El Nino Southern Oscillation's Impact on the Australian Macroeconomy:

A structural VAR approach

By

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Table of Contents

1 Introduction

El Nino Southern Oscillation (ENSO) is the anomalous warming and cooling cycle of the western and eastern zones of the Pacific Ocean. El Nino Southern Oscillation is placed in the context of a structural vector autoregressive model to examine the impact that the medium term climatic phenomenon has on the Australian macroeconomy. A short-run structural vector auto regression is used to model the Australian business cycle because it makes it possible to impose contemporaneous and lagged restrictions. The model builds on the work by Dungey and Pagan (2000, 2009) and finds that the Southern Oscillation plays a relatively large role in Australian macroeconomic fluctuations with a weak la Nina event. El Nino Southern Oscillation has a statistically significant impact on Australian GDP as well as a large impact on inflation, the Australian Q-ratio, and real exports.

2 El Nino Southern Oscillation

El Nino Southern Oscillation is the anomalous warming and cooling cycle of the western and eastern zones of the Pacific Ocean (Figure 1). El Nino is a period of months during which the eastern Pacific Ocean warms and the western Pacific cools. La Nina is an opposite phase which sees the cooling in the eastern and warming in the western Pacific. Both el Nino and la Nina typically begin during November and December with some episodes lasting for a few months while others can remain in place for over a year. Even though the anomalous warming and cooling of the Pacific Ocean might amount to only a few degrees centigrade over the historical seasonal average, it can result in dramatic changes in local short term weather patterns and medium term seasonal climate all over the world.

The anomalous warming and cooling of the Pacific is caused by changes in trade wind patterns in the Pacific Ocean. An el Nino episode occurs when the Pacific Ocean trade winds slow down, or completely reverse, causing the air pressure over the eastern Pacific Ocean to decline (Philander, 1989). This decline in air pressure leads an expansion in warm water in the eastern Pacific's "Nino 3" region. In the western Pacific's "Nino 4" region, the trade wind slowdown increases air pressure which pushes out cold water. La Nina events occur when the trade winds strengthen and cold water expands in the eastern Pacific and warm water expands in the western Pacific. While there is ongoing debate with respect to the role human induced climate change plays in el Nino Southern Oscillation, in the short run it is impossible for economic activity to influence the month by month and year by year variation in sea surface temperature in the Pacific Ocean.

The Japanese Meteorological Agency's (JMA) criteria to define el Nino events defines el Nino periods which are consistent with the consensus of the el Nino Southern Oscillation research community (Trenberth, 1997). According to the JMA criteria, an el Nino event occurs if the 5 month running mean of the Sea Surface Temperature (SST) anomaly in the "Nino 3" region is +0.5 degrees for six or more consecutive months. For the purpose of el Nino Southern Oscillation, the Sea Surface Temperature is an anomaly index of the deviation from seasonal mean in surface temperature. The use of a five month moving average is imperative to smooth inter-seasonal temperature variation in the Pacific Ocean.

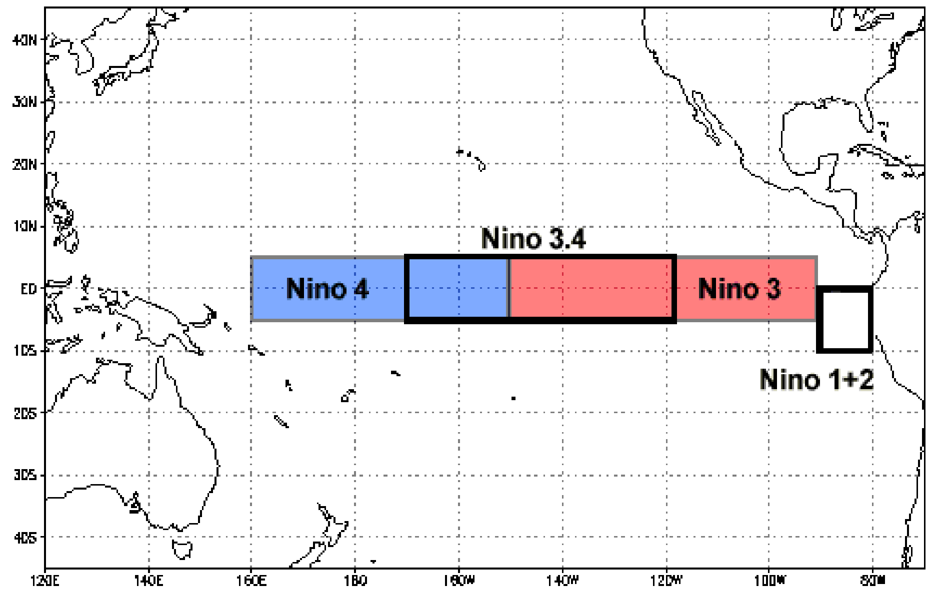


Figure 1. Source: National Oceanic and Atmospheric Administration.

For the purposes of this paper the use of the Sea Surface Temperature (SST) is not the ideal method for describing the el Nino Southern Oscillation. The SST index limits sea surface anomalies to relatively small regions of the Pacific Ocean. For example, Wang and Trenberth (1996) find that the current "Nino" regions specified in Figure 1 do not completely encompass all important regions of atmospheric-ocean interactions in the Oscillation. The Southern Oscillation Index (SOI) is a more appropriate ENSO measure because the index measures the atmospheric conditions which lead to the anomalous warming and cooling of el Nino and la Nina. The SOI is calculated as the difference between the atmospheric air pressures at Tahiti and Darwin. The monthly mean of the index is smoothed to ensure non-ENSO related fluctuations in atmospheric pressure are eliminated from the index. The SOI has a negative correlation with the Sea Surface Temperature Index. A sustained negative SOI value of -1.0 indicates an el Nino event- warmer water in the eastern Pacific and cooler water in the western Pacific. Conversely, a sustained positive value of 1.0 SOI value signifies a la Nina episode- cooler water in the eastern Pacific and warmer water in the western Pacific.

2.1 Climate Change

The influence of climate change on el Nino Southern Oscillation is ambiguous. One reason for the ambiguity is the difficulty global climate models have when trying to effectively model ENSO. Trenberth and Hoar (1997) focus on the Southern Oscillation Index and find there have been more el Nino events and fewer la Nina events since 1970. They note that this trend is not likely to be the result of natural variability in the occurrence of ENSO events but rather due to climatic reasons. Huang and Liu, in a similar study, use sea surface temperature trend data and present results similar to Trenberth and Hoar. There has been an overall warming trend in the eastern Pacific Ocean and cooling in the western Pacific Ocean. Huang and Liu note that climate change has lead to a weakening of the trade winds in the Pacific Ocean. The weakening of the trade winds is likely to have resulted in stronger and more frequent el Nino events and less frequent and weaker la Nina events. Despite this trend, it is not known whether the trade wind slowdown will continue.

Coral fossil evidence suggests that the ENSO cycle is independent of global climate conditions (Cobb et al., 2003). For example, the strongest el Nino episode estimated to have occurred over the past 1,500 years coincided with a period of low global mean temperature. Thus, even though some of the data suggests that climate change has increased the frequency and strength of el Nino events, it is not known whether this trend will continue due to the uncertainty of the internal ENSO system.

2.2 ENSO and Australia

El Nino Southern Oscillation influences eastern Australian precipitation and, consequently impacts stream flow (Piechota et al. 1998). Episodes of el Nino are associated with warmer and drier conditions while la Nina typically leads to cooler and wetter conditions in the eastern states, however, this causality is weaker for western Australia. In this region the inverse relationship between the southern oscillation index and rainfall is weaker. The variability of rainfall in areas that are affected by el Nino Southern Oscillation appears to be substantially higher than regions that are not affected by the cycle (Nicholls, 1987).

There is a stronger relationship linking droughts and el Nino than there is between floods and la Nina. Every major Australian drought since 1960 occurred during or following an el Nino episode. These droughts usually occur in the eastern, more populated, portion of the country where the majority of the Australian agricultural industry is located. Severe droughts are moderately correlated with el Nino strength, with the most destructive occurring during moderate to strong el Nino episodes. Conversely, not all severe floods that have strike Australia over the previous half of the century have been directly linked to la Nina events. For example, the 1993 flood of

Northeast Victoria occurred in the wake of an el Nino event (See Table 2 in the appendix). This variability in water supply is likely to have an impact on numerous industries, such as agriculture,

On average between 2005 and 2010 agriculture directly accounted for 3% of Australian GDP and indirectly accounted for as much as 12.1%. However, these numbers have been on a downward trend over the past five decades. In the 1950's agriculture was directly responsible for 15% of GDP (Marangos and Williams).

Although agriculture accounts for a relatively small portion of the Australian economy, it might be drastically affected by ENSO. Between 2000 and 2005, el Nino years, total irrigated land declined by 8% solely due to reduced water availability. The same time period also experienced a collapse of water intensive crop production due to the lack of water accessibility. This highlights how susceptible Australian agriculture is to fluctuations in water supply and thus el Nino Southern Oscillation.

El Nino Southern Oscillation also has a statistically significant relationship with Australian cyclones. The beginning of the Australian cyclone season, which runs from November through April, corresponds with the appearance of la Nina during the final few months of the calendar year. Australian tropical cyclone activity is concentrated along the North East and North West coasts.

Broadbridge and Hanstrum (1997) examine the cyclones that have made landfall on the western coast of Australian between 1961 and 1996. They find that the Southern Oscillation has a complex relationship with cyclones. More cyclones make a coastal impact during la Nina years when the Southern Oscillation Index is positive. However, the negative SOI of el Nino events is associated with more severe cyclone activity. On average, the western cyclone seasons of el Nino and la Nina years both result in similar levels of damage and coastal impact.

Nicholls (1979) finds that there is a statistically significant relationship between the Southern Oscillation Index and the severity of Australian cyclone activity. The higher levels of the SOI during la Nina holds for the Australian North east and North West coasts. The number of strong tropical cyclones, however, does not appear to be affected by la Nina.

3 Literature Review

Gruen and Shuetrim (1994) place el Nino and la Nina in a bivariate VAR model for the Australian macro economy which places an emphasis on global economic conditions and international trade. Their analysis finds a small but statistically significant relationship between the Southern el Nino and la Nina events and changes in real Australian output. Gruen and Shuetrim use dummy variables to signify el Nino and la Nina events. The use of dummy variables to signify el Nino southern oscillation events is not optimal because it has the effect of averaging out strong events with weak ones. This could potentially weaken the estimated impact of ENSO events.

Debelle and Stevens (1995) build on the work done by Gruen and Shuetrim, including the Southern Oscillation Index in their Australia macroeconomic model, which was constructed to analyze monetary policy. The Southern Oscillation Index is a continuous variable in their model, which avoids to the issues associated with the use of dummy variables to identify the appearance of an ENSO episode. Their empirical analysis again finds a small and statistically significant relationship between the SOI and Australian economic performance.

Brenner (2002) uses a VAR model to study the effect of el Nino Southern Oscillation on non-oil primary commodity prices as well as its effect on G-7 consumer price index inflation (CPI) and GDP growth. The SOI and Sea Surface temperature Index (SSI) are the el Nino indices used and they provide similar empirical results. Brenner finds ENSO has a statistically significant effect on non-oil primary commodity prices and, ENSO accounts for 10% of commodity price inflation over the mid to late ninety-nineties as well as 20% of world economic activity variation, and 10% of CPI movement. One issue with the data is that the G-7 data used in this study are aggregated which suggests it becomes more likely for potential ENSO effects to be canceled out among the various G-7 countries. This effect can potentially lead to statistically insignificant results.

In an attempt to avoid potential cancelling out effects, Laosuthi and Selover (2007) run numerous VARs of the SOI on individual country economic indicators. Their sample of countries places a greater emphasis on developing economies because it is suggested they are more susceptible to climatic fluctuations than developed countries. The results of this study suggest ENSO has little economic influence outside South Africa, Australia, India and possibly Malaysia. This is puzzling because the model specifications and sample are chosen to resolve the issue of using aggregated G-7 data, but the results show a weaker influence of el Nino and la Nina episodes. It is possible that ENSO's influence depends less on the stage of development of an economy and more on the influence it has on a given region's medium term weather.

The utilization of VARs in the analysis of small open economies may be insufficient for the identification of exogenous shocks because it cannot properly account for the exogeneity of external economic, and non-economic conditions. The use of a VAR would be reasonable if the country being modeled has a large, closed economy. Australia is a small open economy which means it has very little, if any, direct impact on global economic conditions. Thus, using a Structural Vector Auto Regression model by imposing constraints on the VAR model may be necessary to properly model and isolate the climate shock. Using a SVAR will ensure domestic economic variables have no contemporaneous or lagged causal effect on global economic and climatic variables.

Buckle et al. (2007) expand on Blanchard and Watson (1986) by constructing a structural vector auto regression model for New Zealand to identify the relative importance of international and domestic factors in the New Zealand business cycle. The model has four blocks: domestic, international, terms of trade, and climatic. The climatic block uses daily water balance to measure domestic climatic conditions. The SVAR model assumes New Zealand is a small open economy. Thus, domestic economic conditions do not have contemporaneous nor lagged impacts on external economic conditions. The domestic climatic conditions block has contemporaneous and lagged effects on total New Zealand GDP and export supply. Climatic shocks are treated as supply shocks. The empirical results suggest that New Zealand's economy is susceptible to climatic shocks. Unfavorable domestic climatic conditions are associated with below trend economic performance which typically lasts roughly two years. Interestingly, their findings suggest export volume initially increase with a negative shock. However, this positive impact does not last as export volume declines a few quarters after the initial shock.

4 Empirical Model

The Australian economy is both relatively small compared to the global economy and open so it is not reasonable to assume that its economic performance influences global economic conditions. Thus, a short-run structural vector auto regression is used to model the Australian business cycle because it makes it possible to impose contemporaneous and lagged restrictions. The theoretical, and empirical model, is a short run structural vector auto regression model based on Dungey and Pagan (2000) and Dungey and Pagan (2009). Both models have an IS-LM framework for their structural equations. The model is a short-run SVAR because el Nino Southern Oscillation is a medium term climatic phenomenon and it is not likely to impact long term growth paths.

The model uses a block exogeneity approach which places restrictions on contemporaneous and lagged relationships. The block exogeneity method aids in identifying reaction functions as well as permitting the inclusion of a large number of international variables which lead to a more accurate identification of contemporaneous and lagged interactions. The model follows Buckle et al. by organizing the equations into three different blocks: the international sector block, the domestic sector block, and the el Nino Southern Oscillation block.

Since Australia is a small, open economy there is no feedback from the domestic sector block to the international block. There is also no feedback between both the international sector block or the domestic sector block, and the el Nino Southern Oscillation block because the el Nino Southern Oscillation is unaffected by global business activities. None of the domestic sector variables appear in the international sector block as contemporaneous lagged relationships.

A case study of the historically large 1997-98 el Nino event finds that there was a $15 billion net benefit due to el Nino (Changnon, 1999). This amounts to 0.2 percent of American GDP in 1998. Thus, the el Nino Southern Oscillation only has a contemporaneous and lagged relationship with the domestic sector block, but contemporaneous and lagged restrictions are imposed to eliminate any unnecessary feedback.

Table one summarizes the structure of the SVAR model estimated. The rows represent the dependent variables while the columns represent the independent variables in the structural equations. The shaded area represents a contemporaneous relationship. A single asterisk indicates that a lagged structure covering three periods is present in the equation. A double asterisk indicates that only the last two lags are included in the equation. A blank cell in the table indicates that the variable is excluded from the equation entirely.

	USGDP	TOT	RUS	USQ	EXPT	AUSQ	GNE	GDP	INF	CASH	RTWI	SOI
USGDP	*		*									
TOT	*	*	*									
RUS	*		*									
USQ	*		*	*								
EXPT	*	*			*							*
AUSQ	*	*	*	*		*	*	*	*	*	*	
GNE		*				*	*	*	*	**	*	
GDP	*	*			*	*	*	*	*	**	*	*
INF		*					*		*		*	*
CASH							*		*	*	*	
RTWI	*	*	*	*		*	*	*	*	*	*	
SOI												*

Table 1. Rows represent dependent variables and columns represent independent variables. Shaded regions represent contemporaneous relationships.
* indicates a lagged relationship.
** indicates only lags after the first lagged relationship.

5 Empirics

Previous papers that construct structural VARs for small open economies have used three lags. This paper will follow this example by using a lag of three quarters.

Logarithms are taken of all of the variables in the model except the real interest rate, the cash rate and the quarterly inflation rate. The data are of quarterly frequency and the sample period of the data used to estimate the model is from the third quarter 1979 to the final quarter of 2006. The sample begins in 1979 because Australia moved to a more flexible exchange rate regime in 1977 (Dungey and Pagan, 2000). The sample's start date relative to the switch in exchange rate regimes is delayed by two years to allow for adjustments due to the change in exchange rate regime.

All variables used to estimate the model are defined as deviations from a steady state trend. Dungey and Pagan (2000) use a linear deterministic trend to de-trend their model's variables. An issue with the use of a linear deterministic trend is that it is possible for there to be sustained and large deviations from trend. This is the case for Australia between the late eighties and the late nineties where Australian economic performance was below trend levels (Figure 2 in the appendix). Therefore, a linear deterministic trend may not be appropriate for de-trending Australian data. Every variable besides the quarterly inflation rate and the Southern Oscillation Index are de-trended using the Hodrick-Prescott filter. Departures from the trend growth rate are regarded as transient following Bernanke and Blinder (1992) and Sims (1980). This suggests that, while shocks might have persistent effects in the model, they do not have permanent ones (Dungey and Pagan, 2000).

Dickey Fuller tests are run on the Southern Oscillation Index to test for stationary. The Dickey Fuller test's statistic of -4.874 suggests that the SOI follows a stationary path. Thus it is not necessary to de-trend the SOI with the HP-filter.

Even though they are the strongest continuous indicators of el Nino Southern Oscillation, the Southern Oscillation Index and the Sea Surface Temperature Index are noisy indicators which provide a relatively poor signal for the occurrence of el Nino and la Nina events. The SOI provides a poor signal because much of its movement is similar to white noise and failure to properly smooth the index may result in large estimated standard errors (Trenberth, 1984). Smoothing the SOI in accordance with Trenberth 1984 drastically increases the strength of the signal. However, the SOI remains quite noisy as not all spikes of the index is associated with episodes of el Nino and la Nina. For example, according to the JMA, there was no la Nina event in 1979 (table 2 in the appendix) even though the SOI spiked up to a value of 4 for one month. The issue arises because ENSO events occur following a sustained high, or low, value of the SOI.

(i) International Sector Block

The international sector block uses the United States as a proxy for the international economy. Iinternational output (USGDP) is a function of the international real interest rate (RUS). The real interest rate does not have a contemporaneous relationship with U.S GDP. Rather, the international interest rate has a lagged influence on U.S. output. The U.S. output equation is rather simple because the purpose of the international sector block is to disconnect the export, terms of trade, and asset market shocks from the international output growth rate (Dungey and Pagan, 2002).

The terms of trade (TOT) is a function of U.S. output and the international real interest rate. The link with international output involves a contemporaneous and lagged relationship. The terms of trade only reacts with the real international interest rate through lags and not through a contemporaneous feedback.

The real international interest rate is a function international output. This relationship is both contemporaneous and involves lags. This equation is mis-specified if the United States Federal Reserve does not adjust the real interest rate according to only the output gap (Dungey and Pagan, 2000). A properly specified equation would likely include the U.S. inflation rate and a measure of international prices (Sims, 1992).

However, it is possible that de-trending the real international interest rate will eliminate the problem of mis-specification due to the omitted variables. The possible mis-specification is unlikely to be a major concern because the real international interest rate is included in the model to separate international output shocks from equity shocks. The de-trending might eliminate the mis-specification because the de-trending possibly compensates for the omitted variables (Dungey).

The final variable included in the international sector block is the U.S. Q ratio. The Q ratio is Tobin's q and it is the market value of an asset divided by the replacement value of the asset. It is obtained by dividing the quarterly average of Dow Jones Industrial average by the U.S. CPI. The US Q statistic is a function of both U.S. output and the international real interest rate. The relationship between both of these variables is contemporaneous and includes lags. Australia's economy is closely integrated into the global market structure (Pukthuanthong and Rool, 2009). The inclusion of the United States Q statistic in both the international and domestic sector blocks is intended to reflect Australia's market integration with the world market. This corresponds with Buckle et al. (2007) who included the United States Q statistic to incorporate New Zealand's growing integration into the global financial market due to the deregulation that took place during the early eighties.

Real exports are a contemporaneous and lagged function of the terms of trade and U.S. output, as well as the el Nino Southern Oscillation. The inclusion of ENSO in the real export equation follows from Buckle et al. Because periods of el Nino are associated with drought, this ought to act as a negative exogenous shock on the supply of exports due to the lack of water supply for industry and agriculture. The opposite is true for la Nina.

The use of hydroelectricity for power generation in Australia has fluctuated greatly during the previous three decades (Harries et al., 2011). Hydroelectric power plants are located almost exclusively in the southeastern states which are highly exposed to effects of the Southern Oscillation. Hydroelectricity generates most of the power consumed in Tasmania and it is a major contributor to power generation in the Australian Capital Territory, as well as New South Wales. However, hydroelectricity generated only 4.6% of total Australian electricity in 2008. Despite its small recent contribution to the overall power requirements of Australia, during the eighties hydro was generating of over 15% of Australian electricity. If el Nino Southern Oscillation causes water levels at hydro facilities to fluctuate, it may well result in a fluctuation in power supplies and thus act as a negative supply shock.

(ii) Domestic Sector Block

The domestic sector block includes seven equations which are determined by domestic, international and, el Nino Southern Oscillation conditions. The climatic and international variables provide a source of exogenous shocks to the domestic sector. The domestic sector variables are a source of policy and non-policy shocks to the domestic sector block.

There are two categories of domestic sector variables. Domestic output is the first category and includes gross national expenditure (GNE) and real gross domestic product (GDP). The real returns to wealth make up the second category and they include the Australian Q ratio (QAUS), the cash rate (CASH), the quarterly inflation rate (INF) and the real trade weighted index of the Australian dollar (RTWI).

The balance of trade is implicitly included in any equation that includes gross national expenditure and gross domestic product. This is the case because:

$$\log(GNE) - \log(GDP) = \log(1 + \frac{BT}{GDP}) \cong \frac{BT}{GDP}$$

Thus, equations that include both log(GNE) and log(GDP) are equivalent to an equation that includes the log(GDP) and BT/GDP (Dungey and Pagan, 2000).

Gross national expenditure has a contemporaneous and lagged relationship with the terms of trade and the Australian Q statistic. Australian GDP, the quarterly inflation rate, the cash rate, and the real trade weighted index of the Australian dollar all have a lagged effect on gross national expenditure but no contemporaneous effect. The cash rate's lagged effect begins only after the first lag (Gruen and Shuetrim, 1994). Shocks to the gross national expenditure equation can be interpreted as domestic aggregate real demand shocks. The terms of trade is the only international variable that has a direct influence on GNE.

Real Australian GDP is a contemporaneous function of international output, the terms of trade, real exports, the Australian Q statistic, gross national expenditure and el Nino Southern Oscillation. Australian GDP also has a lagged relationship with the quarterly inflation rate, the cash rate and the real trade weighted index of the Australian dollar. The lagged relationship with the cash rate does not include the first lags. Gross national expenditure and exports provide the source for domestic demand shocks.

El Nino Southern Oscillation is the source of exogenous supply shocks. This follows from Buckle et al. where the soil moisture condition climate variable act as exogenous supply shocks on New Zealand's real GDP. A priori the impact of ENSO on Australian real GDP might be ambiguous. Episodes of la Nina are associated with more cyclone activity on the western coast of Australia. Conversely, el Nino events are highly correlated with droughts throughout Australia. Due to its constrained water supply, Australia is expected to be on the portion of the output curve with a positive slope. An el Nino event will lower water supply and decrease output. For example, the el Nino of 2002-03, and its accompanying drought, lowered all crop yields by at least 60% (Horridge et al., 2005)

Inflation has a contemporaneous relationship with the terms of trade, which acts as a proxy for international prices, and gross national expenditure, which captures the output gap. Inflation is also a lagged function of the real trade weighted index of the Australian dollar. The inflation equation is a combination of the Phillips curve and markup of prices over costs. El Nino Southern Oscillation is also included in the inflation equation with a lagged effect (Buckle et al.). This is intended to reflect ENSO's influence on output supply and thus the changes in the price level.

The real trade weighted index of the Australian dollar equation allows for the possibility of Uncovered Interest Rate Parity (UIP). As such, the real trade weighted index of the Australian dollar is a function of all of the variables, domestic and international, included in the model except the real export supply and the Southern Oscillation index.

The cash rate equation reflects how the Australian Central Bank responds to lagged and contemporaneous relationships in the economy. The equation suggests that the various variables indirectly influence monetary policy. The cash rate has both a contemporaneous and lagged relationship with the GNE and the inflation rate, as well as a lagged relationship with the real trade weighted index of the Australian dollar.

The Australian Q ratio is a lagged function of all of the variables in the model of the domestic and international variables in the model except the SOI and Australian real exports as well as a contemporaneous relationship with U.S. output, the terms of trade, the U.S. real interest rate, and the U.S. Q ratio. The Australian Q is calculated by dividing the quarterly average of the All Ordinaries Index by the Implicit Price Deflator for Plant and Equipment

(iii) El Nino Southern Oscillation Block

The Southern Oscillation Index is used as a proxy for el Nino Southern Oscillation. The SOI is not a function of either the domestic or international variables in the model because it is un-likely that domestic and international economic conditions have an impact on Pacific trade wind patterns, and therefore on medium term climatic conditions in the Pacific Ocean.

6 Data Description

The Southern Oscillation Index is from the Australian Bureau of Meteorology. The quarterly SOI value is the average of the index over the three months of a given quarter. The data for all other variables is from Dungey and Pagan 2009.

Figure 3 in the appendix charts the smoothed Southern Oscillation Index between the third quarter of 1950 and the third quarter of 2010. The SOI exhibits a fluctuation that is similar to a business cycle with positive peaks (la Nina) followed by negative valleys (el Nino). The most intense el Nino episode during this time period occurred during late 1982 and mid 1983 which corresponds with a sharp recession in Australia (Figure 4 in the appendix). The mid to early seventies experienced two of the strongest la Nina events. The el Nino of 1986 was the longest on record and the la Nina's of the early 1970s and 1990's were the longest of the dataset. The deepest Australian recessions occurred during late 1961, late 1982 to early 1983 and, late 1990 to late 1991. The recession of the early eighties coincided with a global recession (Gruen and Sayegh, 2005).

This Southern Oscillation Index is a proxy used to capture the overall strength of the ENSO affecting Australia because stronger events are correlated with larger magnitudes of the index. However, it is not always the case that strong ENSO events lead to a large influence on Australian weather patterns. Some strong el Nino episodes, for example, hardly impact Australian weather and short term climatic conditions. Figure 2 below contains rainfall in millimeters (top line) and the SOI over September and

February of a given year (lower line) between 1900 and 2010. For much of the series there is a positive correlation between rainfall and the SOI. This positive relationship does not hold during the late eighties and the late nineteen thirties.

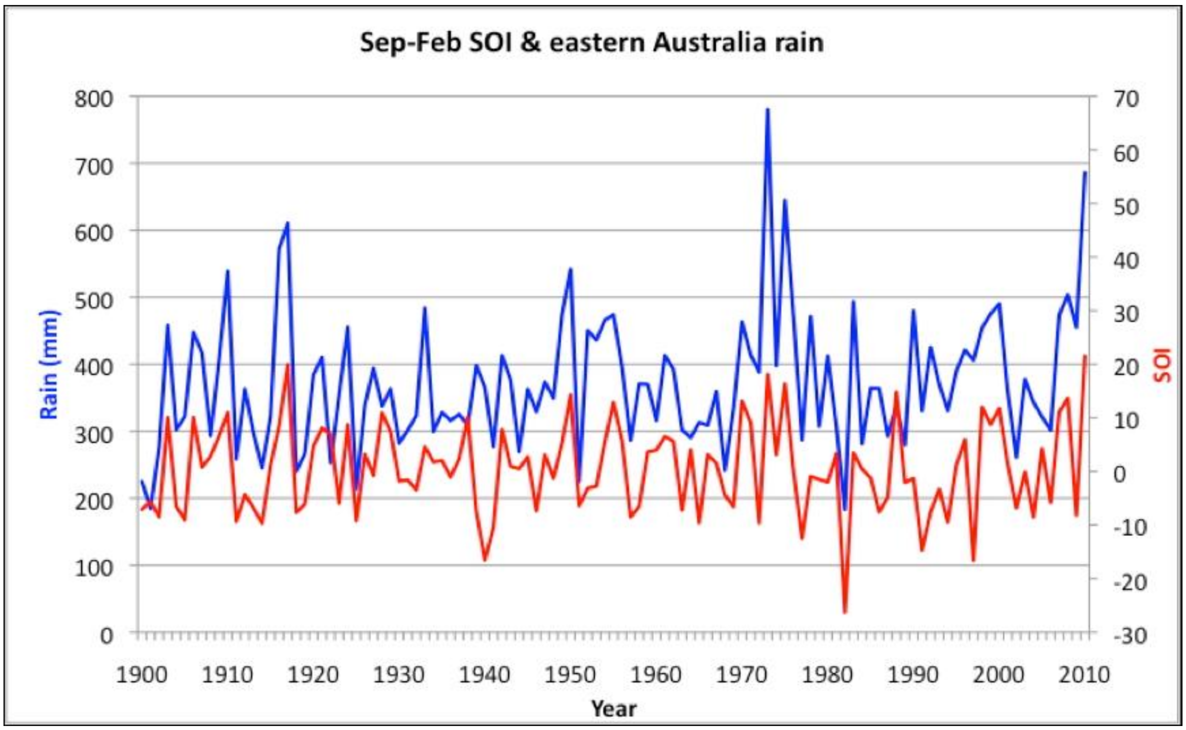
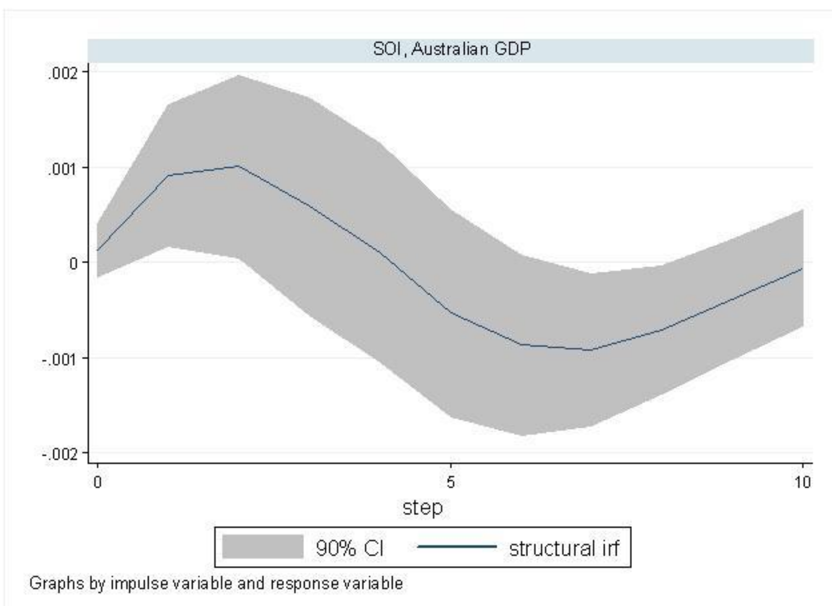


Figure 2. The SOI and eastern Australian rainfall. Source: Australian Bureau of meteorology.

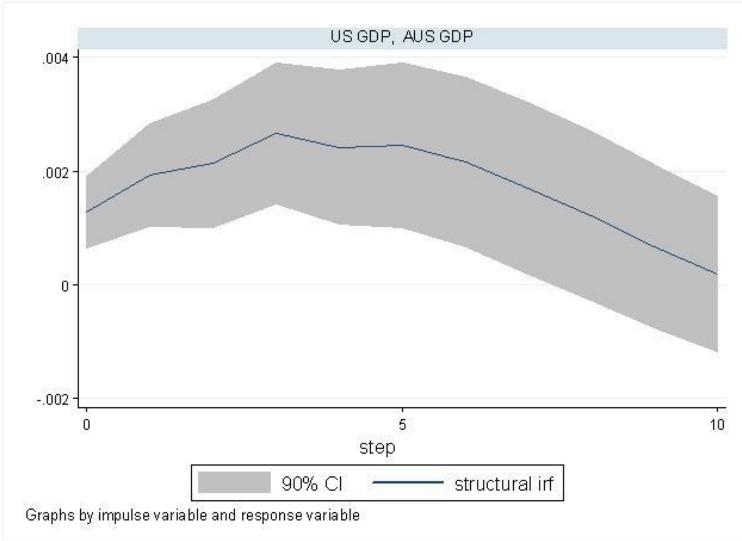
A structural vector auto regression is a vector auto regression with restrictions imposed on contemporaneous relationships as well as the error terms. The variables used in the SVAR must be stationary. All of the variables used in the regression are stationary. The error terms are assumed to be homoskedastic and un-correlated amongst the different equations.

7 Results

The structural impulse response functions (SIRF) with 90% confidence intervals are reported below. Only the SIRF for the Southern Oscillation Index on Australian GDP, inflation, exports, Q-statistic, and U.S. output on Australian GDP are reported. Most variables in the model are the deviation from the logarithm trend of the original variable. For these variables, shocks are defined as a percentage increase, or decrease, above the trend. The shocks are measured as a one unit shock to the endogenous variable. For the Southern Oscillation Index the value of the unit shock is easy to interpret because a one unit shock to the SOI is a rather weak la Nina event. All impulse response functions report the response to a shock over an interval of 10 quarters.

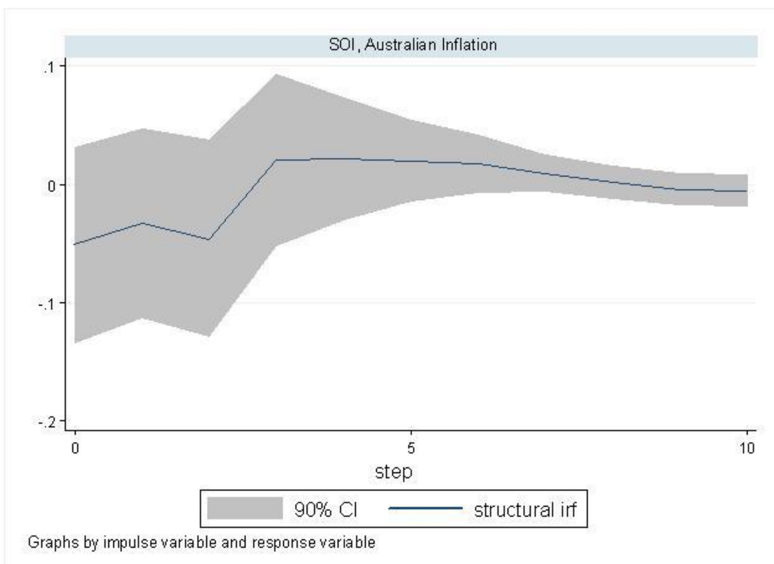


Graph 1



Graph 2

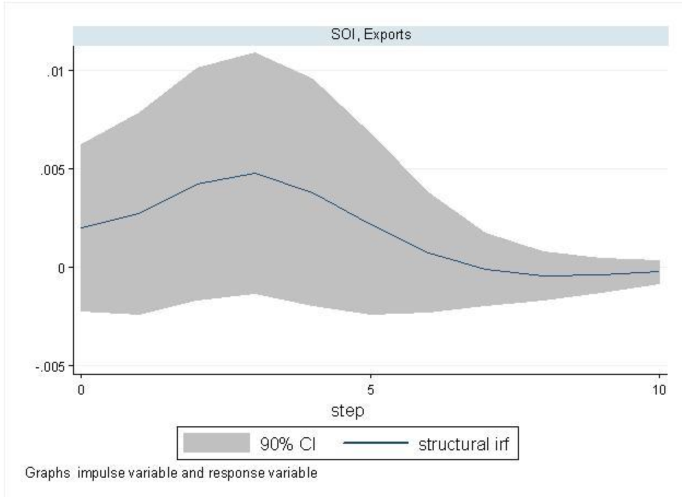
Graphs one and two above report Australian GDP's response to a shock to the Southern Oscillation Index, and American Output respectively. The impulse response functions suggest el Nino Southern Oscillation plays an important role in the Australian business cycle. The impact of a SOI shock on Australian output is surprisingly large, especially when compared to an American GDP shock since global, and American, economic conditions have a large influence on the Australian business cycle (Roll and Pukthuanthong). At its peak, Australian GDP rises by 0.01 percent above the long run growth path two quarters after a la Nina event. This is less than half the impact a U.S GDP shock has to the Australian economy. The relative magnitude of the climate U.S. output shock is similar to that found by Buckle at al. A la Nina event appears to act as a positive shock to the Australian economy which is expected. Graph one suggests that an initial appearance of a relatively weak la Nina event will lead to a modest increase in Australian output above trend levels. This increase is short lived as four quarters after the appearance of la Nina Australian out dips below trend to roughly -0.01 percent below the trend growth rate and appears to eliminate any potential initial gains cause by the favorable climatic shock. The U.S. output shock does impact declines over time and after four quarters appears to return to 0. These graphs highlight the susceptibility even industrialized economies have to fluctuations in climatic conditions. The SOI shock is statistically significantly positive for the second quarter following the shock and it is statistically significantly negative for the seventh quarter.



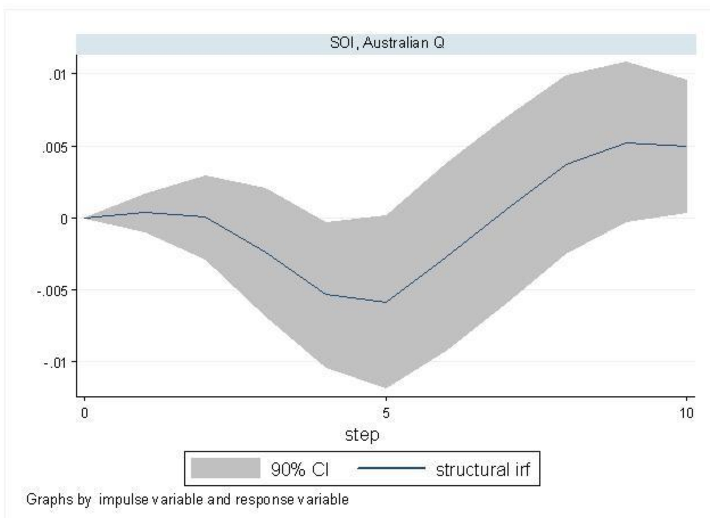
Graph 3

Graph three above plots the impact a la Nina event has on the quarterly inflation rate. It appears a positive SOI shock has a very large impact on the inflation rate with the inflation rate initially declining by 0.5 percent. Buckle (2009) notes the New Zealand export price level experiences a similar response to a positive climatic shock. The graph suggests that a la Nina event will lead to an initial drop in the inflation rate followed by a rise in the inflation rate over time. However, none of the impact on the inflation rate is statistically significant at the 10% level.

Events of el Nino and la Nina are not very predictable (Fedorov at al., 2002). The Southern Oscillation Index also operates with a slight delay of three to four months in measuring anomalous sea surface temperate in the Pacific. Thus, when the la Nina event first appears, and people gain information about it its existence and size, they might adjust their economic activity and expectations. This might prove to be more important for the agricultural sector. The initial decline in the inflation rate following a positive climatic shock could be due to farmers over-planting various crops in an attempt of taking advantage of favorable weather conditions or selling off inventory expecting an increase in future output. Such a narrative might also explain the initial jump followed by gradual decline in exports following a positive climatic shock (graph 4). Exports initially increase by 0.0025 percent and then steadily rise to 0.005 percent after three quarters before declining to back zero. This is similar to Buckle et al.'s results and explanations for adverse climatic conditions causing a decline in prices due to a culling of livestock in anticipation of poor future local weather conditions. The response to the la Nina event, however, is never statistically different that zero.



Graph 4



Graph 5

The one unit increase in the Southern Oscllaiton Index is associated with an eventual decline in the Australian Q ratio is depicted in Graph 5. The Q-ratio appears to respond to a la Nina event after a few quarters after which it declines until the fifth quarter. This decline is followed by a rise in the ratio. This could be due to the stock market responding to the decline in the inflation rate. The SOI's impact on the Q-ratio is statistically significant at the 10% level for the fourth quarter only. One possible exmplanation for a lack of statistical significance could be the noise included in the Southern Oscillation Index and the imperfect link between the SOI and Australian weather patterns.

8 Conclusion

A structural vector auto regression was run to quantify the impact el Nino Southern Oscillation has on the Australian macroeconomy. Empirical results suggest that the Southern Oscillation has a statistically significant and relatively large impact on the Australian economy. A minor la Nina event can result in a 0.05% increase in Australian GDP above trend growth rates. This is half the size of the impact that an increase in American output has on the Australian economy. ENSO also appears to influence real exports, inflation and the Q-ratio.

However, few of the results are statistically significant at the 10% level. One reason for this could be a result of El Nino Southern Oscillation's complicated relationship with Australian weather patterns. Further opportunities for research should attempt to eplain this complicated relationship by attempting to account for a non-linear relationship between ENSO and the Australian economy.

9 Appendix

Data Sources:
The Southern Oscillation Index is from the Australian Bureau of Meteorology
The Australian and International macroeconomic variables are from Dungey and Pagan (2000 and 2009) accessed from: http://www.dungey.bigpondhosting.com/mardihp.php

El Nino events	**La Nina events**
1951Q3-1952Q2	1950Q1-1951Q1
1957Q2-1958Q2	1954Q2-1956Q4
1963Q2-1964Q1	1962Q4-1963Q1
1968Q4-1969Q2	1964Q3-1965Q1
1969Q1-1970Q1	1967Q4-1968Q1
1972Q2-1973Q1	1970Q2-1971Q4
1976Q4-1977Q1	1973Q2-1974Q2
1977Q4-1978Q1	1974Q4-1875Q3
1982Q2-1983Q2	1975Q2-1976Q2
1986Q3-1988Q1	1984Q4-1985Q3
1991Q2-1992Q1	1988Q2-1989Q2
1994Q2-1995Q1	1995Q4-1996Q1
1997Q2-1998Q2	1998Q3-2000Q3
2002Q2-2003Q1	2000Q4-2001Q1
2006Q3-2006Q4	2007Q1-2008Q2
2009Q3-2010Q1	

Table 2. Source: Japanese Meteorology Agency

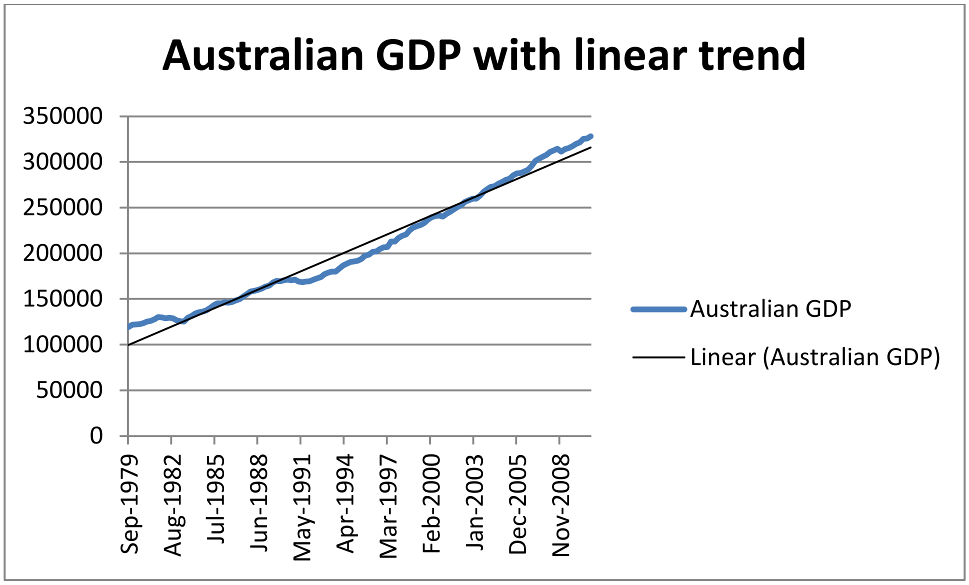


Figure 3

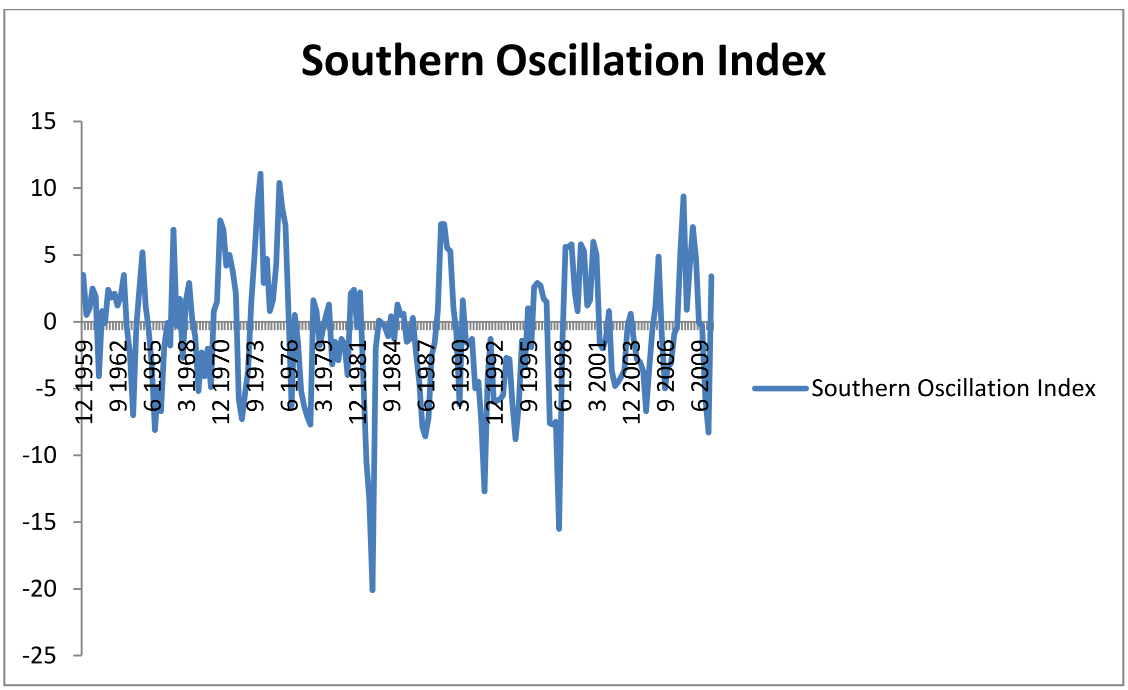


Figure 4

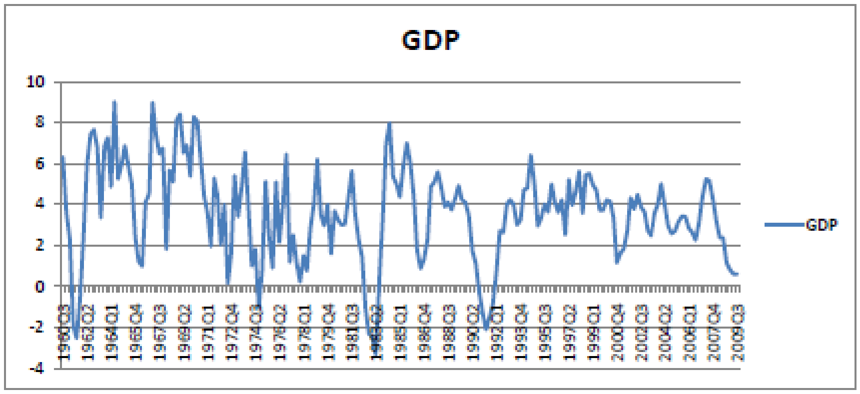

GDP
10
8
6
4
2
0
-2
-4
1960Q3
1962Q2
1964Q1
1965Q4
1967Q3
1969Q2
1971Q1
1972Q4
1974Q3
1976Q2
1978Q1
1979Q4
1981Q3
1985Q1
1986Q4
1988Q3
1990Q2
1992Q1
1993Q4
1995Q3
1997Q2
1999Q1
2000Q4
2002Q3
2004Q2
2006Q1
2007Q4
2009Q3
GDP

Figure 5

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