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Oil Crisis, Market Reforms and Economic Growth: Evidence from Australia, 1970-2010

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Since the imports of crude oil and petroleum products play a vital role in the domestic oil market, Australian economy is potentially vulnerable to world oil crisis. This paper investigates the impacts of oil price shocks upon the Australian GDP growth from 1970 to 2010. Hypotheses concerning whether the immunity of Australian economy against oil crisis is affected after the deregulation of crude oil market since 1980 and whether endogenous oil price shocks accounts for more variations in GDP growth than exogenous oil price shocks are tested. The methodologies are two-fold. One is a theoretic model; the other involves structural co-integrated vector auto-regression, impulse response functions and error variance decomposition based on quarterly data. For the short run dynamics, oil price is integrated into the model using both linear and non-linear forms, oil price shocks are categorized into exogenous supply shocks and endogenous shocks caused by macroeconomic variables; the conclusions are that inflated oil prices exert mainly non-linear negative impacts upon GDP growth, exogenous shocks induce a significant amount of endogenous shocks through labor price, CPI, interest rate and exchange rate. For the long run equilibrium, non-linear form of shocks upon GDP growth decays more slowly than linear-form of shocks and the impacts of endogenous shocks last longer than that of exogenous shocks. Finally, oil market policies are evaluated and proposed.

1. Introduction

The world economy evolves with increasing uncertainties. A significant amount of these uncertainties originate from the fluctuations in world oil prices. From the worldwide oil crisis initiated by the oil embargo of OAPEC countries in the 1970s through the oil price shock and the following recession catalyzed by the Gulf War in the 1990s to the global energy crisis caused by continuing global petroleum demand increases, production stagnation and depreciation of the U.S. dollar in the 2000s; history has taught us about the oil crisis' devastating economic outcomes and the importance of oil crisis management. Australia, as an integrated part of world economy, has undoubtedly been affected by the wide-spread energy crisis. The impacts can be evidenced by the following facts: oil and petrol price spikes during the 1970s when Australia's oil price had reached parity with that of other countries; excess-demand-oriented crude oil price rises and the associated inflation during the early 1990s when Australia had deregulated its crude oil market; rapid decline in oil self-sufficiency and increased dependence on foreign oil production during the 2000s when Australia experienced deregulation in petroleum product market and conducted energy reforms to release the pressure of reliance on oil through expanding production of natural gas, electric power and other renewable energy. Hence, the reality has posed the challenge of identifying the causes of potential oil crisis, evaluating economic impacts of current oil market reforms and enhancing Australian economy's immunity against oil crisis.

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Previous researchers have explored this challenge from different perspectives. However, very few of them analyze the impacts of oil price shocks upon economic growth from the prospective of the nature of shocks in terms of endogenous / exogenous oil price shocks and the functional forms to incorporate oil price shocks into production. The paper is organized as the following: The first part reviews literature in oil crisis history and modeling; the second and the third parts involve theoretic modeling and empirical analysis; and the final part concludes the main findings.

2. Literature Review

The causes of global oil crisis are heatedly discussed among scholars. Akins (1973) attributed the causes to the production loss of oil-exporting countries, panic among oil consumers and the threat to use oil as a political weapon; Belk, Painter and Semenik (1981) summarized the reasons as the mismanagement of fuel policies for large oil-importing countries, the artificial oil shortage created by some companies, the exhaustion of finite energy resources and the actions of oil producing and exporting countries; Han and Wang (1998) emphasized the impacts of timely-released oil price information and the associated political costs; Hamilton (2009) highlighted the effects of physical disruption of oil supply and strong oil demand confronting stagnating world production.

The consequences of Australian crude oil and petroleum markets' deregulation have been evaluated widely by researchers. Nicholls (1989) analysed both the positive and negative effects: oil market deregulation led to equal competitive market structure and would potentially lower oil prices, however, it would also induce efficiency loss in smaller suppliers' operation. Hence, he recommended self-regulation rather than government regulation. Thampapillai and Kolednik (1990) indicated that crude oil market deregulation enabled domestic oil consumers could shift purchases to imported crude oil when world oil prices fell and improved domestic oil market's efficiency. Roarty and Barber (2004) stated that the Australian crude oil pricing mechanism has transformed from the joint determination of import parity component, assessed local component and state subsidies to competitive determination in conjunction with world oil market, which contribute to the fluctuation of Australian economy; he also found out that deregulation of the refined petroleum products market has led to promotion of market transparency and enhancement of competitiveness. Hay (2009) elucidated that oil market deregulation not only minimized supply disruption through supply diversification and reduced individual suppliers' ability to manipulate prices, but also deliver secure supply as well as prosperity through oil inter-dependence of trading nations.

The oil crisis prevention, management and resolution have been debated comprehensively among academics. Blair (1976) pointed out the need to develop deposits of oil shale and rapidly expand new technologies as alternatives to petroleum; he also argued that the formidable power in oil industry should be either broken up or effectively regulated in the public interest. Pratt (1980) suggested exploitation of a broader range of energy sources such as natural gas, electric power and other renewable resources to alleviate the dependence on oil; he also advocated efficient energy use and technology development to decrease oil usage in production. Rowen and Weyant (1981) declared two oil crisis damage control measures in terms of the strategic petroleum reserve on the supply side and emergency tariffs on the demand side. Romm and Curtis (1996) considered the application of energy-saving technology

as the most cost-effective solution; they also raised the importance of grasping the cyclical and trendy patterns of oil prices through experiences. Emerson (1997) contended improved technology to increase oil productivity in non-OPEC countries, regulatory reforms in oil markets to promote effective pricing and innovative financing to hedge oil price risk. Kerr (1998) proposed that oil price stability pivoted on the interplay of geology and technology, specifically, geologists should undertake the task of predicting the oil reserves and consumption speed within the country to balance oil supply and demand, technologists should set about the work of enhancing existing oil fields' production capacity, identifying and retrieving new energy resources to shed light on the sustainability of domestic oil supply. Bohemen (2009) called for the establishment of emergency response system which consisted of continuous assessment of oil market, rapid decision making, flexibility in response measures and communication with OPEC countries.

However, previous academics used to investigate the impacts of oil price shocks upon the economy under the assumption of either endogenous or exogenous oil price shocks, and rarely analyze both endogenous and exogenous oil price shocks under the same framework of oil price modeling. Besides, previous researchers used to presume the functional forms to incorporate oil price shocks into the model without taking into account of the impacts of shocks' different specifications upon the dynamics of the model.

Hence, this paper initially provide generalized methodologies to separate endogenous / exogenous shocks in the model and test the impacts of different oil specifications upon oil shock modeling; then analyze the impacts of historical oil price shocks and oil market reforms upon Australian GDP growth through a theoretic model and empirical analysis; finally, the conclusions are drawn and the policy suggestions are provided.

3. Theoretic Modeling

3.1. Oil Price Shocks' Definition and Specification in the Model

An exogenous oil price shock is defined as an episode of more than or equal to ten percent cumulative positive change in oil price over consecutive four quarters according to Blanchard and Gali (2007). Exogenous oil price shocks originate from world oil market (e.g. global oil supply crisis) according to Killian (2009); endogenous oil price shocks stem from endogenous monetary responses (e.g. central bank changes inflation target and interest rate structure and labor price changes due to global oil price shocks) in accordance with Ratti and Hasan (2011). This paper extends the definition by categorizing and separating the shocks into exogenous and endogenous episodes through granger causality test.

Both linear and non-linear specifications are applied. Three non-linear forms are drawn from literature: I. Scaled specification (Lee, Ni and Ratti (1995)) in terms of standardizing oil price by its volatility; II. Net specification (Hamilton (1996)) in terms of specifying oil price as the difference between current quarter price and the maximum price in the last four quarters; III. Asymmetric specification (Jiménez-Rodríguez and Sánchez (2004)) in terms of modeling the increases and decreases in oil prices asymmetrically.

Negative Oil Price Variation $\Delta\log(P_{ot})^{-} = \begin{cases} \Delta P_{ot} & \text{if } \Delta P_{ot} < 0 \\ 0 & \text{if } \Delta P_{ot} \geq 0 \end{cases}$

Positive Oil Price Variation $\Delta\log(P_{ot})^{+} = \begin{cases} \Delta P_{ot} & \text{if } \Delta P_{ot} > 0 \\ 0 & \text{if } \Delta P_{ot} \leq 0 \end{cases}$

Where $\Delta\log(P_{ot})^{-}$ and $\Delta\log(P_{ot})^{+}$ are a decrease and an increase in log (oil price) respectively.

3.2. Baseline Model Selection and Justification

Modeling oil price shocks have long been the subject of extensive debate and research. There are two main methodologies in terms of Dynamic Stochastic General Equilibrium (DSGE) models and variations of Vector Auto-regression models. The DSGE methodology models oil price shocks as determined by the supply and demand markets endogenously, while the Vector Auto-regression models simulate both exogenous and endogenous oil price shocks. This paper aims to identify both exogenous and endogenous transmission mechanism of global oil price shocks upon Australian Gross Domestic Product. Structural Co-integrated Vector Auto-Regression model is chosen because it captures structural responses to oil price shocks both directly and indirectly.

Structural Vector Auto-regressive Model: $X_t = \sum_{i=1}^{p} \beta_i \cdot X_{t-i} + \Psi T_t + \varepsilon_t$ (1)

Vector Error Correction Form: $\Delta X_t = \phi X_{t-1} + \sum_{i=1}^{p} \gamma_i \cdot \Delta X_{t-i} + \Psi T_t + \varepsilon_t$ (2)

Where X_t=(log(Australian GDP), Australian Consumer Price Index, log(Australian Labor Price Index), RBA Interbank Cash Rate, 10-Year Australian Government Bond Interest Rate, Australia-U.S. Trade-Weighted Exchange Rate Index, log(International Oil Price), log(Australian Oil Price))' is a 8×1 vector of variables; $T = (T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8)'$ is a 8×1 vector of deterministic terms such as linear trends, constants and dummies; ϕ is the auto-regressive coefficient and $\beta_i = (\beta_{i1}, \beta_{i2}, \beta_{i3} \cdots \beta_{ip})$ is a vector of auto-regressive parameters, i=1, 2 ⋯ 8, $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, \varepsilon_{4t}, \varepsilon_{5t}, \varepsilon_{6t}, \varepsilon_{7t}, \varepsilon_{8t})'$ is the white noise process whose components are independent with zero mean and variance Ω.

The baseline VAR models employ real variables and indices. Multivariate specification allows oil price shocks to generate macroeconomic impacts not only directly but also indirectly though other contemporaneous variables in VAR.

According to Davidson (2008), crude oil price is the fundamental of oil market and is affected less by speculation compared to other oil derivatives, hence, the VAR model which simulates crude oil price shock is formulated. The model incorporates Australian Real GDP, Australian Trade-Weighted Exchange Rate Index, International Crude Oil Price, Australian Crude Oil Price, Australian Labor Price Index, Australian Consumer Price Index, RBA Interbank Cash Rate and 10-year Australian Government Bond Interest Rate. The crude oil price shock impacts upon Australian GDP not only directly through international and domestic crude oil prices, but also through Australian Real Trade-Weighted Exchange Rate Index, Australian Wage Price Index, Australian Consumer Price Index, RBA Interbank Cash Rate and 10-year Australian Government

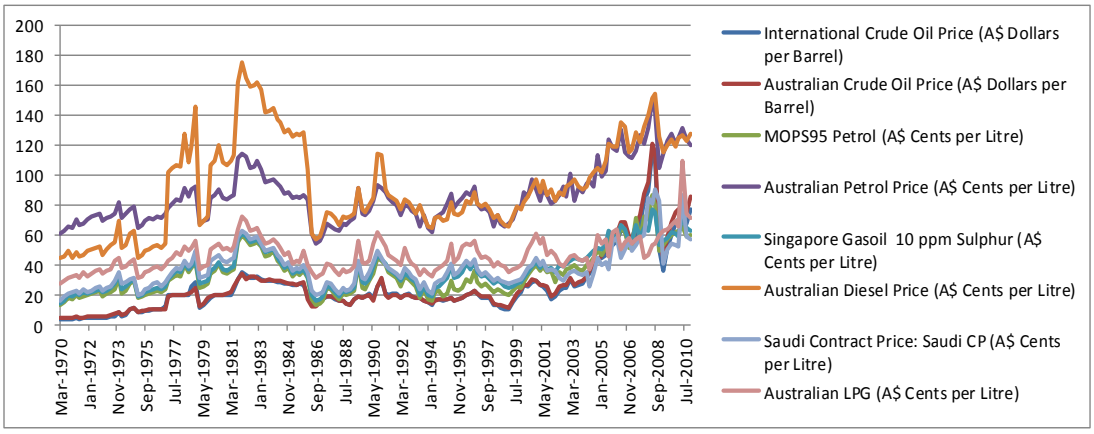
Bond Interest Rate since crude oil price shocks induce economic agents to change expectations and policies. Specifically, monetary policies changes due to inflation/deflation pressures caused by crude oil price shocks are reflected through RBA Interbank Cash Rate and 10-year Australian Government Bond Interest Rate; Labor market changes due to aggregate labor demand/supply changes caused by oil production shocks are represented by Australian Wage Price Index; foreign exchange market changes due to international oil transactions are captured by Australian Real Trade-Weighted Exchange Rate Index.

4. Empirical Analysis

4.1. Oil Price Structure and Macroeconomic Variables

Graph 1 and Graph 2 depict the evolution of oil price structure and the main macroeconomic variables in Australia from Quarter 1, 1970 to Quarter 4, 2010 with Quarterly Frequency. I chose this sample size and frequency because the forty years cover the main oil price shock history and the data are available in these periods.

Graph 1. Real Oil Price Structure (Base Year: 1970)



Sources: International Crude Oil Price is a linear combination of West Texas Intermediate (WTI) Crude Oil Price Index, Dated Brent Crude Oil Price Index, OPEC Reference Basket Oil Price Index and Dubai/Oman Crude Oil Price Index with each country's oil export share as weight; Singapore Benchmark Prices of Petrol (MOPS95 Petrol) and Singapore Gasoil 10 ppm Sulphur Prices are from Australian Institute of Petroleum and Platts; Saudi Contract Prices (Saudi CP) are from Reuters and Caltex Australia; Australian Crude Oil Prices, Australian Petrol Prices, Australian Diesel Prices and Australian LPG Prices are from Parliament of Australia, Australian Competition & Consumer Commission (ACCC), Australian Institute of Petroleum (AIP) and ABARE.

Both international and Australian oil prices exhibit trends although Australian prices lagged behind international prices. Since 1973, a new era characterized by large and persistent oil price fluctuations was triggered with five sharp spikes in 1973, 1979, 1982, 1991 and 2008. Intuitively, the first spike reflected the 1973 world oil market crisis; the second summit was caused by the Iranian Revolution in 1979; the following jump mirrored the oil supply surplus in the 1980s; the third peak stemmed from the contraction of OPEC's oil production; the fourth tide was catalyzed by Iraqi's invasion to Kuwait in the 1990s; the fifth climax in early 2008 was explained by a decline in petroleum reserves and Middle East tension; the declines since late 2008 is attributed to

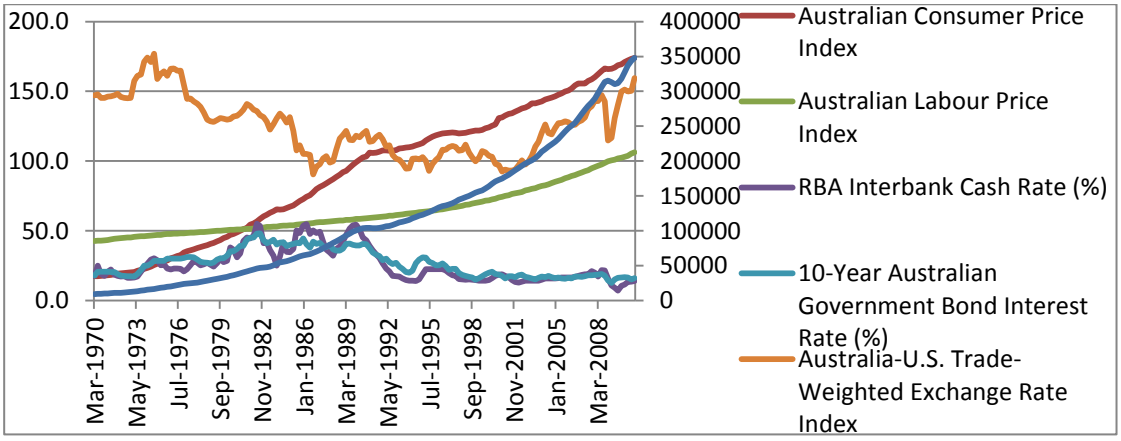
the global recession. These five spikes are attributed to external oil supply shocks, hence should be treated as exogenous shocks.

Table 1. International and Australian Oil Prices' Historical Exogenous Shocks

Episodes	Run-up Periods / Dates of Exceeding Cumulative Threshold Rate of 10% / Cumulative Rise Rates											
	International Crude Oil Price (A$ Dollars per Barrel)			Australian Crude Oil Price (A$ Dollars per Barrel)			MOPS95 Petrol (A$ Cents per Litre)			Australian Petrol Price (A$ Cents per Litre)		
1	Q1 1973-Q4 1973	Q4 1973	0.84	Q1 1973-Q4 1973	Q4 1973	0.19	Q1 1973-Q4 1973	Q4 1973	0.54	Q1 1973-Q4 1973	Q4 1973	0.18
2	Q3 1978-Q2 1979	Q2 1979	0.83	Q1 1979-Q4 1979	Q4 1979	0.13	Q1 1979-Q4 1979	Q4 1979	0.32	Q1 1979-Q4 1979	Q4 1979	0.11
3	Q4 1981-Q3 1982	Q3 1982	0.49	Q1 1982-Q4 1982	Q4 1982	0.13	Q4 1981-Q3 1982	Q3 1982	0.54	Q1 1982-Q4 1982	Q4 1982	0.34
4	Q4 1990-Q3 1991	Q3 1991	0.43	Q1 1991-Q4 1991	Q4 1991	0.21	Q4 1990-Q3 1991	Q3 1991	0.66	Q1 1991-Q4 1991	Q4 1991	0.23
5	Q2 2007-Q1 2008	Q1 2008	0.44	Q4 2007-Q3 2008	Q3 2008	0.11	Q3 2007-Q2 2008	Q2 2008	0.39	Q4 2007-Q3 2008	Q3 2008	0.13

Australian oil price exogenous shocks follow international oil price exogenous shocks with a smaller magnitude and the transmission mechanism of oil price shocks from international oil market to Australian oil market is faster than before due to global economic integration.

Graph 2. The Main Macroeconomic Variables (Base Year: 1970)



Sources: Australian Real GDP, Australian Consumer Price Index, Australian Labor Price Index are from Australian Bureau of Statistics; RBA Interbank Cash Rate, 10-Year Australian Government Bond Interest Rate and Australia-U.S. Real Trade-Weighted Exchange Rate Index are from the Reserve Bank of Australia.

Australian GDP and Australian Consumer Price Index displayed upward trend with fluctuations; Australian Labor Price Index exhibited growth; Australia-U.S. Trade-Weighted Exchange Rate Index rose from 1970 to 1973, and declined from 1973 to 2002, then increased from 2003 to 2010 with volatilities. RBA Interbank Cash Rate and 10-Year Australian Government Bond Interest Rate demonstrated identical trends which increased from 1970 to 1982, varied from 1982 to 1989 and slanted downwards from 1989 to 2010.

4.2. The History of Australian Crude Oil Market Reform

The Australian crude oil market undertook the deregulation reform in 1980, Hart (1986) explained that the Federal Government had regulated domestic crude oil market continuously since production in 1984 and that the crude oil market had substantially deregulated since 1988, Hogan (1996) reported that this deregulation had removed

controls on oil prices and restrictions on oil sales both within and outside Australia, excluding countries subject to an UN embargo. One dummy variable is created to represent the structural policy change in 1980, and its value is 0 before 1980 and 1 since 1980.

4.3. Stochastic Behavior of Variables, Structural Breaks and Exogenous Shocks

Table 2. DF-ADF Unit Root Test

Variable	Test for Unit Root in	ADF Unit Root Test Statistics		Conclusion (10% Level of Significance)
		Intercept	Intercept+Trend	
log (Australian Real Gross Domestic Product)	Level	-0.38	-1.46	I (1): Integrated of Order 1
	First Difference	-9.34	-9.38	I (0): Stationary
Australian Consumer Price Index	Level	-0.55	-1.73	I (1): Integrated of Order 1
	First Difference	-11.88	-11.91	I (0): Stationary
log (Australian Labour Price Index)	Level	3.45	2.65	I (1): Integrated of Order 1
	First Difference	-1.73	-3.18	I (0): Stationary
RBA Interbank Cash Rate (%)	Level	-1.35	-2.19	I (1): Integrated of Order 1
	First Difference	-6.13	-6.27	I (0): Stationary
10-Year Australian Government Bond Interest Rate (%)	Level	-1.15	-2.05	I (1): Integrated of Order 1
	First Difference	-10.46	-10.52	I (0): Stationary
Australia-U.S. Trade-Weighted Exchange Rate Index	Level	-1.25	-0.54	I (1): Integrated of Order 1
	First Difference	-10.73	-10.85	I (0): Stationary
log (International Crude Oil Price)	Level	-0.38	-1.46	I (1): Integrated of Order 1
	First Difference	-9.34	-9.38	I (0): Stationary
log (Australian Crude Oil Price)	Level	-0.55	-1.73	I (1): Integrated of Order 1
	First Difference	-11.88	-11.91	I (0): Stationary
log (MOPS95 Petrol)	Level	-2.57	-3.13	I (1): Integrated of Order 1
	First Difference	-14.91	-14.86	I (0): Stationary
log (Australian Petrol Price)	Level	-2.60	-3.33	I (1): Integrated of Order 1
	First Difference	-11.55	-11.53	I (0): Stationary

Table 3. Chow Breakpoint Test

Oil Type		Date	F-Statistics	Probability	Log likelihood ratio	Probability	Oil Type		Date	F-Statistics	Probability	Log likelihood ratio	Probability
Crude Oil	Oil Price Shock	Q4 1973	2.10	0.05*	15.30	0.03**	Petrol	Oil Price Shock	Q4 1973	8.40	0.01**	54.22	0.00*
		Q2 1979	4.31	0.03**	28.11	0.02**			Q4 1979	12.11	0.00***	73.48	0.00***
		Q3 1982	5.65	0.02**	52.70	0.00***			Q3 1982	12.98	0.00***	77.66	0.00***
		Q3-1991	78.81	0.00***	253.03	0.00***			Q3-1991	23.72	0.00***	122.21	0.00***
		Q3 2008	7.38	0.01**	55.66	0.00***			Q2 2008	3.20	0.04**	22.84	0.02**
	Oil Market Reform	Q1-1980	10.71	0.00***	66.49	0.00***		Oil Market Reform	Q1-1988	20.4	0.00***	109.68	0.00***

All variables are stationary after first differencing. For each VAR, 6 dummy variables are included to capture the structural changes of policy and exogenous oil supply shocks.

4.4. Identification of Oil Prices' Functional Forms in VAR

The significance of oil prices' functional forms in VAR is tested.

Table 4. Granger Causality Test and Significance Test

Granger Causality Test and Significance Test						
Ho: Oil price coefficients are jointly zero in each VAR model, p values are for the asymptotically distributed chi-squared statistics						
Oil Type		Linear	Asymmetric		Scaled	Net
		Δlog(Ot)	Negative Oil Price Variation (Δlog(ot)-)	Positive Oil Price Variation (Δlog(Ot)+)	Δlog(Ot)/SD(Δlog(Ot))	Δlog(Ot)-Δlog(Ot) in Quarter 1, 1970
Crude Oil	International Crude Oil Price	0.0007***	0.001***	0.002***	0.0003***	0.0006***
	Australian Crude Oil Price	0.0092***	0.015**	0.003***	0.0005***	0.0005***
Petrol	MOPS95 Petrol	0.0247**	0.0003***	0.0106**	0.0137**	0.0135**
	Australian Petrol Price	0.0077***	0.0002***	0.009***	0.002***	0.0022***

Note: * indicates significance at 10%, ** indicates significance at 5%, *** indicates significance at a 1%.

For linear oil price specification, both International and Australian crude oil price variations generate significant impacts upon GDP; both MOPS95 and Australian petrol price variations exert significant effects upon GDP. For asymmetric oil price specification, when oil price variations are negative (ΔOt-), all forms of International and Australian oil price variations influence GDP significantly; when oil price variations are positive (ΔOt+), both International and Australian crude oil price variations impose significant effects upon GDP while both MOPS95 and Australian petrol price variations impact upon GDP significantly. For scaled and net oil price variations, both International and Australian crude oil price variations influence GDP significantly while both MOPS95 and Australian petrol price variations act upon GDP significantly. Since, the linear forms of oil price variations are most significant at 1%, this paper incorporates oil price variations in the linear form.

4.5. Transmission Mechanism of Oil Price Variations upon GDP through other Macroeconomic Variables

Two structural auto-regression models are form to detect the transmission mechanism.

$$O_t = \delta_0 + \delta_1 \cdot V_t + \delta_2 \cdot W_t + \omega_t \quad (3)$$

$$U_t = \tau_0 + \tau_1 \cdot V_t + \tau_2 \cdot W_t + \epsilon_t \quad (4)$$

Where δ_0 and τ_0 are 2×1 constant vectors, δ_1 and τ_1 are 2×4 coefficient matrices, δ_2 and τ_2 are 2×12 coefficient matrices, ω_t and ϵ_t are 2×1 disturbance vectors,

$O_t = (\text{International Oil Price}_t,\ \text{Australian Oil Price}_t)'$,

$U_t = (\ \log(\text{Australian GDP}_t),\ \text{Australian CPI}_t,$

$\text{Australia U. S. Exchange Rate}_t,\ \text{Australian Interbank Cash Rate}_t,\ \text{Australian Government Bond Interest Rate}_t,$

$\log(\text{Australian Labour Price})_t)'$

$V_t = (\text{International Oil Price}_{t-1},\ \text{Australian Oil Price}_{t-1}, \text{International Oil Price}_{t-2},\ \text{Australian Oil Price}_{t-2},)'$,

$W_t = (\log(\text{Australian GDP}_{t-1}),\ \log(\text{Australian GDP}_{t-2}),\ \text{Australian CPI}_{t-1},\ \text{Australian CPI}_{t-2},$
$\text{Australia U. S. Exchange Rate}_{t-1}, \text{Australia U. S. Exchange Rate}_{t-2},\ \text{Australian Interbank Cash Rate}_{t-1},$
$\text{Australian Interbank Cash Rate}_{t-2},\ \text{Australian Government Bond Rate}_{t-1},$
$\text{Australian Government Bond Rate}_{t-2}, \log(\text{Australian Labour Price})_{t-1}, \log(\text{Australian Labour Price})_{t-2})''$

O_t is block-exogenous with respect to U_t when $\delta_2 = 0$, while U_t is block-exogenous with respect to O_t when $\tau_1 = 0$. Define Ω_O as the variance-covariance matrix of the residuals from the estimation of model (3) and $\Omega_O(0)$ as the variance-covariance matrix of the residuals from the estimation of model (4) when $\delta_2 = 0$; Ω_U as the variance-covariance matrix of the residuals from the estimation of model (3) and $\Omega_U(0)$ as the variance-covariance matrix of the residuals from the estimation of model (4) when $\tau_1 = 0$; Ω_{OU} as the variance-covariance matrix of the residuals from model (3) and model (4).

The test statistics for $H_0: \delta_2 = 0$ is: $T \times \{\log|\Omega_O(0)| - \log|\Omega_O|\} \sim \chi^2(4 \times 12 \times 2)$.
The test statistics for $H_0: \tau_1 = 0$ is: $T \times \{\log|\Omega_U(0)| - \log|\Omega_U|\} \sim \chi^2(4 \times 12 \times 2)$.
When $\delta_2 = 0$, $\tau_1 = 0$ and $\Omega_{OU} = 0$, there is no relation between O_t and U_t.

Table 5. Block Exogeneity Test and Multivariate Granger Test

The p values of the asymptotically chi-squared distributed statistics T×{log|Ωo (0)|-log|Ωo|} for Ho: δ2=0							
The p values of the asymptotically chi-squared distributed statistics T×{log|Ωu (0)|-log|Ωu|} for Ho: τ1=0							
The p values of the asymptotically chi-squared distributed statistics T×{log|Ωou (0)|-log|Ωou|} for Ho: δ2=0, τ1=0 and Ωou=0							
Oil Type		Null Hypothesis	linear	Asymmetric		Scaled	Net
			Δlog(Ot)	Negative Oil Price Variation (Δlog(ot)-)	Positive Oil Price Variation (Δlog(Ot)+)	Δlog(Ot) / SD(Δlog(Ot))	Δlog(Ot) - Δlog(Ot) in Quarter 1, 1970
Crude Oil	International Crude Oil Price	δ2=0	0.0635*	0.0542*	0.0636*	0.0938*	0.0217**
	Australian Crude Oil Price	τ1=0	0.1017	0.0982*	0.0752*	0.1024	0.0554*
		δ2=0, τ1=0 and Ωou=0	0.0005***	0.0003***	0.0004***	0.0007***	0.0001***
Petrol	MOPS95 Petrol	δ2=0	0.0576*	0.0476**	0.0315**	0.0876*	0.0487**
	Australian Petrol Price	τ1=0	0.0582*	0.0591*	0.0426**	0.0907*	0.0549*
		δ2=0, τ1=0 and Ωou=0	0.0031***	0.0017***	0.0009***	0.0078***	0.0015***

For crude oil, the first null hypothesis that crude oil price variations are not granger-caused by other macroeconomic variables is rejected at 10% of significance; however, the second hypothesis that other macroeconomic variables are not granger-caused by crude oil price variations is rejected for the linear, asymmetric and net forms of crude oil price variations at 10% of significance, but not rejected for the scaled form of crude oil price variations; the third null hypothesis that crude oil price and other macroeconomic variables are not jointly correlated is rejected at 1% of significance. For petrol, the first null hypothesis that petrol price variations are not granger-caused by other macroeconomic variables is rejected at 10% of significance; the second hypothesis that other macroeconomic variables are not granger-caused by petrol price variations is rejected at 10% of significance; the third null hypothesis that petrol price and other macroeconomic variables are not jointly correlated is rejected at 1% of significance.

Thus, oil price variations in linear and non-linear forms generally interact with other macroeconomic variables significantly, and the causality goes in mutual directions between oil price variations and other macroeconomic variables.

4.6. Long-run Structural Co-integrated Vector Auto-regression Model

4.6.1. Summary of Endogenous Variables

Log(Australian GDP)	Log(Australian Crude Oil Price)	Log(International Crude Oil Price)	Log(Australian Labor Price)	Australian CPI	Australian Government Bond Interest Rate	RBA Interbank Cash Rate	Australian U.S. Trade Weighted Exchange Rate Index
1	2.4843	-1.6837	-8.3028	0.0453	0.0178	-0.0123	-0.0945
	[0.9207]	[0.0615]*	[0.0001]***	[0.9532]	[0.9042]	[0.0431]**	[0.0527]**

Note: P value in [ ], * indicates significant at 10%, ** indicates significant at 5%, *** indicates significant at 1%.

4.6.2. Summary of Exogenous Variables

International Crude Oil Price Shock (Exogenous Shock)					**Australian Crude Oil Market Reform**
Q4 1973	Q2 1979	Q3 1982	Q3 1991	Q3 2008	Q1 1980
Before Q4 1973 is zero, since Q4 1973 is one.	Before Q2 19 is zero, since (1979 is one.	Before Q3 1982 is zero, since Q3 1982 is one.	Before Q3 1991 is zero, since Q3 1991 is one.	Before Q3 2008 zero, since Q3 2008 one.	Before Q1 1980 is zei since Q1 1980 is one.

The estimated long-run relationship is:

$$\log(\text{Australian GDP}) = -34.2618 + 2.4843 \cdot \log(\text{Australian Crude Oil Price}) - 1.6837 \cdot \log(\text{International Crude Oil Price}) - 8.3028 \cdot \log(\text{Australian Labor Price}) + 0.0453 \cdot \text{Australian Consumer Price Index} + 0.0178 \cdot \text{Australian Government Bond Interest Rate} - 0.0123 \cdot \text{RBA Interbank Cash Rate} - 0.0945 \cdot \text{Australia U. S. Trade Weighted Exchange Rate Index}$$

In the long run international crude oil price growth, Australian labor price growth, RBA interbank cash rate and trade weighted exchange rate all generate negative impacts upon GDP growth significantly.

4.7. Short-run Vector Error Correction Model

Δlog(Australian Crude Oil Price)	Δlog(International Crude Oil Price)	Δlog(Australian Labor Price Index)	ΔAustralian CPI	ΔAustralian Government Bond Interest Rate	ΔRBA Interbank Cash Rate	ΔAustralia U.S. Trade Weighted Exchange Rate Index
0.0114	-0.0070	-0.2066	0.0001	0.0001	-0.0284	-0.0034
[0.8128]	[0.0971]*	[0.9937]	[0.0354]**	[0.4322]	[0.0001]***	[0.8036]
Error ε_t	Crude Oil Price Shock in 1973	Crude Oil Price Shock in 1979	Crude Oil Price Shock in 1982	Crude Oil Price Shock in 1991	Crude Oil Price Shock in 2008	Crude Oil Market Reform
0.0013	-0.0028	-0.0019	-0.0003	0.0002	-0.0014	0.0001
[0.0414]**	[0.0053]***	[0.0452]**	[0.6510]	[0.3532]	[0.0445]**	[0.0770]*

Note: P value in [ ], * indicates significant at 10%, ** indicates significant at 5%, *** indicates significant at 1%.

The estimated short-run relationship is:

$$\Delta \log(\text{Australian GDP}_t) = 0.0052 + 0.0114 \cdot \Delta \log(\text{Australian Crude Oil Price}_t) - 0.0070 \cdot \Delta \log(\text{International Crude Oil Price}_t) - 0.2066 \cdot \log(\text{Australian Labor Price Index}_t) + 0.0001\Delta\text{Australian CPI}_t + 0.0001\Delta\text{Australian Government Bond Interest Rate}_t - 0.0284 \cdot$$

ΔRBA Interbank Cash Rate $- 0.0034 \cdot$
ΔAustralia U. S. Trade Weighted Exchange Rate Index $+ 0.0013 \cdot \varepsilon_t - 0.0028 \cdot$
Crude Oil Price Shock in 1973 $- 0.0019 \cdot$ Crude Oil Price Shock in 1979 $- 0.0003 \cdot$
Crude Oil Price Shock in 1982 $+ 0.0002 \cdot$ Crude Oil Price Shock in 1991 $- 0.0014 \cdot$
Crude Oil Price Shock in 2008 $+ 0.0001 \cdot$ Crude Oil Market Reform

Where $\varepsilon_t = \log(\text{Australian GDP}_{t-1}) - 0.0052 - 0.0114 \cdot \log(\text{Australian Crude Oil Price}_t) + 0.0070 \cdot \log(\text{International Crude Oil Price}_t) + 0.2066 \cdot \log(\text{Australian Labor Price Index}_t) - 0.0001 \cdot \text{Australian CPI}_t - 0.0001 \cdot \text{Australian Government Bond Interest Rate}_t + 0.0284 \cdot$ RBA Interbank Cash Rate $+ 0.0034 \cdot \Delta$Australia U. S. Trade Weighted Exchange Rate Index is the error.

In the short run, Δlog(International Crude Oil Price), Crude Oil Price Shock in 1973, Crude Oil Price Shock in 1979 and Crude Oil Price Shock in 2008 exert negative effects upon Australian GDP growth significantly; while ΔAustralian CPI, Error ε_t and Crude Oil Market Reform influence Australian GDP growth positively and significantly. The error term $\varepsilon_t = 0.0013$ conveys that the convergence speed to equilibrium is slow.

4.8. Separation of Exogenous Shocks and Endogenous Shocks in the Crude Oil Market under the Framework of VAR Model

In the crude oil market, the exogenous oil supply shocks are represented by the five dummy variables and are discrete. However, the endogenous oil shocks are the oil price variations caused by deviations of log(Australian Labor Price Index), Australian CPI, RBA Interbank Cash Rate which are originally catalyzed by exogenous oil supply shocks. The endogenous oil shocks occur in every investigation period.

The measurement of endogenous oil price shock in period t:

Endogenous Oil Price Shock caused by log (Australian Labor Price Index) at t

$$= \frac{-0.2066 \cdot \Delta\log(\text{Australian Labor Price Index})}{\Delta\log(\text{Australian GDP}_t)} \cdot \Delta\log(\text{International Crude Oil Price})$$

Endogenous Oil Price Shock caused by Australian CPI at t

$$= \frac{0.0001 \cdot \Delta\text{Australian CPI}}{\Delta\log(\text{Australian GDP}_t)} \cdot \Delta\log(\text{International Crude Oil Price})$$

Endogenous Oil Price Shock caused by log (RBA Interbank Cash Rate) at t

$$= \frac{-0.0284 \cdot \Delta\text{RBA Interbank Cash Rate}}{\Delta\log(\text{Australian GDP}_t)} \cdot \Delta\log(\text{International Crude Oil Price})$$

Endogenous Oil Price Shock caused Australia U.S. Trade Weighted Exchange Rate at t

$$= \frac{-0.0034 \cdot \Delta\text{Australia U. S. Trade Weighted Exchange Rate}}{\Delta\log(\text{Australian GDP}_t)} \cdot \Delta\log(\text{International Crude Oil Price})$$

Plug in the data and three endogenous oil price shock series are obtained. Denote them as:
Endogenous Oil Price Shock caused by Australian Labor Price Index= $\Delta O_{t,L}$,
Endogenous Oil Price Shock caused by Australian CPI= $\Delta O_{t,CPI}$,

Endogenous Oil Price Shock caused by RBA Interbank Cash Rate= $\Delta O_{t,I}$,
Endogenous Oil Price Shock caused by Australia U.S. Trade Weighted Exchange Rate $= \Delta O_{t,E}$

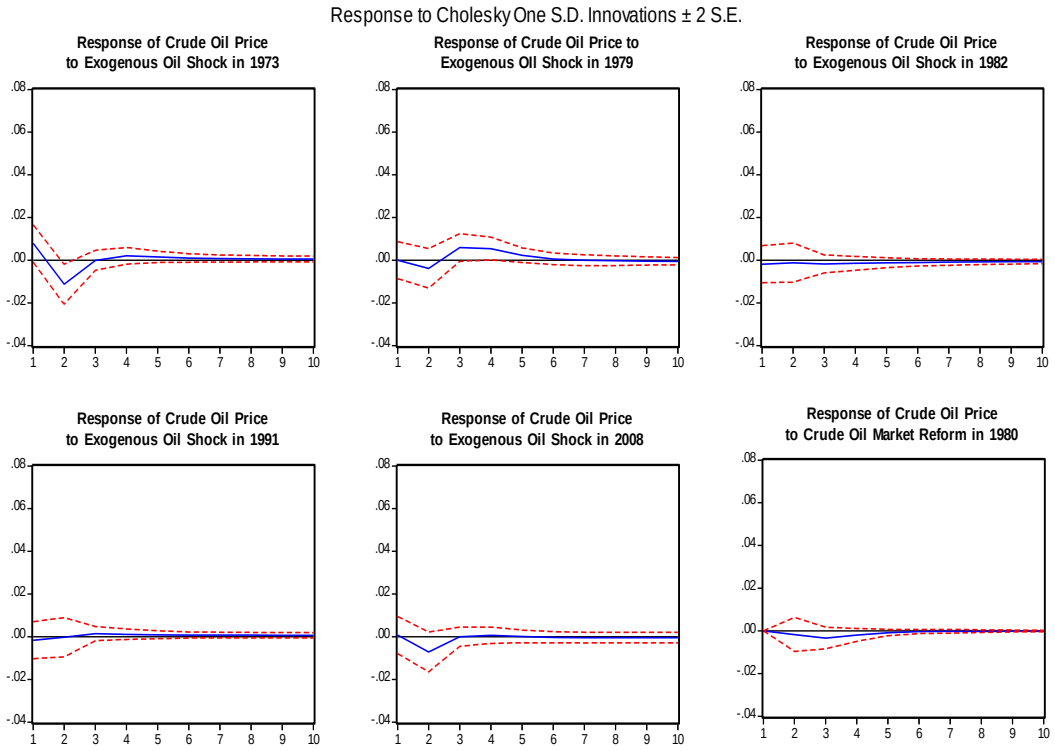
4.9. Assessment of Exogenous Crude Oil Price Shocks, Endogenous Crude Oil Price Shocks and Australian Crude Oil Market Reform

The impacts of exogenous crude oil price shocks, endogenous crude oil price shocks and Australian oil market reforms upon macro-economy are examined through impulse response functions.

4.9.1. Impulse Responses of Exogenous and Endogenous Oil Price Shocks

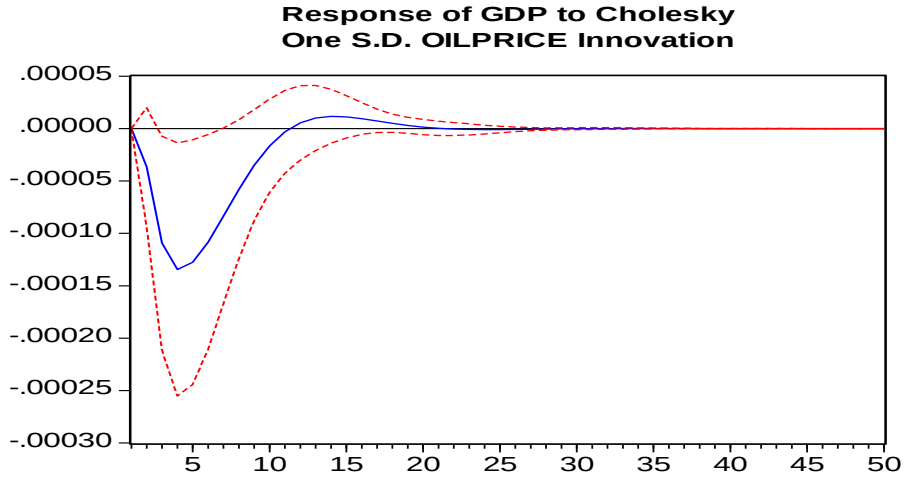
4.9.1.1. Exogenous Oil Price Shocks and Australian Crude Oil Market Reform upon Australian GDP Growth

Graph 3. Effects of Exogenous Crude Oil Price Shocks upon Australian Crude Oil Price



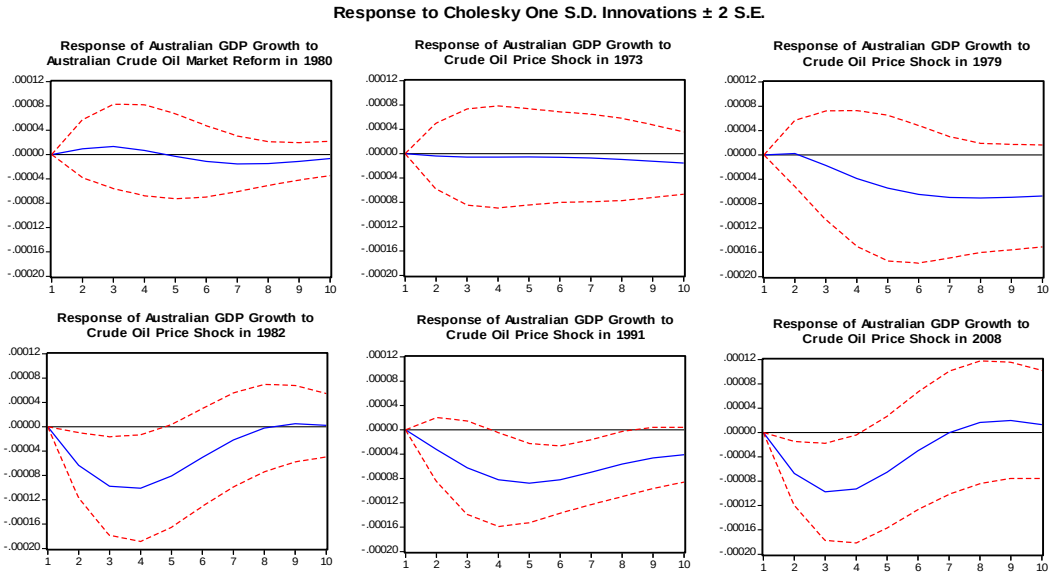
The crude oil price shocks in 1973,1979 and 1991 initially generated negative effects upon oil price variations, then exerted positive effects. The crude oil price shocks in 1982 and 2008 influenced oil price variations negatively first then positively afterwards, although the effect of the 1982 shock decayed more slowly. The crude oil market reform in 1980 impacted upon oil price variations negatively at first, and the negative effects eventually disappeared.

Graph 4. Effects of Crude Oil Price Variations upon Australian GDP Growth



Crude oil price variations generated negative impacts upon Australian GDP growth in the short run buy positive impacts in the long run although the impacts eventually faded away.

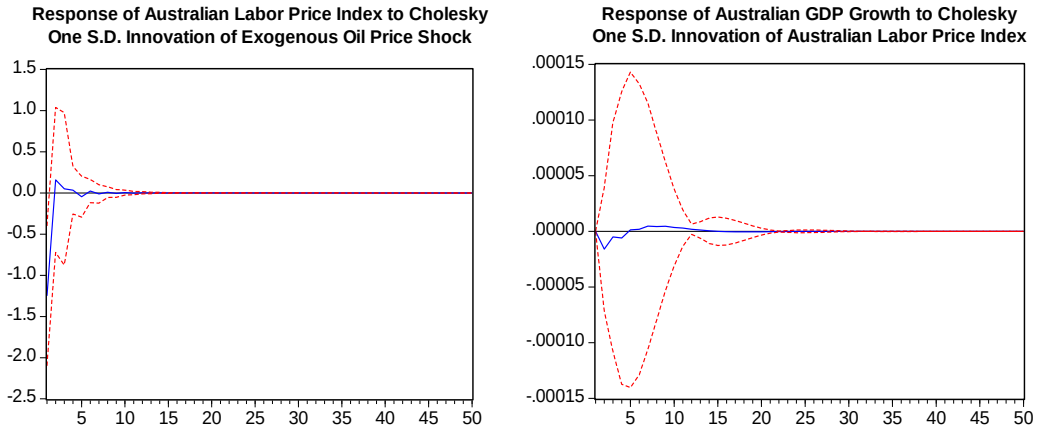
Graph 5. Effects of Exogenous Crude Oil Price Shocks upon Australian GDP Growth



The crude oil price shocks in 1982 and 2008 initially generated negative effects upon Australian GDP growth, then the effects reversed to slightly positive. The crude oil price shocks in 1973 and 1979 influenced Australian GDP growth negatively and the negative effects expanded in the long time. The crude oil market reform in 1991 impacted upon Australian GDP growth negatively and the negative impacts decayed in the long run. The crude oil market reform in 1980 initially generated positive effects upon Australian GDP growth, however, the effects turned to negative in the long run.

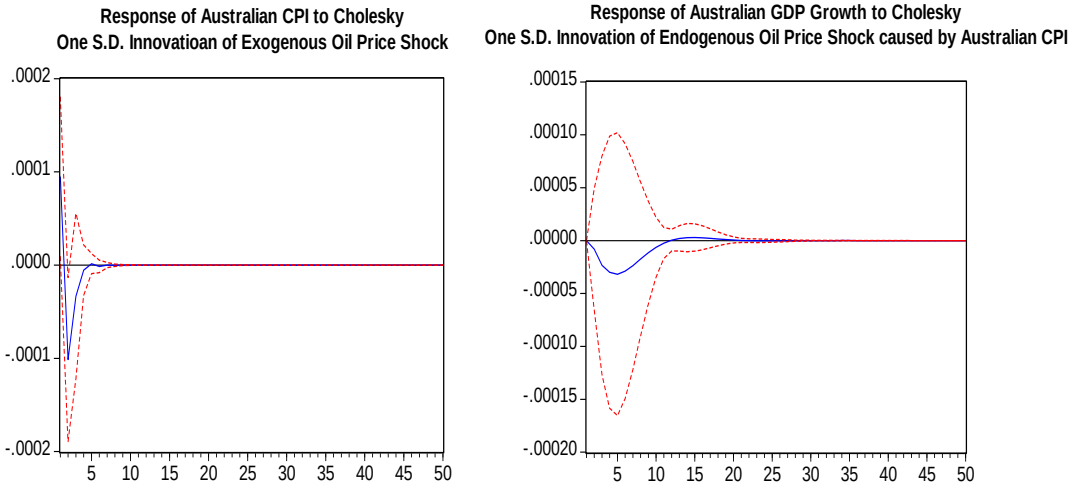
4.9.1.2. Endogenous Oil Price Shocks upon Australian GDP Growth

Graph 6. Transmission Mechanism of Exogenous Oil Price Shocks through Australian Labor Price Index to Australia GDP Growth



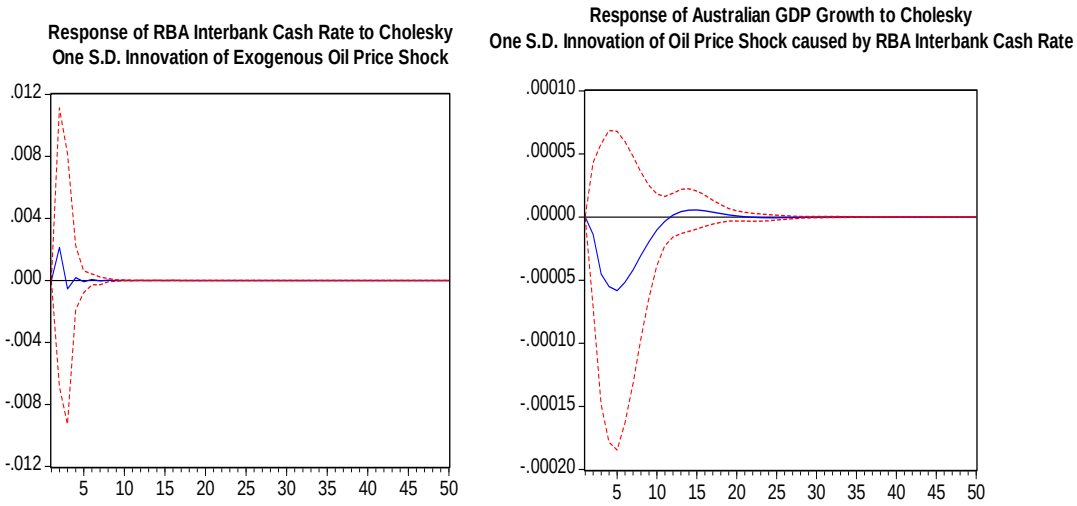
Exogenous oil price shocks raise people's inflation expectation and leads to high labor price index, which results in lower output growth since input costs increase. Australian labor price index responds to shocks faster and converges to new equilibrium.

Graph 7. Transmission Mechanism of Exogenous Oil Price Shocks through Australian CPI to Australia GDP Growth



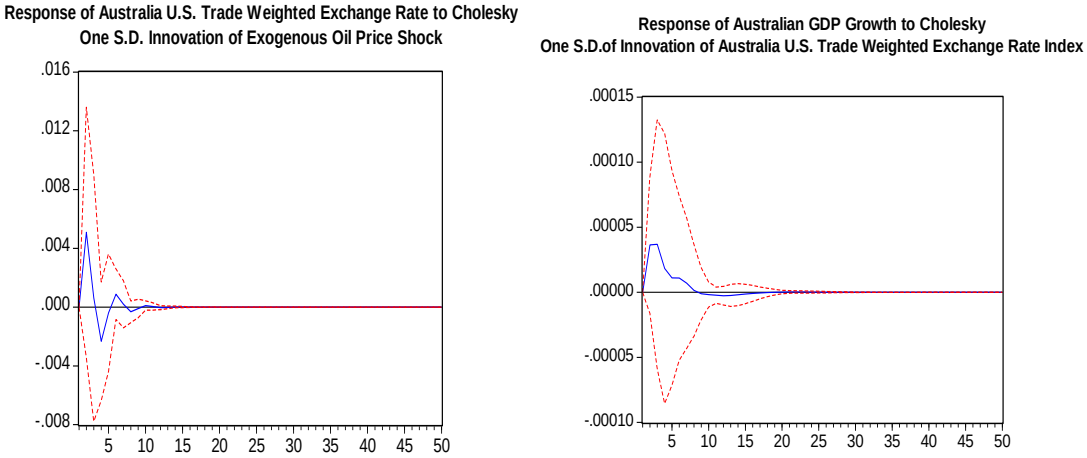
Exogenous oil price shocks raise Australian CPI and lead to lower output growth since input costs increase. Australian CPI responds to shocks faster and converges to a new equilibrium.

Graph 8. Transmission Mechanism of Exogenous Oil Price Shocks through RBA Interbank Cash Rate to Australia GDP Growth



Exogenous oil price shocks raise people's inflation expectation, central banks raises interest rate to control the inflation, higher interest rate induces lower output. RBA Interbank Cash Rate responds to shocks faster and converges to a new equilibrium.

Graph 9. Transmission of Exogenous Oil Price Shocks through Australia U.S. Trade Weighted Exchange Rate to Australia GDP Growth



Exogenous oil shocks raise people's inflation expectation and exchange rate.

4.9.2. Variance Decomposition

Table VII explains the percentages of the variations in Australian GDP growth that are attributed to Exogenous Crude Oil Price Shocks, Australian crude oil market reform in 1980, Australian Labor Price Index, Australian CPI, Australian Government Bond Interest Rate, RBA Interbank Cash Rate, Australia-U.S. Trade-weighted Exchange Rate.

Table 6. Variance Decomposition of Australian GDP Growth (I)

Variance Decomposition of Log(Australian GDP)									
Period	S.E.	log(Australia GDP)	Log(Australia Crude Oil Price Shock)	Log(International Crude Oil Price Shock)	log(Australia Labor Price Index)	Australian CPI	Government Bond Interest	RBA Interbank Cash Rate	Exchange Rate
1	0.0020	100	0	0	0	0	0	0	0
2	0.0044	96.9345	0.3358	0.0573	0.7556	0.0130	0.0006	0.2526	1.6507
3	0.0071	94.2680	0.4307	0.2318	1.1938	0.0075	0.0348	0.4317	3.4017
4	0.0099	92.5050	0.4489	0.3993	1.4113	0.0039	0.0621	0.5000	4.6694
5	0.0128	91.3367	0.4519	0.5633	1.5243	0.0026	0.0788	0.5098	5.5327
6	0.0155	90.5297	0.4548	0.7165	1.5814	0.0022	0.0893	0.4906	6.1354
7	0.0183	89.9436	0.4595	0.8594	1.6082	0.0022	0.0964	0.4593	6.5714
8	0.0209	89.4998	0.4655	0.9927	1.6176	0.0023	0.1014	0.4239	6.8969
9	0.0235	89.1524	0.4722	1.1169	1.6165	0.0023	0.1050	0.3885	7.1461
10	0.0260	88.8731	0.4792	1.2326	1.6092	0.0024	0.1077	0.3550	7.3407

Table 6 explains the percentages of the variations in Australian GDP growth that are attributed to Exogenous Crude Oil Price Shocks, Endogenous Crude Oil Price Shocks and Australian crude oil market reform in 1980.

Table 7. Variance Decomposition of Australian GDP Growth (II)

Variance Decomposition of Australian GDP Growth												
Period	S.E.	Log(Australian GDP0	Endogenous Oil Price Shocks caused by Australian CPI	Endogenous Oil Price Shocks caused by RBA Interbank Cash Rate	Endogenous Oil Price Shocks caused by Australian Government Bond Interest Rate	Endogenous Oil Price Shocks caused by Australian Labor Price Index	Exogenous Oil Price Shock in 1973	Exogenous Oil Price Shock in 1979	Exogenous Oil Price Shock in 1982	Exogenous Oil Price Shock in 1991	Exogenous Oil Price Shock in 2008	Australian Crude Oil Market Reform in 1980
1	0.0003	100	0	0	0	0	0	0	0	0	0	0
2	0.0006	96.6773	0.3996	0.0679	0.0097	0.0277	0.0017	0.0054	1.4337	0.1515	1.1985	0.0269
3	0.0007	90.9871	1.2250	0.4597	0.0551	0.0832	0.0027	0.0424	2.7096	0.4048	3.9797	0.0507
4	0.0008	85.9808	2.3213	0.9429	0.1093	0.1321	0.0038	0.2300	3.7141	0.6729	5.8443	0.0483
5	0.0008	82.5079	3.4017	1.2147	0.1620	0.1693	0.0059	0.6019	4.3310	0.9486	6.6102	0.0468
6	0.0009	80.8111	3.9739	1.2908	0.2080	0.1918	0.0089	1.1329	4.5224	1.1406	6.6575	0.0622
7	0.0009	80.1388	4.1524	1.2626	0.2429	0.2013	0.0125	1.7290	4.4569	1.2168	6.4988	0.0880
8	0.0009	79.5491	4.1731	1.2454	0.2656	0.2055	0.0190	2.3152	4.3472	1.2342	6.5366	0.1090
9	0.0009	78.7763	4.2044	1.2692	0.2803	0.2107	0.0310	2.8762	4.2798	1.2410	6.7118	0.1193
10	0.0009	78.0131	4.2854	1.2972	0.2901	0.2187	0.0515	3.4047	4.2398	1.2509	6.8270	0.1216

The variance decomposition indicates that for Australian GDP growth, Australian crude oil price shock, Australian CPI growth, Australia-U.S. exchange rate growth, Australian interbank cash rate, Australian 10-year government bond interest rate growth, Australian labor price index growth are all significant sources of variation other than itself. Since oil prices shocks granger-caused Australian CPI growth, Australia-U.S. exchange rate growth, Australian interbank cash rate, Australian 10-year government bond interest rate growth and Australian labor price index growth, it could be concluded that oil price shocks explain a significant portion of Australian GDP growth both directly and indirectly through other macroeconomic variables.

5. Conclusion

This paper aims to investigate the impacts of energy crisis in terms of oil price shocks upon the Australian GDP growth over the period of 1970 to 2010. Hypotheses concerning whether the immunity of Australian economy against oil crisis is affected after the deregulation of Australian crude oil market since is tested. The theoretic growth model and the empirical analysis draws the following conclusions: I. The deregulation of Australian crude oil market has followed the world-wide oil market deregulation trend and generated positive impacts in the short run, however, its long term effects are unpredictable; II. Exogenous oil prices shocks explains a larger proportion of variations in GDP growth and induce a significant amount of endogenous oil price shocks through mainly labor price, CPI, interest rate and exchange rate, and the impacts of endogenous oil price shocks last longer than exogenous oil price shocks. III. Oil prices shocks are significantly correlated with GDP, CPI, Australia-U.S. exchange rate, Australian Interbank Cash Rate, Australian 10-Year Government Bond Interest Rate, Australian Labor Price Index; IV. Inflated oil prices exert mainly non-linear negative impacts upon GDP growth; V. Oil price increases influence GDP growth of a greater magnitude than the effect of oil price decreases, with the later being statistically insignificant. For the long run equilibrium, non-linear form of oil price shocks upon GDP growth seems to decay more slowly than linear-form of oil price shocks.

The paper generalizes the following for policy makers:

I Policy makers should examine the direct linear forms of oil shocks impacts upon the Australian GDP growth, but also the non-linear forms of oil price shocks upon GDP growth directly and other macro-economic variables which influence GDP growth indirectly.

II. Policy makers should be aware of oil, market policies' indeterminable long term effects and take actions to prevent negative effects.

III. Endogenous oil price shocks caused by exogenous oil supply shocks through other macroeconomic variables explain a significant amount of variations in Australian GDP growth, and the effects of endogenous oil price shocks last longer than exogenous oil price shocks.

IV. Policy makers should take advantage of the oil price rises and falls' asymmetric impacts upon macro-economic variables to hedge the potential risk and design flexible anti-crisis schemes to utilize this asymmetric price volatility effects.

The limitations are that it discusses mainly the Australian crude oil market without taking account of the impacts of the crude oil market's interaction with other oil markets (e.g. petroleum, diesel and LPG markets) and the effects of oil price speculation. Further research can be done from these perspectives.

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