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Abstract

Understanding the impact of economic uncertainty shocks at the industrial disaggregated level is critical for both fiscal and monetary policy response to economic uncertainty shocks. We estimate an SVAR model using quarterly Australian data from 1987:2 to 2018:4. The results of this paper emphasise that individual industries have unique responses to economic uncertainty shocks and do not necessarily reflect the response of the broader aggregate macroeconomy. We found the following stylized facts; i) The construction industry is the most negatively impacted industry by an economic uncertainty shock in terms of investment, output and employment in Australia; ii) The financial and insurance services industry also endures a substantial decline to these shocks, particularly on investment and employment indicators; iii) Economic uncertainty is shown to have less impact on the mining, health care and social assistance and public administration and safety industry, where the government plays a significant role.

Keywords: Economic Uncertainty, Economic Uncertainty Shocks, SVAR, Australian economy, Australian Industries

JEL classification: C10, C32, E00, E30

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1. INTRODUCTION

This paper is the first empirical work studying the impact of economic uncertainty shocks on industry-level investment, output and employment in Australia. The literature related to economic uncertainty has significantly expanded during the past decade; however, most studies focus at the aggregate level, rather than at an industrial level.

Most empirical studies found that an unexpected, temporary economic uncertainty shock causes aggregate investment, output, and employment to decline in an economy (Caggiano, Castelnuovo & Groshenny, 2014; Baker, Bloom & Davis, 2016; Gieseck & Largent 2016; Moore 2017). Uncovering the relationship at an industry level is crucial as this well-established response is unlikely to be similar for all industries within an economy as different industries have different characteristics in terms of investments timeframe and labour and capital compositions. The empirical findings in this paper will help to guide policymakers to provide support to specific in periods of high uncertainty such as the current Covid-19 crisis.

In this study, we use the measure of economic uncertainty for Australia developed by Moore (2017) which covers a longer time frame, which we use. The index is a weighted average of four uncertainty measures: newspaper-based uncertainty, forward-looking stock market volatility, analyst earning forecast uncertainty and gross domestic product (GDP) growth forecast dispersion.[1] Figure 1 presents the index, key events (both of a domestic and international nature) which are intuitively expected to alter the level of economic uncertainty in Australia are linked to the index.

Using quarterly data from 1987:2 to 2018:4, we estimate a Structural Vector Autoregression (SVAR) model. The industrial data is from Australian and New Zealand

[1] There are many different proxies to measure the level of economic uncertainty for an economy. More traditionally, finance-based proxies and forecaster disagreement between macroeconomic variables were commonly used. In more recent years newspaper-based measures have become increasingly popular in the literature, in particular Baker, Bloom & Davis, (2016) developed newspaper-based economic policy uncertainty indices for numerous countries, including Australia. For a description of each type of uncertainty measure and their relative weights, refer to Moore (2017) pages 551-556.

Standard Industrial Classifications. Of these, we focus our discussion on the seven largest industries in Australia (in terms of their GVA as a percentage of GDP by 2018:4).[2]

The study finds that Australian industry-specific investment, output and employment respond very different to economic uncertainty shock. The most striking results are that the *construction* industry is consistently the most impacted large industry in Australia by economic uncertainty shocks. One standard deviation economic uncertainty shock is associated with a maximum statistically significant decline in investment, output and employment of around 4.5, 0.6 and 0.3% respectively. The sensitive nature of the industry may be linked to the 'risk premia' channel of uncertainty, as the industry has a high reliance on financing when undertaking investment projects. *The financial and insurance services* industry also endures a substantial decline, particularly investment (4.1%) and employment (0.2%) in response to one standard deviation economic uncertainty shock. This is likely due to the industries responsive nature to news and other related economic uncertainty events, causing firms to re-access their investment and hiring activates in a much faster time frame compared to other industries. The *mining* industry is observed to be less impacted large industry by this shock which likely reflects the long-term investment timeframes of the industry, as increased economic uncertainty will likely subside between when investment occurs and returns are realised.

We also find very different responses to economic uncertainty shocks for smaller industries and sub-industry output. *The transport, postal and warehousing* industry investment, output and employment decline 5.0, 0.4 and 0.3% in response to the same economic uncertainty shock. In terms of disaggregated industries. The most affected outputs of sub-industries in the *manufacturing* sector are *metal products*; *petroleum, coal, chemical and rubber products*, and

[2] These include *financial and insurance services* (9%); *mining* (8%); *construction* (8%); *health care and social assistance* (7%); *professional, scientific and technical services* (7%); *manufacturing* (6%); and *public administration and safety* (5%). The number adjacent to each industry indicates the relative size of that industry compared to the total economy. Overall these seven industries comprise of 50% of the total Australian economy.

air and space transport declining by 1.0, 0.8 and 0.7% (respectively) to one standard deviation economic uncertainty shock

The paper proceeds as follows. Section 2 provides a review of existing literature. Section 3 outlines the data description, Section 4 describes the methodology employed (SVAR model), Section 5 shows results of impulse response functions and variance decomposition for large, small and disaggregated industries, in Section 6 we present a robustness analysis; and Section 7 concludes.

2. LITERATURE REVIEW

We outline the existing theory and empirical literature to gain a better understanding of the role that economic uncertainty plays on the macroeconomy and how economic uncertainty shocks impact key macroeconomic indicators such as output, investment and employment. There are several avenues through which uncertainty impacts macroeconomic performance; these are extensively studied and outlined in the literature.

The relationship between uncertainty and investment decisions has been established by several important contributions (Bernanke 1983; Bloom 2009). These studies argue that there is value in waiting for increased information when agents are making decisions which are costly to reverse, such as investment (and hiring), establishing what is known as the 'real-options' channel of uncertainty. The channel predicts an initial decline in investment and employment in response to a temporary increase in uncertainty, after which firms realise their demand for capital and labour, causing both investment and employment to rebound and overshoot.

Bloom (2014) outlines how greater uncertainty will lead to consumers increasing their savings ('precautionary savings' channel of uncertainty) which is likely to depress economic activity in the short-run. He also emphasises that in times of heightened uncertainty investors will want to be compensated for absorbing higher risk, raising the risk premium. Consequently,

the cost of finance will increase ('risk premia' channel of uncertainty) which can reduce macroeconomic growth. Bloom (2014) also discusses two channels in which uncertainty can have a positive effect on long-run growth. Firstly, the 'growth options' mechanism and secondly, the 'Oi-Hartman-Abel effect'.

The relationship between economic uncertainty and industry-level investment, output and employment is understudied worldwide and currently unexplored in Australia. As such, the remaining paragraphs of this section outline empirical evidence of economic uncertainty shocks on the broader macroeconomy to gain an understanding of what may be expected at the industry-level, see Table A.1, in Appendix A which summarises each paper discussed below.

Bloom (2009) conducts one of the first empirical studies to uncover the relationship between uncertainty and the macroeconomy. Establishing that output and employment experience a rapid decline, followed by a recovery and overshoot from a temporary unexpected uncertainty shock. More recently, using a VAR approach with U.S data and a 12-country panel VAR, Baker, Bloom & Davis, (2016) establish that gross investment, industrial production and employment decline in response to an economic policy uncertainty shock. Following this study, using his economic uncertainty index for Australia and two VAR models of different data frequencies, Moore (2017) found that a shock to economic uncertainty reduces machinery and equipment investment growth and employment growth in Australia, supporting the 'real options' channel.

Kang, Lee & Ratti, (2014) find that when firms are in doubt of policy factors they become more cautious of their investment decisions; however, the impact is much more negligible on large firms. Besides, when examining fixed firm investment of listed and delisted non-financial companies on the Australian stock exchange, Tran (2014) finds a negative relationship between investment and uncertainty, and that financially constrained firms are more sensitive to uncertainty. Gulen & Ion (2016), Gieseck & Largent (2016) and Carrière-Swallow & Céspedes (2013) uncover that a shock to economic uncertainty causes as a drop and

rebound of investment. Cerda, Silva & Valente, (2018) uncover a similar result for Chile, also, they find that the decline in investment is mostly attributed to private investment. Finally, Meinen & Roehe (2017) find that periods of low or negative investment growth can be partly explained by increased economic uncertainty.

Gieseck & Largent (2016), Girardi & Reuter (2017), and Istiak & Serletis (2018) outline how a temporary economic uncertainty shock depresses economic activity (real GDP and/or industrial production), causing a rapid decline followed by a rebound in output, complementing the findings of Bloom (2009) and Baker, Bloom & Davis, (2016).

More recently, Caggiano, Castelnuovo & Nodari, (2017) outline that the responses of real activity indicators are more sensitive when economic uncertainty shocks occur in a recessionary period. Similarly Sorić & Lolić (2017) outline the decline is more pronounced in the contractionary phases of the business cycle.

3. DATA DESCRIPTION

This study builds on Australian macroeconomic SVAR literature using quarterly data from 1987:2 to 2018:4. The starting period is dictated by the availability of industrial data in Australia. We assume that Australia is a small open economy which cannot influence global economic conditions (Dungey & Pagan 2000). This assumption is maintained by introducing separate domestic and foreign blocks of variables in the model.

In line with previous industry-level Australian macroeconomic SVAR studies (Lawson & Rees 2008; Vespignani 2013; Knop & Vespignani 2014; Manalo, Perera & Rees, 2015) our model estimate one industry at a time. Sections 3.1 and 3.2 outline the variables which are included in the model, for further detail, refer to Table A.2, in Appendix B.

3.1 Foreign Variables

The foreign block captures the influence of global economic developments on the Australian economic. The following variables represent the global economy, the Australian terms of trade (TOT_t), the Australian index of commodity prices (COM_t), world real GDP ($WGDP_t$), the world inflation rate ($WINF_t$), and the world short-term interest rate ($WINT_t$).

Overtime Australian studies have considered alternative approaches to representing the foreign economy; in absent of global data, U.S variables, such as U.S GDP were incorporated to measure the global economy.[3] However, compositions of the global economy are constantly changing, and as such, the significance of one country may shift over time. Consequently, we follow Knop & Vespignani (2014) and we use Australia's five largest trade partners (China, Japan, U.S, Euro Area and the Republic of Korea) based on the total (two-way) trade value as a proxy for the global economy.[4] We construct $WGDP_t$ through aggregating the real GDP (in U.S dollars) of each major trade partner and develop proxies for $WINT_t$ and $WINF_t$ by aggregating the central bank policy rate and the quarterly change of the consumer price index, weighting by their share of total Australian trade.[5]

In line with Dungey & Pagan (2000) and Manalo, Perera & Rees, (2015) we use the Australian terms of trade index to control for changes in the trade conditions for Australia. Following Lawson & Rees (2008) and Jacobs & Rayner (2012), we include the Australian commodity price index variable to account for Australia's high dependence on commodity prices.

[3] Studies which use this specification include: Dungey & Pagan (2000), Berkelmans (2005), Claus, Dungey & Fry, (2008), Liu (2010), Jääskelä and Jennings (2011), Vespignani (2013) and Manalo, Perera & Rees, (2015).
[4] Based on information from the Department of Foreign Affairs and Trade - Trade Statistics. On average, during sample period, these five countries comprise of 52 per cent of Australia's total trade value.
[5] The trade-weights are adjusted to sum to one.

3.2 Domestic Variables

When analysing specific industries, it is a common practice to include both the industry being analysed and the sum of all other aggregated industries to allow interaction between the industry i and the rest of the Australian economy j. This method is first used by Lawson & Rees (2008), Vespignani (2013), Knop & Vespignani (2014) and Manalo, Perera & Rees, (2015). Firstly, when considering industry output (real GVA), $AGDP_{j\text{-}i,t}$ is defined as the Australian real non-farm GDP minus the real GVA of industry i, (GVA_{it}). Secondly, we refer to the industry-specific investment i as INV_{it}. $INV_{j\text{-}i,t}$ is defined as a total investment (j) minus the investment of industry i. Lastly, we refer to EMP_{it} as the number of people employed in industry i. $EMP_{j\text{-}i,t}$ is defined as total employment (j) minus the employment of industry i. In line with Berkelmans (2005), Knop & Vespignani (2014), Vespignani (2015) and Dungey et al. (2017), real Australian GDP ($AGDP_t$) is used to measuring domestic output. Consistent with Jääskelä & Jennings (2011) and Dungey et al. (2017) real non-farm GDP is used since real farm GDP can suffer from short-term volatility due to extreme weather events.

The trimmed mean consumer price index quarterly change (INF_t) is used to measure relative prices in Australia, this follows Dungey, Fry-McKibbin & Linehan, (2014), and Dungey et al. (2017). The inclusion of inflation as a rate compared to a price level is consistent with a majority of Australian studies. We also introduce the Australian short-term policy rate (INT_t) to represent the Australian interest rate set by the Reserve Bank of Australia (RBA), and the Australian trade-weighted index (TWI_t) to account for the real exchange rate. Lawson & Rees (2008) outline the trade-weighted index is an important macroeconomic variable due to its influence on Australia's trade flows.

We introduce to the SVAR model the Australian economic uncertainty index ($UNCER_t$) variable constructed by Moore (2017). Economic uncertainty variable is an important inclusion in SVAR-type of models in international studies (see, Bloom 2009; Baker, Bloom & Davis,

2016) and might be a potential cause and/or consequence of business cycle fluctuations (Castelnuovo, Lim & Pellegrino 2017).

4 Methodology

We assume the following structural form equation represents the Australian economy (ignoring, for simplicity, any constant terms in the model):

$$B_0 X_t = B(L)X_{t-1} + K(L)Y_t + \varepsilon_t \quad (1)$$

B_0 is a matrix which is normalised to have ones on the diagonal, while the off-diagonal elements summarise the contemporaneous relationships between the variables in the vector X_t (a vector of the endogenous (domestic) variables). Y_t is a vector of the exogenous (foreign) variables. $B(L)$ and $K(L)$ are matrices which summarise the lag structure of the variables in vectors X_t and Y_t. The vector ε_t contains orthogonal structural disturbances, which are identified by placing restrictions on the B_0 matrix. Fry & Pagan (2011) outline five methods to impose adequate restrictions on the model. We place zero restrictions on the B_0 matrix to recover the endogenous variables in the structural equation (Equation 2). In line with Dungey & Pagan (2000), Lawson and Rees (2008) and Vespignani (2013), a lag length of $p = 3$ is selected for the model.

4.1 Identification Restrictions

We impose identification restrictions on the contemporaneous relationships between the variables summarized in Equation (2). Because of data limitations, investment is not considered in all industries, in which case, the investment variables are removed from Equation (2), however, the same restrictions still apply to all other variables. Likewise, when analysing sub-industries, both the investment and employment variables are excluded from equation (2).

$$B_0 X_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{41} & b_{42} & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{51} & b_{52} & 0 & b_{54} & 1 & 0 & 0 & 0 & 0 & 0 \\ b_{61} & b_{62} & 0 & b_{64} & 0 & 1 & 0 & 0 & 0 & 0 \\ b_{71} & b_{72} & 0 & b_{74} & 0 & b_{76} & 1 & 0 & 0 & 0 \\ b_{81} & b_{82} & 0 & b_{84} & 0 & b_{86} & 0 & 1 & 0 & 0 \\ b_{91} & b_{92} & 0 & b_{94} & 0 & b_{96} & 0 & b_{97} & 1 & 0 \\ b_{101} & b_{102} & 0 & b_{104} & 0 & b_{106} & 0 & b_{108} & b_{109} & 1 \end{bmatrix} \begin{bmatrix} UNCER_t \\ \Delta\log(INV_{i,t}) \\ \Delta\log(INV_{(j-i),t}) \\ \Delta\log(EMP_{i,t}) \\ \Delta\log(EMP_{(j-i),t}) \\ \Delta\log(AGDP_{(j-i),t}) \\ \Delta\log(GVA_{it}) \\ INF_t \\ INT_t \\ \Delta\log(TWI_t) \end{bmatrix} \quad (2)$$

We order $UNCER_t$ first out of the domestic block variables, this allows $UNCER_t$ to contemporaneously impact all other domestic block variables. This approach is consistent with international VAR uncertainty literature.[6] The ordering of economic uncertainty is investigated in Section 6.

Following the argument of Vespignani (2013) and Knop & Vespignani (2014) the industry *i* variable proceeds the rest of the Australian economy *(j-i)* variable, denoted because each industry *i* is only a small proportion of Australian real GDP, hence, the largest part of the economy is more likely to impact an individual industry, but the opposite is less likely. We also assume that a single industry *i* cannot impact any other variable in the domestic block in contemporaneous terms, but rather only with a lagged effect. This is based on the premise that in terms of GVA all industries hold a share of the total economic output of less than 10%.

INV_{it} and $INV_{(j-i),t}$ proceed the variable $UNCER_t$ in Equation (2); investment has not been previously introduced in an Australian SVAR study, thus, there is no Australian context to base the ordering of the investment variables. We follow the international literature such as Baker, Bloom & Davis, (2016) who order investment before output; intuitively, investment should contemporaneously impact output since investment is a component of real GDP. The ordering is further examined in Section 6.

[6] For example: Caggiano, Castelnuovo & Groshenny, (2014), Baker, Bloom & Davis, (2016), Gieseck & Largent (2016), Girardi & Reuter (2017), Sorić & Lolić (2017) and Cerda, Silva & Valente, (2018).

EMP_{it} and $EMP_{(j-i),t}$ are contemporaneously impacted by economic uncertainty and investment. Likewise, as with investment, there is no Australian context to base the ordering of the employment variables. Following Baker, Bloom & Davis, (2016) employment is ordered before output, additionally, we assume that investment will immediately impact employment, hence ordering employment after investment.

Commonly, Australian output ($AGDP_{(j-i),t}$ and GVA_{it}) is ordered first and considered as the most exogenous of the domestic block variables (Berkelmans 2005; Lawson & Rees 2008). For the reasons discussed above, we order economic uncertainty, investment and employment before domestic output.

Following Dungey & Pagan (2000) and Knop & Vespignani (2014), INF_t responds contemporaneously to Australian output. We assume inflation also reacts immediately to economic uncertainty, investment and employment. Inflation does not immediately respond to the interest rate, as changes to the interest rate take considerably longer to impact consumption and investment decisions, and therefore flow through to prices (Knop & Vespignani 2014). Following Jacobs & Rayner (2012), INF_t does not respond contemporaneously to TWI_t, since the pass-through of exchange rate movements to consumer prices occurs gradually over time (Chung, Kohler & Lewis, 2011).

There are two conventional methods in the literature on specifying the contemporaneous restrictions for the domestic interest rate equation, which Knop & Vespignani (2014) concisely outline. One of which involves specifying a Taylor type monetary policy rule, allowing domestic output and inflation to contemporaneously impact the domestic interest rate, which this study follows.

We order TWI_t last in the domestic block of variables, meaning it responds contemporaneously to all other domestic variables (besides the industry variables), this is standard across Australian SVAR literature. The reason for this restriction is that exchange markets respond rapidly to all new and available information (Vespignani 2013).

In line with the small open economy assumption, the foreign block of variables is strictly exogenous, this follows Jacobs & Rayner (2012), Vespignani (2013) and Knop & Vespignani (2014). Three lags of the exogenous foreign variables affect all domestic variables, with $WGDP_t$, COM_t and TOT_t having an immediate impact as well. Allowing $WGDP_t$ and COM_t to contemporaneously impact the domestic block follows Lawson & Rees (2008) and Dungey et al. (2017) while allowing TOT_t is consistent with Dungey & Pagan (2000) and Vespignani (2013) and Vespignani (2015). The ordering of all variables is further analysed in Section 6.

4.2 Autocorrelation, Heteroskedasticity and Stability Condition

In this section, we discuss statistical tests of the SVAR model described in Equation 1 and 2.We use the residual serial correlation LM test of first-order serial correlation to check for autocorrelation, the null hypothesis of no first-order serial correlation cannot be rejected at the 5% significance level for a majority of the industry models. Similarly, we conduct the residual White Heteroskedasticity Test to check for heteroskedasticity, the null hypothesis of no heteroskedasticity cannot be rejected at the 5% significance level for all industry-specific models. An important condition to be satisfied in any VAR model is that the lag structure included also has to be stationary. The stability condition test results suggest that for most models no root lies outside the unit circle, suggesting that our models have stable roots (note that results are available from the author).

5. RESULTS

In this section, we present the IRF to evaluate the impact of a temporary and unanticipated economic uncertainty shock on industry-level investment, output and employment. This is introduced into the model by applying a one standard deviation impulse to the economic uncertainty variable. We also analyse the variance decomposition of each industry variable to examine the relative importance of the structural shock, by outlining the

proportion of variation in each industry variable that can be attributed to the economic uncertainty shock.

5.1 Response of Australia's Largest Industries to an Economic Uncertainty Shock

Figure 2 reports the IRF for Australia's largest (aggregated) industries in response to an unexpected, temporary economic uncertainty shock. Each row represents the response of investment, output and employment for that particular industry.[7]

Construction is the most negatively affected industry. A one standard deviation economic uncertainty shock is associated with a statistically significant decline in investment (4.5%), output (0.6%) and employment (0.3%) at their respective minimum which occurs in the third, fourth and second quarters respectively. This large response may reflect the industries reliance on financing when undertaking investment projects. Heightened uncertainty causes the cost of financing to increase ('risk premia' channel of uncertainty), which translates to lower investment from businesses as investment projects become more expensive. The declining investment flows through to lower output and employment opportunities for the industry.

Investment in the *financial and insurance services* is also heavily impacted by heightened economic uncertainty in the Australian economy. A one standard deviation economic uncertainty shock is associated with a decline of approximately 2.9% in investment in the second quarter which is statistically significant for the period. Immediately after the response rebounds and overshoots, becoming positive in the third quarter. Likewise, declines are observed for both employment and output, which rebound and overshoot soon after the initial instance. The fast response and recovery are likely due to the industries responsive nature to news and other related events. Meaning businesses readily adjust investment and employment strategies in response to unanticipated economic uncertainty shock.

[7] Where there are no investment results reported there was insufficient data to conduct the estimation.

In terms of magnitude, *manufacturing* appears to be less impacted than other industries, although consistent declines do occur. *Manufacturing* is seen to be largely impacted through a reduction of around 0.3% in both output and employment in response to a one standard deviation economic uncertainty shock which is statistically significant for a single quarter. This response may be consumer-driven since heightened economic uncertainty generally causes consumers to respond through increasing savings to protection against temporary loses to income ('precautionary savings' channel of uncertainty) causing a reduction in purchases. However, conclusions are difficult to draw as the aggregate *manufacturing* sector is quite heterogeneous in terms of production, investment and employment (we explore sub-industry responses in the next section).

A one standard deviation economic uncertainty shock is associated with a statistically significant decline of approximately 2.0% in outputs of the *professional, scientific and technical services* industry is somewhat less impacted than others. The responses to investment and outputs are less clear for this sector and may respond to the broad nature of this aggregate measure as this category is broadly defined by the ABS (unfortunately no further disaggregation is reported by the ABS).

The results for the *mining* industry are somewhat inconsistent with one another. Firstly, investment endures a brief and immediate statistically significant decline, which is more subdued compared to the other industries, likely reflecting the long-term investment nature of the industry. Topp et al. (2008) outline that when capital investment occurs in the *mining* industry there is roughly a three-year lag until returns are realised, meaning a temporary shock to economic uncertainty today is unlikely to alter long-term investment decisions. *Mining* output and employment display positive responses to an economic uncertainty shock. Later in this section *mining* is disaggregated to analysis if a particular sub-industry is driving this unique response to output.

The *health care and social assistance* industry shows mixed results, as both output and employment experience immediate increases, followed by large declines which rebound and overshoot. In terms of magnitude, the statistically significant decline in output of approximately 0.4% is substantial when compared to other industries. Due to the diverse nature of this industry and without sub-industries disaggregation, it is difficult to draw sound conclusions from the observed responses. *Public administration and safety* is one of the least impacted industries as both responses are relatively statistically insignificant, which likely reflects the government input in this industry. Whereby employment contracts are more secure and employment decisions cannot be readily adjusted in response to a temporary economic uncertainty shock.

5.2 Response of Australia's Smaller Industries to an Economic Uncertainty Shock

Table 1 is utilized to compress information for many other small industries. In this table, we show the maximum and minimum points of the impulse response function for industrial investment, output and employment to an economic uncertainty shock. We also show the quarter (period) in which the maximum/minimum points takes places.

Results in this table show that *transport, postal and warehousing* investment, output and employment decline by 5.1, 0.4 and 0.3% (respectively) in response to a one standard deviation uncertainty shock. The three responses are statistically significant at the forth, third and second quarters (respectively). For *wholesale trade*, only investment and outputs measures declined by 2.0% and 0.4% in response to the same shock and are responses are also statistically significant. Also in response to a one standard deviation uncertainty shock, investment declined 2.6%, being the only measure which is statistically significant for this industry.

The only industry which consistently shows a positive response to in response to a one standard deviation uncertainty shock is *electricity, gas and waste services* which show an increase of 3.0, 0.2 and 0.9% for investment, output and employment (respectively). For *rental,*

hiring and real estate services; *arts and recreation*, *administrative and support services*; and *education and training* results are less conclusive.

5.3 Response of Australia's Sub-Industries to an Economic Uncertainty Shock

Table 2 shows the maximum/minimum (to conserve space) of the impulse response of sub-industries to a one standard deviation economic uncertainty shock. The ABS does not report data for investment or unemployment in this sub-industries. These results are important to understand the disaggregated effect of uncertainty shocks for sub-industries which have different characteristics in terms of capital, labour compositions, and investment timeframes. Results in Table 2 shows the sub-industries responses to a one standard deviation economic uncertainty shock. Statistical significant and negative responses results are found for the following sub-industries output: *Metal products* (the most affected industry in Australia) decline around 0.1% after 3 quartes; *petroleum, coal, chemical and rubber products* decline around 0.8% after 2 quarters; *air and space transport* decline by 0.7% after 1 quarter; *Oil and gas exploration*; and *Road* sub-industries decline by around 0.5% after 1 year and 3 quarters respectively.

There is also some sub-industries which positively respond to a one standard deviation economic uncertainty shock. Statistical significant and positive responses results are found for the following sub-industries output: *Transport, postal and storage services* increase by 0.8% after one year; *food, beverage and tobacco products* increase by 0.4% after one year; *rail, pipeline and other transport* increase by 0.3% after 5 quarters.[8] For the rest of the sub-industries (*mining excluding exploration* and *mining support services*; *exploration and mining support services*; *Other manufacturing*; and *Other mining*), results are statistically insignificant.

[8] Note that the theoretical explanations about this positive responses are beyond the scope of this empirical paper and hopefully will be explore by economic theorists.

5.4 Variance Decomposition for Australia's Largest Industries

Table 3 outlines the variance decomposition results for each industry variable (either INV_{it}, GVA_{it}, or EMP_{it}) to an economic uncertainty shock, reflecting the significance of economic uncertainty in particular industries. Economic uncertainty explains up to 5.3% on investment and 4.9% on output after eight quarters of the variation in *financial and insurance services*, which is the most substantial compared to the other industries.

In the *construction* industry, economic uncertainty accounts for 4.9% of the variation in investment, and 3.3% of the variation in outputs after eight quarters, which is comparable to the variation in *manufacturing* investment and output (4.1 and 2.2% respectively). The largest proportion of forecast error variance on employment due to economic uncertainty shock is reported by the *construction* industry (3.5%) after 8 quarters, while employment is significantly less affected by any other industry.

Economic uncertainty explains a relatively small variation in *health care and social assistance* output and employment (2.2 and 2.4% after eight periods) and only contribute 2.1% variation after eight quarter in *public administration and safety* output and employment. Highlighting the lesser extent economic uncertainty plays for these industries, particularly *public administration and safety*.

The effect of economic uncertainty accounts for only 1.1 and 1.9% variation after eight periods for *professional, scientific and technical services* employment and investment, compared to 2.9% for output. Lastly, economic uncertainty explains 3.8, 2.1 and 3.5% variation after eight quarters for *mining* investment, output and employment.

6. ROBUSTNESS ANALYSIS

SVAR models can be sensitive to the alternative specification. Consequently, we examine numerous alternative specifications and variables measures to ensure the results are

robust. In Figure 3, we compare the baseline model to the following alternative specifications: replacing global variables for global data from the Federal Reserve Bank of Dallas, Global Economic Indicators (DGEI); ordering the index of economic uncertainty last; specifying the SVAR model with only 2 lags; and an estimating of a more parsimonious model. Details of this can be found in sub-sections 6.1-6.3.

In Figure 4, we show results for the following alternative specifications: a different measure of inflation (Weighted-median); a different measure different of real GDP (including farming sector); including in the model a measure of consumer confidence; including a dummy variable for since the adoption of inflation-targeting by the RBA; and a dummy variable for the global financial crisis (GFC). Details of this can be found in sub-sections 6.4 and variables descriptions are in Table 4.

For all IRF in this section, the various colours and dash types represent the impulse responses for various alternative specifications and variable measures of each industry. The vertical axis represents the percentage change and the horizontal axis represents periods (quarters).

6.1 Lag Length

Imposing two lags on the model is common amongst Australian SVAR studies (Claus, Dungey & Fry 2008; Manalo, Perera & Rees, 2015), it is also suggested by the Akaike Information Criterium (AIC) and Hannan-Quinn (HQ) tests on the baseline model. Two lags tend to make the immediate response of industries more severe and subdue to the maximum or minimum response in later periods. Exceptions being *mining* output and *manufacturing* investment where the decline becomes larger.

6.2 Variable Ordering and Contemporaneous Restrictions

Consistent with Bloom (2009) in his robustness analysis, the economic uncertainty index is ordered last, meaning it is contemporaneously impacted by every other domestic block

variable in the system (excluding the industry variables). Similar to the findings of Moore (2017), ordering economic uncertainty last generally subdues the IRF. With the clear exception being the *construction* industry, as the IRF are varying magnitudes and direction compared to the baseline response.

The ordering of investment and employment in the model was not based on prior Australia literature, consequently, we examine how sensitive these variables are to alternative restrictions. Firstly, we allow the output variables to be ordered before investment and employment, and secondly, we position both the investment and employment variables second and third last (before the exchange rate). There is no visible impact to the baseline response, allowing us to conclude that regardless of the ordering scheme applied to the model, our results are robust to these new specifications.

6.3 Parsimonious SVAR model

We separate baseline model (described in Equation 1 and 2) into three, one for each industry measure (investment, output or employment). Each of the three models excludes the other two industry-specific measures. In Equation 3, we show the $B_0 X_t$,where IND_{it} represent three separate estimations (industry-specific investment, output and employment).

$$B_0 X_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & 1 & 0 & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & 1 & 0 & 0 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & 1 & 0 & 0 \\ b_{61} & b_{62} & b_{63} & 0 & b_{65} & 1 & 0 \\ b_{71} & b_{72} & b_{73} & b_{74} & b_{75} & b_{76} & 1 \end{bmatrix} * \begin{bmatrix} UNCER_t \\ \Delta \log(AGDP_t) \\ \Delta \log(IND_{it}) \\ \Delta \log(IND_{j-i,t}) \\ INF_t \\ INT_t \\ \Delta \log(TWI_t) \end{bmatrix} \quad (3)$$

This method is more parsimonious reducing the numbers of domestic variables from 10 to 7, but a potential misspecification issue may arise and important interactions between the industry variables may be lost.[9] Overall the results are relatively unchanged when the parsimonious

[9] Note that when output is estimated the model number of variables is reduced to 6 as aggregated GVA total equate real GDP. Therefore, the variable IND_{j-t} drop for the model.

SVAR is estimated. The main exception to this is the *professional, scientific and technical services* industries which undergo a different array of responses.

6.4 Alternative and Additional Variables

We explore additional and alternate variables/proxies in the model. Table 4 outlines the alternative variables that are considered in place of the existing variables and are substituted into each model one at a time.[10] The measures for the global headline inflation, the short-term policy rate and real GDP are from the Database of Global Economic Indicators (DGEI) (for details, please see Grossman, Mack & Martínez-Garcia, 2014). Overall, the results are similar in terms of magnitude and direction. In some instances, the DGEI are shown to alter the magnitude of the IRF, but the signs are generally consistent with the baseline model.

Baker, Bloom & Davis, (2016) and Cerda, Silva & Valente, (2018) discuss the endogeneity concerns between measures of uncertainty and (consumer) confidence. To address the problem, they each introduce a measure of consumer confidence as an endogenous variable. Following the same ordering of both studies, we order consumer confidence ($CONSU_t$) below economic uncertainty and allow it to contemporaneously impact all other domestic variables.

Two dummy variables are also introduced to account for structural changes in the Australian economy. Firstly to capture the adjustment of the RBA to inflation-targeting, and secondly to account for the global financial crisis.[11] In some instances, the additional variables alter the magnitude of the response; although, the difference is generally small to the baseline model.

[10] The exception of this is the global headline inflation, short-term policy rate and real GDP, which are substituted together.
[11] The inflation-targeting dummy variable is equal to 1 during the inflation-targeting period from 1993:1 to current, and 0 otherwise (Jääskelä & Smith 2013). The global financial crisis dummy variable is equal to 1 during 2008:4 to 2009:3 and 0 otherwise (Manalo, Perera & Rees, 2015).

7. CONCLUSION

This is the first study to present empirical evidence of the impact of economic uncertainty shocks on industry-specific investment, output, and employment in Australia. Overall, the *construction*, and *financial and insurance services* industries are the most impacted from heightened economic uncertainty. The sensitive nature of the *construction* industry may be linked to the industries high reliance on financing when undertaking investment projects. We also find a substantial impact on the *financial and insurance services* industry, likely due to the industries responsive nature to news and other related economic uncertainty events. *Mining* is less affected compared to most, reflecting the longer-term investment timeframes of the industry. *Public administration and safety* is unaffected, most likely due to the government nature of the industry as employment cannot be as readily adjusted in response to an economic uncertainty shock. We also show that sub-industrial outputs for the *manufacturing* industry response very differently economic uncertainty shocks. We found that *metal products* are the most affected industry in Australia declining 0.1% to a one standard deviation economic uncertainty shock, following by *petroleum, coal, chemical and rubber products* (0.8%); *air and space transport* (0.7%); *Oil and gas exploration*; and *Road* sub-industries (0.5%).

The results of this paper emphasise that individual industries have unique responses to an economic uncertainty shock, and do not necessarily reflect the response of the broader aggregate macroeconomy. In current times of great uncertainty (Covid-19 pandemic), quantify the response of individual industries and sub-industries is critical to guide public policy to provide adequate support for each industry.

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Table 1. The impulse response of all other industries to a one standard deviation economic uncertainty shock

Industries	Investment		Output		Employment	
	Max(+) or Min(-)	Period of effect	Max(+) or Min(-)	Period of effect	Max(+) or Min(-)	Period of effect
Transport, Postal and Warehousing	-0.051*	4	-0.004*	3	-0.003*	2
Wholesale Trade	-0.020*	1	-0.004*	2	-0.004	3
Retail Trade	-0.026*	3	-0.001	4	-0.001	3
Rental, Hiring and Real Estate Services	-0.015	4	0.003*	4	0.005*	1
Electricity, Gas and Waste Services	0.030*	1	0.002*	1	0.009*	2
Information, Media and Telecommunications	0.036*	1	0.003	2	-0.004*	1
Arts and Recreation			-0.004*	5	-0.009*	2
Administrative and Support Services			-0.004*	1	0.004*	3
Education and Training			0.001*	3	0.003*	2
Other Services			-0.004*	2	-0.003	3

#Where * indicate coefficients are statistically significant at 5% level.

Table 2. Impulse response of sub-industries to a one standard deviation economic uncertainty shock

Sub-Industries	Output	
	Max(+) or Min(-)	Period of effect
Metal Products	-0.010*	3
Petroleum, Coal, Chemical and Rubber Products	-0.008*	2
Air and Space Transport	-0.007*	1
Road	-0.005*	3
Oil and Gas Extraction	-0.005*	4
Iron Ore Mining	-0.005	3
Other Manufacturing	-0.003	3
Electricity	0.002*	1
Water Supply and Waste Services	0.002*	4
Coal Mining	0.002	6
Mining Excluding Exploration and Mining Support Services	0.002	2
Rail, Pipeline and Other Transport	0.003*	5
Food, Beverage and Tobacco Products	0.004*	4
Machinery and Equipment	0.004*	3
Other Mining	0.004	2
Gas	0.004*	1
Transport, Postal and Storage Services	0.005*	4
Exploration and Mining Support Services	0.008	4

#Where * indicate coefficients are statistically significant at 10% level.

Table 3. Variance decomposition of the largest industries to an economic uncertainty shock

	Proportion of forecast error variance					
	Investment		**Output**		**Employment**	
Quarter	4	8	4	8	4	8
Mining	3.56	3.85	1.92	2.10	2.63	3.47
Manufacturing	2.77	4.08	2.22	2.16	1.42	1.42
Construction	4.88	4.94	3.13	3.38	3.17	3.50
Financial and insurance services	5.41	5.34	4.17	4.96	1.95	2.63
Professional, scientific and technical services	1.76	1.94	3.00	2.94	0.78	1.09
Public administration and safety			1.78	2.15	2.06	2.15
Health care			2.53	2.23	2.87	2.46

Table 4. Alternative variable measures used in the robustness analysis

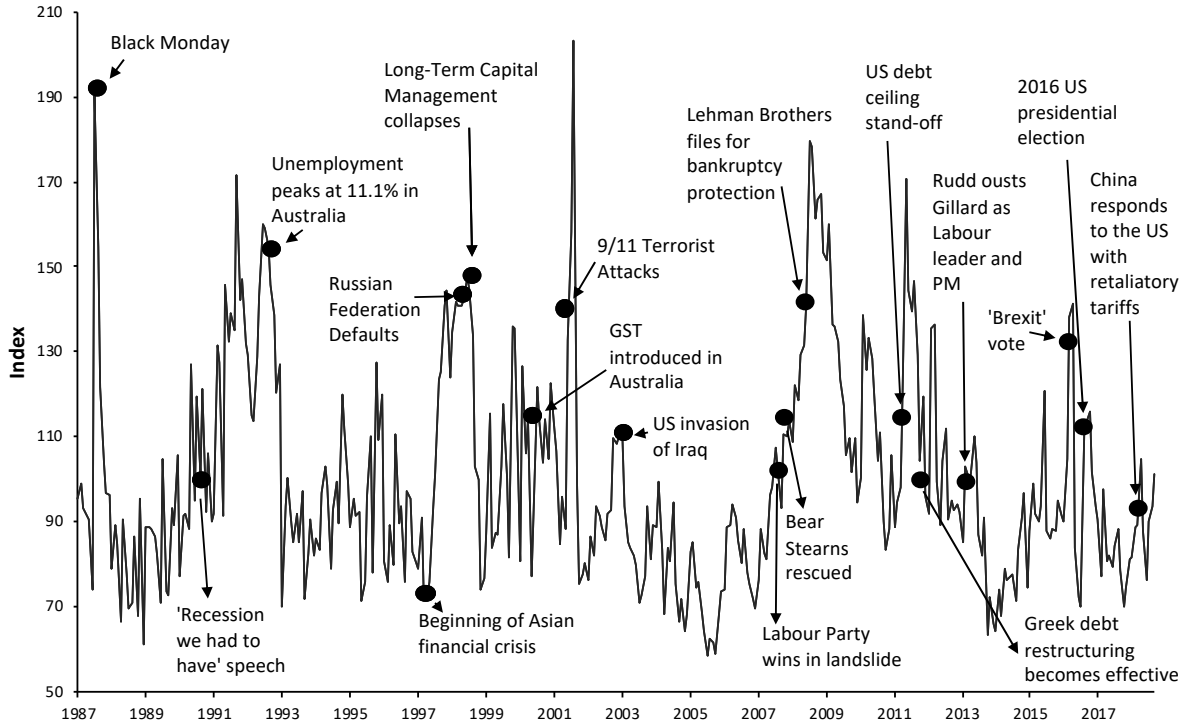
Variables in the original three models	**Alternative variables to be considered**
Trade-weighted world economic variables (inflation and interest rates)	Global headline inflation and short-term policy rate
Major trade partner real GDP	Global real GDP
Real Australian non-farm GDP	Total real Australian GDP
Trimmed mean inflation rate	Weighted-median inflation rate

Note these variable measures are substituted into the model outlined in Equation 1 and follow the same contemporaneous interactions set out in Equation 2.

Table 5. Data description, sources and transformations (robustness analysis variables)

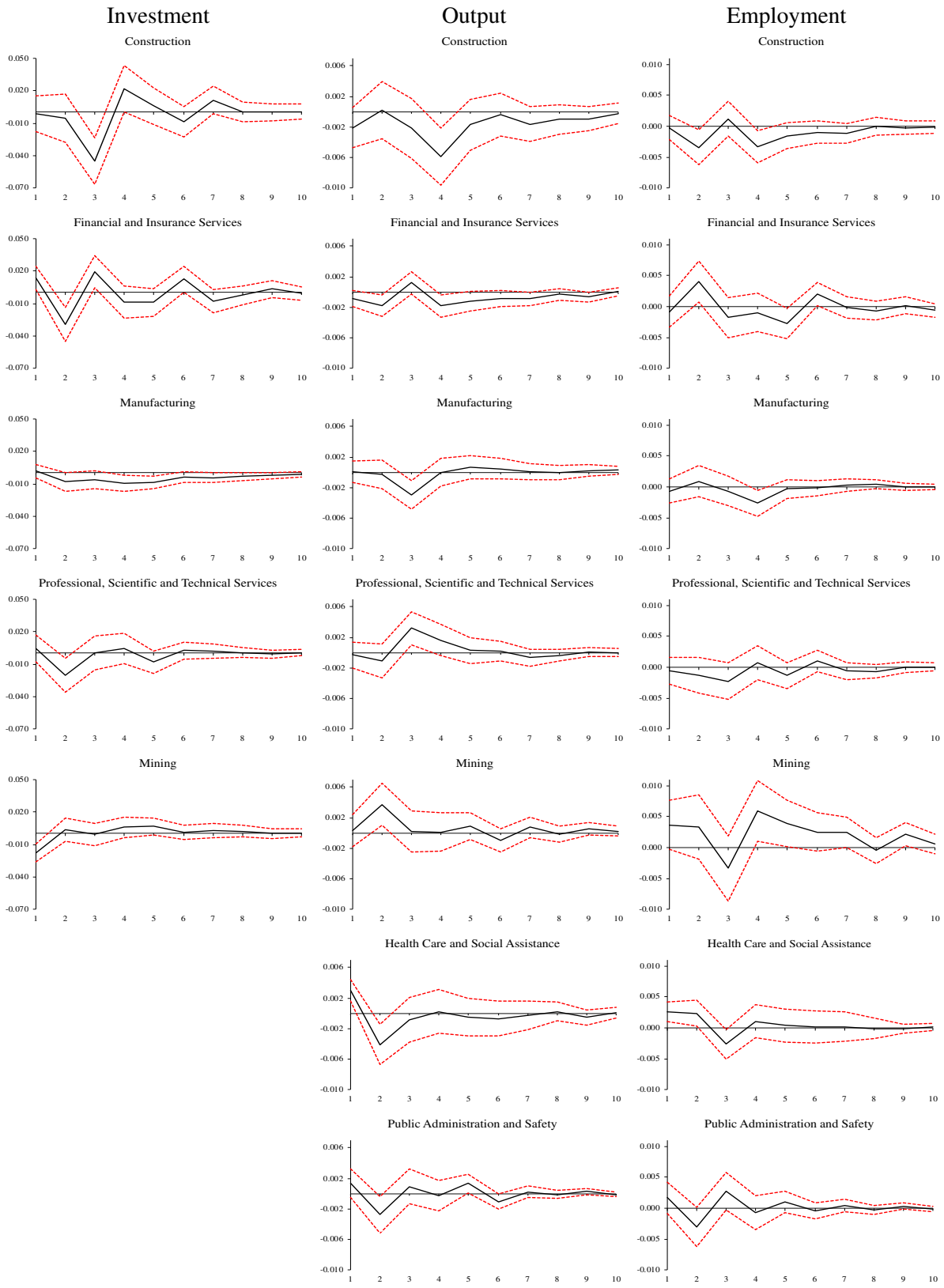
Variable	Description and Source	Transformations
$WGDP_t$	Seasonally adjusted, real GDP (Database of Global Economic Indicators).	To include the U.S economy, a weighted average using the U.S share of the world economy was employed (based on the shares of the world economy from the International Monetary Fund).
$WINF_t$	Seasonally adjusted, headline inflation (Database of Global Economic Indicators).	To include the U.S economy, a weighted average using the U.S share of the world economy was employed (based on the shares of the world economy from the International Monetary Fund). Additionally, the data was converted from monthly to quarterly using a 3-month average.
$WINT_t$	Seasonally adjusted, short-term official/policy rate (Database of Global Economic Indicators).	
$AGDP_t$	Seasonally adjusted, chain volume measure of gross domestic product, (ABS, Cat No. 5606.0, Table 6).	
INF_t	Seasonally adjusted consumer price index; Weighted median; Quarterly change (in per cent), (RBA, Statistical Table, G1).	
$CONSU_t$	ANZ Roy-Morgan Australian consumer confidence index (Roy Morgan, Morgan Poll).	Converted from monthly to quarterly using a 3-month average.
DUM_INF_t	Equal to 1 during the inflation-targeting period from 1993:1 to current and 0 otherwise.	
DUM_GFC_t	Equal to 1 during 2008:4 to 2009:3 and 0 otherwise.	

Figure 1. Australian index of economic uncertainty (monthly frequency)



Source: Moore (2017), Thomson Reuters and policyuncertainty.com.

Figure 2. Impulse response functions of the largest industries to a one standard deviation economic uncertainty shock



* For all IRF in this section, the solid black line represents the impulse response of each industry, and the dashed red lines represent the asymptotic standard error. The vertical axis represents the percentage change and the horizontal axis represents periods (quarters).

Figure 3. Summary robustness analysis impulse responses of the largest industries to a one standard deviation economic uncertainty shock

*For all IRF in this section, the various colours and dash types represent the impulse responses for various alternative specifications and variable measures of each industry. The vertical axis represents the percentage change and the horizontal axis represents periods (quarters).

Figure 4. Additional robustness analysis impulse responses of the largest industries to a one standard deviation economic uncertainty shock

*For all IRF in this section, the various colours and dash types represent the impulse responses for various alternative specifications and variable measures of each industry. The vertical axis represents the percentage change and the horizontal axis represents periods (quarters).

APPENDIX A: LITERATURE REVIEW SUMMARY

Table A.1. Summary of literature

Author(s)	Measure of uncertainty	Countries of study	Methodology	Study period
Bloom (2009)	Uncertainty dummy based on the VXO	United States	VAR and a model with a time-varying second moment	June 1962 to June 2008
Sorić & Lolić (2017)	Several measures *	Croatia	SVAR (fixed and timing-varying parameters)	November 2002 to December 2016
Carrière-Swallow & Céspedes (2013)	VXO index	Developed and developing Countries **	Open-economy VAR	March 1990 to March 2011
Kang, Lee & Ratti, (2014)	Economic policy uncertainty	United States	Error correction model of capital stock adjustment	January 1985 to December 2010
Gulen & Ion (2016)	Economic policy uncertainty	United States	Investment model and VAR	January 1987 to December 2013
Tran (2014)	Several measures ##	Australia	Investment model	1987 to 2009
Istiak & Serletis (2018)	Economic policy uncertainty	G7 countries	Non-linear SVAR	January 1985 to March 2015
Gieseck & Largent (2016)	Several measures ^	Euro Area	Multivariate SVAR	March 1999 to December 2015
Caggiano, Castelnuovo & Groshenny, (2014)	VIX	United States	Non-linear, Smooth Transition VAR	September 1962 to September 2012
Baker, Bloom & Davis, (2016)	Economic policy uncertainty	Various countries ^^	Firm-level regressions, VAR, panel-VAR	January 1985 to December 2014
Caggiano, Castelnuovo & Nodari, (2017)	Uncertainty dummy based on the VXO	United States	Non-linear, Smooth Transition VAR	July 1962 to June 2008
Girardi & Reuter (2017)	Survey-based measures	Euro Area	VAR	March 1999 to December 2014
Moore (2017)	Broad measure	Australia	VAR	October 1986 to December 2014
Cerda, Silva & Valente, (2018)	News-based uncertainty	Chile	VAR	March 1992 to December 2015

* 5 media-based measures, 4 disagreement measures, and 1 composite measure of uncertainty.

** Developed countries: Australia, Austria, Canada, Denmark, Finland, France, Italy, Japan, Netherlands, New Zealand, Norway, Switzerland, United Kingdom, United States, Belgium, Israel, Germany, Russia, Spain and Sweden. Developing countries: Chile, Hong Kong, Mexico, Philippines, South Africa, South Korea, Turkey, Argentina, Brazil, Colombia, Croatia, Czech Republic, Estonia, Hungary, Indonesia, Malaysia, Peru, Poland, Portugal and Thailand.

Implied volatility of stock market returns, economic policy uncertainty, the cross-sectional dispersion of production expectations in business surveys, and the unpredictable components of a large set of macroeconomic indicators.

Volatility of returns of firms' stock prices, idiosyncratic (micro) uncertainty, and market (macro) uncertainty.

^ Systematic stress indicator, political uncertainty indicator, macroeconomic uncertainty indicator and financial market uncertainty indicator.

^^ United States, India, Canada, South Korea, France, Germany, Italy, Japan, Spain, United Kingdom, China and Russia.

APPENDIX B: DATA DESCRIPTION

Table A.2. Data description, sources and transformations

Variable	Description and Source	Transformations
$WGDP_t$	Real world GDP, 2015 $US, constant prices (Datastream codes: CHXGDP$.C, JPXGDP$.D, USXGDP$.D, EKXGDP$.D, KOXGDP$.D).	Weighted average adjustment. Series which were not previously seasonally adjusted are seasonally adjusted using X12 ARIMA
$WINF_t$	World quarterly change in the consumer price index (Datastream codes: CHXCPI.%R, JPXCPI.%R, USXCPI.%Q, EKXCPI.%R, KOXCPI.%R).	Weighted average adjustment. Series which were not previously seasonally adjusted are seasonally adjusted using X12 ARIMA
$WINT_t$	World short-term official/policy rate (Datastream codes: CHXRCB..R, JPXRCB..R, USXRCB..R, EKXRCB..R, KOXRCB..R).	Weighted average adjustment.
$AGDP_t$	Seasonally adjusted, chain volume measure of non-farm GDP (RBA, Statistical Table, H1).	
GVA_{it}	Seasonally adjusted, chain volume measure of industry gross value added (ABS, Cat No. 5206.0 Table 6).	
EMP_{it}	Employed persons by industry division of main job, seasonally adjusted (ABS, Cat No. 6291.0.55.003, Table 4). *	
INV_{it}	Private new capital expenditure, actual expenditure, detailed industries, seasonally adjusted, current prices (ABS, Cat No. 5625.0, Table 2E).	Deflated by the Australian consumer price index, all groups.
INT_t	Australian cash rate target/interbank overnight cash rate (RBA, Statistical Table, F1.1).	Converted from monthly to quarterly using a 3-month average.
INF_t	Seasonally adjusted consumer price index; Trimmed mean; Quarterly change (in per cent) (RBA, Statistical Table, G1).	
COM_t	Australian index of commodity prices, all items, 2017/18 = 100, US$ (RBA, Statistical Table, I2).	Converted from monthly to quarterly using a 3-month average. Deflated by the US CPI for all Urban Consumers (FRED).
TOT_t	Seasonally adjusted Australian terms of trade index (ABS, Cat No. 5206.0 Table 1).	
TWI_t	Real Australian dollar trade-weighted exchange rate index, adjusted for relative consumer price levels, March 1995 = 100 (RBA, Statistical Table, F15).	
$UNCER_t$	Australian economic uncertainty index (Moore 2017)	Converted from monthly to quarterly using a 3-month average.

* The observations are collected in the second month of the collection period, compared to the third month as with all other quarterly data in this study. It is assumed that this month difference has no impact on the results and is treated if it was collected in the third month.