China's Demand for Energy Imports and Implications for Sino-Australian Bilateral Trade[*]

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Abstract Sustained economic growth in China has induced a surge of energy imports, especially oil imports. This paper investigates the determinants of China's energy import demand by using cointegraiton and VECM techniques. It shows that, in the long run, growth of industrial production and expansion of transport sectors are important factors influencing China's oil imports, while domestic energy output has a substitution effect. These findings have important implications for energy trade between China and Australia. In addition, the paper also discusses other factors such as political relationship and bilateral preferential trade agreements which may affect China-Australia energy trade.

Key words: Energy consumption, energy imports, China and Australia, and VECM

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1. Introduction

In the past twenty-seven years, China has undertaken market-oriented economic reforms and achieved an average annual growth rate of 9.62%.[1] The expansion of economic activities and growth of household expenditure have led to a surge of demand for primary energy consumption, which gradually cannot be satisfied by the domestic production since the 1990s. The gap between domestic energy production and consumption has been increasing (Figure 1). As a result, China has been a net importer of crude oil since 1993 and surpassed Japan to become the world's second-largest oil importer in 2003 (only behind the United States).

<insert Figure 1 here>

The development of China's energy market in the past decades can be divided into three stages. The first stage covers the period from 1953 to the early 1970s during which China's energy consumption grew relatively slowly and kept pace with domestic production. The second period falls between 1973 and 1992, during which total output of energy production exceeded total consumption with a modest annual growth rate. The third stage began in the early 1990s. Since then, China's energy consumption has overtaken domestic production and hence the country has become a net energy importer. Energy consumption has expanded even faster in recent years.

Another important feature of China's energy market is its unbalanced product mix which is dominated by coal (with a share of 68.7% in total energy usage in 2005). The

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[1] This figure is calculated using SSB data (National Bureau of Statistics various issues).

clean energy such as natural gas and hydroelectricity plays a relative small role (with 2.8% and 7.3% market shares in 2005, respectively) (National Bureau of Statistics, 2006). With the growing environmental concern among the Chinese people, there is great pressure for China's energy industries and policy makers to change the energy structure and resort to cleaner energy sources (i.e., natural gas and hydroelectricity) as well as renewable resources (i.e., solar, geothermal and wind energies).

In order to fill the gap between domestic energy production and consumption and maintain the impressive economic growth (the Sixteenth National Congress set a target of four-fold growth between 2000 and 2020, with a growth of 7% per annum) without further environmental damage, China has adopted the strategy of diversifying the sources and composition of energy. China has now established extensive cooperation relationships with many energy exporting countries such as Russia, the Gulf States, Canada, Azerbaijan, Kazakhstan, Venezuela, Sudan, Indonesia, Iraq, and Iran. According to IEA (2005), China now imports 40% of its oil, of which some 60% comes from the Middle East. The same source suggests that China's total oil demand would increase from 6.4 million barrels per day (mb/d) in 2004 to over 13 mb/d in 2030, which implies that a large proportion of China's oil demand will have to be met by imports and the country's net oil imports would rise from 2.3 mb/d in 2004 to 4.5 mb/d in 2010 and 10.5 mb/d in 2030. This would raise China's dependency on imported oil to 75% within the next 25 years.

The projected growth in energy imports implies great opportunity for energy cooperation between China and Australia, one of the major mineral and energy production and export countries in the world. The two countries are currently in the process of negotiating a free trade agreement (FTA). In August 2002, China and Australia signed a contract to ship over 3.3 million tones per annum of liquefied natural gas (LNG) from Australian North West Shelf project to Guangdong province and the supply commenced in May 2006 and will run for 25 years. In 2003, Australia's Gorgon gas project reached an agreement with China National Offshore Oil Company to supply China with 100 million tones of LNG over 25 year period. In 2004, China became Australia's second largest trading partner as well as the second largest market for Australian exports (behind Japan). In the same year, the bilateral trade value approached 21.17 billion US dollars, with an annual growth rate of 37.4%.[2] In April 2006, Australia signed an agreement to sell uranium to China for use in nuclear power plants.[3]

With the growing flow of primary energy (i.e. LNG and crude oil) from Australia to China, we wonder what factors affect and determine China's demand for energy imports, which is critical to the understanding of China's energy supply and demand as well as energy import strategy in the country. Unfortunately, the energy trade between China and Australia just commenced and there is no enough historical data available for econometric analysis. Instead, we construct an econometric model which

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[2] MOFCOM (2005). Country Report-Australia, Jan, 2005. http://countryreport.mofcom.gov.cn/index.asp.

[3] Jane Perlez (2006). Australia to sell uranium to China for energy, *The New York Times*, Apr 3, 2006.

is applied to China’s total energy import data from 1995:Q1 to 2006:Q1. The findings are then employed to draw implications for China-Australia energy trade.

The rest of the paper is organized as follows. Section 2 presents a brief review of the relevant studies. Section 3 discusses the main factors affecting China’s energy import demand. The econometric method and model specification are introduced in Section 4. This is followed by description of data issues and interpretation of the empirical findings in Section 5. The implications for Sino-Australian energy trade are discussed in Section 6. Finally, Section 7 concludes the paper.

2. Literature review

In the literature, there are a variety of studies on China’s energy issues. Some researchers argue that economic growth and key macro-variables are the determinants of energy consumption and hence apply these variables to project energy consumption (Hirschhausen and Andres 2000; Li 2003; Crompton and Wu 2005; Skeer and Wang 2006b). Others examine the determinants of energy demand before the forecasts are conducted (Chan and Lee 1996; Wei 2002; Zou and Chau 2006; Skeer and Wang 2006a). For example, Chan and Lee (1997) forecasted the demand for coal in China by using Engel-Granger’s error correction model and Hendry’s general to special approach. Keii (2000) predicted that China's demand for coal would reach 1.3 billion tones in 2010, accounting for about 65% of China’s primary energy, and coal consumption in China would grow at a more modest annual rate of 2% in the first decade of 21^{st} century. Hirschhausen and Andres (2000) examined the outlook for electricity demand in China until 2010 at a national, sectoral and regional level, and projected gross electricity demand of 1500 terawatt-hour (Twh) in 2010. Han et al. (2000) and Zhou (1999) argued that growth in natural gas demand would be much greater in the first decade of the 21^{st} century. The implied annual rate of growth in natural gas consumption in the first two decades of the 21^{st} century is about 9% and 11% according to Han et al. (2000) and Zhou (1999), respectively. Li (2003) simulated China's economy, energy and environment in an integrated econometric model and projected that economic growth rate in China would be around 7% annually in the coming 30 years and would result in unsolvable difficulties for energy security, air protection, and CO_2 emission reductions. Crompton and Wu (2005) employed a Bayesian vector autoregressive (BVAR) model to project China's primary energy demand up to 2010. Their results suggest that total energy consumption should increase to 2173 million tons coal-equivalent (MtCE) in 2010 with an annual growth rate of 3.8%, which is slightly smaller than the average rate in the past decade. Their projection also indicates that the share of coal and natural gas in primary energy consumption will be around 65% and 3.4%, respectively. Moreover, oil imports will reach 120-182 million tones by 2010, accounting for a half of China's total oil consumption. Skeer and Wang (2006b) examined the trends in China's freight and passenger traffic sector and projected the sector's demand for oil in 2020 to be in the range from 191 to 363 million tons oil-equivalent (MtOE). They also found that the new demand from China's transport sector would likely push up world oil prices in

2020 with a range of 1-10% under different scenarios.

Chan and Lee (1996) used cointegration and vector error correction model (VECM) techniques to analyze China’s energy consumption behavior, and concluded that energy price, income and the share of heavy industry output in national income were significant factors affecting energy consumption. Wei (2002) examined the long-run relationship between total energy consumption and some main economic factors such as energy price, income and share of heavy industry in GDP and found that energy consumption and main variables are cointegrated. Wolde-Rufael (2004) investigated the causal relationship between various kinds of industrial energy consumption and real GDP in Shanghai for 1952-1999. The empirical evidence suggested that there was a uni-directional Granger causality running from coal, coke, electricity and total energy consumption to real GDP, except oil consumption. Zou and Chau (2006) examined the relationship between oil consumption and economic growth in China using cointegration and ECM models and suggested that oil consumption had a great effect on economic growth. Zhang (2003) investigated the change in energy consumption in China’s industrial sector and showed that the drop of real energy intensity contributed to the decline in industrial energy use in the 1990s. Skeer and Wang (2006a) studied the possibility of substitution of natural gas for coal in China’s power sector and suggested that under average cost conditions today, gas-fired power is roughly two-thirds more costly than coal fired power.

In summary, two general conclusions can be drawn from the current studies. First, economic growth is the most important factor in determining China’s energy consumption. With sustained growth, China’s energy consumption will grow dramatically in the coming two decades and domestic production cannot meet the demand because of the constrained production capacity or requirement for vast investment in energy transport facilities. Second, although China aims to reduce coal consumption and increase the share of clean energy (i.e., natural gas and renewable energy), China’s energy consumption structure will change slowly. The share of coal will decrease to around 65% and that of natural gas will increase from 3% at present to about 7% in 2010 (Crompton and Wu 2005; IEA 2005). However, current studies have mainly focused on China’s aggregate energy supply and demand and the determinants of China’s demand for energy imports are rarely considered. This paper adds to the literature by examining China’s energy import determinants and using the findings to draw implications for Sino-Australian energy trade.

3. Factors affecting China’s oil import

With rapid economic growth and improvement of the standard of living, China is confronted with energy shortage and has to quest for energy security world-wide. So far China’s energy imports are mainly crude oil and petroleum products. Thus, this section discusses the major determinants of China’s oil imports including the price of crude oil, domestic energy production, industrial output and total traffic volume.

3.1 The price of crude oil

Crude oil price is an important variable influencing oil imports. Economic theories suggest that when energy price rises, the quantity of energy demanded should fall, holding all other factors constant. But, in empirical studies, energy demand is considered to be inelastic with respect to price, especially in the short-run (Dahl and Sterner 1991; Bernstein and Griffin 2005). This may be due to the absence of alternative choices or substitute fuels for the households and industry sectors. Even when the price of the energy goes up dramatically, people continue to consume gas and electricity in their everyday life, and factories cannot reduce energy use so as to avoid production interruptions in the short run. As a result, energy demand may not change significantly following a price change, especially in the short-run. In addition, international oil price, which changes constantly in response to the global shocks in both supply and demand sides, can be seen as a proxy of international market condition that China faces.

As to energy demand by the industrial sectors, the relative price between inputs (i.e., energy) and outputs (industrial products) may be more important than the international energy price in absolute terms. If the prices of industrial products and energy products change by the same proportion, the quantity of energy demand may not change. Since most primary energy products, especially crude oil, are used as production factors in the industrial sector, to examine the response of import demand to changes in real energy price, the price of oil in relative terms (i.e. the ratio of crude oil price to industrial product price index) is employed in the empirical analysis.[4]

3.2 Domestic energy production

Domestic energy output is considered as another important factor affecting China's energy imports. Although China is the second largest energy producer in the world after the US, the country is poorly endowed on a per capita basis. In addition, China's energy production is dominated by coal with an output share over 70% (Table 1), which is very similar to the consumption pattern. This kind of structure is due to China's rich coal reserve and relatively low production cost. The shares of natural gas and hydroelectricity are relatively constant around 3% and 8%, respectively. In 2004, China's total energy output was 1.85 billion tones of coal equivalent (BtCE), which was insufficient to meet the total consumption of 1.97 BtCE. In the same year, the country produced 174.5 million tones of crude oil, which was about 4.5% of world output, and consumed 308.6 million tones which amounted to about 8.2% of world oil consumption.[5] As a result, China's oil imports reached 122.7 million tones in 2004 (Table 2). The apparent gap between oil supply and demand is expected to widen in the coming two decades due to China's limited capacity of oil production. China's major oil fields accounting for about 90% of total crude oil production are located in eastern China and their production capacity has peaked and is in decline. New proved oil resources are in western China and too expensive to be explored. In addition, the shortage of energy transport infrastructure restrains China's eastern energy users from

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[4] Industrial consumption of energy accounted for about 70% of China's total energy consumption in 2005 according to the National Bureau of Statistics (2006).

[5] BP (2005). BP Statistical review of world energy, June, 2005, p4.

access to the country's western energy resources.

<insert Table 1 here>

<insert Table 2 here>

Furthermore, China's gas production is very small due to a limited reserve. At the end of 2004, the proved reserve of natural gas in China was 2.23 trillion cubic meters, which accounted for about 1.2% of world's total reserve.[6] To increase production capacity and consumption of natural gas, China has embarked on a major expansion of gas infrastructure. The West-East pipeline linking Shanghai and Xingjiang is now operating commercially and several LNG receiving terminals are also under construction or consideration.[7]

3.3 Industrial output

Strong economic growth, especially in industrial production, continues to boost China's total primary energy consumption. Although economic growth seems to be the most important factor affecting energy demand, industrial production rather than gross domestic product (GDP) is chosen as the indicator of growth for two reasons. First, the industry sector amounted to about 70% of China's total primary energy consumption in 2005.[8] As China is now in the process of industrialization, the expansion of industrial production leads to rapid growth in energy consumption in both absolute and per capita terms. In 2004, China's total value added of industry (VAI) reached 5480.51 billion RMB, about 16.7% greater than that in the preceding

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[6] BP (2005). BP Statistical review of world energy, June, 2005, p20.

[7] IEA (2005). Findings of recent IEA work, 2005, p72.

[8] See footnote 2.

year. The shares of heavy and light industries in total VAI were 67.6% and 32.5%, respectively. According to a study by the National Development and Reform Commission (NDRC), China has come to the stage of developing heavy chemical industry and the output of high energy consuming goods such as steel, cement, soda ash and caustic ash et al, increased dramatically in recent years (Table 3).[9] Thus, the industrial sector with high energy intensity will be one of the major energy users in China. Second, the sectoral effect of energy import cannot be captured by employing GDP. For example, crude oil is imported largely as an industrial production input. Therefore, because of the importance of the industrial sector in energy trade (i.e. oil imports), the value-added of industry (VAI) is chosen as one of the explanatory variables in the regression analysis. In addition, the impacts of heavy industry and light industry are also considered separately in the empirical exercises. Thus, the value-added of either heavy industry (VAHI) or light industry (VALI) is included in the analysis.

<insert Table 3 here>

3.4 Total Traffic Volume

Rapid expansion of the transport sector inevitably leads to a surge of demand for energy, especially for oil products. From 1990 to 2004, the number of passenger vehicles and civil aircrafts increased by about 9 and 1.5 times, respectively (Table 4). The total number of vehicles increased over ten millions since 2000, over 80% of

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[9] NDRC Energy Research Institute (ERI) (2004). The mid and long run trends of China’s energy supply and demand and the strategy of sustainable development (wo guo neng yuan gong qiu zhong chang qi fa zhan qu shi ji ke chi xu fa zhan zhan lue), Econonics Study Reference (Jing ji yan jiu can kao), 92.

which is accounted by the growth of passenger vehicles. As for passenger traffic, vehicles and airplanes seem to become increasingly important in China, while the role of railways and waterways is declining (Table 5). With increasing incomes and development of the automotive industry in China, private cars are becoming affordable for more families. As a result, the number of privately owned vehicles increased from 2.5 million units in 1995 to 6.25 million units in 2000 and to 14.8 million units in 2004 (National Bureau of Statistics, 2005).

<insert Table 4 here>

<insert Table 5 here>

The increase in travel by cars and airplanes creates great demand for oil products and this trend is likely to continue in the coming two decades, as the process of industrialization in China advances. As demonstrated in Table 6, from 1990 to 2004, total volume of freight traffic increased by 2.6 times, with an average annual growth rate of 7.6%. According to Skeer and Wang (2006a), although the share of highways in total transport volume (passenger and freight) is only 14%, the share of its energy use is 68% in 2000. The greater energy use in highway transport is due to rapid growth in highway traffic and the number of vehicles. Therefore, to capture the effects of the transport sector expansion on energy imports, total volumes of freight traffic (billion tone-km) as well as passenger traffic (billion passenger-km) are included in our empirical analysis.

<insert Table 6 here>

4. Analytical framework

To investigate the long run relationship between macroeconomic variables (i.e., crude oil, refined petroleum and liquefied petroleum gas) most of which are not stationary, cointegration technique and vector error correction model (VECM) are often employed as the main research tools. There are two reasons for choosing these two techniques. First, conventional econometric approaches such as OLS are subjected to spurious regressions (Granger and Newbold 1974). Second, because most economic variables employed in the energy import demand equation such as output, price and value added of industry, are likely to be endogenous, estimating energy demand by a single equation may produce simultaneous bias and hence lead to unreliable results. Both problems can be overcome with the help of the vector error-correction model (VECM). In addition, a VEC model can capture the long-run relationship between the economic variables and energy import demand.

To examine whether there exist long-run cointegrating relationships among variables or not, two popular approaches are used in the literature, that is, the Engle-Granger (EG) procedure (1987) and the Johansen-Juselius (JJ) test (1990). In multivariate circumstances, the results of EG method is variant to the choice of variables selected for normalization, and can only produce one cointegrating vector. In addition, the EG procedure is implemented in two steps. Any error in the first step will be carried over into step two (Enders 2003). For these reasons, the JJ test is employed in this paper. It is based on the following vector auto-regression (VAR) model

$$X_t = A_0 + A_1 X_{t-1} + A_1 X_{t-1} + A_1 X_{t-2} + \cdots + A_1 X_{t-k} + u_t \quad (1)$$

where X_t is (n*1) vector $(x_{1t}, x_{2t}, \cdots, x_{nt})'$, A_i is (n*n) coefficients matrix of the lag term of X_t, u_t is an independently and identically distributed (n*1) vector with zero mean and variance matrix Ω, A_0 is (n*1) vector of intercept terms. If the factors of X_t are integrated with the same order, equation (1) can be rewritten in the following form

$$\Delta X_t = A_0 + \pi X_{t-1} + \sum_{i=1}^{p} \pi_i \Delta X_{t-i} + u_t \quad (2)$$

where $\pi = (\sum_{i=1}^{p} A_i - I)$ and $\pi_i = -\sum_{j=i+1}^{p} A_j$. The key feature of the JJ method is to examine the rank (r) of coefficient matrix π, which is equal to the number of independent cointegrating vectors. If r=rank(π)=0, the matrix is null and equation (2) becomes the usual VAR in first differences; if r=rank(π)=n, the vector process is stationary; and if 1<r=rank(π)<n, there are multiple cointegrating vectors. Then the matrix π can be decomposed such that $\pi = \alpha \cdot \beta$, where α is a (n*r) matrix and $\beta = (\beta_1, \cdots, \beta_r)'$ is a (r*n) matrix, α is called the adjustment coefficient matrix and β is called cointegrating matrix, each row of which is a cointegrating vector. To obtain the number of distinct cointegrating vectors, JJ method introduced two statistics:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \quad (3)$$

$$\lambda_{\max}(r, r+1) = -T \ln(1 - \hat{\lambda}_{i+1}) \quad (4)$$

where $\hat{\lambda}_i$ is the estimated value of the characteristic roots (also called eigenvalues), and T is the number of the observations. The first statistic, trace test (also called the likelihood ratio test), tests the null hypothesis that there are at most r cointegrating vectors against alternative cases of more than r cointegrating vectors. The second statistic, known as maximum eigenvalue test, tests the null hypothesis that the number of cointegrating vectors is r against the alternative r+1. The critical values of these two statistics, λ_{trace} and $\lambda_{\max}$, are obtained by Osterwald-Lenum (1992) using the Monte Carlo simulation. If the above cointegration test suggests that there exists at least one cointegrating vector, the VECM can be expressed as

$$\Delta X_t = A_0 + \alpha\beta X_{t-1} + \sum_{i=1}^{p} \pi_i \Delta X_{t-i} + u_t \tag{5}$$

In equation (5), the long-run equilibrium relationships between variables in X_t are captured by the cointegrating term βX_{t-1} and the error correction mechanism is reflected by the adjustment coefficient matrix α. The coefficient matrix of the lagged first differences terms π_i, catches the short-run dynamics. To estimate the above described system of equations, several steps are followed. We first determine the order of integration of the variables by conducting the Augmented Dickey Fuller (ADF) test. If the variables are not stationary, we then conduct tests for cointegration among variables by applying the Johansen-Juselius (1990) approach. Finally, if the variables are cointegrated, an Error Correction Model (ECM) will be estimated to examine the long-run relationship between the variables.

5. Empirical Results

Since the original data used in this paper are monthly series, so we make the following adjustment before the modeling exercises. First, we convert the monthly series to quarterly series through arithmetical sum-up for variables in quantity terms (oil imports, domestic output, and total freight passenger traffic). For variables in value terms (crude oil price and industry value added), the monthly price indexes (1995:01=100) of industrial products are used to deflate the series before the conversion.[10] Second, to remove the seasonal factors, we make seasonal adjustment for all variables through moving average before taking logarithms. All data but oil prices are obtained from China economic information network (CEI) database. Table 7 lists the abbreviations for all the variables. Oil price data are obtained from International Financial Statistics (IMF).

<insert Table 7 here>

The empirical work begins with the test of stationarity of the variables. The augmented Dickey-Fuller (ADF) tests are applied to all variables at level as well as their first difference series. The results are summarized in Table 8. It can be seen that the null hypothesis of unit root cannot be rejected for the level of all variables at the 5% level of significance, while the first difference series seem to be stationary. Hence, we conclude that all variables are I(1).

<insert Table 8 here>

To investigate the long-run relationship between different macro-variables (i.e., relative crude oil price, domestic energy output, industry value-added and total freight traffic) and energy imports (i.e., crude oil and petroleum products), we consider nine optional groupings as shown in Table 9 and construct VAR models for each group.

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[10] There are several reasons for converting monthly series to seasonal series. First, the frequency of the monthly data may be too short to capture the long run behavior of energy market, since changes of these macro-variables in aggregate terms cannot be seen as the long run trends. Second, strong cycling factors are included in the monthly data and will confuse our analysis of long-run relationship. Finally, the seasonal data are not available.

Group 1 investigates the long-run relationship between oil imports and relative oil price, total energy output and total industry value added; groups 2 and 3 examine oil imports and value added of heavy and light industry, respectively; groups 4-7 investigate the relationship between China's output of each variety of primary energy goods (i.e., crude oil, coal, natural gas and hydroelectricity) and oil imports; and the last two groups, 8 and 9, examine the effects of freight traffic and passenger traffic on China's energy imports. The relative price of crude oil is included in all models as an important explanatory variable.

<insert Table 9 here>

For each group, the JJ cointegration tests are conducted to identify whether there exist long-run relationships or cointegrating relationships between the variables. Since the results of the JJ cointegration tests are very sensitive to the lag length selected and assumption of the testing forms, we employ both Akaike's information criterion (AIC) and Schwarz information criterion (SIC) to choose the optimal lag length of the variables and include a constant term in the cointegrating equations.[11]

The results of the JJ cointegration tests are reported in Table 10 which suggests that most groups have at least one cointegrating relationship among the variables. At the 5% significance level, the hypothesis of no cointegration (r=0) is rejected for all models except models (6) and (7). These findings suggest that there seems to exist long-run relationships between China's oil imports and the main macroeconomic

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[11] The ADF tests also show that there are trends in most of the variables.

variables, i.e., relative price of crude oil, domestic energy production, industry value-added (both heavy and light), whereas there is no cointegration relationship between oil imports and domestic natural gas or hydroelectricity output. Therefore, we construct the vector error correction procedures for all models except models (6) and (7). Since the aim of this study is to investigate the long-run determinants of energy imports in China, we just report the long-run equilibrium relationship extracted from the corresponding VECMs and did not report the full regression results of VECMs. The results are reported in Table 11. Several conclusions can be drawn.

<insert Table 10 here>

<insert Table 11 here>

First, international relative price of oil seems not to be a major determinant of China's oil imports. In the long-run relationship reported in the table, the coefficients of relative oil price (Lnrpoilsa) are either significantly positive or not significant. In the models (1), (4) and (5), the sample ranges from 1995:Q1 to 2006:Q1, and the oil price variable shows a significantly positive relationship with imports, which implies that the price elasticity of crude oil is positive. This result is somewhat surprising as the classical economic theories tell us that demand and market price have a negative relationship.[12] However, when other variables are introduced in models (2), (3), (8) and (9), the coefficient of relative price of oil is not statistically significant and its sign is not consistent. We hence argue that the international relative price of crude oil appears to have no stable long-run relationship with China's oil imports and it plays a

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[12] The positive relationship between oil import and oil price may due to two reasons: (1) we miss some key explaining variables in the models; (2) the increase of oil price may be induced by China's strong import growth and therefore they exhibit a positive relation.

trivial role in China's oil imports. This conclusion is consistent with the intuition from the reality. Even when international crude oil spot price (West Texas Intermediate) increased from US$18.42 in 1995 to US$41.49 per barrel in 2004, China's crude oil imports increased by almost 8 times from 17.09 million tones to 122.72 million tones, with an average annual growth rate of 25%.[13] In addition, most of China's oil imports are spot transactions such that China has little flexibility to respond to the constant fluctuation of international oil price. Moreover, the segmentation between domestic market and international market also weakened the function of price mechanism in the oil markets.

Second, the value added of the industrial sector shows a positive effect on oil imports. From the results reported in Table 11, the long run effects of total industry value-added on oil imports are significantly positive, as shown in models (1), (4) and (5). The same results can be obtained for both heavy and light industries as shown in models (2) and (3). The elasticity of oil imports on heavy and light industries is greater than unity, which implies that oil imports are elastic with respect to the value-added of both heavy and light industries. This confirms that China's industrialization will be a driving force for energy consumption, and hence demand for energy imports.

Third, domestic energy production has a strong substitution effects on oil imports,

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[13] BP (2005). BP statistical review of world energy, June, 2005, p14.

especially for oil and coal outputs. The coefficients of total energy output in all models except (9) are significantly negative, although their magnitudes are different. This implies that the increase of China's total energy output is a substitute for oil imports and therefore reduces China's dependence on oversea oil sources. The failure of the cointegration tests to identify long-run relationships between oil imports and domestic natural gas or hydroelectricity reported in Table 10 suggests that the increase in natural and hydroelectricity output could not weaken oil imports. This result may be due to the fact that the shares of natural gas and hydroelectricity in total energy consumption are too small (about 10% together) to affect oil imports. For domestic output of coal and oil, the substitution effects also exist in the long run, although the magnitude is different (-9.49 for oil and -0.63 for coal). The coefficient of coal output is less than unity which suggests that coal has limit substitution effects for oil and the share of coal in total energy consumption is declining due to China's pro-clean energy policies.

Finally, the transport sector also plays an influential role in China's oil imports. As showed in models (8) and (9) reported in Table 11, the coefficients of total freight traffic and passenger traffic are 1.92 and 3.60, with both being statistically significant. Since all variables are in log forms, these two coefficients can be seen as the elasticity of oil import demand with respect to traffic volume. The results imply that rapid expansion of China's transport sector has contributed to the rise in oil imports. This conclusion is confirmed by Skeer and Wang (2006b). They argue that increase in the transport sector will result in dramatic oil imports and hence push the world oil prices to increase in 2020.

6. Implications for Sino-Australia Energy Trade

Trade between China and Australia has grown dramatically since the late 1990s (Figure 3). During 1992-2004, for example, China's imports from and exports to Australia increased by about 7 and 13 times, respectively. The major exports of Australia to China are agricultural, mineral and energy products (eg. iron ore, wool, crude petroleum and copper ores), and imports from China are manufacture goods (eg. computers, toys, telecommunication equipment, clothing and textile fabrics).[14] The trade structure between the two countries is mainly complementary. As for energy trade between China and Australia, crude oil and natural gas may be the focus in the coming decades. As shown in Table 12, Australia's crude oil exports to China increased dramatically since the mid 1990s, while imports remained constant at around 2 million tones. Although the share of Australia's oil in China's total oil imports is relatively small (i.e. about 1.96% in 2003), there is great potential for expansion.

<Insert Figure 3 here>

<Insert Table 12 here>

According to a projection by ABARE (2005), liquefied natural gas (LNG) is expected to be Australia's fastest growing energy export in the long run. Australia's LNG

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[14] Australia Department of Foreign Affairs & Trade (2006). Composition of trade Australia 2005, May 2006.

exports will increase to 19 million tons in the mid term to 2019-20, and 62 million tons in the long term to 2029-30, implying an average growth rate of 8.2 per cent a year.[15] The share of LNG exports in Australia's total production is projected to increase from 29% currently to almost two-thirds by 2029-30. China, as a big potential buyer, will likely be one of Australia's most important exporting markets. Apart from the macro-economic issues discussed in the preceding section, the realization of China-Australia energy trade potential will however be affected by several other factors such as the political relationship and trade liberalization between the two countries.

A mature China-Australia political relationship is the precondition for sustained development of energy trade between the two countries. Although the political relationship between the two countries was disrupted due to differences in ideology and political systems in the past, China and Australia have now entered into a period of pragmatism (Jia and Zhong, 2005). Leaders' frequent summits and deepening economic relationship indicate the positive development and maturity of bilateral political relationship between the two countries. Jia and Zhong (2005) argued that the expanding shared interests, convergence of value and increasing pragmatism underpinned the increasingly intimate political ties between the two countries. Closer political relationship, in turn, facilitates further economic and trade cooperation between the two countries. As to the energy sector, China has signed several contracts

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[15] See ABARE (2005). Australian Energy, national and state projections to 2029-30, p43.

to buy Australian LNG and an agreement to import Australian uranium for the production of nuclear energy.[16] Although a closer and stable political relationship between China and Australia is likely to continue, there are some challenges ahead. Examples include the uncertainty of Australia's policy towards China-US relations and Australia's role in potential cross Taiwan Strait conflicts.

<insert Table 13 here>

In addition, further trade and investment liberalization underpinned by the likelihood of China-Australia free trade agreement (CAFTA) will push the energy trade between the two countries to grow faster. Despite of the low tariff barriers of mineral and energy trade between two countries (Table 13), removal of a variety of non-tariff barriers (i.e., standards and technical regulations, quarantine administration, customs administration and valuation, transparency of administration and appeal and dispute resolution, and intellectual property rights) and investment liberalization will deepen the China-Australia energy co-operation. Resources exploration is one of the major areas of investment between China and Australia. Australia is one of the world's leading countries in developing and providing mining technology services (MTS), with over 60 per cent of world's mining operation utilizing software developed by Australian companies.[17] Since China's government is making efforts to meet the higher safety standards and stricter environmental conditions, liberalization of barriers to MTS provision through FTA will benefit both countries. Moreover, simplification of investment provisions in mining sector under a possible FTA would promote

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[16] Xinhua News Agency (2006). China, Australia Sign Nuclear Energy Agreements, April 4, 2006. http://english.China.com/zh_cn/business/energy/11025895/20060404/13219363.html.

[17] DFAT (2005). ACFTA Joint feasibility study, March 2005, p83.

further cooperation and thus facilitate energy trade. But it should be noticed that the free trade between the two countries may involve great benefits as well as losses for various groups in both countries. Therefore, the losers associated with economic liberalization may be against free trade. For example, the interests of oil producers in China may be threatened by the relatively lower price of oil in the international market. The redistribution of benefits in both countries may be needed to reduce the adjustment cost due to free trade.

7. Conclusions

Sustained economic growth in China induced a surge of energy consumption as well as energy imports. This paper analyzes the determinants of China's energy import demand (i.e., oil) by using cointegraiton and VECM techniques. It is found that international oil price is not a major determinant in China's oil imports. The unstable relationship between oil price and imports confirms that China is a "large country" in the international market and its trade behavior thus can influence the international price. It is also shown that strong growth in industrial production is a key contributor to China's oil imports. Both heavy industry and light industry outputs are significant factors affecting oil imports. China's continued industrialization will result in continuous growth in energy imports in the coming decades. This study also demonstrates that domestic energy production, especially oil and coal outputs, has a strong substitution effect on oil imports. Finally, expansion of the transport sector also seems to play an influential role in China's oil imports. With advancement of urbanization in China, considerable energy demand in the transport sector would further boost China's oil imports.

This study also discussed the implication of China's oil import demand for China-Australia bilateral energy trade. Australia has rich mineral and energy recourses as well as advanced mining technology services (MTS). Given China's current growth momentum, further expansion in Australia's exports of resources and energy commodities to China can be anticipated. Although there is likely a bright future for energy cooperation between the two countries, the realization of the potential benefits may be affected by other factors. For example, a mature political relationship between two countries can provide a foundation for further economic and energy cooperation. In addition, the liberalization of trade and investment underpinned by the ongoing negotiation of China-Australia free trade agreement (CAFTA) would deepen the energy relationship and widen the areas of cooperation.

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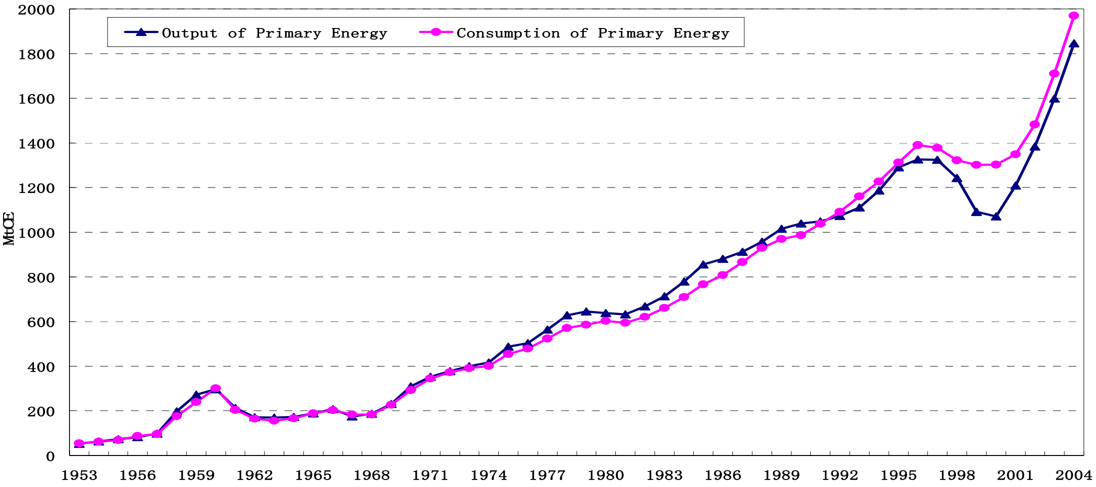
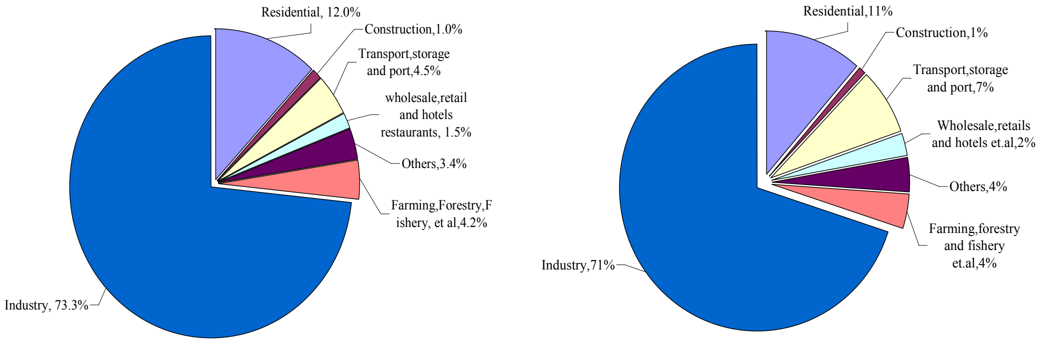


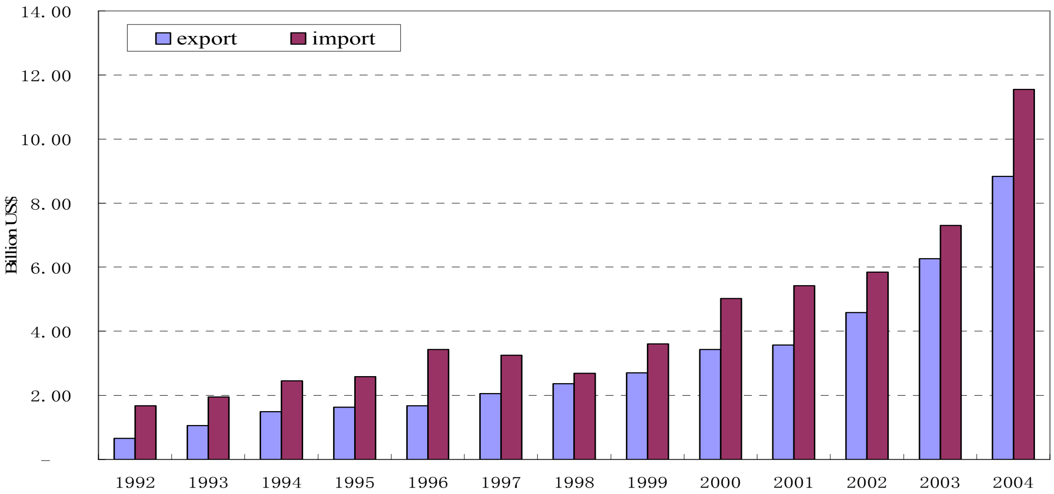
Source: CEI database.

Figure 1 Total primary energy output and consumption in China, 1953-2004.



Source: National Bureau of Statistics, 2005.

Figure 2 Primary energy consumption by sector, 1995 (left) and 2003 (right).



Source: United Nations Comtrade database.

Figure 3 China's commodities export to and import from Australia.

Table 1 China total production of energy and its composition (1995-2004)

Year	Total Energy Production (10 000 tones of SCE)	As Per centage of Total Energy Production (%) Coal	Crude Oil	Natural Gas	Hydro-power
1995	129034	75.3	16.6	1.9	6.2
1996	132616	75.2	17.0	2.0	5.8
1997	132410	74.1	17.3	2.1	6.5
1998	124250	71.9	18.5	2.5	7.1
1999	109126	68.3	21.0	3.1	7.6
2000	106988	66.6	21.8	3.4	8.2
2001	120900	68.6	19.4	3.3	8.7
2002	138369	71.2	17.3	3.1	8.4
2003	159912	74.5	15.1	2.9	7.5
2004	184600	75.6	13.5	3.0	7.9

Notes: Growth rate is from author's calculation.

Source: National Bureau of Statistics, 2005.

Table 2 China's production, consumption and trade of crude oil (1995-2004) (Million tones)

							Annul growth rate (%)	
Year	1995	2000	2001	2002	2003	2004	95-04	00-04
Production	149.0	162.6	164.8	166.9	169.6	174.5	1.77	1.78
Consumption	160.7	230.1	232.2	246.9	266.4	308.6	7.52	7.61
Import	17.1	70.3	60.3	69.4	91.0	122.7	24.49	14.96
Export	48.85	10.31	7.55	7.21	8.13	5.49	-21.56	-14.58

Notes: Growth rate is from author's calculation.

Source: BP Statistical review of world energy, June, 2005; State Custom Administration, P. R. China.

Table 3 Outputs of some high energy intensity goods in China (1995-2004) (Million tones)

	1995	2000	2001	2002	2003	2004	Average annual growth rate (%)	
Products							1995-2000	2000-04
Crude Steel	95.36	128.50	151.63	182.37	222.34	272.80	6.15	20.71
Rolled Steel	89.80	131.46	160.68	192.52	241.08	297.23	7.92	22.62
Cement	475.61	597.00	661.04	725.00	862.08	970.00	4.65	12.90
Ethylene	2.40	4.70	4.81	5.43	6.12	6.27	14.38	7.45
Soda Ash	5.98	8.34	9.14	10.33	11.34	13.02	6.89	11.79
Caustic Soda	5.32	6.68	7.88	8.78	9.45	10.60	4.66	12.25

Notes: Growth rate is from author's calculation.

Source: National Bureau of Statistics, 2005.

Table 4 Number of civil Vehicles and civil aircrafts (1990-2004) (10000 units)

Year	1990	1995	2000	2004	Absolute growth (units) 90-95	95-00	00-04
total vehicles	551.36	1040.00	1608.91	2693.71	488.64	568.91	1084.80
passenger vehicles	162.19	417.90	853.73	1735.91	255.71	435.83	882.18
trunks	368.48	585.43	716.32	893.00	216.95	130.89	176.68
civil aircrafts	499.00	852.00	982.00	1245.00	353.00	130.00	263.00

Notes: Growth is from author's calculation.

Source: National Bureau of Statistics, 2003, 2005.

Table 5 Composition of total passenger traffic (1990-2004) (billion passenger-km)

Year	1990	1995	2000	2004	Average annual growth (%) 1990-1995	1995-2004
Total	562.8 (100.0%)	900.2 (100.0%)	1226.1 (100.0%)	1630.9 (100.0%)	9.85	6.83
Railways	261.3 (46.4%)	354.6 (39.4%)	453.3 (37.0%)	571.2 (35.0%)	6.30	5.44
Highways	262.0 (46.6%)	460.3 (51.1%)	665.7 (54.3%)	874.8 (53.6%)	11.93	7.40
Waterways	16.5 (2.9%)	17.2 (1.9%)	10.1 (0.8%)	6.6 (0.4%)	0.82	-10.04
Civil aviation	23.0 (4.1%)	68.1 (7.6%)	97.1 (7.9%)	178.2 (10.9%)	24.21	11.28

Notes: the per centage shares are reported in the parenthesis and Growth rate is from author's calculation.

Source: National Bureau of Statistics, 2005.

Table 6 Composition of total freight traffic (1990-2004) (billion tone-km)

Year	1990	1995	2000	2004	Average annual growth (%) 1990-1995	1995-2004
Total	2620.7 (100.0%)	3590.9 (100.0%)	4432.1 (100.0%)	6944.5 (100.0%)	6.50	7.60
Railways	1062.2 (40.5%)	1305.0 (36.3%)	1377.1 (31.1%)	1928.9 (27.8%)	4.20	4.44
Highways	335.8 (12.8%)	469.5 (13.1%)	612.9 (13.8%)	784.1 (11.3%)	6.93	5.86
Waterways	1159.2 (44.2%)	1755.2 (48.9%)	2373.4 (53.6%)	4142.9 (59.7%)	8.65	10.01
Aviation	0.8 (0.0%)	2.2 (0.1%)	5.0 (0.1%)	7.2 (0.1%)	22.15	13.87
Oil and Gas pipelines	62.7 (2.4%)	59.0 (1.6%)	63.6 (1.4%)	81.5 (1.2%)	-1.21	3.65

Notes: the percentage shares are reported in the parenthesis and growth rate is from author's calculation.

Source: National Bureau of Statistics, 2005.

Table 7 List of Variables

Variables	Details	Observations range
Lncoimsa	Crude oil import	1995Q1-2006Q1
Lnrpoilsa	Relative price of crude oil	1995Q1-2006Q1
Lnvaisa	Value added of industry	1995Q1-2006Q1
Lnvahisa	Value added of heavy industry	1998Q1-2006Q1
Lnvalisa	Value added of light industry	1998Q1-2006Q1
Lnteopsa	Total domestic energy output	1995Q1-2006Q1
Lncoilopsa	Domestic crude oil output	1995Q1-2006Q1
Lncoalopsa	Domestic coal output	1995Q1-2006Q1
Lnngopsa	Domestic natural gas output	1995Q1-2006Q1
lnhyeopsa	Domestic hydroelectricity output	1995Q1-2006Q1
Lntvftsa	Total volume of freight traffic	1998Q3-2006Q1
Lntvptsa	Total volume of passenger traffic	1998Q3-2006Q1

Table 8 The results of ADF unit root tests (1995:Q1-2006:Q1)

	Level series		First difference series	
Variables	With intercept	With intercept and trend	Without intercept	With intercept
Lncoimsa	-1.94	-3.49*	-8.91***	-4.35***
Lnrpoilsa	0.39	-2.76	-4.82***	-3.93***
Lnvaisa	-0.77	-2.08	-1.78*	-3.50***
Lnvahisa	1.44	-1.92	-2.31**	-5.50***
Lnvalisa	2.71	-2.15	-3.41**	-5.02***
Lnteopsa	-1.25	-0.04	-2.89**	-3.14**
Lncoilopsa	1.57	-2.18	-7.75***	-9.16***
Lncoalopsa	-1.91	-0.27	-3.27***	-3.36**
Lnngopsa	0.57	-1.39	-5.02***	-6.26***
lnhyeopsa	2.23	-1.68	-3.19***	-4.09***
Lntvftsa	-0.76	-2.89	-2.18**	-4.09***
Lntvptsa	-0.91	-2.75	-7.17***	-7.55***

Notes: a. ***, **, * means to reject the null hypothesis of a unit root at 1%, 5% and 10% critical value, respectively. The sample ranges of Lnvahisa and Lnvalisa are from 1998:Q1 through 2006:Q1; and Lntvftsa and Lntvptsa range from 1998:Q3 to 2006:Q1. b. the selection of the lags is based on the Akaike's information criterion (AIC) and Schwarz information criterion (SIC).

Table 9 Variables grouping

Group number	Variables	Sample Range
1	Lncoimsa, Lnrpoilsa, Lnteopsa, Lnvaisa	1995Q1-2006Q1
2	Lncoimsa, Lnrpoilsa, Lnteopsa, Lnvahisa	1998Q1-2006Q1
3	Lncoimsa, Lnrpoilsa, Lnteopsa,Lnvalisa	1998Q1-2006Q1
4	Lncoimsa, Lnrpoilsa, Lncruoilopsa, Lnvaisa	1995Q1-2006Q1
5	Lncoimsa, Lnrpoilsa, Lncoalopsa, Lnvaisa	1995Q1-2006Q1
6	Lncoimsa, Lnrpoilsa, Lnngopsa, Lnvaisa	1995Q1-2006Q1
7	Lncoimsa, Lnrpoilsa, Lnhyeopsa, Lnvaisa	1995Q1-2006Q1
8	Lncoimsa, Lnrpoilsa, Lnteopsa, Lntvftsa	1998Q3-2006Q1
9	Lncoimsa, Lnrpoilsa, Lnteopsa, Lntvptsa	1998Q3-2006Q1

Table 10 Results of Johansen & Juliusen Cointegration Test

	Trace test						Maximum eigenvalues test				
VAR^a	Lag^b	H_0	H_1	Trace Statistic λ_{trace}	5% critical value^c	Prob.	H_0	H_1	Max-Eigen Statistic $\lambda_{\max}$	5% critical value^c	Prob.
(1)	4	r=0	r=1	65.175***	47.856	0.001	r=0	r≥1	40.077***	27.584	0.001
		r≤1	r=2	25.098	29.797	0.158	r=1	r≥2	16.260	21.132	0.210
		r≤2	r=3	8.838	15.495	0.381	r=2	r≥3	5.869	14.265	0.630
(2)	2	r=0	r=1	63.980***	47.856	0.001	r=0	r≥1	31.135**	27.584	0.017
		r≤1	r=2	32.845**	29.797	0.022	r=1	r≥2	18.970*	21.132	0.098
		r≤2	r=3	13.875*	15.495	0.086	r=2	r≥3	13.454*	14.265	0.067
(3)	2	r=0	r=1	58.186***	47.856	0.004	r=0	r≥1	30.687***	27.584	0.019
		r≤1	r=2	27.500*	29.797	0.090	r=1	r≥2	15.539	21.132	0.253
		r≤2	r=3	11.961	15.495	0.159	r=2	r≥3	11.819	14.265	0.118
(4)	1	r=0	r=1	64.153***	47.856	0.001	r=0	r≥1	36.719***	27.584	0.003
		r≤1	r=2	27.434*	29.797	0.092	r=1	r≥2	12.882	21.132	0.463
		r≤2	r=3	14.552*	15.495	0.069	r=2	r≥3	10.136	14.265	0.203
(5)	4	r=0	r=1	66.664***	47.856	0.000	r=0	r≥1	42.381***	27.584	0.000
		r≤1	r=2	24.283	29.797	0.189	r=1	r≥2	16.260	21.132	0.210
		r≤2	r=3	8.023	15.495	0.463	r=2	r≥3	5.096	14.265	0.730
(6)	2	r=0	r=1	42.006	47.856	0.159	r=0	r≥1	17.968	27.584	0.498
		r≤1	r=2	24.038	29.797	0.199	r=1	r≥2	11.955	21.132	0.552
		r≤2	r=3	12.083	15.495	0.153	r=2	r≥3	9.681	14.265	0.234
(7)	1	r=0	r=1	50.759**	47.856	0.026	r=0	r≥1	24.396	27.584	0.122
		r≤1	r=2	26.363	29.797	0.118	r=1	r≥2	15.056	21.132	0.285
		r≤2	r=3	11.307	15.495	0.193	r=2	r≥3	9.110	14.265	0.277
(8)	4	r=0	r=1	77.205***	47.856	0.000	r=0	r≥1	51.320***	27.584	0.000
		r≤1	r=2	25.885	29.797	0.132	r=1	r≥2	15.450	21.132	0.259
		r≤2	r=3	10.436	15.495	0.249	r=2	r≥3	10.382	14.265	0.188
(9)	2	r=0	r=1	67.583***	47.856	0.000	r=0	r≥1	37.826***	27.584	0.002
		r≤1	r=2	29.757*	29.797	0.051	r=1	r≥2	15.719	21.132	0.242
		r≤2	r=3	14.039*	15.495	0.082	r=2	r≥3	13.350*	14.265	0.069

Notes: The vector autoregression (VAR) models (1)-(9) are corresponding to the 9 groups listed in Table 9 and r represents the number of cointegrating vectors. The lag length in each model is identified by both Akaike's information criterion (AIC) and Schwarz information criterion (SIC). The critical values are drawn from Osterwald-Lenum (1992). ***,** and * indicate significance at the level of 1%, 5% and 10%, respectively.

Table 11 Long-run equilibrium relationship from VCEMs

Dependent variables	Lncoimsa						
Models	(1) 95Q1-06Q1	(2) 98Q1-06Q1	(3) 98Q1-06Q1	(4) 95Q1-06Q1	(5) 95Q1-06Q1	(8) 98Q3-06Q1	(9) 98Q3-06Q1
C	12.43	32.73	65.61	80.43	9.56	-2.19	-15.53
Lnrpoilsa	0.58***	0.17	-0.37	0.81***	0.51***	0.19	-0.38
	(3.36)	(1.07)	(-1.14)	(2.72)	(3.13)	(1.00)	(-1.20)
Lnvaisa	1.01***			1.23***	0.89***		
	(4.35)			(2.93)	(4.26)		
Lnvahisa		2.76***					
		(7.55)					
Lnvalisa			7.28***				
			(6.37)				
Lnteopsa	-0.96***	-3.49***	-8.08***			-0.83***	-0.57
	(-4.64)	(-6.49)	(-6.05)			-3.70	(-1.52)
Lncoilopsa				-9.49***			
				(-3.01)			
Lncoalopsa					-0.63***		
					(-5.21)		
Lntvftsa						1.92***	
						(4.92)	
Lntvptsa							3.60***
							(6.64)

Notes: The long run cointegration relationship reported in this table is extracted from each of the vector error correction models (VECMs). The subscripts (t-1) for all variables are dropped. The t-statistics are reported in the parenthesis. ***, ** and * indicate significance at the level of 1%, 5% and 10%, respectively.

Table 12 China's crude oil trade with Australia (1996-2003) (Thousand tones)

Year	1996	1997	1998	1999	2000	2001	2002	2003	annual growth rate 1996-2003
import	188.16	325.49	353.86	901.04	1108.40	709.12	1156.44	1779.94	37.85%
export	163.54	170.41	306.49	262.63	224.31	145.51	204.28	221.53	4.43%
net import	24.62	155.07	47.37	638.42	884.09	563.61	952.16	1558.41	80.86%

Notes: Growth rate is from author's calculation.

Source: UN Comtrade database.

Table 13 Tariffs applied to China's major mining and energy import from Australia 2004

Product	Value of import 2004 Billion US$	China's 2005 applied tariffs
Iron ores and concentrates, including roasted iron pyrites	3346	0%
Crude oil	464	0%
Coal	387	3-6%
Petroleum gases and other gaseous hydrocarbons	274	0-11%
Unwrought aluminum	261	5-7%
Manganese ores and concentrates	227	0%
Unwrought nickel	186	3%
Copper ores and concentrates	157	0%
Unwrought zinc	136	3%
Copper waste and scrap	132	1.5%

Source: China's Ministry of Finance 2005: Tariff Schedule. Cited from Australia-China Free Trade Agreement Joint Feasibility Study, DFAT, Australia, March 2005.