past 20 years. Both factors are likely to have influenced the evolution of house prices over this period. Changes in monetary policy affect household borrowing costs and overall economic activity, both of which influence housing demand. Moreover, because the Australian economy is heavily dependent on commodity exports, changes in commodity prices can have large effects on national income and wealth, which also affect housing demand.[1]

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[1] In 2021, the value of Australia's commodity exports was $422.3 billion which represented 92 per cent of Australia's export income (ABS, 2022a). Approximately 2 per cent of Australia's employed population worked in the mining industry in 2021 (ABS, 2022b).

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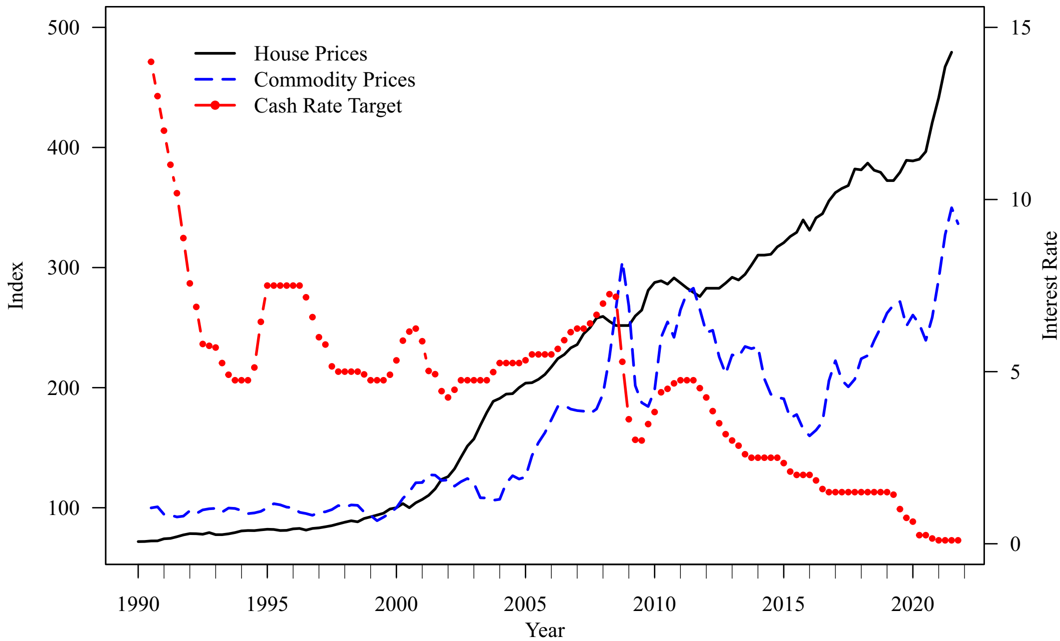
FIGURE 1
Real Australian House Prices, Real Commodity Prices and Cash Rate Target



Notes: House prices and commodity prices are indexed to 100 in 2000Q1.
Source: Authors' calculations using data from ABS, CoreLogic, RBA.

In this paper, we study the effects of monetary policy and commodity price shocks on house prices in Australia. Our empirical approach combines geographically disaggregated panel data, local projection methods for estimation of dynamic effects (Jordà, 2005) and instrumental variables strategies to identify the causal effects of shocks. In doing so, we first address several endogeneity issues associated with our factors of interest. We then exploit the significant heterogeneity in our dataset to explore the particular channels through which monetary policy and commodity prices impact the housing market.

The primary empirical challenge for our study is to deal with the endogeneity between monetary policy, commodity prices and house prices. House prices are equilibrium objects that respond to changes in demand due to income, credit conditions and expectations about the future. However, monetary policy and commodity prices both affect and respond to these factors. In addition, monetary policy and commodity prices affect each other: while monetary policy can affect commodity income through their effect on the exchange rate, changes in commodity prices can influence monetary policy decisions through its impact on economic activity. These interactions between our factors of interest can confound attempts to separately identify effects on house prices. To deal with these endogeneity issues, we use two instrumental variables methods to estimate causal effects. First, to identify exogenous monetary policy shocks we follow the narrative identification approach of Romer and Romer (2004), which removes the anticipated component of policy changes by controlling for the central bank's internal forecasts of economic activity.[2] Importantly for this study, the method ensures that movements in monetary policy are

[2] Bishop and Tulip (2017), Beckers (2020), and La Cava and He (2021) adapted and made use of the Romer and Romer (2004) instrument for Australia.

not affected by any predicted increase in household incomes due to higher commodity prices. Second, to identify exogenous commodity price shocks we produce a shift-share instrument that combines cross-state variation in exposure to commodity exports with time-series variation in international commodity prices.[3] Because there is significant variation across Australian states in exposure to commodity exports (see Fig. 3), local housing markets differ in their exposure to fluctuations in commodity prices. Moreover, commodity prices are largely determined by developments in international markets, so these shocks are uncorrelated with the local economic conditions that otherwise drive house prices. Furthermore, because international commodity prices are expressed in US dollars, there is no risk of contamination by the effect of monetary policy on the Australian exchange rate.

The second contribution of our study is to identify the particular channels through which monetary policy and commodity prices affect house prices. That is, we want to understand the extent to which monetary policy and commodity prices affect house prices through direct (*i.e.* interest rate) and indirect (*i.e.* income and wealth) channels.[4] We explore these channels by exploiting the heterogeneity across our disaggregated panel data. We observe quarterly house price movements across housing markets in Level 2 Australian Statistical Areas (SA2), which have an average population of around 10,000 people (ABS, 2016).[5] Combining our housing market panel data with cross-sectional data on local incomes, industries of employment, homeownership, mortgage costs and wealth, we can study the heterogeneous effects of monetary policy and commodity prices along various dimensions. Our analysis of these heterogeneous effects is enabled using local projection methods, which allow us to estimate non-linearities in the response of house prices to shocks (see Jordà, 2005).

In our main exercises, we estimate the dynamic effects of monetary policy and commodity prices on house prices using the local projection method with instrumented shocks. Our benchmark instrumental variables estimates suggest that both shocks have statistically and economically significant effects on house prices in Australia. Following a one standard deviation expansionary monetary policy shock, the response of house prices peaks at 1.47 per cent after 1 year. Following a one standard deviation positive commodity price shock, house prices increase by a peak 1.38 per cent around 3 years after the shock. While monetary policy shocks lead to an immediate and persistent rise in house prices, the effect of commodity price shocks is much more delayed. These benchmark estimates reflect the average response of house prices across small geographic areas in Australia. However, we find that there is significant cross-sectional heterogeneity in responses to each shock. For example, when we estimate house price responses to the shocks for each area separately, the variance of the estimates at peak effects is 6.4 and 2.5 times larger than the pooled average estimated effects for monetary policy and commodity prices, respectively.

This cross-sectional heterogeneity in house price responses allows us to estimate the importance of the various channels through which monetary policy and commodity prices operate. First, we estimate heterogeneous responses to monetary policy across areas with different levels of income and different degrees of employment sensitivity to monetary policy. Areas with low incomes or high employment sensitivity to interest rates are likely to be much more exposed to the indirect effects of monetary policy through household incomes. We find that house prices in regions with more low-income earners or higher employment sensitivity are much more responsive to monetary policy shocks. Unlike the average effect of monetary policy on house prices, these heterogeneous effects are observable only after several years. However, these results are consistent with the view that the effect of monetary policy on the macroeconomy operates with long (and variable) lags.[6] Second, we estimate heterogeneous responses to monetary policy across areas with different numbers of renters and different sizes of houses. Because

[3] Shift-share instruments are often described as Bartik-style instruments following Bartik (1991). See Goldsmith-Pinkham *et al.* (2020), Borusyak *et al.* (2018), and Adao *et al.* (2019) for recent discussions of these instruments.

[4] For a theoretical discussion of the impact of monetary policy channels on aggregate demand, see Auclert (2019) and Kaplan *et al.* (2018).

[5] This level of geographic aggregation is comparable to the macroeconomics and housing literature that studies cross-sectional data from US counties or metropolitan statistical areas. See, for example, Mian *et al.* (2013), Aladangady (2017), Guren *et al.* (2021), and Graham and Makridis (Forthcoming).

[6] See, *e.g.*, Ellis (2018).

areas with more renters and smaller houses are both more responsive to monetary policy and more likely to attract housing investors, we take this as evidence that monetary policy may also operate directly through an interest rate-sensitive housing investment channel.

Third, we study the effects of commodity price shocks through income and wealth channels. Income effects occur through changes in wages and employment in commodity-related industries, while the wealth channel works through household ownership of commodity-producing or -related businesses (*e.g.* equity or stocks). To assess the influence of income effects, we study heterogeneous responses to commodity price shocks across areas with different employment shares in commodity-related industries. To assess the influence of wealth effects, we test for heterogeneous responses to commodity price shocks across areas with different stock and business equity ownership rates. We find strong evidence that commodity price shocks affect house prices through an income channel rather than a wealth channel.

(i) Related Literature

Our research first relates to a strand of the literature studying the relationship between monetary policy and house prices. Much of this literature uses data from the USA (Fratantoni & Schuh, 2003; Jarocinski & Smets, 2008; Aastveit & Anundsen, 2018; Moulton & Wentland, 2018; Paul, 2020), Europe (Nocera & Roma, 2018; Robstad, 2018) or large cross-country panel datasets (Kuttner & Shim, 2012; Jordà *et al.*, 2015; Williams, 2016).

There is also a small but growing literature using data from Australia.[7] Abelson *et al.* (2005) study the long-run determinants of Australian house prices using an error correction model and data from 1970 to 2003. They find that house prices are significantly positively affected by disposable income and negatively affected by changes in real mortgage interest rates. Fry *et al.* (2010) use a structural vector autoregressive (SVAR) model to study overvaluation in the Australian housing market with data from 1980 to 2008. They find that monetary policy contributed very little to overvaluation in the housing market in the mid-2000s. Instead, aggregate demand shocks explain a significant fraction of the increase in house prices in this period. Interestingly, this was a period of especially high prices for Australian commodities (see Fig. 1), although this is not explicitly explored in Fry *et al.* (2010). Wadud *et al.* (2012) also adopt an SVAR methodology and use data from 1974 to 2008. However, they find that a contractionary monetary policy shock raises house prices on impact and then leads to a small but insignificant decline after 1 year. Saunders and Tulip (2020) build a structural macroeconometric model to study the main drivers of the Australian housing market from 1987 to 2018. They find that much of the growth in house prices in recent years can be explained by declining real interest rates, some of which is cyclical in nature. In response to a temporary 1 per cent decrease in interest rates (*i.e.* expansionary monetary policy), house prices rise by around 8 per cent over the next 2 years.

Several papers have studied Australian housing markets using cross-state or cross-city panel data. Bourassa and Hendershott (1995) use an error correction model with Australian capital cities panel data from 1979 to 1993. They find that increases in real interest rates have a negative but statistically insignificant effect on house prices, while growth in real wages and employment are the most significant drivers of house prices over this period. Otto (2007) uses an autoregressive distributed lag model to study the effect of fundamentals on Australia house price growth across capital cities from 1986 to 2005.[8] They find that a 1 percentage point permanent increase in mortgage rates leads to increases in long-run house price growth of between 1.6 per cent (Adelaide) and 4 per cent (Sydney). Costello *et al.* (2015) uses an SVAR with capital city–level data from 1982 to 2012 to study the effect of monetary policy shocks on house prices. They find that a 1 per cent increase in real interest rates results in a 0.57 per cent increase in national house prices after 1 year. They also find some heterogeneity in responses across cities, with Sydney, Melbourne and Perth significantly more sensitive to interest rate changes than other cities.

[7] A related literature considers the ability of machine learning and time series models to forecast house prices. See, *e.g.*, Milunovich (2020).

[8] Conversely, Costello *et al.* (2011) studies the contribution of non-fundamental factors to Australian capital city house price movements, finding that house prices often significantly deviate from levels justified by household incomes.

Little prior work uses the highly geographically disaggregated Australian data adopted in the current paper to study heterogeneous effects across housing markets. However, La Cava and He (2021) makes progress in this direction. They use house prices measured at the Statistical Area 3 level along with local projection methods to study the effects of monetary policy across local housing markets.[9] They show that, on average, a 1 per cent increase in the monetary policy cash rate is associated with a 2.2 per cent decline in house prices after 2 years. They also show that house prices in initially more expensive housing markets are more sensitive to monetary policy shocks than less expensive markets. They also suggest that house prices are more sensitive to monetary policy in markets with tighter housing supply conditions, higher average incomes, larger mortgage debts and a greater number of property investors.[10] Our paper differs from La Cava and He (2021) in several dimensions. First, we use instrumental variables methods to identify the effects of our shocks. Second, we explore the heterogeneous effects of our shocks across housing markets more systematically, and link these effects to the direct and indirect channels of monetary policy.[11]

Our research is also related to a strand of the literature studying the relationship between commodity prices and house prices. Because Australia is a net exporter of commodities, commodity price shocks play a significant role in the evolution of the macroeconomy. However, the link between Australian commodity prices and house prices has received much less attention in the literature than the relationship between monetary policy and house prices. In recent work, Gibbs *et al*. (2021) study a small open-economy Bayesian dynamic stochastic general equilibrium (DSGE) model estimated with Australian data to analyse the effects of commodity price shocks on housing investment and prices. The model predicts a commodity price boom crowds out housing investment as investment funds are directed towards commodity-producing industries. In the short run, house prices fall with declining investment, but as the commodity price shock dissipates investment is re-directed towards the housing sector causing a large and persistent increase in house prices.

Much of the empirical literature on the relationship between commodity prices and house prices uses cross-country panel data on the commodity exporting countries of Australia, New Zealand and Canada. Tumbarello and Wang (2010) use both a vector error-correction model (VECM) and event analysis techniques to empirically investigate the relationship between terms of trade shocks and house prices. They find that higher commodity prices have a significant positive effect on house prices, with a 1 per cent increase in the terms of trade associated with a 0.5 per cent increase in house prices. Corrigan (2017) extends the model of Tumbarello and Wang (2010) by including other developed economies that are not commodity exporters, but they find that the relationship between real export prices and house prices is generally weak and ambiguous. This is even the case in commodity exporting countries such as Australia. However, the difference in results across Tumbarello and Wang (2010) and Corrigan (2017) may be because the latter uses export prices, rather than commodity prices, which includes many goods that are also consumed domestically. In Australia commodity price shocks are closer to pure income shocks because it exports significantly more commodities than it imports or consumes domestically (Leung *et al*., 2013). In contrast, export price shocks include a cost component that effectively reduces real domestic income. In the current paper, we isolate the income effect using commodity prices in our primary exercises, but we also show that there is indeed a cost effect by comparing results with export price shocks.

Unlike the existing literature which identifies commodity price shocks semi-theoretically in VECM models, we use an instrumental variable approach to identify the effect of commodity price shocks on house prices. Shift-share instruments have been used in a variety of other settings to account for heterogeneity in the response of regions to a common shock (see, *e.g*., Bartik, 1991; Card, 2009; Autor, 2014). The most closely related paper to our own is Bernstein *et al*. (2022), who construct a shift-share

[9] An SA3 has a population of between 30,000 and 130,000 people.

[10] Phelps *et al*. (2021) study the variance of house prices movements across Australia at the Statistical Area 2 level from 2001 to 2016. They find that house prices across neighbourhoods within cities appear to have diverged since 2011, and they speculate that this may be due to low and falling real interest rates over this period.

[11] See Auclert (2019) and Kaplan *et al*. (2018) for further discussion.

instrument for agricultural export prices. They exploit the differential exposure of Brazilian municipalities to changes in the international price of agricultural commodities to predict local employment and income responses to agricultural price shocks. In our paper, we construct a shift-share instrument using the share of commodities in overall exports measured at the Australian state level interacted with changes in the international prices of these commodities. In doing so, we make use of the fact that Australian states display marked variation in their exposure to commodities *via* export shares (see Fig. 3). Moreover, because commodity prices are typically reported in US dollars, our instrument for commodities is uncorrelated with the effect of our monetary policy shocks on the exchange rate.

II Data

All panel and time-series data used in this study are observed at the quarterly frequency from 1995Q3 to 2018Q3. The bottom of the data range is determined by the availability of exports data, while the top of the range is limited by the availability of the monetary policy shock series. All our data sources are summarised in Appendix I.

(i) House Prices

In this study, we restrict attention to fluctuations in *house* prices (*i.e.* excluding apartments and units). Our data are time-series property price data from CoreLogic, accessed through the Australian Urban Research Infrastructure Network (AURIN) portal. The variable of interest is the quarterly median sales price in a given geographic area. We use highly disaggregated data categorised according to the 2016 Level 2 Statistical Area (SA2) geographical standard as defined by the Australian Bureau of Statistics (ABS). There are 2,310 SA2 areas in Australia which have a population range from 3,000 to 25,000, and an average population of 10,000 (ABS, 2016).[12] To remove outliers in the data, we drop all observations for which there are fewer than 15 house sales in an SA2 within a quarter. Our final sample consists of 2,240 SA2 areas and 178,060 observations in total. Finally, to compute the real value of house prices, we deflate median sales prices by the consumer price index (CPI) of the state in which an SA2 region is located. Table 1 reports the summary statistics for our house price data.

Table 1
Quarterly House Price Summary Statistics

Statistic	Deflated Price Growth	Deflated Median Sale Price	Number of Sales
N	152,323	161,983	161,983
Mean	0.01	269,914.20	47.00
St. Dev.	0.12	203,366.00	28.47
Min	−4.47	1,605.30	15.00
Pctl(25)	−0.04	143,719.90	26.00
Pctl(75)	0.07	324,715.10	60.00
Max	4.36	3,609,067.00	423.00

Source: Authors' calculations using data from CoreLogic.

(ii) Explanatory Variables

To measure the effect of monetary policy, we use the interest rate on 90-day Australian Treasury bonds sourced from the Federal Reserve Economic Data (FRED). Note that Treasury bonds move closely with the RBA's benchmark policy rate, but display more quarterly variation than the policy rate itself, which may be held constant for long periods of time. Our commodity price data are drawn from two sources. First, we observe the total value of different exported goods for each state at a monthly frequency (ABS, 2021c). Each export good is classified using the Standard International Trade Classification (SITC) revision three at the 2-digit level. Second, we observe national, quarterly export price indexes for goods classified using the SITC revision four at the 2-digit level (ABS, 2021b).

ABS (2021a) reports that exports are priced in Australian currency using a 'free on board' basis at the main Australian ports of export (this price excludes taxes on products). Where export prices are reported in foreign currency, they are converted to Australian dollars by the ABS using the relevant exchange rate at the time of trade. The export price index also prices to constant quality to remove price changes that are associated with a quality change.

While the ABS uses different revisions of the SITC codes for the export values and price datasets, they are still comparable. Changes to the classification labels and components were

[12] Note that house price data for SA2 areas in the Northern Territory are available only from 1999Q1.

made at the very disaggregated level, so there was no material impact on comparability between revisions (ABS, 2021a). When using this data to construct the commodity price instrument, we remove 18 export classifications that were uncommon between the export value and export price datasets. This leaves 43 export classifications which represent 87.4 per cent of Australian exports by value. Of the 43 export classifications, we define 23 as commodity exports. See Section 'Commodity price shock' for details.

(iii) Controls

In addition to the instrumental variables strategy described in Section III, we include several control variables in our regressions. First, we observe state-level economic activity *via* annual growth gross state product (GSP) from the ABS. Second, we control for local household characteristics at the SA2 level using data from the 1996 Australian Census (see Table B4). In particular, we observe the fraction of households in 5-year age groups, the fraction of households used in different industries by ANZSIC code, the fraction of households by employment status, the fraction of households by educational attainment and average weekly household income. These observables help to control for factors that might predict the response of housing demand to changes in monetary policy or commodity prices. Third, we control for local housing characteristics at the SA2 level using the 2011 Australian Census (see Table B5). Specifically, we use the fraction of houses with different numbers of bedrooms. These variables capture variation in the availability of different types across areas, and therefore partly control for differences in local housing supply.[13] While the 2011 Census provides the earliest, high-quality measure of housing characteristics across locations, we note that these data are observed later than the beginning of our sample period in 1996. However, we are confident this does not materially affect our results because Graham and Makridis (Forthcoming) points out that the evolution of housing characteristics within a neighbourhood is sticky due to the slow process of replacing the existing housing stock.

[13] Graham and Makridis (Forthcoming) use differences in local house characteristics as the basis of a shift-share instrument for house prices in the USA.

III Empirical Strategy

(i) Local Projection Method

To estimate the effects of monetary policy and commodity prices on house prices, we use the local projections regression method of Jordà (2005). This approach to the estimation of impulse response functions has become increasingly common in the applied macroeconomics literature studying the impact of various shocks on the housing market (see, *e.g.*, Jordà *et al.*, 2015; Aastveit & Anundsen, 2018). Local projections methods require that shocks are identified through instrumental variables or observed shocks. In contrast, commonly used SVAR methods require shocks to be identified *via* theoretical restrictions on the impulse responses themselves. Despite these different approaches to shock identification, Plagborg-Møller and Wolf (2021) show that local projections and SVARs asymptotically estimate the same impulse response functions.

We estimate the effect of monetary policy and commodity price shocks on house prices using the following empirical models, respectively:

$$\Delta P_{i,t-1,t+h} = \alpha_{i,h} + \alpha_{y,h} + \alpha_{q,h} + \beta_h \Delta r_t + \delta_h X_{i,s,t} + \epsilon_{i,t,h} \tag{1}$$

$$\Delta P_{i,t-1,t+h} = \alpha_{i,h} + \alpha_{y,h} + \alpha_{q,h} + \theta_h \Delta r_t + \psi_h \Delta CP_{s,t} + \delta_h X_{i,s,t} + \epsilon_{i,t,h}. \tag{2}$$

Equations (1) and (2) estimate the impulse response of house prices at horizon h following a shock that occurred between dates $t-1$ and t. Subscript i denotes the SA2 area, t denotes the date of observation, s denotes the Australian state in which an SA2 is located and h denotes the number of quarters ahead of date t at which the h-period impulse response is estimated. The variable $\Delta P_{i,t-1,t+h}$ is the log-change in house prices between periods $t-1$ and $t+h$, $\alpha_{i,h}$ is an SA2-specific fixed effect that accounts for time-invariant differences in the growth of median house prices across local housing markets, $\alpha_{y,h}$ and $\alpha_{q,h}$ are year and quarter fixed effects that absorb common cyclical and seasonal patterns in house prices. The variables Δr_t and $\Delta CP_{s,t}$ are our potentially endogenous explanatory variables of interest. Δr_t is the quarterly change in the interest rate on 90-day Australian Treasury bonds, and β_h is the estimated sensitivity of house prices to monetary policy. $\Delta CP_{s,t}$ is the change in commodity prices for the state s in which the SA2 region i is located, and ψ_h is the estimated sensitivity of house prices to commodity prices. While we observe national interest rates, we observe commodity prices at the state level for the reasons outlined in Section 'Commodity price shock'. Finally, $X_{i,s,t}$ is a vector of control variables that may be SA2-, state- or time-dependent, and $\epsilon_{i,t,h}$ is the error term.

Finally, we cluster all standard errors at the state level because our commodity price instrument varies by state.

(ii) Identification

OLS estimates of the parameters β_h and ψ_h in Equations (1) and (2) are likely to suffer from endogeneity bias because house prices, monetary policy and commodity prices are all related through unobserved factors. For example, during an economic boom, house prices rise due to increasing demand and the central bank raises interest rates to control inflation. However, the positive correlation this induces between interest rates and house prices confounds the dampening effect of higher financing costs on housing demand. Similarly, rising Australian commodity prices in recent years are likely to have kept interest rates higher than would otherwise have been the case. To address these sources of endogeneity, we use instrumental variables strategies when estimating Equations (1) and (2).

Monetary policy shock

To generate plausibly exogenous variation in interest rates, we use monetary policy shocks derived by the narrative identification method of Romer and Romer (2004). This method removes the endogenous component of monetary policy decisions by controlling for the central bank's internal forecasts of economic activity. Romer and Romer (2004) regress changes in the US monetary policy rate on the Federal Reserve's internal forecasts for past, current and future inflation, unemployment and output growth. The residual variation in the interest rate generates their measure of US monetary policy shocks. Romer and Romer (2004) argue that because Federal Reserve forecasts are reasonably accurate and central to monetary policy discussions, they contain much of the information used to make policy decisions. Therefore, controlling for the effect of these forecasts on interest rates removes the component of monetary policy that is endogenous to fluctuations in the macroeconomy.

Bishop and Tulip (2017) and Beckers (2020) develop monetary policy shocks for Australia using the narrative identification method of Romer and Romer (2004). La Cava and He (2021) update the data series to provide quarterly monetary policy shocks for Australia from 1992:Q3 to 2018:Q3. These monetary policy shocks are illustrated in Figure 2a.

Denote the monetary policy shocks by MP_t. For these shocks to be valid instruments for the change in interest rates Δr_t in Equation (1), they must satisfy the exogeneity condition:

$$\mathrm{cov}\left(\epsilon_{i,t+j,h}, MP_t\right) = 0, \ \ \forall\ j, \tag{3}$$

where the subscript j indicates that the condition must hold contemporaneously and for all leads and lags of the error term (Ramey, 2016; Stock & Watson, 2018). One concern about the validity of the instruments is that many narratively identified monetary policy shocks in the literature appear to display significant serial correlation (Alloza *et al.*, 2019). To address this concern, in Appendix III we report a range of serial correlation tests for the La Cava and He (2021) monetary shocks but find no evidence of this problem.[14]

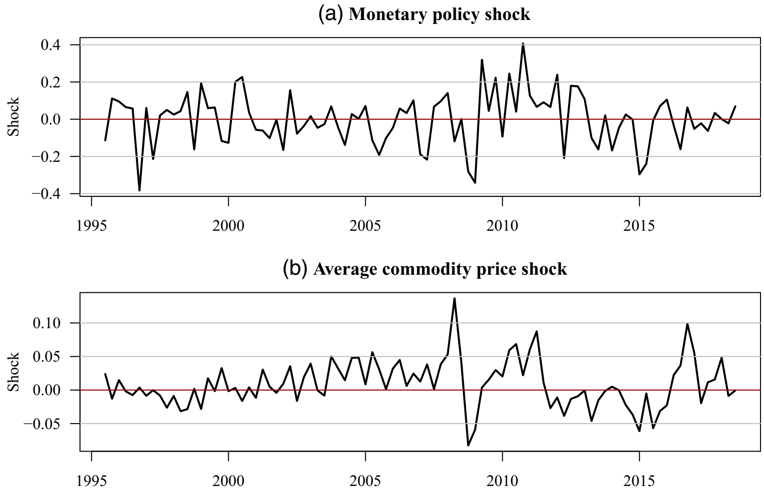
Commodity price shock

To generate plausibly exogenous variation in commodity prices, we construct a novel Bartik-like or shift-share instrument for commodity prices in the spirit of Bartik (1991) and Blanchard and Katz (1992). Our instrument is similar to the instrument for Brazilian agricultural prices of Bernstein *et al.* (2022).

Our instrument exploits geographic variation in exposure to commodity price shocks. Fluctuations in international commodity prices will have a larger effect on states that export more commodities. For example, Figure 3 shows that commodities represent a significantly larger proportion of Western Australia's (WA) exports than other Australian states. If there is a substantial increase in the global price of commodities relative to other exports, then WA will disproportionately benefit from increased export receipts compared to other states that are less concentrated in commodities exports.

[14] Appendix III shows the estimates from an AR(4) model of both the monetary policy and commodity price shocks. Additional tests included using portmanteau-type tests which could not reject the null hypothesis of independence.

FIGURE 2
Time Series of the Australia's Monetary Policy and Commodity Price Shocks



Notes: The commodity price shock is adjusted to account for the exchange rate between the Australian dollar (AUD) and US dollar (USD). The commodity price shock represents the average of all the state commodity price shocks.
Source: Authors' calculations using data from ABS and La Cava and He (2021)

Our shift-share commodity price instrument is constructed as

$$\Delta CP_{s,t} = \sum_{e} w^{e}_{s,0} \Delta P^{e}_{t}. \tag{4}$$

Let $w^{e}_{s,0}$ be the share (or weight) of commodity export e in the overall export value of state s at the start of the sample period. These shares are fixed at the start of the sample period to satisfy the identifying assumption that the export shares are not correlated with changes in export prices (Goldsmith-Pinkham *et al.*, 2020).[15] Let ΔP^{e}_{t} be the change in the international price for commodity export e in quarter t. The commodity price instrument $\Delta CP_{s,t}$ for state s in quarter t is then the state-specific weighted sum of growth rates in international commodity prices.

The weights $w^{e}_{s,0}$ in Equation (4) introduce cross-sectional variation in commodity prices that are determined by the pre-existing exposure of different states to different commodities. The price movements ΔP^{e}_{t} in Equation (4) capture changes in international commodity prices which represents a series of aggregate exogenous demand shocks. Figure 2b shows the average of commodity price shocks across states.

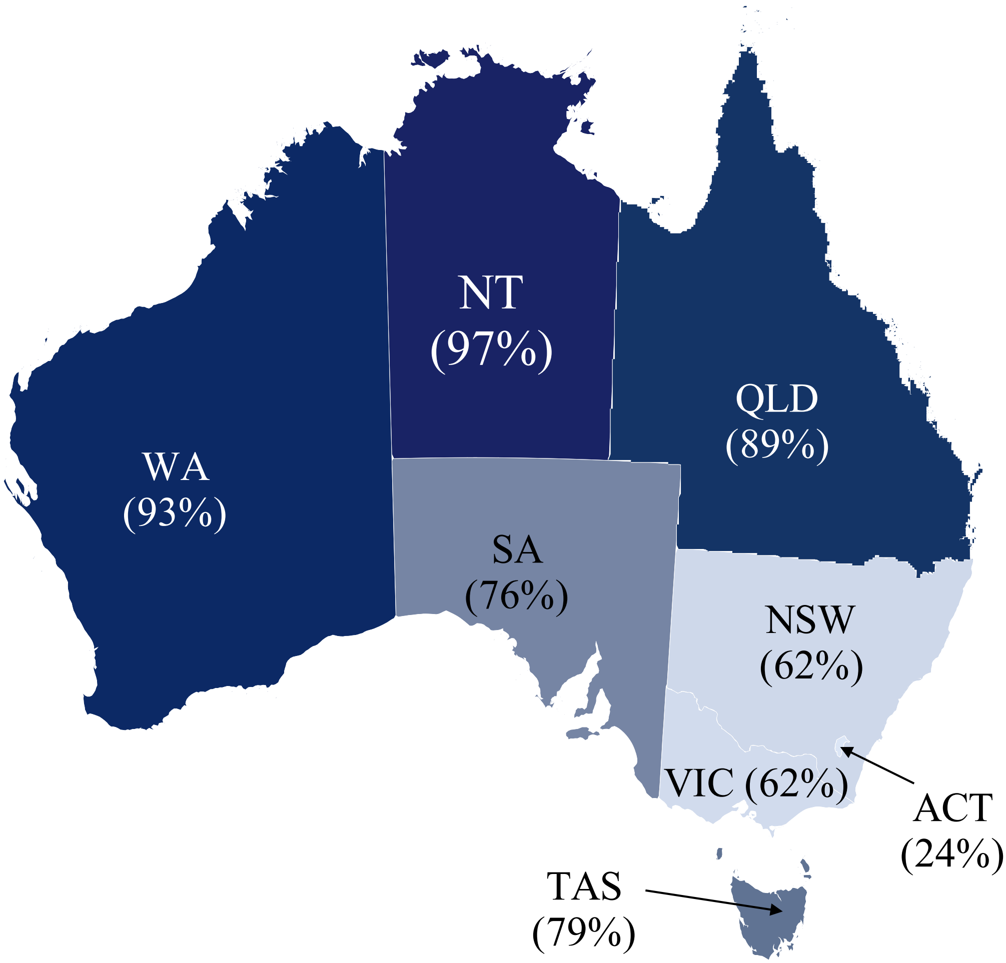
To isolate the effect of commodity prices, the instrument only includes exports that are classified as commodities. To define commodities, we follow the World Trade Organisation (WTO) definition of primary products (World Trade Organization, 2011), which includes mineral fuels, crude materials and agricultural products.

Note that the value of Australia's commodity imports is small compared to the value of its commodity exports. For primary products in 2018–2019, the value of Australia's imports was 78.15 per cent smaller by value that its exports (Department of Foreign Affairs and Trade, 2020).[16] The insignificance of the import channel is important because fluctuations in the price of imports may have cost effects on housing demand. That is,

[15] In calculating the export weights for each state, we use the mean value of each export for the first 9 months of the sample period.

[16] Most of the value of Australia's primary product imports come from crude and refined petroleum imports. If Australia's crude and refined petroleum imports are excluded, the value of Australia's primary product imports is 91.24 per cent smaller that its primary product exports in 2018–2019.

FIGURE 3
Proportion of State Export Value that Is Derived from Commodity Exports



Source: Authors' calculations using data from ABS

higher import prices reduce the purchasing power of Australian households, which would decrease housing demand and therefore house prices. However, as this import channel is especially small for Australian commodities, an increase in commodity prices predominantly affects house prices through export incomes.

The recent literature on Bartik and shift-share instruments has formalised the identification conditions associated with the validity of these instruments (see, *e.g.*, Adao *et al.*, 2019; Borusyak *et al.*, 2018; Goldsmith-Pinkham *et al.*, 2020). These papers present two identification strategies for these instruments. The first relies on the exogeneity of the instrument's shares (*i.e.* $w^{e}_{s,0}$), whereas the second relies on the exogeneity of the instruments aggregate-level shocks (*i.e.* ΔP^{e}_{t}). Our instrument relies on the latter identification strategy because movements in international commodity prices are exogenous to developments in Australian housing markets. Specifically, our key assumption is that changes in international commodity prices are uncorrelated with both unobservable determinants of local house prices (see Borusyak *et al*., 2018).

There are two primary threats to our identification assumptions. First, it may be the case that unobserved Australian shocks influence both international commodity prices and local house prices. However, Australia is widely considered to be a small open economy and therefore its exporters are price takers in international commodity markets (see, for example, Chen & Rogoff, 2003; Knop & Vespignani, 2014; Rees *et al*., 2016). Nevertheless, to test the robustness of this assumption, in Appendix IV we remove from our commodities those goods for which Australian's production represents over 11 per cent of global supply. This test excludes commodity markets where unobserved Australian shocks could potentially affect international prices. However, our results are robust to this test, which suggests that this threat to exogeneity is not a concern.

Second, changes in exchange rates may influence the price of Australian commodity receipts, which could introduce a correlation with other macroeconomic shocks including changes in monetary policy. This is because our measure of commodity prices is expressed in Australian dollars (AUD). As noted in Section II, all international trade that occurs in foreign currency is exchanged to AUD by the ABS using the relevant exchange rate at the time of trade. This means that changes in the relative value of AUD and international currencies will have a direct impact on the prices of commodities that are bought and sold in international currencies (ABS, 2021a). Because any Australian macroeconomic shock that affects the exchange rate will affect the AUD-price of commodities, we need to adjust our commodity price instrument for changes in the exchange rate. To do this, we exploit the fact that the vast majority of commodities are traded in US dollars (USD) (see Chen & Rogoff, 2003; Goldberg & Tille, 2008; Gopinath *et al*., 2010; Gopinath, 2015). When constructing the commodity price instrument, we multiply the commodity price indices by the average AUD/USD exchange rate within the quarter.

Finally, note that our commodity price shocks exhibit evidence of serial correlation (see Appendix III). Serial correlation in the commodity price instrument is problematic as it can bias the local projections estimates (Alloza *et al*., 2019). We overcome this by including four lags of the commodity price instrument in the panel of controls, which purges the commodity price shock of serial correlation (Ramey, 2016). This allows for the identification of the impulse response of house prices to a one-off commodity price shock. Our results are robust to the number of lags chosen (see Appendix IV).

(iii) Controls

Finally, we include several control variables in $X_{i,s,t}$ in Equations (1) and (2). First, we include annual GSP to control for state-varying differences in economic activity. Second, we interact our SA2-level census variables on household and housing characteristics with year fixed effects.[17] These controls account cross-sectional variation in house price movements due to local factors that induce local exposure to unobserved aggregate shocks. For example, it may be that locations with higher proportions of low skilled households are more sensitive to business cycle fluctuations, and so housing markets in these locations are more correlated with aggregate business cycles. Note that our inclusion of these interaction variables is a relatively demanding test on the data because it generates a very large number of dummy variables which can absorb a significant proportion of the variation in the data. Third, we include four lags of the local house price growth rate to account for serial correlation in the dependent variable. Fourth, we include the change in the interest rates as a control in Equation (2) to control for any residual effect of monetary policy on house prices and commodity prices.

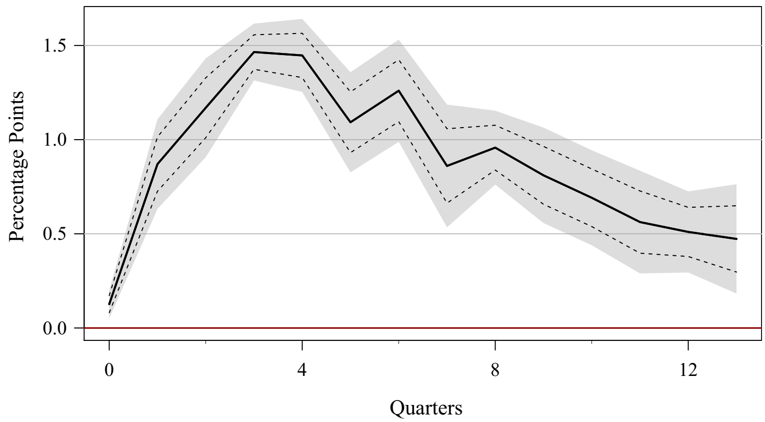
(iv) Exogeneity of Shocks

Although our instruments are constructed to generate exogenous variation in monetary policy and commodity prices, we might still be concerned about the possibility of endogeneity between the two sets of shocks. For this reason, we report the statistical relationship between our instruments.

First, we find that the simple correlation between the monetary policy shocks and the average of the commodity shocks, as illustrated in

[17] This follows the recommendation of Goldsmith-Pinkham et al. (2020) when using shift-share instruments.

FIGURE 4
Impulse Response of House Prices to an Expansionary Monetary Policy Shock



Notes: The response is to a one standard deviation (0.4 per cent) decrease in the interest rate (expansionary monetary policy shock). The dotted lines and shaded area represent the 68 and 90 per cent confidence intervals, respectively.

Figure 2, is 0.21. Second, correlations between the monetary policy shocks and commodity price shocks constructed for each state range from −0.02 (QLD) to 0.33 (SA). Third, we compute the correlation between the residualised shocks after conditioning on the same set of controls as in our main specifications, Equations (1) and (2). This yields a conditional correlation between shocks of 0.11. Finally, if we also include as controls the four lags of commodity prices used to address serial correlation (see Section 'Commodity price shock'), the conditional correlation between our shocks falls to 0.01.

Overall, then, we find a statistically weak relationship between our shocks. For this reason we are confident that our instruments identify plausibly causal channels of monetary policy and commodity price shocks on house prices.

IV Results

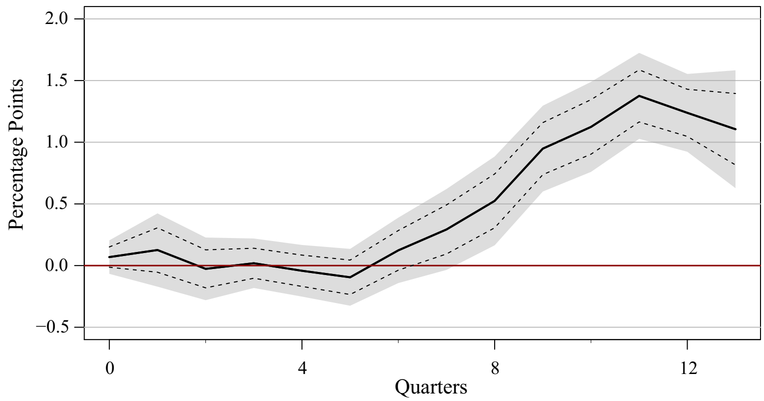
We report our impulse response functions from Equations (1) and (2), estimated *via* two-stage least squares using the instruments described in Section III. We report responses to each shock scaled by their respective standard deviations.

Figure 4 reports the impulse responses of house prices to an expansionary monetary policy shock (*i.e.* $-\beta_h$ from Equation (1)). Monetary policy has a small but significant contemporaneous effect on house prices, with large peak effects three to four quarters after the shock takes place, and a slowly dissipating effect over the next 2 years. At its peak, a one standard deviation expansionary monetary policy shock is associated with a 1.47 per cent increase in house prices. An alternative interpretation of our estimates is that a 1 per cent decrease in interest rates is associated with a 3.68 per cent increase in house prices.

The size of the estimated response to monetary policy is well within the range of estimates provided by recent Australian studies. Using VECM, SVAR and semi-structural macroeconometric approaches, authors have estimated peak effects in response to a temporary 1 per cent decline in interest rates of: 0.41–0.72 per cent (Bourassa & Hendershott, 1995), 0.57 per cent (Costello *et al.*, 2015), 5.4 per cent (Abelson *et al.*, 2005) and 8 per cent (Saunders & Tulip, 2020).[18] Using a similar empirical strategy to this paper, La Cava and He (2021) estimate an average that a 1 per cent decline in interest rates is associated with a 2.3 per cent increase in house prices.

[18] Wadud *et al.* (2012) report that house prices rise by 0.4 per cent at peak following a one standard deviation monetary policy shock.

FIGURE 5
Impulse Response of House Prices to a Positive Commodity Price Shock.



Notes: The response is to a one standard deviation (4.3 per cent) positive commodity price shock. The dotted lines and shaded area represent the 68 and 90 per cent confidence intervals, respectively.

Figure 5 presents the impulse response of house prices to a commodity price shock (*i.e.* ψ_h from Equation (2)). House prices do not respond to commodity price shocks for up to six quarters, then rise sharply until a peak effect around 2.5–3 years after the shock.[19] A one standard deviation increase in commodity prices is associated with a peak house price increase of 1.38 per cent.

The delayed response of house prices may be due to the use of long-term (or forward) contract pricing in commodities markets. These contracts are generally set annually and were particularly common in iron ore and coking coal trade until 2010. Since then there has been a shift towards shorter-term pricing mechanisms (Caputo *et al.*, 2013). Following an unexpected increase in commodity prices, exporters may continue to receive prices at previously agreed-upon rates for up to another year. This means they will not see any additional income until they are able to sign a new contract which factors in the higher commodity prices. This may explain why housing demand is so slow to respond to commodity price changes.

[19] The delayed effects in our impulse responses may be related to the results in Milunovich (2020). He finds that multivariate time-series models have relatively poor house price forecasting performance at short horizons, but that they perform relatively well over longer horizons.

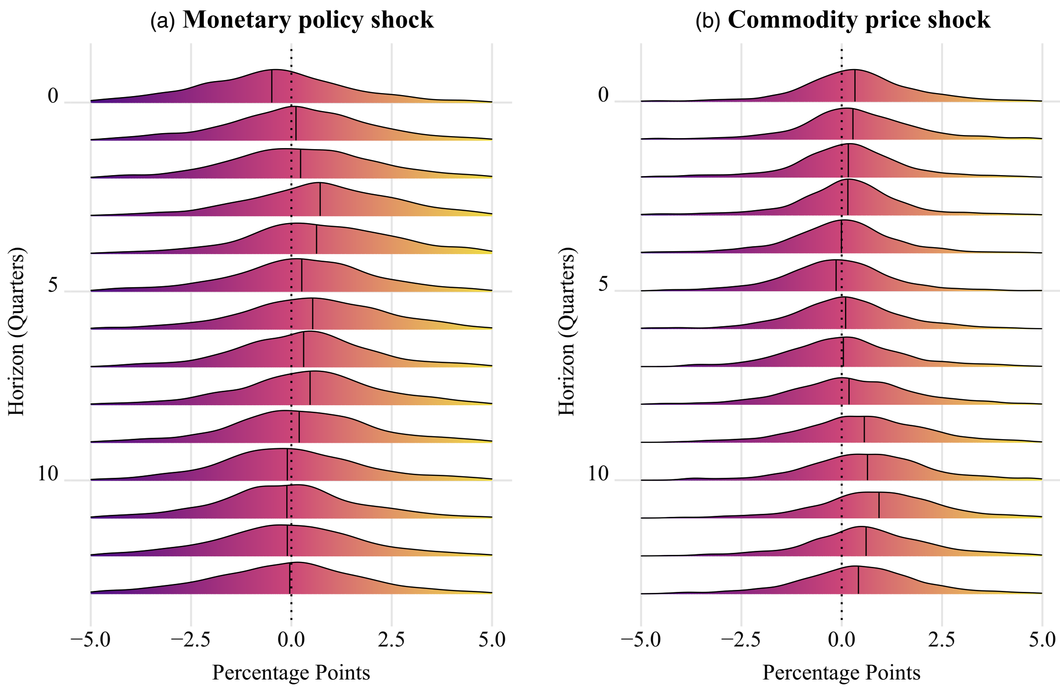
V Heterogeneity in the Sensitivity of House Prices

We now explore heterogeneity in the response of house prices to monetary policy and commodity price shocks. While previous literature has also found evidence of heterogeneous responses of Australian housing markets to monetary policy (Costello *et al.*, 2015; La Cava & He, 2021; Phelps *et al.*, 2021), to the best of our knowledge there is no prior research on heterogeneous responses of house prices to commodity price shocks across Australia.

To explore heterogeneous responses to shocks, we exploit the significant cross-sectional variation in our large panel dataset. To begin, we re-estimate Equations (1) and (2) for every Australian SA2 and plot a kernel density estimate of the distribution of market-specific responses. The results are illustrated in Figure 6.

Figure 6 shows the response of each SA2 to one standard deviation shocks. While the size of monetary policy shock is the same across locations, the size of the commodity price shock depends on the Australian state in which the SA2 is located. The results show that a significant amount of heterogeneity exists in the sensitivity of house prices across Australia to

FIGURE 6
Distribution of the Response of House Prices to each Shock.



Notes: The density plot of responses is shown for each horizon. For monetary policy, house prices in each SA2 region are responding to a one standard deviation (0.4 per cent) expansionary monetary policy shock. For commodity price, the house prices in each SA2 region are responding to a one standard deviation positive commodity price shock. The size of this shock depends on which state the SA2 region is located in. The black line represents the response of the median SA2 region at each horizon. Horizon represents the number of quarters after the shock. Fixed effects are included for the year and quarter. We exclude all SA2 regions that do not have at least 17 consecutive observations. At each horizon, the top and bottom 2.5 per cent of distribution is also removed.

both shocks. Over all horizons, the average difference in response between the SA2 region at the 25th and 75th percentiles of the distribution is 2.7 and 1.8 per cent for the monetary policy and commodity price shocks, respectively. At peak effect, the variances of the estimates are 6.4 and 2.5 times larger than the pooled, average estimated effects for monetary policy (Fig. 4) and commodity prices (Fig. 5), respectively. Finally, note that heterogeneity in the sensitivity of house prices to these shocks is roughly constant over the horizon period. That is, the difference between the response of the most and least affected regions does not change substantially over time in response to the shocks.

We also use the estimated market-specific responses to consider local characteristics that may affect the sensitivity of house prices to the shocks. After matching the coefficients and SA2-level Census control variables for each region, we compute the correlation coefficients between estimated responses and local characteristics. The results are shown in Table 2. Although the correlations are generally weak, we find that the sensitivity of house prices to monetary policy shocks, for example, is positively correlated with the fraction of households with a university degree,

TABLE 2
Correlation between House Price Responses and Regional Characteristics

Region Characteristic	Monetary Policy	Commodity Price
Age		
20–29	0.03	−0.02
30–39	−0.01	0.01
40–49	0	0.02
50–59	0.04	0
60–69	0.03	0
70+	0.03	−0.01
Education		
Bachelors +	0.06	0
Post high school diploma	−0.02	0.03
Sex and labour force		
Males	−0.02	0.03
Unemployed	−0.01	−0.03
NILF	0.01	−0.01
Weekly household income	0.02	0
Industry of occupation		
Agriculture, forestry and fishing	−0.03	0.04
Mining	−0.07	0.03
Manufacturing	0.02	−0.06
Construction	−0.03	0.01
Finance and insurance	0.08	−0.04
Government administration and defence	0.01	0.08
House characteristics		
Separate house	−0.04	0.03
Semi-detached house	0.02	−0.01
Total dwellings	0.04	−0.02
One bedroom	0.02	0
Two bedrooms	0.05	−0.02
Three bedrooms	0.02	−0.02
Four+ bedrooms	−0.04	0.03

Notes: We calculate the response of house prices for each SA2 at each horizon. These coefficients are then matched with the relevant census controls, and the correlation is taken across all SA2 regions. For both shocks, a positive value means that the characteristic is correlated with a larger response in house prices.
Sources: Authors' calculations using data from Corelogic, ABS.

TABLE 3
Cut-off Values Used to Generate the Interaction Dummy Variables

Region characteristic dummy variable	Mean proportion (%)	Mean value
Earning < $52,000	35.7	
University educated	13.7	
Employment is more sensitive to monetary policy		46.7
Receiving a large amount of dividends		1731.5
Receiving a large amount of business income		2178.2
Renting	23.2	
Living in a smaller (<4 bedroom) house	57.6	

Notes: The interaction dummy variables equal 1 if the proportion/value of a characteristic in the SA2 region is greater than the mean in this table. Otherwise, the dummy variable is equal to 0.

the fraction of households working in finance and insurance and the locations with more two-bedroom houses (*i.e.* typically inner city areas).

To better understand the drivers of the cross-sectional variation in sensitivity to shocks, we introduce interaction terms into Equation (1) and (2):

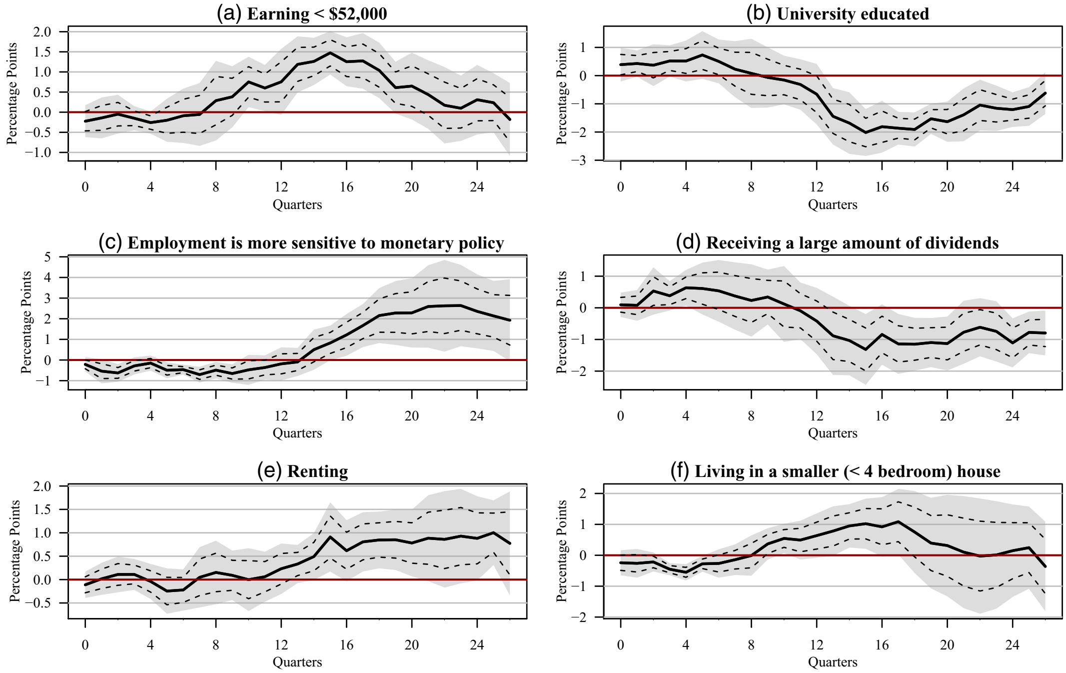
$$\Delta P_{i,t-1,t+h} = \alpha_{i,h} + \alpha_{y,h} + \alpha_{q,h} + \beta_h \Delta r_t + \Phi_h \Delta r_t \times D_i + \delta_h X_{i,s,t} + \epsilon_{i,t,h} \quad (5)$$

$$\Delta P_{i,t-1,t+h} = \alpha_{i,h} + \alpha_{y,h} + \alpha_{q,h} + \theta_h \Delta r_t + \psi_h \Delta CP_{s,t} + \gamma_h CP_{s,t} \times D_i + \delta_h X_{i,s,t} + \epsilon_{i,t,h}. \quad (6)$$

The interaction terms combine the shocks Δr_t and $CP_{s,t}$ with a dummy variable D_i that summarises a particular characteristic of a local area. The coefficients Φ_h and γ_h describe the average difference between the effects of a shock on areas with a particular characteristic and areas without that characteristic. As before, we scale responses (Φ_h and γ_h) by a 100 times the standard deviation of the respective shock.

We focus on a range of salient characteristics including income, education, employment in the commodity industry, wealth, the fraction of renters, house size and employment sensitivity to monetary policy. The dummy variable threshold values for each characteristic are reported in Table 3. For the income variable, we measure the fraction of households in an SA2 earning less than $52,000, which is approximately the median

FIGURE 7
Comparing the Impulse Response of House Prices to an Expansionary Monetary Policy Shock in Regions with a High Proportion of Households



Notes: The response is to a one standard deviation (0.4 per cent) expansionary monetary policy shock. The dotted lines and shaded area represent the 1 and 1.65 standard deviation confidence intervals, respectively. Each characteristic is represented by a dummy variable which is equal to 1 if the proportion of a characteristic in the region is above the mean across all SA2 regions. The control for total houses in a region is not included. The title of Panel F is for readability; to be more precise it is the proportion of houses in a region with fewer than four bedrooms.

income in 2006 (AbS, 2007a,b).[20] For the education variable, we measure the fraction of households that hold a university degree. For the employment variable, we compute the proportion of workers in the commodity industry. For the wealth variable, we compute the fraction of households with large reported values of dividends and business income (Australian Taxation Office, 2017). We compute the fraction of renters in each SA2 and the fraction of houses with three or fewer bedrooms using Census data. Finally, we compute the sensitivity of unemployment to monetary policy in each SA2 using the local projections method and our monetary policy shocks (see Appendix VI for details).

[20] The ABS 2005–2006 Survey of Income and Housing (SIH) estimates a median household income of $54,080, whereas the 2006 ABS Census of Population and Housing estimates a median household income of $53,404.

(i) Monetary Policy Shock

The results of our baseline exercise reported in Figure 4 show that house prices increase in response to an expansionary monetary policy shock. We now explore several possible transmissions mechanisms of monetary policy by exploiting the cross-sectional variation in house price responses to monetary shocks. First, in Figure 7 Panels A and B, we explore the income channel of monetary policy (see, for example, Kaplan *et al.*, 2018; Auclert, 2019). We find that house prices in areas with more low income households and fewer university educated households experience faster house price appreciation in response to an expansionary monetary shock. Because expansionary monetary policy increases income *via* an increase in aggregate demand, and because low income households are typically less able to self-insure against income fluctuations, we expect to see larger fluctuations in their housing demand through the income channel.

It is possible that low income households are simply more sensitive to changes in interest rates. In that case Panels A and B of Figure 7 do not provide evidence of the monetary policy income channel, but are instead consistent with heterogeneity in responses to the direct (*i.e.* interest rate) channel of monetary policy. To address this, in Figure 7 Panel C we consider the differential response of house prices to monetary policy in areas where employment itself is more sensitive to monetary policy. We find that, indeed, more employment sensitive areas have house prices that are more sensitive to monetary policy. Together, these results provide strong evidence in favour of the income channel of monetary policy.

Third, Figure 7 Panel D tests for the wealth channel of monetary policy. Because expansionary monetary policy tends to inflate equity markets, a rise in stock market wealth may spill over into housing markets. We find no evidence of this effect. Instead, areas with greater stock market participation (as measured by receipt of dividends) have house prices that are less sensitive to monetary policy shocks. We interpret this as further evidence in favour of the income channel, because higher income households are more likely to hold stocks, and are likely to be less sensitive to the income effects of monetary policy.

Fourth, Figure 7 Panel E shows that areas with a greater proportion of renters have house prices that are more sensitive to monetary policy. Because rental properties are traded by housing investors, we interpret this result as evidence of an investment channel of monetary policy. That is, expansionary monetary policy decreases interest rates which increase the returns on investment in housing, which disproportionately increases the price of houses in more investor-friendly locations. Finally, Figure 7 Panel F shows that house prices in areas with smaller houses are also more sensitive to monetary policy. This may reflect both income and investment channels, because lower income households are more likely to purchase smaller homes but these homes are also more likely to be purchased by investor landlords.

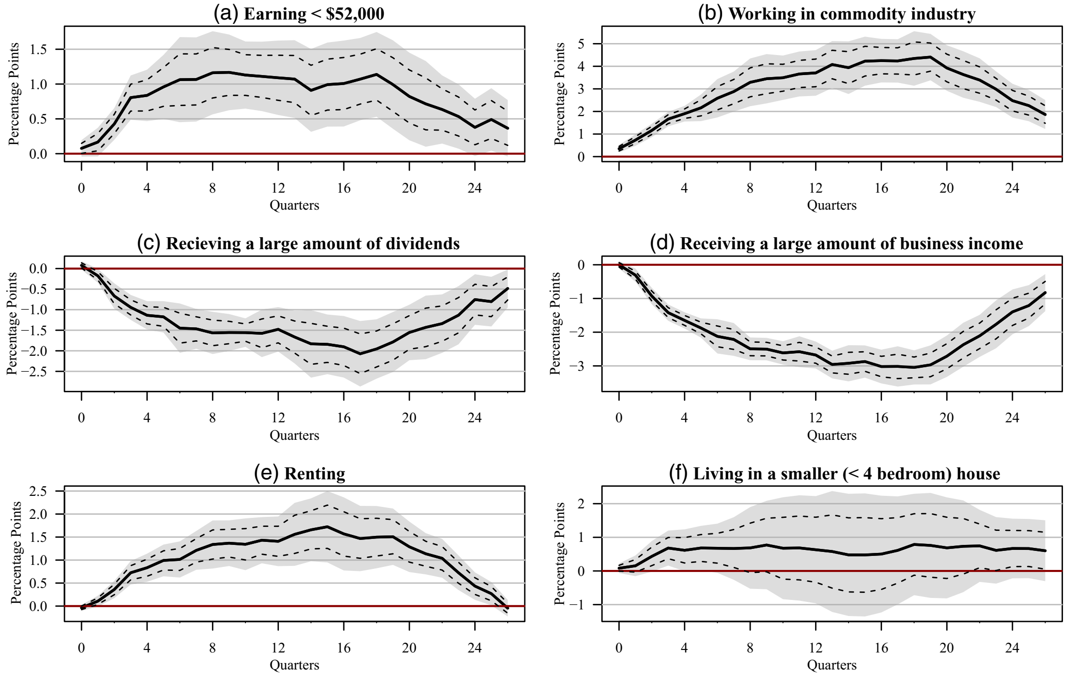
(ii) *Commodity Price Shock*

The results of our baseline exercise reported in Figure 5 show that house prices increase in response to a positive commodity price shock. We now explore several possible transmissions mechanisms of commodity prices by exploiting the cross-sectional variation in house price responses to commodity shocks. First, Figure 8 Panel A shows that areas with low income households are much more sensitive to commodity price shocks. Panel B shows that areas with larger proportions of workers in commodity industries are also much more sensitive to commodity price shocks. Together, these results suggest that commodity price shocks have strong income effects on housing markets.

Second, Figure 8 Panels C and D test for wealth effects of commodity prices. We find that areas with more households owning equity or private businesses are much less sensitive to commodity price shocks. Because the value of businesses in commodity-related industries should rise on news of higher commodity prices, equity and business owners might be expected to increase housing demand following the gain in wealth. That this does not occur suggests the commodity wealth channel is not an important one for housing markets, although we do recognise that ownership of any equity or private business is an imperfect measure of exposure to commodity industries, specifically. As was the case for Figure 7 Panel D, these results may also reflect a strong income channel because equity and business owners are also likely to be high income households that are less sensitive to income shocks.

Third, Figure 8 Panel E shows that areas with more renters have house prices that are significantly more sensitive to commodity price shocks than other areas. Because we found that the wealth effect of commodity prices is weak, the result in Panel E is unlikely to reflect a housing investment channel. Instead, this result must also reflect income effects because renters are typically lower income and therefore their housing demand is more sensitive to income shocks.

FIGURE 8
Comparing the Impulse Response of House Prices to a Positive Commodity Price Shock in Regions with a High Proportion of Households.



Notes: The Response Is to a One Standard Deviation (4.3 per Cent) Positive Commodity Price Shock. The Dotted Lines and Shaded Area Represent the 1 and 1.65 Standard Deviation Confidence Intervals Respectively. Each Characteristic Is Represented by a Dummy Variable which Is Equal to 1 if the Proportion of a Characteristic in the Region Is above the Mean across all SA2 Regions. The Control for Total Houses in a Region Is Not Included. The Title of Panel E Is for Readability; to be more Precise it Is the Proportion of Houses in a Region with Fewer than Four Bedrooms.

VI Conclusion

Both monetary policy and commodity prices are likely important factors in Australian housing markets; however, endogeneity between these variables makes it difficult to identify the causal effects of each. In this paper, we address this difficulty with the help of two instrumental variables strategies: narrative identification of monetary policy shocks (Romer & Romer, 2004) and a shift-share instrument for commodity price shocks. We estimate that one standard deviation expansionary monetary policy shocks and positive commodity price shocks are associated with 1.5 and 1.4 per cent peak increases in house prices, respectively. Exploiting the substantial cross-sectional variation in our geographically disaggregated panel dataset, we study several transmission mechanisms through which these shocks affect house prices. We find evidence supporting a strong income channel of monetary policy, some evidence of a housing investment channel and no evidence of a wealth channel. With respect to commodity price shocks, we find strong evidence of income channels and no evidence of wealth channels. Further research might use our methods along with disaggregated mortgage data to investigate the extent to which monetary policy affects housing markets through credit channels.

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Conflict of interest

The authors certify they have no affiliations with or involvement in any organization or entity with any financial or non -financial interest in the subject matter or materials discussed in this manuscript.

Data availability statement

The data and codes are available at the Github Repository https://github.com/jagman88/GrahamRead2022.

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Appendix I. Data Sources

This study used the NCRIS-enabled Australian Urban Research Infrastructure Network (AURIN) Portal e-Infrastructure to access the dataset 'CoreLogic – Total Properties – Market Trends (SA2) Jan 1980–Feb 2021' on 14/5/21 (RP Data Pty Ltd trading as CoreLogic, 2021).

Data	Date	Frequency	Source
Export Price	1995Q3–2018Q3	M	ABS
State CPI	1995Q3–2018Q3	M	ABS
-day Treasury bond interest rate	1995Q3–2018Q3		FRED
AUD/USD exchange rate	1995Q3–2018Q3	M	RBA
House prices	1995Q3–2018Q3	Q	CoreLogic (AURIN Portal)
Export value	1995Q3–2018Q3	Q	ABS
Monetary policy shocks	1995Q3–2018Q3	Q	He and La Cava (2020)
Gross state product (GSP)	1995Q3–2018Q3	A	ABS
SA2 household characteristics	1996		ABS Census
SA2 housing characteristics	2011		ABS Census
SA2 interaction data	2006		ABS Census
SA2 wealth data	2016		ATO Tax Statistics

Notes: For the frequency, M is monthly, Q is quarterly and A is annual.

Data Disclaimer

The disclaimer and copyright notices for the CoreLogic housing data can be found at https://www.corelogic.com.au/about-us/copyright-disclaimer.

Appendix II. Census Control Variables

See Tables B4 and B5

TABLE B4
Household Controls from the 1996 ABS Census

Age	Employment Industry (ANZSIC)
0–4	Agriculture, forestry and fishing
5–9	Mining
10–14	Manufacturing
15–19	Electricity, gas and water supply
20–24	Construction
25–29	Wholesale trade
30–34	Retail trade
35–39	Accommodation, cafes and restaurants
40–44	Transport and storage
45–49	Communication services
50–54	Finance and insurance
55–59	Property and business services
60–64	Government administration and defence
65–69	Education
70–74	Health and community services
75–79	Cultural and recreation services
80–84	Personal and other services
85 or over	Non-classifiable economic units
	Not stated
Labour force status	Education
Employed	Higher degree
Unemployed	Postgraduate degree
Not in labour force	Bachelor's degree
Aged 15 and over	Undergraduate diploma
Other	Associate diploma
Weekly household income	Skilled vocational qualification
Separate houses	Basic vocational qualification
Semi-detached houses	Total higher educated
Total dwellings	

Notes: ANZSIC stands for Australian and New Zealand Standard Industrial Classification.

TABLE B5
Housing Controls from the 2011 ABS Census

Housing Characteristics
One bedroom
Two bedrooms
Three bedrooms
Four bedrooms
Five bedrooms
Six or more bedrooms
No bedrooms (includes bedsitters)
Not stated
Total houses

Appendix III. Autocorrelation Table for Shock Variables

To test for serial correlation in the shock series, the shocks are regressed on four lags of themselves. We only find evidence of serial correlation in the commodity price shock. Strong serial correlation exists with one lag of the commodity price shock for most states.

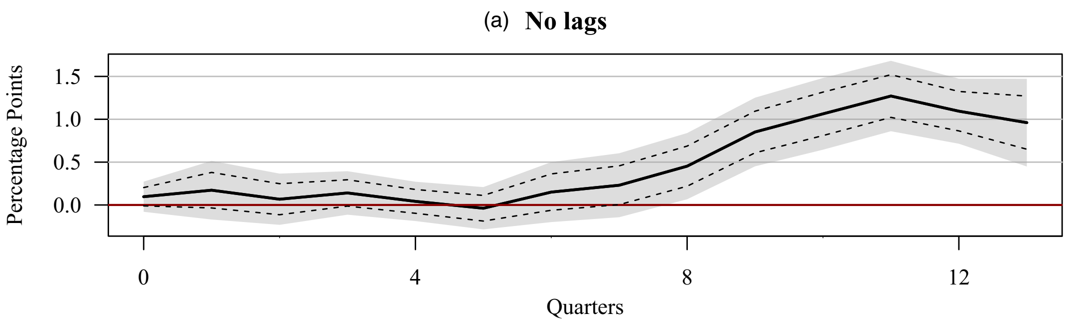
		Commodity Price Shock							
	MP Shock	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
1	0.065								
	(0.109)								
2	0.084								
	(0.107)								
3	−0.170								
	(0.107)								
4	0.047								
	(0.108)								
1		0.532***	0.498***	0.527***	0.552***	0.455***	0.451***	0.189*	0.558***
		(0.109)	(0.109)	(0.109)	(0.108)	(0.109)	(0.108)	(0.108)	(0.108)
2		−0.217*	−0.091	−0.228*	−0.111	0.096	−0.079	−0.085	−0.260**
		(0.124)	(0.121)	(0.123)	(0.122)	(0.119)	(0.119)	(0.110)	(0.123)
3		0.084	−0.044	0.104	−0.153	−0.035	−0.109	0.037	0.133
		(0.124)	(0.121)	(0.124)	(0.122)	(0.120)	(0.121)	(0.112)	(0.122)
4		0.019	0.029	−0.101	0.116	0.037	0.170	0.126	−0.136
		(0.110)	(0.109)	(0.109)	(0.108)	(0.109)	(0.109)	(0.109)	(0.107)
Constant	−0.003	0.005	0.004	0.008	0.004	0.006	0.004	0.011	0.001
	(0.015)	(0.004)	(0.003)	(0.006)	(0.003)	(0.005)	(0.004)	(0.008)	(0.001)
Observations	89	89	89	89	89	89	89	89	89
R^2	0.039	0.226	0.214	0.225	0.265	0.255	0.197	0.057	0.252
Adjusted R^2	−0.007	0.189	0.177	0.188	0.230	0.220	0.159	0.012	0.217
Residual std. error (df = 84)	0.144	0.035	0.028	0.051	0.030	0.042	0.040	0.070	0.006
F statistic (df = 4; 84)	0.842	6.140***	5.734***	6.106***	7.570***	7.190***	5.160***	1.262	7.084***

Notes: *$P < 0.1$; **$P < 0.05$; ***$P < 0.01$.

Appendix IV. Robustness Checks

(i) Robustness to the Lag Structure Used on the Commodity Price Shocks

Because the series of commodity price shocks that we construct experiences serial correlation (Appendix III), we include four lags of the commodity price shocks. This ensures that we can isolate the effect of a one-off commodity price shock because it removes the effect of previous commodity price shocks. For robustness, we test how sensitive of the response of house prices is to the lag structure that is chosen for the commodity price shock. As shown in the figures below, the lag structure chosen has no significant impact on the impulse response of house prices.

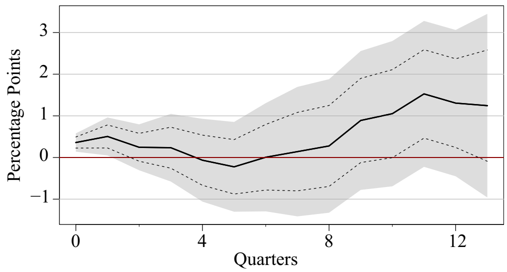


Notes: The response of house prices to a one standard deviation (4.3 per cent) positive commodity price shock. For Panel A, there are no lags of the commodity price shock. For Panel B, eight lags of the commodity price shock are included. The dotted lines and shaded area represent the 1 and 1.65 standard deviation confidence intervals respectively.

(ii) Robustness of the Response of House Prices to Commodity Prices After Removing Commodities That May Influence Global Prices

It is possible that Australia is a large enough player in a few commodity markets (mainly mineral resource markets) that shocks to the Australian economy could affect international commodity prices. If this was the case, then this threatens the identification assumptions of the Bartik instrument. For robustness, we remove any classifications that contained a commodity for which Australia represents over 11 per cent of world production. These commodities were identified using Britt *et al.* (2017). The table below shows the classifications that were removed. The figure below suggests that our results are robust to the removal of these commodities that threaten the identifying assumptions of the Bartik instrument.

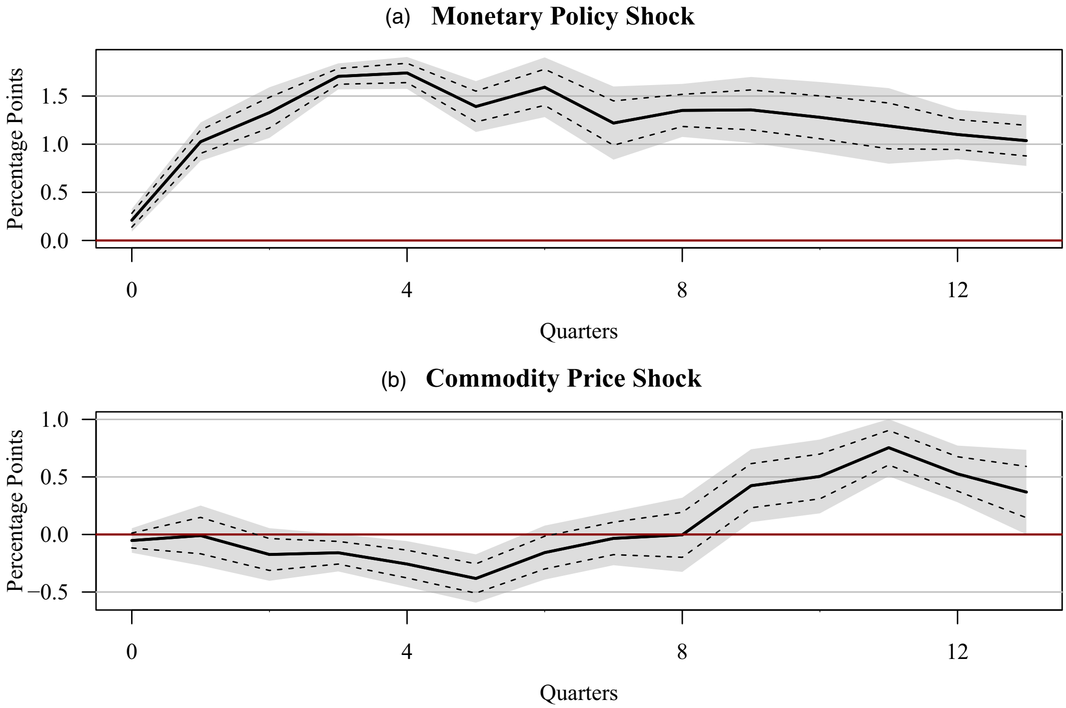
SITC Code	Description
27	Crude fertilisers and crude minerals (excluding coal, petroleum and precious stones)
28	Metalliferous ores and metal scrap
32	Coal, coke and briquettes



Notes: The response is to a one standard deviation (4.3 per cent) positive commodity price shock. The dotted lines and shaded area represent the 1 and 1.65 standard deviation confidence intervals respectively.

(iii) Robustness to Removing House Prices Lags from the Model

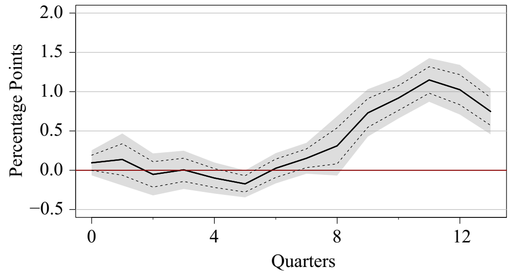
The model used in the paper contains four lags of house prices. To test whether the results are robust to no house price lags, we use Equations 1 and 2 but remove the house price lags. We find that our results are robust to this specification.



Notes: The response of house prices to a one standard deviation shock. This is equivalent to a 0.4 per cent expansionary monetary policy shock and a 4.3 per cent positive commodity price shock. The dotted lines and shaded area represent the 1 and 1.65 standard deviation confidence intervals, respectively.

Appendix V. Export Price Shock

In Figure 5, we only look at the effect of a commodity price shock. If we include all exports (not just commodities) in our instrument, then we can examine the effect of an export price shock. As seen below, the response of house prices to an export price shock is similar to that of a commodity price shock. This is expected given commodities account for a significant proportion of Australian exports. In this model, we can see that the response of house prices slightly decreases when all exports are included. This is likely because when we account for all exports, we include many items that are imported. Therefore the smaller response in house prices is likely due to a cost effect. The cost channel operates through the effect of rising commodity prices on the cost of local consumption goods, which reduces household purchasing power and dampens housing demand.



Notes: The response of house prices to a one standard deviation shock. This is equivalent to a 5.1 per cent positive export price shock. Both panels include four lags of house prices. The dotted lines and shaded area represent the 1 and 1.65 standard deviation confidence intervals respectively.

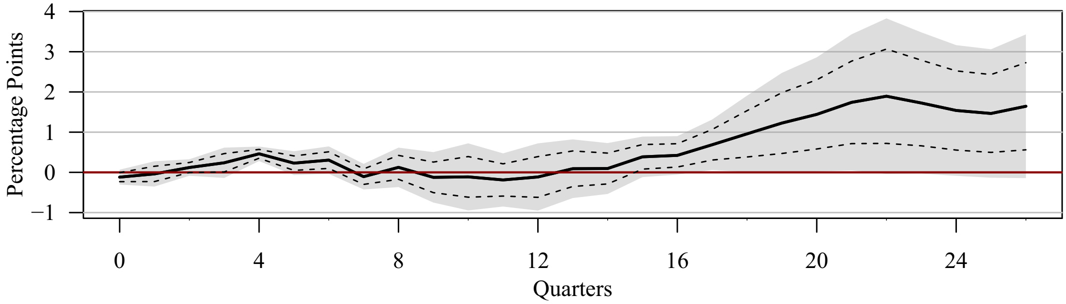
Appendix VI. Sensitivity of Employment to Monetary Policy Interaction

In Figure 7, Panel C, we investigate if house prices areas with a higher sensitivity of employment to monetary policy are more affected by a monetary policy shock. To perform this analysis, we had to generate a measure of employment sensitivity to monetary policy. To generate this measure, we used the local projection in Equation 7 to generate the sensitivity of unemployment in each SA2 region h quarters after the monetary policy shock.

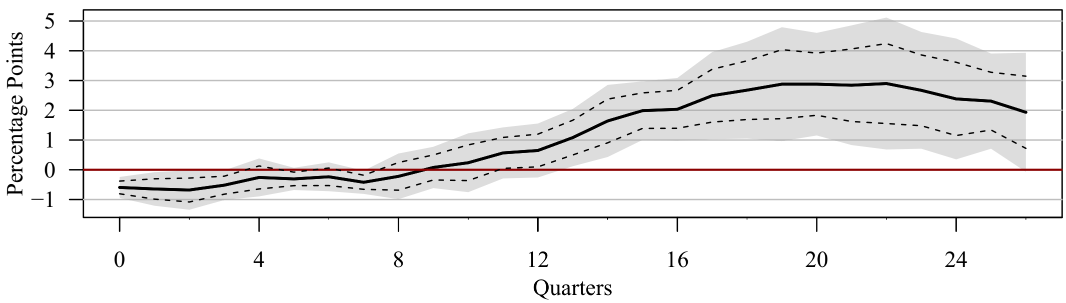
$$\Delta UE_{i,t-1,t+h} = \beta_h \Delta r_t + \epsilon_{i,t,h} \tag{7}$$

In Figure 7, Panel C, we set h to eight quarters. To test whether this selection of horizon length was important, we analysed the sensitivity of unemployment monetary policy 4 and 12 quarters after the shock. We found a positive effect in both cases; however, the size of the effect does increase over time. We conclude that the sensitivity of employment to monetary policy is robust to the choice of horizon length.

(a) **4 quarters**



(b) **12 quarters**



Notes: The response of house prices to a one standard deviation shock. This is equivalent to a 0.4 per cent expansionary monetary policy shock. The dotted lines and shaded area represent the 1 and 1.65 standard deviation confidence intervals, respectively.

Appendix VII. The Effect of Each Commodity Classification on House Prices

In this appendix, we perform an exercise to understand how each commodity within the commodity price instrument affects house prices. To do this we separate the commodity price instrument for each state into seven instruments (one for each one-digit export classification). We then use Equation 2 and replace the commodity price instrument with these new instruments. The new instruments are created by grouping the SITC two-digit classifications using their one-digit classification (except for SITC 68 because this is the only commodity in the SITC code 6 classification). The SITC one-digit classifications used are described in the table below.

SITC One-Digit Code Descriptions and Standard Deviations.

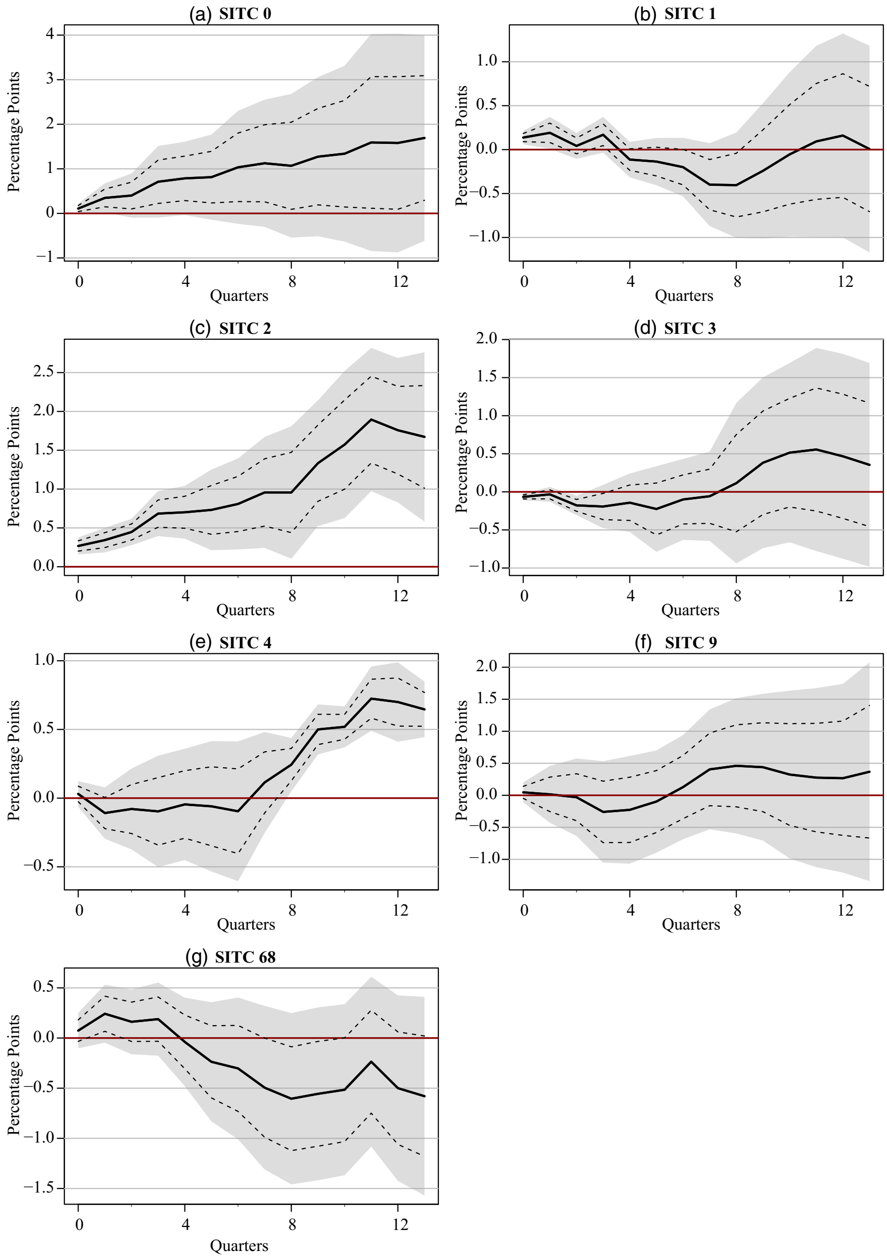
SITC code	Description	Standard deviation (%)
0	Food and live animals	0.6
1	Beverages and tobacco	0.5
2	Crude materials, inedible, except fuels	1.1

(continued)

SITC code	Description	Standard deviation (%)
3	Mineral fuels, lubricants and related materials	3.0
4	Animal and vegetable oils, fats and waxes	0.5
9	Commodities and transactions not classified elsewhere in the SITC	0.7
68	Non-ferrous metals	0.9

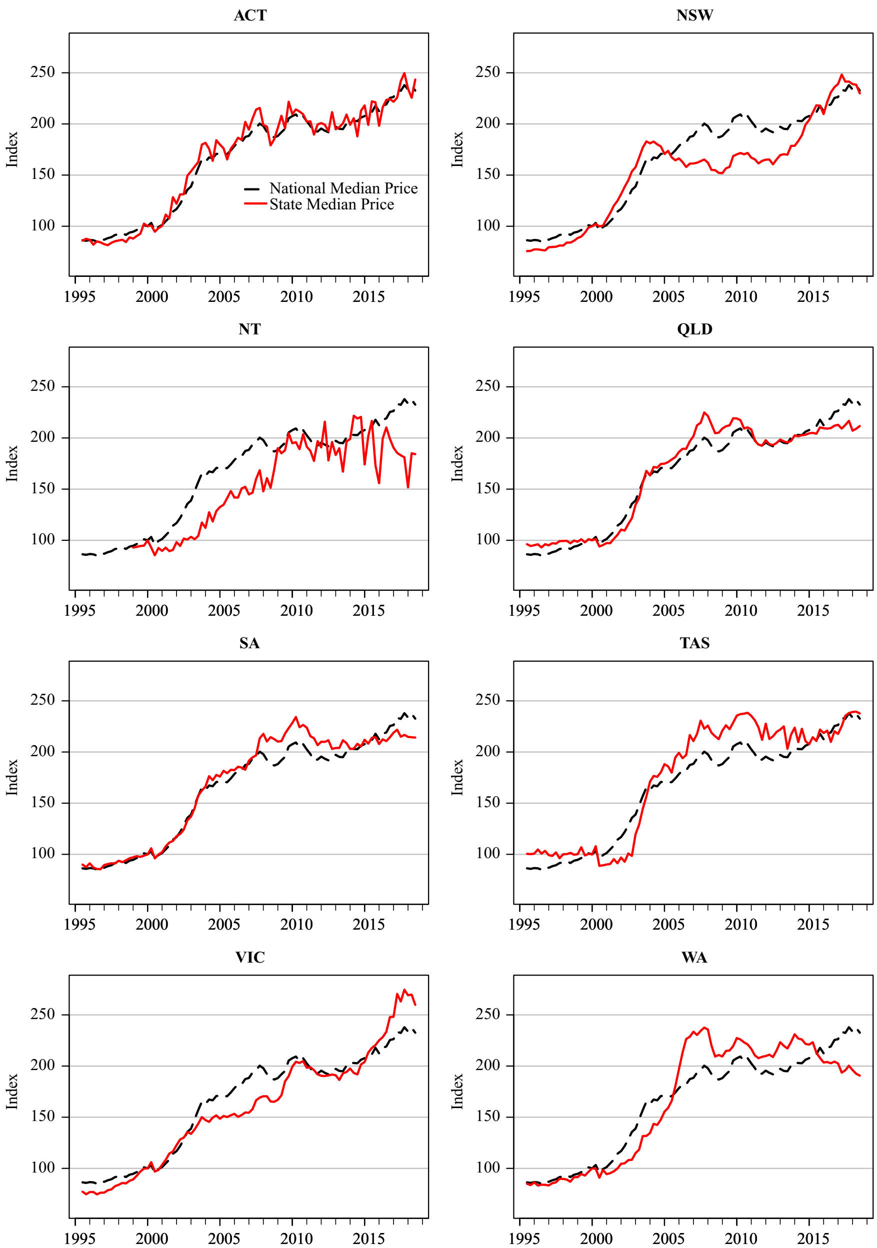
The figure below shows the response of house prices to a one standard deviation positive shock to the price of each SITC code. The standard deviations of each one-digit commodity classification can be found in the table above. For example, Panel A shows the response of house prices to a one standard deviation (0.6 per cent) increase in the price of SITC code 0. **Response of house prices to shocks in the prices of different commodities.**

Response of house prices to shocks in the prices of different commodities



Notes: The response is to a one standard deviation shock to the relevant SITC one-digit code. These standard deviations can be found in the table above. The dotted lines and shaded area represent the 1 and 1.65 standard deviation confidence intervals, respectively.

Appendix VIII. Comparison of State and National Median House Prices



Notes: House prices are indexed at 2000Q1. Both the state and national measures use the median sales price of houses in each quarter. Data for the Northern Territory only from 1999Q1.