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DISCUSSION PAPER: 18.03
AUGUST 2018

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TECHNOLOGY DEVELOPMENT, SELF-RELIANCE, AND OIL IMPORTS IN CHINA

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Discussion Paper 18.03ISSN
1179-8823 (Online)

Technology development, self-reliance, and oil imports in China

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ABSTRACT

The objective of this study is to examine the role of technology development and self-reliance in oil production on China's oil import function from 1986 to 2014. Using the autoregressive distributed lag model (ARDL), we find that technology development reduces oil imports in the long run. However, we find oil imports to be independent from self-reliance in the long run. We also find that the country's accession to the World Trade Organization (WTO) has significantly changed the nature of the cointegrating relationship in the oil import function. Our results suggest that government should continue to bolster incentives for adopting energy-saving measures and fund research projects on viable alternatives to non-renewable energy sources such as oil. Furthermore, deregulation in oil market involving pricing and institutions (e.g. upgradation and expansion of refinery facilities, improve import-supporting logistics, etc.) is important for energy security and stable economic growth.

Key Words: Technology development; Oil production; Oil import; Cointegration; China
JEL Classifications: C32, Q40, O10, O53

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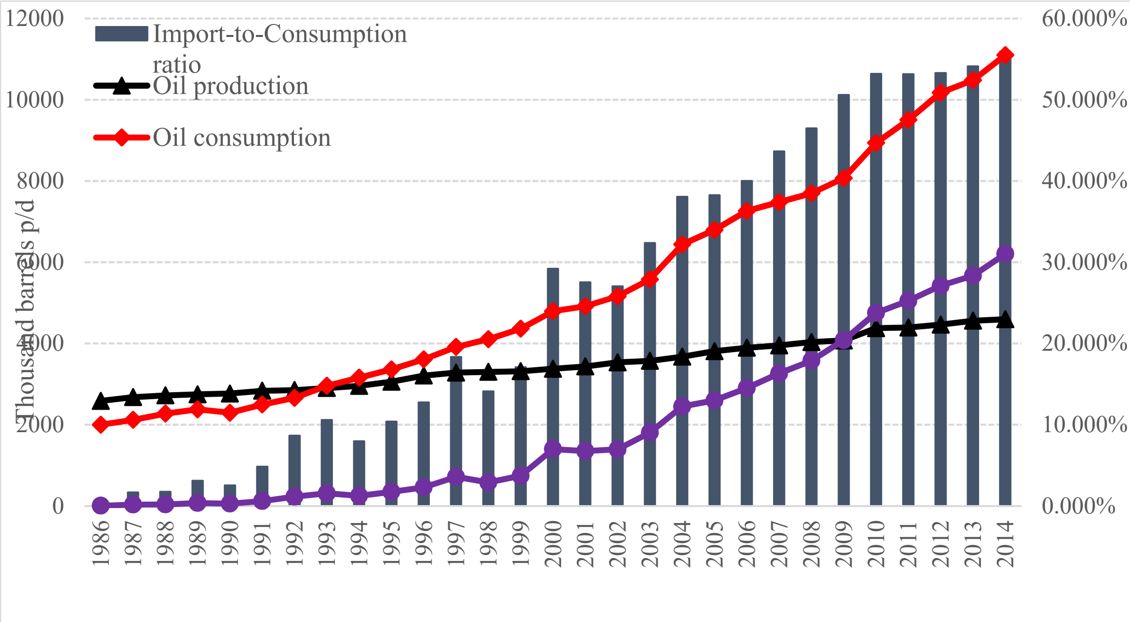
1. INTRODUCTION

China's seemingly unsatiated demand for oil since the 1990s has created a major concern over energy security in the country. To address this concern the Chinese government, for the very first time, identified the need to maintain a stable supply of oil as one of the key priorities in its 10th (2001–2005) Five-Year Plan (FYP). Currently, oil ranks behind coal as the second largest source of primary commercial energy in China. However, unlike coal for which she was a net exporter until 2009, China has started to import oil since 1993. China's dependence on imported oil can clearly be seen from Figure 1, where the import-to-consumption ratio has consistently exceeded 50% for years ensuing 2009. To put this development into perspective, in 2014 China imported an average of 6.19 million barrel per day (b/d), placing her behind the United States (US) as the world's second largest oil importer.

Figure 1: Crude oil production, consumption and importation of China, 1986-2014.



Source: The authors' own construction based on the data from EIA.

Apart from the long-run security concern, China's high dependency on oil imports became an immediate economic issue during the oil shock of 2007–2008. The supply–demand imbalance in the international oil market, coupled with wild speculations, drove the price of a barrel of the West Taxes Intermediate (WTI) crude to a historical high of US$145 in July 2008. To grasp the extent of her oil import bill, in 2014 China imported approximately US$134 billion worth of oil, or more than 10% of total merchandise imports during that year. Aware of the danger that mounting oil import bill could exert on the growth trajectory the Chinese government announced in its 12th (2011– 2015) FYP that oil imports should not exceed 61% of the total oil demand by the end of 2015 (NEA, 2013).

Despite the ambitious goals set out in her successive FYPs, it is difficult for China to formulate strategies around these goals without an in-depth understanding of her oil imports function. Whilst numerous studies on the determinants of oil imports exist in the extant literature, they have mostly focused on the case of a small open economy (see, for example, Altinay (2007) for Turkey, Ziramba (2010) for South Africa, and Kim and Baek (2013) for South Korea). Moreover, whereas the lack of oil reserves and refining capacity have forced many countries into importing oil, China's refining capacity and proven oil reserves are ranked as the fifth and thirteenth largest in the world, respectively (OPEC, 2015). Last, but not the least, her oil market, like many other markets in the country, exhibits distinct 'Chinese characteristics' found nowhere else in the world.[1] With these backdrops, an evaluation of the Chinese demand for oil imports is both warranted and timely.

In general, studies on China's oil import market have primarily focused on the effect of her huge oil demand on the global oil prices and how oil-price fluctuations affect her economic growth. In this study, we seek to broaden our current understanding by introducing two additional factors into her oil imports function; namely, technology development and self-reliance in oil production. Although these two factors have featured prominently following their initial announcement in the 10th (2001–2005) FYP, there has been no systematic assessment of their impact on China's oil imports to date. To address this apparent gap in the literature, we examine the dynamics of China's oil imports function during the 1986–2014 period. Using the autoregressive distributed lag (ARDL) model, we find a cointegrating relationship among oil imports, global oil prices, real output, technology development, and self-reliance in oil production for the entire sample period. However, we detect a change in the nature of this relationship after China's accession to the World Trade Organization (WTO). Specifically, we identify four key results pertinent to the post-WTO period: (1) the price elasticity of oil imports has changed from perfectly inelastic to relatively inelastic; (2) the magnitude of the income elasticity of oil imports has decreased; (3) technology development has reduced oil imports; and (4) self-reliance in oil production has not been achieved. We argue that while these results lend support to the success of a series of programs designed to diversify China's energy mix away from oil, her goal of realizing self-reliance in oil production remains out-of-reach to date.

The rest of this paper is organized as follows. Section 2 provides an overview of the Chinese oil market. Section 3 examines recent literature on China's demand function for oil imports. Research methodology and discussion on dataset are presented in Section 4, followed by analysis of empirical results in Section 5. Finally, concluding remarks and relevant policy implications are provided in Section 6.

2. AN OVERVIEW OF THE CHINESE OIL MARKET

2.1 The trend

In 2015 at least 17% (or 735 million tons) of coal equivalent (MtCE) emitted in China originated from burning oil. Historically, this level is consistent with the 18% share of oil reported in her annual energy consumption mix between 1986 and 2014.[2] In part, this

[1] Examples of these distinct `Chinese characteristics' in the oil market include the two-tier pricing system and two-grade distribution network, among others.

[2] The comparable figure for coal was estimated to be around 72% of the annual energy consumption mix during the 1986–2014 period.

unsatiated demand for oil *"has been strong in China since the early 1990s, driven primarily by the transportation, petrochemical, and road construction sectors as well as expanding foreign trade"* (Wu, 2014, p. 5).

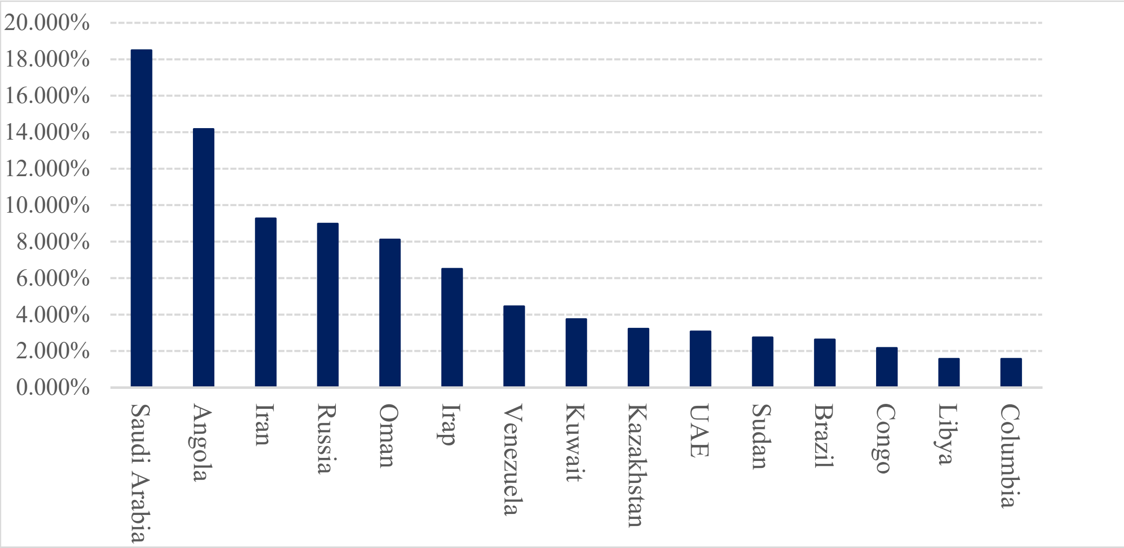
China's reliance on imported oil is a recent phenomenon that started in 1993 when she became a net oil importer (Zou and Chau, 2006). Specifically, Figure 1 shows that this trend has accelerated since 2000 when her net oil imports increased from less than 0.54 million b/d in 1998 to nearly 2.9 million b/d in 2005, and an all-time high of over 6 million b/d in 2014. To put these figures into perspective, her daily oil imports grew at an annual average of 25% during the 1986–2014 period. Many expect this trend to continue into the near future, with some predicting her import to account for about 20% of the world's oil output in 2020 (Adams and Shachmurove, 2008). In addition, the upward tendency of the import-to-consumption ratio in Figure 1 suggests that much of the gap between stagnated oil production and skyrocketing oil consumption is being filled by oil imports.

2.2 Oil production

For China, closing the apparent gap between production and consumption of oil represents a major challenge over the next five to ten years. In part, her lack of oil production can be attributed to falling production capacity in major oil fields and the shortage of energy transport infrastructure for accessing oil reserves in the western region (Zhao and Wu, 2007). Furthermore, unlike many countries facing limited refining capacity, China remains *"largely self-sufficient in producing most of the main petroleum products it needs except for fuel oil, LPG and naphtha"* (Wu, 2014, p. 5).

In terms of oil sources, Figure 2 shows that, between 2008 and 2015, nearly 20% of China's oil imports originated from Saudi Arabia (18%), followed by Angola (14%) and Iran (9%). However, Figure 2 also reveals that she mostly imported *"oil from politically unstable countries and the potentially insecure route through the Malacca Strait"* (Odgaard and Delman, 2014, p. 113). This energy security concern was formally articulated in the 10th (2001–2005) FYP, where she announced her intention to develop a stable and uninterrupted supply of oil (Wu, 2014). Following that announcement, she started to import oil from Russia via the Eastern Siberia–Pacific Ocean Oil Pipeline opened in 2011. Since then, Russia quickly rose as her fourth largest oil supplier. Meanwhile, she has continued to diversify her oil sources by constructing the Kazakhstan–China Oil Pipeline and the Myanmar–China Oil and Gas Pipeline. Despite these initiatives, Leung (2011, p. 1334) speculates that *"the contribution of these pipelines to China's energy security…is smaller than many assumed."* Indeed, Odgaard and Delman (2014, p. 113) estimate that these pipelines *"will only be able to cover about 10 percent of China's expected oil import in 2030."*

Figure 2: Crude oil import of China, by countries.



Source: The authors' own construction based on the data from GACC.

Apart from their high construction and maintenance costs, another obvious downside associated with these aforementioned pipelines is that they are prone to sabotage by China's adversaries during armed conflicts (Cao and Bluth, 2013). To minimize this risk, she has proactively encouraged her state-owned oil companies to engage in bilateral oil deals and invest in foreign oil fields. For example, Odgaard and Delman (2014) report that in 2010 her state-owned oil companies controlled shares in oil fields spreading over 20 countries, which contributed to 36% of her oil imports. Furthermore, China has used her massive foreign exchange reserves to draw up oil-for-credit agreements with Latin American countries, such as Brazil, Ecuador, and Venezuela (Kong, 2011).

China's huge appetite for oil means that diversifying oil sources and procuring foreign oil fields cannot fully protect her from unexpected, short-run fluctuations in oil supply. To address these concerns the government introduced the idea of strategic petroleum reserves (SPRs) for the first time in the 10th (2001–2005) FYP *"to meet possible oil price fluctuations and ensure the stable and sustainable growth of economy"* (Cao and Bluth, 2013, p. 386). The basic principles in establishing SPRs include setting up a two-grade energy reserve system of nation and enterprises, a two-tiered pre-warning mechanism of state and local government, and emergency response capabilities to unexpected disruptions (Cao and Bluth, 2013; Wu, 2014). The aim is to reach a total SPR capacity of about 500 million barrels by 2016 (Wu, 2014). At a rate of 6 million b/d reported for 2014, this level translates into a grace period of around 83 days during which China can operate under the business-as-usual (BAU) case without the need to import any oil. Although stockpiling SPRs is currently running behind the schedule outlined in the 11th (2006–2011) FYP the modeling has suggested that developing such a capability is indispensable to enhancing energy security towards 2030 (Li, 2003). Indeed, this point is summarized by Wu (2014, p. 10), who suggests that *"China should establish a system that SPR facilitates truly address the issue of energy security rather than just another to manage oil supply and demand in the country."*

2.3 Oil prices

Prior to 1982 China practiced self-reliance in oil production and banned oil imports outright (Cao and Bluth, 2013). It also retained full control over domestic oil prices and exported excess petroleum products to the rest of the world (Wu, 2014). Reforms in the oil prices have only begun in 1982 when *"the two-tiered pricing system was introduced in the oil sector for the purpose of phasing out subsidized prices for petroleum products"* (Hang and Tu, 2007, p. 2980). Since then, domestic oil prices were managed subject to changes in the demand–supply conditions for the most part of the 1990s, before they were allowed to follow fluctuations in the global oil prices in the early 2000s.

Despite repeated oil-price deregulations in China, anecdotal evidence point to a clear mismatch between global oil prices and her oil imports. For example, the 125%-increase in the spot price of the West Texas Intermediate (WTI) crude from 1995 to 2004 did not reduce oil imports at all; to the contrary, her oil imports grew at an annual average of 25% over this period (Zhao and Wu, 2007). Meanwhile, Zhou et al. (2010, p. 6444) find that, between 2006 and 2008, *"the Chinese government has set oil product price low compared with the price of crude oil, creating a situation that causes the government to pay large subsidies to the upstream oil industry."* These observations suggest that if the government is serious about addressing energy security in the long run, it must pursue deeper reform in the oil market, particularly in its pricing mechanism (Hang and Tu, 2007; Cao and Bluth, 2013). This call was answered in 2013 when the National Development and Reform Commission (NDRC) introduced a new oil pricing system to promote market transparency by allowing limited fluctuations in domestic oil prices around the spot oil prices in New York, Rotterdam, and Singapore. Specifically, adjustments in the retail oil prices are permitted if the price of a barrel of imported oil increased by more than US$1.10 over a 10-day period (EIA, 2015).

The weak oil-pricing mechanism in China cannot be explained by the segmentation between domestic and international oil markets alone. For example, Sinton and Fridley (2000) attribute this weak mechanism to rampant oil smuggling activities during the 1990s. Meanwhile, Zhao and Wu (2007, p. 4244) suggest that this mechanism might have been weakened by the fact that *"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."* In fact, this concern came to the forefront when a barrel of WTI crude shot up from a mere $US18 in 1995 to an all-time high of $145 in July 2008. To minimize the fallout from extreme volatility in the global spot oil prices the Chinese government started to consider establishing an oil futures market in the 10th FYP (2001–2005) and 11th (2006–2011) FYP (Zhou et al., 2010; Wu, 2014). According to the published timeline, trading in the first oil futures contract was set to commence in 2016, but the China Securities Regulatory Commission has pushed back the opening date by up to a year due to excessive speculation and concerns over the complex design of the futures contracts (Sanderson, 2016).

2.4 Energy-saving technology development

Undoubtedly, diversifying oil sources, strengthening SPRs, and deregulating oil prices represent key pillars supporting China's energy security into the future. However, these factors mostly deal with the supply side of the oil market. Since 2000 the government has repeatedly emphasized the need to establish a more efficient and sustainable oil consumption pattern towards 2020 (Odgaard and Delman, 2014). In this demand-side consideration, reducing energy intensity, which is defined as *"an overall measure of how much energy is used to produce a unit of economic output in a country or a sector"*, has received the widest attention (Sinton and Fridley, 2000, p. 684). Historically, Hang and Tu (2007) attribute China's declining energy intensity in oil consumption to the rise of oil prices and the expansion of the tertiary industry.

Whilst this decline in energy intensity is consistent with substantial changes to China's economic structure the role of the government in championing energy conservation cannot be underestimated. For example, in 2004 the NDRC released the *Medium and Long-Term Plan for Energy Conservation*, which clearly *"sets out specific targets for the industrial, transportation, and building sectors"* (Zhou et al., 2010, p. 6441). Apart from these sector-specific policies, it also revised the energy conservation law, provided in-kind supports to energy-saving measures, and identified key energy-conservation projects, among others (Cao and Bluth, 2013).

Deteriorating air quality and recurring smog in major cities in recent years have also strengthened the Chinese government's resolve to search for viable alternatives to burning oil. A case in point is the announcement of the *Top-1000 Energy-Consuming Enterprise Program*, which offers incentives for these enterprises to engage in energy-efficient technology development. These enterprises are identified as prime targets because they account for *"approximately 50% of total industrial sector energy consumption and 30% of total energy consumption in China"* (Zhou et al., 2010, p. 6446). Although it is still early days to assess the effectiveness of such initiative, past experience has shown that expenditures on technology development appeared to be a key driving forces behind declining energy intensity and oil consumption in the country during the late 1990s (Fisher-Vanden et al., 2004). Indeed, Fisher-Vanden et al. (2006, p. 690) describe the importance of technology development in enhancing energy productivity by concluding that *"whether internal or imported, however, we find technology development to exhibit an energy-saving bias. We also find that the firm's in-house technology development activities are important for creating the absorptive capacity required for the successful diffusion of imported technology."*

In summary, the Chinese oil market has undergone a series of reforms since the 1980s. From the supply side, China has started to diversify her oil sources by shifting the focus away from the Middle East to her neighboring countries. Many Chinese state-owned oil companies are also encouraged to participate in the exploration and production of foreign oil fields. To maintain self-reliance and to shield the economy from unexpected oil shocks, she has established SPRs to meet her oil needs in the short run. In terms of the demand side, China has gradually allowed retail oil prices to fluctuate with the global oil market. In part, such deregulations are designed to reduce energy intensity in oil consumption via the mediation of the price mechanism. Meanwhile, she has implemented energy-efficiency policies to reduce oil demand in certain sectors of the economy. In relation to this, generous tax concessions on energy-saving technology development are introduced to assist transition into a low-carbon future.

3. LITERATURE REVIEW

China's rise to prominence as one of the world's leading oil importers since the 1990s has attracted researchers' attention. In general, the extant literature can be divided into three main strains. The first, and most prominent, strain focuses on the extent to which the ever-growing oil demand from China might have contributed to the oil shock of 2007–2008. Krugman (2008) and Hamilton (2009) conjecture that a mismatch between huge oil demand by the emerging markets and insufficient global oil supply could have caused that oil shock. Applying Kaufmann's et al. (2004) oil-pricing rule to the Chinese and Indian data, Li and Lin (2011, p. 4629) find supporting evidence for the demand-led shock hypothesis and conclude the *"Chindia (combined China and India) factor as an additional driver in the long-run relationship from August 2003 to March 2010."* Rafiq et al. (2014) also reach to similar conclusion. However, Li and Lin (2011) caution against over-interpreting the "Chindia" factor as they cover a relatively short period of time and combine the Chinese and Indian data together in the analysis. To isolate the effect of the 'China factor' on the global oil price, Beirne et al. (2013) examine only the Chinese data over the period 1965 and 2011. To overcome the limitations posed by the deterministic oil-pricing rule, they apply a two-stage model to analyze the oil imports–oil price nexus by, firstly, estimating China's oil imports function, before inserting it into the world aggregate price demand function. They report that *"this 'China factor' lies around 1.00% of the price in 2011 and rises to approximately 3 and 4% of the price in 2030"*, or as they put it differently, *"the annual cost of China's growth could be as high as some US$300 bn in 2030 in constant 2010 US$"* (Beirne et al., 2013, p. 38).

For Beirne et al. (2013), a major contributing factor to China's unsatiated oil demand lies in her low efficiency in oil consumption. This is particularly relevant to the country's rapidly expanding, but notoriously inefficient, transport sector. Indeed, the simulations by Skeer and Wang (2007, p. 678) show that, if left unmanaged, the oil demand emanating from that sector alone can raise the global oil price *"by 3–10% if oil supply investment in constrained"* over the period 2002 to 2020. From a different perspective, Ratti and Vespignani (2013) investigate the spillover effect of an unexpected change in liquidity on real oil prices for China, Eurozone, Japan, and the US. Using the growth rate of real M2 as a measure of a liquidity shock in a structural vector autoregression (VAR) model, they find that *"increased liquidity in China relative to that in the US, Eurozone and Japan significantly raises real oil prices over 1996:1–2011:12"* (Ratti and Vespignani, 2013, p. 524).

However, not everyone prescribes to this so-called 'China factor' hypothesis when explaining the oil shock of 2007–2008. For example, Mu and Ye (2011) analyze the Chinese data from January 1997 to June 2010 and find that the 'China factor' only contributed marginally to the oil-price hikes in the early 2000s. Furthermore, since they cannot establish Granger causality between changes in China's oil imports and fluctuations in the global oil prices, they *"cast doubt on the popular view that the demand growth from China is the predominant reason for* *the dramatic oil price increase between 2002 and 2008"* (Mu and Ye, 2011, p. 90). Similarly, Wu and Zhang (2014) examine the data spanning over October 2005 to November 2013 in the Toda–Yamamoto (1995) augmented VAR model and detect no discernable patterns on the oil imports–oil price nexus in China. Instead, they suggest that speculations over the US dollar exchange rate might have been the culprit causing the historical high oil price in 2008 and conclude that *"the blame for China's huge crude oil imports to cause sharp volatility of international crude oil price has no solid evidence"* (Wu and Zhang, 2014, p. 84).

The second strain of the research focuses on the relationship between output growth and oil consumption in China. For example, Zou and Chau (2006) find a long-run cointegrating relationship between output growth and oil consumption when applied the vector error-correction model (VECM) to the Chinese data spanning over 1985–2002. Importantly, they conclude that *"oil consumption could be thought of as a leading factor of the economy in the short run as well as in the long run"* (Zou and Chau, 2006, p. 3654). Meanwhile, using similar techniques to examine the period between 1995 and 2004, Zhao and Wu (2007, p.4245) suggest that *"both heavy industry and light industry outputs are significant factors affecting oil imports."* From the perspective of monetary policy, Ratti and Vespignani (2013) find that rising industrial production can amplify the effect of the liquidity shock in China on the global oil prices. However, Hölscher et al. (2008) warn that this significant output growth–oil consumption nexus may be a statistical artifact associated with China's fixed exchange rate regime at the time. Instead, they argue that *"a far more superior conversion is to use PPP adjustments but this statistic is at present not sufficiently developed in the Chinese economy to insure consistency"* (Hölscher et al., 2008, p. 67). In relation to this, increases in output need not always induce rises in oil consumption. For example, Hang and Tu (2007, p. 2986) identify that *"the growth of tertiary industry also contributed to China's declining energy intensity"* during the 1985–2004 period.

Another focus on this output growth–oil consumption nexus emphasizes on predicting future oil demand in China. Using an integrated econometric model consisting of macroeconomic, energy, and environment sub-models, Li (2003, p. 1146) forecasts that if China were to grow at 7% per annum, then by 2030 she will need to import oil with *"the share of import-dependence to go up to some 76%."* Meanwhile, Crompton and Wu (2005) construct a Bayesian VAR model and predict that her oil consumption must be growing at an annual average of 4.5% to sustain a modest growth rate of 7–8 % per annum over the forecasted period 2004–2010. Instead, if China were to grow at 5.6% each year, Adams and Shachmurove (2008, p. 1277) estimate that the *"Chinese petroleum imports in 2020 are likely to amount to almost 12 million b/d, almost 20% of world imports at that time."* In short, while these mixed forecasts largely reflect different assumptions over the rate of motorization, sectoral shifts, and energy efficiency, they prove to be fairly accurate to date.

The final strain of the research relates to the effect of technology development on oil consumption in China. This nascent line of inquiry mainly stems from the criticism that the successful roll out of energy-saving technology is expected to significantly reduce her oil consumption, particularly from the industry and transport sectors. For example, after examining the data on 2500 energy-intensive industrial enterprises between 1997 and 1999, Fisher-Vanden et al. (2004, p. 77) suggest that expenditures on such technology *"emerge as* *the principle drivers of China's declining energy intensity and use."* Using the same dataset, Fisher-Vanden et al. (2006, p. 701) consider the effects of internal and imported technology on energy intensity and find *"internal technology development to be important for the absorption of foreign technology transferred through FDI or mediated through the market."* Taken these results together the government should incentivize the indigenous firms to develop energy-saving capability as such capability generates the synergy required to curtail the unsustainable growth in the country's oil demand.

Overall, our review of the extant literature reveals that the rise of China has made an indelible impression on the global oil market. The debate on the effect of the 'China factor' on the global oil prices remains an open empirical question. However, it is beyond reasonable doubt that her oil demand will continue to expand in the near future. We have also seen that the pace of this expansion will crucially depend on the growth rate of her output level and how successful she adapts to energy-saving technology. Last, but not the least, we have identified domestic oil production, including the establishment of SPRs, as another key determinant affecting her demand for oil imports.

4. RESEARCH DESIGN

4.1 Methodology

Based on the review of her oil market and recent literature, China's oil imports function can be specified as follows:

$$m_t = \alpha_0 + \alpha_1 p_t + \alpha_2 y_t + \alpha_3 r_t + \alpha_4 s_t + \varepsilon_t \tag{1}$$

where m_t is the quantity of oil imports, p_t is the benchmark of real oil price, y_t is the size of real output, r_t is the level of energy-saving technology development, s_t is the capacity of self-reliance in oil production, and ε_t is the stochastic error term. Since all variables in Equation (1) are stated in their natural logarithms the estimated coefficients can be interpreted as elasticities. Although the law of demand predicts a negative coefficient for the oil price the empirical evidence suggests that the sign of α_1 remains indeterminate. Given that a rise in the real output raises the derived demand for petroleum products the sign of α_2 is expected to be positive. In contrast, the sign of α_3 should be negative as energy-saving technology development moderates the demand for oil imports. Finally, an enhancement to self-reliance in oil production reduces need to import oil, leading to a negative sign for α_4.

In estimating Equation (1), we introduce two novelties. The first relates to technology development for which relevant and reliable measures are not available in China. Consequently, environmental economists often gauge the level of technology development in China by observing the expenditures and workforce devoted to research and development (R&D) or the number of scientific research papers and registered patents. However, neither approach completely captures the interactions between input (expenditures and workforce) and output (papers and patents) sides of technology development. To capture these input-output interactions, we use the success rate of patent applications, or the ratio of the number of patents granted (output) to the number of patent applications (input), as the proxy for technology development. Logically, higher success rates reflect more commercialization of basic research, and thus, better realization of technology development. Meanwhile, the second novelty stems from measuring the capacity of self-reliance in oil production. In energy economics, although either proven oil reserves or domestic refining capacity is frequently used as the proxy for such capacity, neither captures the input-output interactions in domestic oil production. With this in mind, we propose a self-reliance index, which is defined as the ratio of the volume of proven oil reserves (input) to the daily refining capacity (output), with higher ratios representing greater self-reliance in oil production.

In examining the long-run relationship and short-run dynamics in China's oil imports function, we apply the bounds testing procedure to the following ARDL representation derived from Equation (1):

$$\begin{aligned}\Delta m_t = \beta_0 &+ \sum_{i=1}^{m}\beta_{1i}\Delta m_{t-i} + \sum_{i=1}^{m}\beta_{2i}\Delta p_{t-i} + \sum_{i=1}^{m}\beta_{3i}\Delta y_{t-i} + \sum_{i=1}^{m}\beta_{4i}\Delta r_{t-i} + \sum_{i=1}^{m}\beta_{5i}\Delta s_{t-i} \\ &+\lambda_1 m_{t-1} + \lambda_2 p_{t-1} + \lambda_3 y_{t-1} + \lambda_4 r_{t-1} + \lambda_5 s_{t-1} + v_t\end{aligned} \qquad (2)$$

We have chosen the ARDL representation because simulations have shown that its long-run and short-run coefficients are consistent even when the sample size is small (Pesaran and Shin, 1998; Pesaran et al., 2001). Given the small sample size in our study, such property ensures valid hypothesis testing based on standard normal asymptotic theory. Furthermore, unlike conventional cointegration tests, which require the regressors to share the same order of integration, the ARDL representation remains applicable when the model contains regressors with mixed order of integration (Altinay, 2007; Ghosh, 2009; Liu, 2009; Kim and Baek, 2013). Finally, the ARDL representation mitigates common problems, such as endogeneity and invalid hypothesis testing, surrounding conventional cointegration tests (Ang, 2009; Halicioglu, 2009).

In essence, the bounds testing procedure involves testing the null hypothesis of no cointegration $\left(H_0 : \lambda_1 = \ldots = \lambda_5 = 0\right)$ against the alternative hypothesis of cointegration $\left(H_1 : \lambda_1 \neq \ldots \neq \lambda_5 \neq 0\right)$ in Eq. (2). Pesaran et al. (2001) show that the *F*-statistic used in this joint significance test follows a non-standard distribution and report the upper and lower critical values for a given level of significance.[3] As expected, cointegration exists in Equation (2) if the *F*-statistic exceeds the upper critical bounds value. In contrast, the null hypothesis cannot be rejected if the *F*-statistic falls below the lower critical bounds value. However, the test becomes indeterminate if the *F*-statistic lies between the upper and lower bounds.[4] To avoid such outcome, this study extracts the critical values computed by Narayan (2005), which are

[3] The key difference between the upper and lower asymptotic critical values is that the former assumes all regressors are $I(1)$, whereas the latter assumes all regressors are $I(0)$.
[4] In the case of an inconclusive test, Ghosh (2009) suggests that one should check the order of integration of the regressors and consider the multivariate cointegration procedure proposed by Johansen and Juselius (1990).

designed for the small sample size in this study.[5] Furthermore, a battery of diagnostic tests is conducted to ascertain the most appropriate lag structure for regressor in Equation (2).

Having established cointegration in the first stage of the bounds testing procedure the second stage involves examining parameter stability in Equation (2) of the error-correction model (ECM). Engle and Granger (1987) suggest that such examination is necessary to avoid any misleading VAR estimation in first differences arising from cointegrated series in Eq. (2).[6] As such, we transform Eq. (2) into the Granger-type causality test model with a one-period lagged error-correction term $\left(ECT_{t-1}\right)$:

$$\begin{aligned}\Delta m_t = \gamma_0 &+ \sum_{i=0}^{m}\gamma_{1i}\Delta m_{t-i} + \sum_{i=0}^{m}\gamma_{2i}\Delta p_{t-i} + \sum_{i=0}^{m}\gamma_{3i}\Delta y_{t-i} + \sum_{i=0}^{m}\gamma_{4i}\Delta r_{t-i} + \sum_{i=0}^{m}\gamma_{5i}\Delta s_{t-i} \\ &+\phi ECT_{t-1} + \mu_t\end{aligned} \tag{3}$$

where ϕ denotes the speed of adjustment towards the long-run equilibrium and *ECT* represents the residuals obtained from the cointegrating vectors of Eq. (2). Finally, we follow Engle and Granger (1987) and obtain the long-run causal effects by conducting a *t*-test on the coefficient of *ETC*, with the null hypothesis of no Granger causality $\left(H_0 : \phi = 0\right)$.

4.2 Data

The dataset used in this study is compiled from multiple sources and contains annual observations covering the 1986–2014 period. Specifically, the real output series is calculated by dividing nominal GDP with consumer price index, both of which are available from the *China Statistical Yearbook* (CSY). The same source is used to obtain the series on patent applications and patent granted. The data on oil imports, proven oil reserves, and daily refining capacity for China are acquired from Energy Information Administration (EIA). Finally, the *BP Statistical Review of World Energy* (2015) provides the yearly average oil price benchmarks. Since China imports more than 50% of her oil from the Middle East and mostly engages in spot transactions, we select the Global Dubai oil price as the main oil-price benchmark in the analysis. However, one may speculate that the findings are sensitive to the chosen benchmark. To settle this speculation, we also consider another commonly used global oil price benchmark, the Brent oil price, in this study. Given the strong co-movement patterns between these two benchmarks, we expect our main findings to remain robust irrespective of the benchmark (Fattouh, 2010; Reboredo, 2011).[7] In passing note, given that these oil price benchmarks are

[5] Narayan (2005) reports two sets of critical values (with and without a time trend) for a sample size consisting of 30 to 80 observations.

[6] If there is no evidence of cointegration between regressors in Eq. (2), then the specification of the Granger causality test will be a simple VAR in first difference form (Liu, 2009).

[7] Two basic physical properties that determine crude quality are known as API (American Petroleum Institute) gravity and sulphur content. Lower gravity, or the light crude, usually yields a higher proportion of valuable final petroleum products, such as gasoline and diesel. Sulphur, a naturally occurring element in crude oil, is an undesirable property that requires heavy investment by the refiners to remove it. The Brent is a combination of crude oil from different fields located in the North Sea, with the API gravity of 38.3° and 0.37% of sulphur. Meanwhile, Global Dubai is the main benchmark for oil exports from the Middle East to Asia, with the API gravity of 32° and 2% of sulphur. Based on these properties, Global Dubai is considered as a 'heavy variety' in the global oil market (Fattouh, 2010).

denominated in the US dollar, we convert them into their Chinese currency equivalent (RMB) to maintain consistency in our analysis.[8] Table 1 provides the summary statistics for the variables in Equation (1).

Table 1: Summary statistics, by variable.

Variable	Mean	Median	Max.	Min.	S.D.
m	6.585	7.210	8.733	1.937	1.823
y	28.567	28.463	29.981	27.328	0.859
p_1	5.502	5.431	6.510	4.361	0.696
p_2	5.577	5.500	5.500	4.458	0.667
r	-0.683	-0.611	-0.218	-1.812	0.303
s	8.624	8.616	9.297	7.817	0.536

Note: m is the quantity of oil imports. y_t is the size of real output. p_1 and p_2 denote the Global Dubai and Brent oil price, respectively. r_t is the level of energy-saving technology development. s_t is the volume of domestic oil production capability. All variables are stated in logarithm.

Although the bounds testing procedure places no restrictions on the order of integration for the selected variables, we still conduct the Clemente-Montane-Reyes (CMR) detrended structural break unit root test to ensure that none of our variables are integrated of order two or higher (Clemente et al., 1998).[9] Unlike standard unit root tests the CMR test introduces additive outliers and innovative outliers to detect sudden and gradual changes in the mean of a series, respectively.[10] Table 2 shows that every variable in Equation (1) is either integrated of order zero or one.

[8] The conversion process involves obtaining the product between the global oil price and the average RMB–US dollar exchange rate, before dividing that product by the US implicit GDP deflator. The bilateral exchange rate and the GDP deflator series are collected from the People's Bank of China and the Bureau of Economic Analysis, respectively.

[9] Given that the upper and lower bounds value tabulated by Pesaran et al. (2001) and Narayan (2005) are based on the assumption that the selected variables are either $I(0)$ or $I(1)$ the bounds testing results may be spurious in the presence of $I(2)$ variables in the ARDL specification. However, this should not be a major concern as the evidence suggests that the majority of the variables used in the analysis of energy markets are either $I(0)$ or $I(1)$ in nature (Narayan and Smyth, 2007b, a; Narayan et al., 2008).

[10] We also conduct the ADF unit root test and find that every variable in Eq. (1) is stationary at first differences (with or without trend.) We do not report these results to conserve space, but are available upon requests from the authors.

Table 2: Clemente-Montanes-Reyes two structural breaks unit root test, by variable.

Variable	Innovative outliers							
	Level				First-differenced			
	T_{B1}	T_{B2}	Test statistic	Lag	T_{B1}	T_{B2}	Test statistic	Lag
m	1989	1998	-7.007^{***}	3	1989	1993	-7.285^{***}	1
y	1988	2001	-3.773	1	1988	2009	-6.213^{**}	1
p_1	1992	2003	-4.222	0	1997	2008	-7.963^{***}	1
p_2	1988	2002	-3.157	4	1997	2008	-8.209^{***}	1
r	1992	1998	-3.856	5	1988	1998	-6.773^{***}	0
s	1997	2001	-3.763	0	1993	2008	-6.810^{***}	2
	Additive outliers							
	Level				First-differenced			
m	1992	2001	-1.715(4)	4	1988	1991	-7.292^{***}	1
y	1995	2006	-2.780(0)	0	1987	2008	-5.927^{**}	1
p_1	1991	2003	-4.596(0)	0	1996	2007	-7.585^{***}	1
p_2	1991	2003	-4.558(0)	0	1996	2007	-7.769^{***}	1
r	1986	1990	-3.684(6)	6	1987	1994	-6.552^{**}	0
s	1996	2003	-4.321(0)	0	1992	2008	-7.879^{***}	1

Notes: p_1 and p_2 denote the Global Dubai and Brent oil price, respectively. The asterisks *** and ** denote the significance at 1 and 5% levels, respectively. T_{B1} and T_{B2} are the dates of two structural breaks. Optimal lag lengths selected by SIC are reported in the parentheses.

5. EMPIRICAL RESULTS

5.1 The bounds testing procedure

To carry out the bounds testing procedure, we avoid the unnecessary loss in the degrees of freedom to our small sample size by restricting the maximum lag length to three years. We then determine the optimal ARDL representation of Equation (2) by inspecting several lag selection criteria, including AIC (Akaike Information Criterion), SBC (Schwarz' Bayesian Information Criterion), and the Breusch-Godfrey LM test (Enders, 2008). After performing sequential grid search and ruling out those ECM (error correction model) specifications that failed a battery of diagnostic tests, we identify the optimal lag structure for Equation (2) to be *ARDL*(1,0,1,2,2).[11] We then perform the bounds testing procedure on the *ARDL*(1,0,1,2,2) specification by comparing its *F*-statistic for the null hypothesis of no cointegration against the critical bounds value provided by Narayan (2005). Panel I of Table 3 reports that the *ARDL*(1,0,1,2,2) representation rejects the null hypothesis. Furthermore, Panel II shows that its stochastic error terms are free from serial correlation, non-normal distribution, and autoregressive conditional heteroskedasticity. Finally, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests indicate that the test statistics generally fall within, or on, the 5% confidence interval bands, suggesting no structural instability in those stochastic error terms (Brown et al., 1975; Pesaran et al., 2001).[12] Overall, we conclude that a cointegrating relationship exists in Equation (2) and its corresponding *ARDL*(1,0,1,2,2) representation is correctly specified.

[11] The full set of results for lag selection are available upon requests from the authors.
[12] The CUSUM and CUSUMSQ tests are usually shown using graphical representations. However, we do not report them here to conserve space, but are available upon the request from the authors.

Table 3: ARDL estimates, by oil price.

	(1) Global Dubai	(2) Brent
I. The bounds testing procedure		
Optimal lag structure	(1,0,1,2,2)	(1,0,1,2,2)
F-statistic for ARDL (1,0,1,2,2)	8.046***	8.046***
II. Diagnostic tests		
χ^2_{SERIAL}	2.926	2.786
χ^2_{NORMAL}	0.344	0.474
χ^2_{ARCH}	0.301	0.667
χ^2_{RESET}	0.121	0.002
CUSUM	Stable	Stable
CUSUMSQ	Stable	Stable
III. The long-run relationship		
Constant	-27.323	-23.244
	(14.551)	(15.121)
p_1	-1.092	
	(0.630)	
p_2		-0.826
		(0.606)
y	1.704***	1.496***
	(0.470)	(0.453)
r	1.186**	1.224**
	(0.533)	(0.569)
s	-0.886	-0.826
	(0.533)	(0.567)
IV. The short-run relationship		
ECT_{t-1}	-0.485***	-0.470***
	(0.068)	(0.069)
Δp_1	-0.049	
	(0.153)	
Δp_2		0.016
		(0.155)
Δy	0.989***	0.864**
	(0.312)	(0.325)
Δr	-0.859***	-0.792***
	(0.233)	(0.235)
Δs	-0.986***	-0.909**
	(0.317)	(0.327)

Notes: p_1 and p_2 denote the Global Dubai and Brent oil price, respectively. χ^2_{SERIAL} is Breusch-Godfrey LM test statistic for no first-order seral correlation. χ^2_{NORMAL} is the Jarque-Bera statistic of the test for normal residuals. χ^2_{ARCH} is the Engle's test statistic for no autoregressive conditional heteroskedasticity. χ^2_{RESET} is the Ramsey's test statistic for no function misspecification. CUSUM and CUSUMSQ denote cumulative sum and cumulative sum of squares statistic, respectively. The asterisks *** and ** denote the significance at 1 and 5% levels, respectively.

5.2 Long-run ARDL estimates

Panel III in Table 3 presents the results of the long-run coefficient estimates for Equation (2). Four key results are worth mentioning. Firstly, the coefficients on the global oil prices $\left(p_1 \text{ and } p_2\right)$ are not statistically significant at any conventional level, implying that the long-run demand for oil imports is perfectly price inelastic. Secondly, the coefficients of real output (y) are positive and statistically significant at all conventional levels, indicating a positive relationship between a booming economy and the derived demand for oil imports. In fact, a 1%–increase in real output (y) raises oil imports by 1.50%–1.70%, holding all things constant. If we interpret real output as synonymous to income, then we may conclude that the demand for oil imports is income elastic the long run. Thirdly, whilst the coefficients of technology development (r) are statistically significant at the 5% level, their sign is opposite to our *a priori* expectation. To our surprise, a 1%–increase technology development (r) raises her oil imports by 1.19%–1.22%, all things being equal. Finally, the statistically insignificant coefficients of the self-reliance index (s) suggest that fluctuations in domestic oil production capacity do not influence oil imports in the long run.

5.3 Short-run ARDL estimates

Panel IV in Table 3 reports the results of the short-run coefficient estimates for Equation (3). Five main points are worth highlighting. Firstly, the coefficients of the global oil prices $\left(p_1 \text{ and } p_2\right)$ remain statistically insignificant at all conventional levels. Secondly, although the coefficients of the short-run coefficients on real output (y) are at least statistically significant at the 5% level or better, their magnitude has almost halved, from 1.50%–1.70% in the long run to 0.86%–0.99% in the short run. In jargon, this reduction implies that the income elasticity of demand for oil imports has changed from elastic in the long run to inelastic in the short run. Thirdly, the coefficients of technology development (r) are negative and statistically significant at all conventional levels. In fact, a 1%–increase in technology development reduces China's oil imports by 0.79%–0.86% in the short run, holding all things constant. Fourthly, the coefficients of the self-reliance index (s) are at least statistically significant at the 5% or better and suggest that a 1%– increase in self-reliance (s) reduces oil imports by 0.91%–0.99% in the short run, all things being equal. Finally, since the coefficients of the error correction term $\left(ECT_{t-1}\right)$ are statistically significant at all conventional levels and occupy the range between –0.47 and –0.49, we conclude that Eq. (3) is not explosive and its long-run equilibrium is attainable. Specifically, it will take slightly over two years for the oil imports function to return to its steady state from an unexpected shock, with approximately 47%–49% of the equilibrium adjustment happening during the first year.[13]

5.4 The Gregory-Hansen structural break cointegration test

A major concern in the ARDL representations relates to their sensitivity over structural breaks in the cointegrating series (Li and Lin, 2011; Shahbaz et al., 2012). To ensure the robustness of our results, we apply the Gregory-Hansen (1996) test to assess cointegration in China's oil

[13] For the Global Dubai and Brent oil prices the adjustment time to the long-run equation for China's oil imports function will be 2.06years (=1/0.485) and 2.13 (=1/0.47) years, respectively.

imports function with a structural break.[14] Table 4 reports that whilst the Gregory-Hansen test rejects the null hypothesis of no cointegration in the oil imports function, a structural break is detected around 2002, corresponding to China's accession to the WTO one year earlier.

Table 4: The Gregory-Hansen structural break cointegration test, by oil price.

	(1) Global Dubai	(2) Brent
Lag	2	2
ADF test	-7.18***	-7.03***
Break data	2002	2002

Notes: The asterisks *** and ** denote the significance at 1 and 5% levels, respectively. The optimal lag length are determined by AIC. The trimming region is set at 0.15. The critical values are 1% (-6.92) and 5% (-6.41) from Gregory and Hansen (1996).

5.5 Post-WTO analysis

Based on the Gregory-Hansen test, we suspect that the structural break might have being a contributing factor to the insignificance of global oil prices in affecting China's oil imports. Therefore, we examine this hypothesis by focusing on the post-WTO (2002Q1–2014Q4) period. Specifically, we construct the quarterly oil price benchmark series by taking the three-month average of the monthly oil price benchmark published by the EIA. We then obtain the quarterly real GDP series from China's National Bureau of Statistics. Since data on technology development and the self-reliance index are only available as annual observations, we use the quadratic-match sum method to convert them into quarterly frequency.[15] To ensure the robustness of our results, we also apply the dynamic OLS (DOLS) procedure to estimate Equation (2). Similar to its ARDL counterpart the DOLS procedure corrects potential endogeneity problems and small sample bias, as well as providing asymptotically-efficient estimates of the cointegrating vectors.[16]

Table 5 reports three important results for Eq. (2) under the ARDL and DOLS estimators. Firstly, Panel I shows that the coefficients of the global oil prices $\left(p_1 \text{ and } p_2\right)$ are both negative and enter significantly at the 5% level into Equation (2). Furthermore, the estimated coefficients fall within the range between –0.29 and –0.33, indicating oil imports to be relatively price inelastic during this period. Secondly, whilst the coefficients on real output (y) are positive and statistically significant at all conventional levels, their magnitude is now considerably smaller than previously reported. Thirdly, most of the coefficients on technology development (r) display the correct sign and are statistically significant at the 5% level. In

[14] To carry out the Gregory-Hansen test procedure, we examine the model sequentially for all break dates and compute a test statistic for the null hypothesis of no cointegration for each break date. If the most extreme value obtained for our test statistic exceeds the Gregory-Hansen (1996) critical value, we reject the null hypothesis of no cointegration with a structural break. Detailed test parameters and exposition on the Gregory-Hansen structural break cointegration test are available from the authors.

[15] All variables in quarterly frequency are either $I(0)$ or $I(1)$, satisfying the conditions for the ARDL and DOLS estimators. The unit root test results are available upon the request from the authors.

[16] The DOLS procedure allows for the presence of a mix of $I(0)$ and $I(1)$ variables in the cointegrated system. The estimation involves regressing one of the $I(1)$ variables on the remaining $I(1)$ variables, the $I(0)$ variables, leads and lags of the first difference of the $I(1)$ variables, and a constant.

passing note, Panel II suggests that both the ARDL and DOLS estimators are correctly specified and their respective stochastic error terms exhibit the desirable properties.[17]

Table 5: Estimates for 2002Q1–2014Q4, by the ARDL and DOLS estimator.

	ARDL			DOLS	
	(1) Global Dubai	(2) Brent		(1) Global Dubai	(2) Brent
I. The long-run relationship					
Constant	-21.220***	-19.592***		-23.056***	-22.906***
	(1.709)	(4.867)		(2.363)	(2.485)
p_1	-0.219**			-0.211**	
	(0.091)			(0.081)	
p_2		-0.329**			-0.190**
		(0.191)			(0.092)
y	1.047***	0.941***		1.133***	1.118***
	(0.057)	(0.125)		(0.153)	(0.07)
r	-0.219**	0.337		-0.292**	-0.294**
	(0.091)	(0.357)		(0.153)	(0.167)
s	-0.055	0.281		-0.175	-0.153
	(0.133)	(0.265)		(0.113)	(0.118)
II. Diagnostic tests					
χ^2_{SERIAL}	4.693	0.803	χ^2_{NORMAL}	0.347	0.344
χ^2_{NORMAL}	1.478	4.803	Ljung-Box Q statistic [2]	0.543	0.818
χ^2_{ARCH}	0.253	1.638	Ljung-Box Q statistic [4]	2.468	3.084
χ^2_{RESET}	1.267	5.452	Ljung-Box Q statistic [6]	6.305	7.634
CUSUM	Stable	Stable			
CUSUMSQ	Stable	Stable			

Notes: The *F*-statistic for the 5% critical value bound is (2.56, 3.49), which is obtained from Narayan (2005). χ^2_{SERIAL} is Breusch-Godfrey LM test statistic for no first-order seral correlation. χ^2_{NORMAL} is the Jarque-Bera statistic of the test for normal residuals. χ^2_{ARCH} is the Engle's test statistic for no autoregressive conditional heteroskedasticity. χ^2_{RESET} is the Ramsey's test statistic for no function misspecification. CUSUM and CUSUMSQ denote cumulative sum and cumulative sum of squares statistic, respectively. The asterisks *** and ** denote the significance at 1 and 5% levels, respectively.

[17] The Ljung-Box *Q*-statistic in Table 5 show that the null hypothesis of no autocorrelated error is not rejected for up to the twelfth order at any reasonable level of significance. For brevity, we only report the results for the cases of the selected single, even-order autocorrelation. The full set of results are available from the authors.

6. CONCLUSION AND POLICY IMPLICATIONS

The objective of this paper is to examine the role of technology development and self-reliance in oil production on China's oil imports function from 1986 to 2014. Using the ARDL model we find a cointegrating relationship among oil imports, global oil prices, real output, technology development, and self-reliance on oil production in China for the entire sample period. However, the nature of this relationship appears to have changed around 2002, which corresponds to China's accession to the WTO in 2010. This, coupled with our short-run and long-run estimates of the oil import function, suggests four important policy implications for the government to consider. The first relates to the change in the price elasticity of oil imports from perfectly inelastic during the 1990s to relatively inelastic since 2002. In part, the missing price mechanism during the 1990s can be attributed to the unsatiated oil demand fueled by government subsidies, decoupling the domestic oil prices from their global counterparts. In contrast, the negative and statistical significant coefficients on the global oil prices since 2002 partly reflect the effects from the removal of subsidies and distortions in the domestic oil markets at the request of the WTO, and partly the effect of the new oil-pricing system introduced by the NRDC. These results lend support to deeper reforms in the domestic oil market, particularly in deregulating oil prices. Indeed, oil-price deregulation must be an integral part of China's environmental and energy policy as it sends the correct price signals on the true costs of burning oil to the society.

The second key policy implication stems from the cointegrating relationship between oil imports and real output in China, as well as the positive and statistically significant elasticity of the oil imports with respect to real output in the short and long run. This positive nexus is entirely consistent with the growth-centric economic and social model in which the performance of the government is constantly being judged by its track record on achieving certain growth targets outlined in each FYP. With this backdrop, making oil imports cheap and readily available poses an attractive and easy policy option for the government to stimulate the economy as required. It is worth pointing out that since the income elasticity of oil imports is less than unity in the short run, it suggests that using oil imports to a short-run economic stimulus entails inefficiency and waste. In contrast, the income elasticity of oil imports is elastic in the long run, indicating that the energy-saving measures introduced in the 10th (2001–2005) and 11th (2006–2011) FYP had worked as intended. Indeed, the smaller magnitude of the long-run income elasticity for the post-WTP period implies that oil imports grew at a much slower rate than income, reflecting gradual shifts into alternative energy sources other than oil. Overall, whilst some of the energy-saving measures outlined in the 12th (2011–2015) and 13th (2016–2020) FYP may temporarily reduce growth, this may be a small cost borne by the society for transforming China into a low-carbon economy in the long run.

Technology development represents the third area that the policy makers in China need to address. To our surprise, we find a positive relationship between technology development and oil imports in the long run. However, we attribute this unexpected result to our choice of the success rate of patent applications as the proxy for technology development. Ideally, we should have only considered energy-saving technology development in the analysis, but such series is currently not available in China. Instead, we select the success rate of patent applications, on the premise that higher success rates should, in theory, translate into more energy-saving inventions and innovations. Although our premise is not entirely wrong the endogenous growth models show that higher success rates of patent applications may lead to greater product varieties being produced and consumed in the economy (Ang, 2009). Following this line of reasoning, an increase in the demand for these new varieties raises the derived demand for oil imports, thus giving rise to the positive sign. Since the endogenous growth models belong to the long-run analytical framework, we suspect that this positive technology development–oil imports nexus only exists in the long run. Indeed, we find a negative relationship between technology development and oil imports in the short run and attribute it to the fact that temporary energy shocks often force cost-sensitive Chinese firms into implementing energy-saving measures. Furthermore, the same negative relationship is also found during the post-WTO period, indicating that many firms adopted energy-saving measures and responded to the energy-intensity targets outlined in the 12th (2011–2015) and 13th (2016–2020) FYP. Undoubtedly, these evidence lends support to the government's pursue in promoting energy-saving technology and raising public awareness on the significance of achieving sustainable oil consumption in the near future.

The final policy implication concerning the Chinese policy makers focuses on the notion of enhancing self-reliance in oil production. Since 2000, successive FYPs have emphasized self-reliance as a key strategic area for maintaining long-term energy security. Nevertheless, our results show that such initiative has only managed to reduce oil imports in the short run rather than the long run as intended. Although this result is consistent with the 83-day worth of SPRs available in the short run, it also indicates that the government needs to persevere with its effort in diversifying the energy mix away from oil. Indeed, as articulated in the 10th (2001–2005) and 11th (2006–2011) FYP, reducing oil consumption will be the most effective means to protect the economy from temporary oil shocks, while achieving self-reliance in oil production in the long run.

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