Symmetric and asymmetric relationships between renewable energy, oil imports, arms exports, military spending, and economic growth in China

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Abstract: This paper evaluates the symmetric and asymmetric relationships between military spending (MS) and oil imports (OIM) in China. For this purpose, we use the autoregressive distributed lag (ARDL) and the non-linear ARDL approaches, with annual data ranging from 1989 to 2016. In the long-run, MS increases OIM, renewable energy (RE) consumption, and gross domestic product (GDP). RE consumption increases arms exports (AE) and GDP but reduces OIM. Interestingly, OIM reduces AE and AE harm GDP. OIM seem to have a non-linear and asymmetric impact on MS both in the short- and long-run. In the long-run, an increase in OIM by 1% increases MS by 0.853%, while a reduction of OIM by 1% reduces MS by 1.467%. The cumulative dynamic multiplier effects indicate that China reacts very rapidly to positive shocks, but is very cautious about reducing its MS in the event of a negative shock. It appears that China is prompt to reduce considerably its MS whenever it is assured about its energy security. This could be partially achieved by increasing its RE consumption, and the military sector is invited to contribute especially through its R&D activities. This could lead to a cleaner environment and a more peaceful world.

Keywords: Renewable energy; oil imports; arms exports; military spending; non-linear and linear autoregressive distributed lag; China.

JEL classifications: C32; H56 ; O53; Q42.

1. Introduction

There is growing literature about arms conflicts and energy. China is nowadays the first consumer of energy in the world, the first CO_2 emitter, the second importer of crude oil, the second military spender, has the second gross domestic product (GDP), and is the leader in renewable energy investments. These reasons pushed us to look for a possible relationship between China's energy needs and its military efforts. Does China invest more in defense to secure its provision in energy and especially crude oil? What are the main determinants for China's military spending? What role could play renewable energy? These are some questions to which our study will try to give some explanations.

In 2016, China is the second importer of crude oil including lease condensate in the world after the USA. Indeed, It imported about 7621 thousand barrels per day compared to 7850 for the USA (Energy Information Administration, 2021). What is more attractive is that these imports are increasing at a consistent rate as shown by Fig. 1. The five biggest oil producer countries of the Gulf region (Saudi Arabia, Iraq, United Arab Emirates, Iran, and Kuwait) account for a total share of 27% in international oil production and are situated in a region characterized by political and armed conflicts.

Zhang et al. (2017) recall that, in 2015, China has become both the largest energy consumer and CO_2 emitter country in the world. It consumed 23% of global energy and is responsible for 61% of the growth of net energy consumption. China has committed itself to a reduction of 40 to 45% in its CO_2 emissions in 2020 compared to the level of 2005. These authors pointed out that China has great potential in renewable energy resources, which are currently not sufficiently exploited. They think that the best way for China to deal with the sharp conflict between both high economic growth and CO_2 emission is the transition to efficient and renewable energy systems.

According to the International Energy Agency (2019), the government of China has decided on several policies to transform the investment in renewables as a key goal. As a consequence, China is responsible for over a third of global investments in renewable energy. In 2016, five of the world’s six important solar-module manufacturing companies are in China. This has created new job opportunities. There are 3.5 million jobs in China in the renewable energy sector, compared to the 8.1 million in the globe. The Institute for Energy Economics and Financial Analysis (2017) highlights that China’s investment in renewables has surpassed all expectations making it the world leader in domestic investment in renewable energy and associated low-emissions-energy sectors. It has invested $103bn in this sector in 2015, two and half times the amount undertaken by the U.S. Nowadays, China is the world leader in renewable energy production and consumption in the world. Its electricity mix in 2020 comprises 26% of renewables.[1] This was helped by the rapidly improving cost competitiveness of renewable energy. Fig. 1 shows that renewable energy consumption is expanding continuously.

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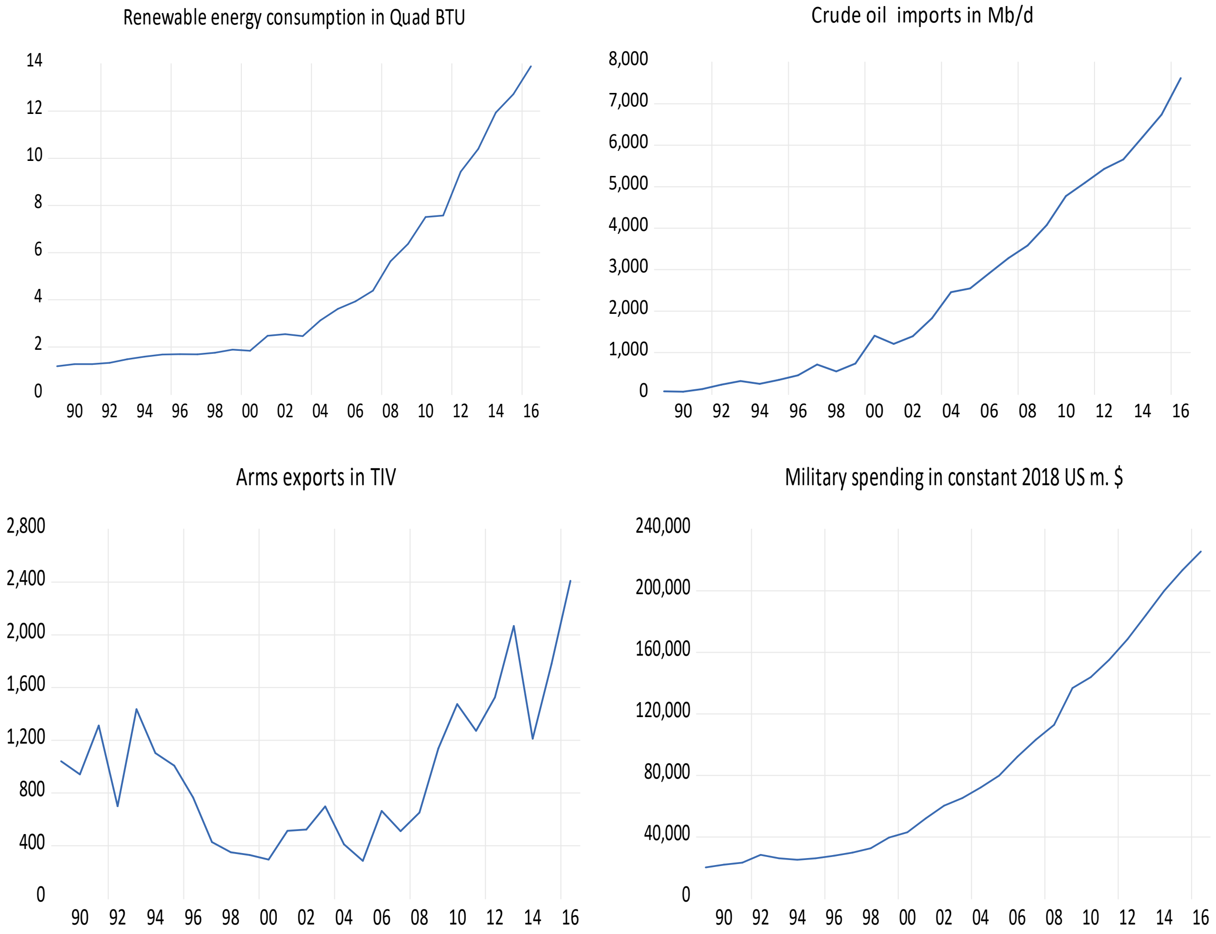
[1] See : https://www.iea.org/data-and-statistics/charts/electricity-mix-in-china-january-november-2020.

China has also the second defense budget in the world after the USA in 2019. According to Tian et *al.* (2020), military expenditures have been estimated to be 732 and 261 $ billion for the USA and China, respectively. These military expenditures are increasing at an important rate as shown by Fig. 1. China's military expenditures have grown by 56.7% between 2010 and 2016. According to Wezeman et *al.* (2019), international transfers of major arms have grown steadily in volume since 2003 and China is among the top five biggest exporters in the period 2014-18. Moreover, arms imports by the Middle East states have grown by 87% between 2009–13 and 2014–18, which invites us to think about the relationship between arms exports and oil imports.

Regarding economic growth, it is well recognized that China is one of the countries realizing continuous interesting economic growth during the last decades. All the above reasons recall us to wonder whether there is a relationship between military spending and exports, oil imports, and renewable energy consumption in China. Let us notice that Fig. 1 shows nearly similar graphs for economic growth, military spending, oil imports, and renewable energy consumption.



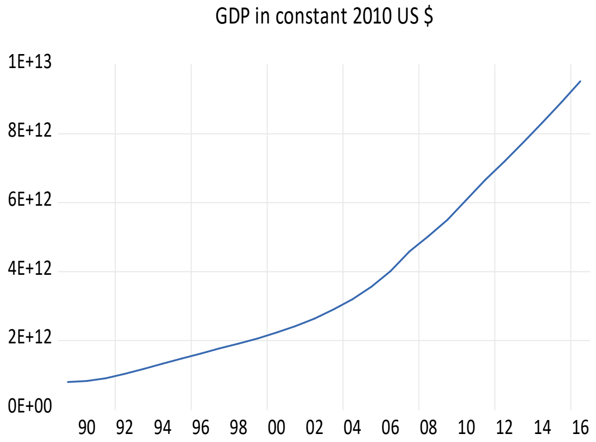


Fig. 1. Variables plots

The relationship between arms conflicts and energy has been considered by several analytical papers, but there is a lack of empirical studies on this subject. Most of the existing studies have estimated the impact of defense spending on pollution. To the best of our knowledge, Bove et al. (2018) is the unique paper estimating the impact of net energy imports (NEI) on arms exports (AE). In our paper, we estimate the long-run impact of crude oil imports (OIM) and renewable energy (RE) consumption on arms exports, which is one of the major contributions of our paper.

Bove (2018) and Bove et al. (2018) have deeply treated the question of the relationships between energy security and arms exports. To assure the security and stability of exporter countries, net energy importer countries export arms to them because any disruption in fossil fuels provision has dramatic effects on their economy. This dependence could be considered as bilateral between an importer of oil and an importer of arms. It could be also considered as regional or global as the disruption in oil provision in one major exporting country has a systematic impact on international oil prices. There is a need for empirical studies concerning this interesting question that our work will try to fill.

We will estimate the relationship between military expenditures and oil imports in the case of China. We know that China has not the tradition to intervene militarily in other regions of the globe, but having an important military force can dissuade from touching its oil security. What is better for China to invest in a very expensive dissuasive military force or export arms to its energy providers, for securing its provision in oil? We will try to give some responses to these interesting questions.

Another interesting challenge is whether the military sector in China is contributing to boosting renewable energy use? Samaras et al. (2019) noted that energy issues in military and non-military fields have not been sufficiently addressed by the literature. It is well admitted that research and development (R&D) in the defense sector has implied noticeable technological change in several domains as civil aviation or aerospace (radar, jet engines, satellite communication, etc.). These authors support the idea that we are now on the cusp of a likely transfer of energy technology due to economic and military concerns. Indeed, energy innovation, and in particular that in renewable energies, could considerably reduce the heavy military energy bill and improve the autonomy of troops on the battlefield about energy supply, in particular fossil fuels. For example, the technology of installing home mini-grids has been improved as an alternative fuel for major weapon systems. Samaras et al. (2019) advise those concerned with civilian energy to take innovations coming from the military sector seriously and take advantage of technological externalities in both directions.

The main contributions of this paper are the following: *i)* it is the first econometric study dealing with military spending, arms exports, oil imports, and renewable energy consumption, for the case of China; *ii)* it is the first econometric study considering non-linear modeling in the relationship between military spending and oil imports. For this purpose, we use annual data about China between 1989 and 2016. Our variables include military spending (MS), arms exports, crude oil imports, renewable energy consumption, and gross domestic product. We use the autoregressive distributed lag (ARDL) bounds testing approach and consider at each time OIM, RE, AE, and GDP as dependent variables. Then, we use the non-linear ARDL (NARDL) bounds testing approach to evaluate the asymmetric effect of oil imports on military spending. Our paper comprises a literature review (Section 2), a data and econometric analysis (Section 3), a discussion of the results (Section 4), and a conclusion with policy recommendations (Section 5).

2. Review of the literature

Only a few papers have been devoted to the econometric analysis of the relationship between arms conflicts and energy, while analytical literature about this interesting subject is very rich. Bove et al. (2018) try to explain how oil dependency affects weapons trade between countries. For this purpose, they use gravity models and data about 149 countries. They conclude that the magnitude of dependence on oil supply from a given country impacts the volume of arms transferred to that country. As expected, even in the case of no direct bilateral trade of oil-for-weapons, global oil dependence pushes to export arms to countries' wealth in oil. Military burden (as a percentage of GDP) and net energy imports increase arms exports.

The literature about the relationships between energy consumption and defense expenditures has mainly been interested in evaluating the effect of these latter on carbon dioxide (CO_2) emissions. Some studies concluded that MS increases CO_2 emissions in the long-run (Bildirici, 2017b, 2017c). By using cross-national panel analyses, Jorgenson et al. (2010) conclude that both the number of soldiers and military technological sophistication have harmful effects on the environment. Bildirici (2017a) finds a unidirectional causality running from military spending to carbon emissions in the case of the USA, and bidirectional causality between military spending and ethanol consumption. Military expenditures increase CO_2 emissions in the long-run, while ethanol consumption reduces it.

A mixed effect concerning the impact of military spending on the environment has been found by another strand of literature. Solarin et al. (2018) use two measures of military spending and estimate several time series models for the case of the USA. Depending on the user database, they find the mixed impact of military spending on CO_2 emissions. By considering an unbalanced cross-national panel data sample comprised of 68 countries, Clark et al. (2010) show that both high-tech militarization and military personnel boost total energy consumption. Bildirici (2016) considers time series data on China and found bidirectional causalities between military spending, economic growth, and energy consumption. Economic growth and military spending increase energy consumption, in the long run.

There is a consistent number of econometric studies about energy consumption whether it is renewable or non-renewable (Ang, 2007; Ozturk and Acaravci, 2010; Apergis and Payne, 2011; Sadorsky, 2012; Al-Mulali et al., 2014; Inglesi-Lotz and Dogan, 2018; Ben Jebli et al., 2020; Ben Youssef, 2020). Shahbaz et al. (2017) consider data about the USA and show that the relationship between GDP and carbon emissions is inverted-U shaped and even N-shaped. Moreover, biomass energy consumption, trade, exports, and imports reduce CO_2 emissions. Mohamed et al. (2019) find long-run bidirectional causalities between renewable energy consumption and terrorism in France. In the long-run, renewable energy consumption and international trade increase both terrorism and GDP.

Several energy studies concern China like Long et al. (2015) and Fan and Hao (2020). Lin and Moubarak (2014) show the presence of long-run bidirectional causality between renewable energy consumption and GDP in China, and labor impacts RE consumption in the short-run. In addition, economic growth, carbon emissions, and labor have a long-run positive impact on renewable energy consumption. Chen et al. (2019) use data about China spanning the period 1980-2014 and both the ARDL and the vector error correction model (VECM) approaches. They show that, with the inclusion of renewable energy production variable, the inverted U-shaped environmental Kuznets curve (EKC) hypothesis is verified in the long-run. Renewable energy and international trade reduce carbon dioxide emissions, and short-run unidirectional causalities are running from trade, CO_2 emissions, and economic growth to renewable energy.

Another branch of the energy literature deals with the asymmetric effects (Kocaarslan et al., 2020; Nusair, 2020). Apergis and Gangopadhyay (2020) use data about Vietnam and show that the long-run relationships between energy use, pollution, and oil prices are characterized by hidden cointegration necessitating the use of NARDL models. Liao and Baek (2020) use NARDL modeling and data about China to support asymmetric price transmission occurring between the prices of crude oil and gasoline in both the short- and long-run. For diesel prices, asymmetry effects seem to be a long-run phenomenon. Shahbaz et al. (2018) use time-series data about the BRICS (Brazil, Russia, India, China, South Africa) and the NARDL bounds approach. They conclude that energy consumption is positively and negatively affected by the positive and negative shocks, respectively, of globalization or economic growth.

According to the literature review, there is no empirical research estimating the long-run impact of military expenditures or arms exports on renewable energy consumption or energy imports. Also, no previous study has estimated the long-run impact of renewable energy consumption or oil imports on arms exports, nor that of arms exports on economic growth. Finally, there is no research estimating the asymmetric effect of oil imports on military spending. Our paper tries to fill these shortcomings by using data about China and by employing both the ARDL and NARDL bounds testing approaches.

3) Data and econometric analysis

Our annual data range from 1989 to 2016 and concerns China. The considered variables are *i)* renewable energy consumption (RE) in Quad BTU; *ii)* crude oil, including lease condensate, imports (OIM) in thousands of barrels per day (Mb/d); *iii)* military spending (MS) in constant 2018 US m. $; *iv)* arms exports (AE) in trend-indicator value (TIV); *v)* gross domestic product (GDP, Y) in constant 2010 US $. Data about RE and OIM are obtained from the Energy Information Administration (2021), those about MS and AE are collected from the Stockholm International Peace Research Institute (SIPRI, 2021), and GDP data are obtained from the World Bank (2021). We were limited by data availability without the ability to use monthly or quarterly data. In particular, data about military spending are available only from 1989, and those about oil imports are available only until 2016. We use Eviews 12 software for econometric computations made after the natural logarithmic transformation of variables.

Our econometric analysis begins by studying the stationarity properties of our considered variables. For this purpose we will use two standard but powerful unit root tests: augmented Dickey and Fuller (ADF, 1979) and Phillips and Perron (PP, 1988). Table 1 gives these stationary tests for the case of intercept and trend. We can see that all our variables are not stationary at level, but they become stationary after the first difference. Thus, we conclude that all our variables are integrated of order 1, i.e., are I (1).

Table 1. Stationary tests

	ADF stat				P-P stat			
Variables	Level	k	1st diff	k	Level	k	1st diff	k
re	-1.636	0	-6.363^a	0	-1.548	6	-6.526^a	5
oim	-1.445	3	-6.889^a	2	-1.621	26	-12.985^a	25
ae	-1.670	0	-6.717^a	0	-1.496	1	-6.836^a	2
ms	-1.845	0	-4.248^b	0	-1.936	2	-4.244^b	1
y	-2.737	3	-3.698^b	0	-1.435	2	-3.672^b	2

Only the intercept and trend case is given. ADF and P-P are notations for Augmented Dickey-Fuller and Phillips-Perron tests, respectively. For the ADF test, the optimal lag length selected by the Schwarz information criterion (SIC) is k, with a maximum lag of 7. For the PP test, the Newey-West Bandwidth using Bartlett Kernel is k. Statistical significance levels at the 1% and 5% are, respectively, denoted by ^{a} and ^{b}.

3.1. ARDL models

Our study uses five variables and at each time we will take one as a dependent. In this subsection, we will estimate five models by using the ARDL bounds testing approach. These models are the following:

$$oim_t = c_1 + \alpha_{11} ms_t + \alpha_{12} re_t + \alpha_{13} y_t + \alpha_{14} ae_t + \varepsilon_{1t} \qquad \text{(Model 1)}$$

$$re_t = c_2 + \alpha_{21} ae_t + \alpha_{22} ms_t + \alpha_{23} oim_t + \alpha_{24} y_t + \varepsilon_{2t} \qquad \text{(Model 2)}$$

$$ae_t = c_3 + \alpha_{31} re_t + \alpha_{32} oim_t + \varepsilon_{3t} \qquad \text{(Model 3)}$$

$$y_t = c_4 + \alpha_{41} re_t + \alpha_{42} oim_t + \alpha_{43} ae_t + \alpha_{44} ms_t + \varepsilon_{4t} \qquad \text{(Model 4)}$$

$$ms_t = c_5 + \alpha_{51} oim_t + \alpha_{52} re_t + \alpha_{53} y_t + \alpha_{54} ae_t + \varepsilon_{5t} \qquad \text{(Model 5)}$$

Where c_i and α_{ij} denote the constant terms and the long-run elasticity of the independent variable with respect to the corresponding dependent variable; ε_{it} denote the residual terms.

For the above five models, the autoregressive distributed lag approach developed by Pesaran and Pesaran (1997), Pesaran and Smith (1998), and Pesaran et al. (2001) is used for assessing the long-run cointegration between variables and estimating long-run elasticities. The most advantages of the ARDL bounds approach compared to other methods are that it can procure good estimates even with small samples while endogeneity problems are avoided. In addition, variables could be stationary, i.e. I (0), integrated of order one, i.e. I (1), or mixed. When Y_t is the dependent variable and $X_{it}, i = 1, \ldots k$ are the independent variables, the ARDL equation may be written as:

$$\begin{aligned} \Delta Y_t = {} & c + \beta_0 Y_{t-1} + \beta_1 X_{1,t-1} + \beta_2 X_{2,t-1} + \ldots + \beta_k X_{k,t-1} + \\ & \sum_{j=1}^{q0} \lambda_{0j} \Delta Y_{t-j} + \sum_{j=0}^{q1} \lambda_{1j} \Delta X_{1,t-j} + \sum_{j=0}^{q2} \lambda_{2j} \Delta X_{2,t-j} + \ldots + \sum_{j=0}^{qk} \lambda_{kj} \Delta X_{k,t-j} + \varepsilon_t \end{aligned} \qquad (1)$$

Where Δ, ε_t, and $q_i, i = 0,1,2,\ldots k$ denote the first differences, the residual terms, and the numbers of lags, respectively. The estimated coefficients are denoted by c, β_i, and λ_{ij}. The optimal number of lags could be determined by the Akaike information criterion (AIC). According to Pesaran et al. (2001), the estimated Fisher-statistics (F) of the Wald test should be compared to two critical values: a lower value (LV) and an upper value (UV). Three conclusions may be deduced: *i)* if F<LV, there is no cointegration between variables; *ii)* if F>UV, there is cointegration between variables; *iii)* when LV≤F≤UV, this test is inconclusive.

To be sure about the robustness of our results, some tests for normality, heteroskedasticity, and serial correlation are made. Table 2 gathers the cointegration results for the five considered models. For Models 1 to 4, we can see that there is a long-run cointegration between the considered variables. However, for Model 5, we have a problem with serial correlation as we can reject the null of no serial correlation even with a lag equal to one.

Table 2. ARDL cointegration

Model	Optimal lags	F-statistics	ECT_{t-1}	Normality test	LM-test	BPG-test	Conclusion
F_1(oim/ms,re,y,ae)	(3,3,3,3,0)	5.248^{a}	-2.883^{a}	0.966	0.443	0.399	Cointegration
F_2(re/ae,ms,oim,y)	(2,0,3,3,1)	10.173^{a}	-1.385^{a}	0.928	0.364	0.637	Cointegration
F_3(ae/re,oim)	(1,0,0)	3.800^{b}	-0.631^{a}	0.918	0.480	0.728	Cointegration
F_4(y/re,oim,ae,ms)	(3,2,1,2,0)	5.999^{a}	-0.272^{a}	0.704	0.468	0.149	Cointegration
F_5(ms/oim,re,y,ae)	(4,0,0,0,1)	10.779^{a}	-0.553^{a}	0.687	0.006^{a}	0.324	No-Cointegration

The F(.) statistics are calculated for the case of a restricted constant. We obtain critical values from Pesaran et al. (2001) for a finite sample n=30. For models 1-5, the maximum number of lags selected for the dependent and independent variables are (3,3), (2,3), (3,3), (3,2), and (4,1), respectively. Optimal lags are fixed by the Akaike information criterion (AIC). Our diagnostic tests comprise serial correlation LM test (Breusch-Godfrey), heteroscedasticity test (Breusch-Pagan-Godfrey(BPG)), and normality test (Jarque-Bera); we provide the probability of rejecting the null hypothesis. The LM test is computed with lag=2; only for models 4 and 5, it is computed with lag=1.

1% and 5% statistical significance levels are denoted by [a] and [b], respectively.

Long-run parameter estimates are gathered in Table 3. For Models 1-4, all these estimates are statistically significant except for the coefficients of arms exports in Models 1 and 2. For Model 5, only the coefficient of economic growth is statistically significant, confirming the non-validity of this model.

Table 3. ARDL long-run elasticities

	Independent variables					
Model/ Dependent variable	c	re	oim	ms	y	ae
Model 1: oim	-87.344 (0.000)[a]	-2.033 (0.000)[a]	-	0.729 (0.020)[b]	3.096 (0.000)[a]	0.021 (0.613)
Model 2: re	-34.799 (0.000)[a]	-	-0.369 (0.000)[a]	0.576 (0.002)[a]	1.120 (0.000)[a]	0.031 (0.220)
Model 3: ae	9.953 (0.000)[a]	1.588 (0.000)[a]	-0.717 (0.001)[a]	-	-	-
Model 4: y	25.163 (0.000)[a]	0.463 (0.001)[a]	0.170 (0.002)[a]	0.223 (0.089)[c]	-	-0.091 (0.021)[b]
Model 5: ms	-15.089 (0.152)	0.123 (0.591)	0.074 (0.532)	-	0.897 (0.033)[b]	-0.053 (0.476)

1%, 5%, and 10% statistical significance levels are denoted by [a], [b], and [c], respectively.

3.2. NARDL model

In the preceding sub-section, we saw that Model 5 is not valid. We tried to explain military spending in the function of at least one or more of our other considered variables with a linear model, but without succeeding in obtaining significant results. Thus, we thought about a non-linear model such as a NARDL model. Indeed, non-linear ARDL models developed by Shin et al. (2014) enables detection of ‘‘hidden cointegration’’ when linear models, such as ARDL ones, cannot. NARDL models can detect asymmetric effects both in the long- and short-run. In addition, they have the advantages of ARDL models, and thus used variables could be I (0), I (1), or mixed. Looking at Fig. 1, we can see that the graphs of military spending and oil imports are nearly similar with a very high correlation coefficient equal to 0.996. Therefore, we are trying to estimate military spending as a function of oil imports by using the following long-run asymmetric model:

$$ms_t = \phi_0 + \phi^+ oim_t^+ + \phi^- oim_t^- + \omega_t \qquad \text{(Model 6)}$$

Where oim_t is decomposed as $oim_t = oim_0 + oim_t^+ + oim_t^-$ with oim_t^+ and oim_t^- are partial sums of increases and decreases in oim_t:

$$oim_t^+ = \sum_{i=1}^{t} \Delta x_i^+ = \sum_{i=1}^{t} max(\Delta \mathrm{x}_i, 0) \quad , \quad oim_t^- = \sum_{i=1}^{t} \Delta x_i^- = \sum_{i=1}^{t} \min(\Delta \mathrm{x}_i, 0) \qquad (2)$$

We can now write our non-linear ARDL model:

$$\begin{aligned} \Delta ms_t &= d + \rho ms_{t-1} + \delta^+ oim_{t-1}^+ + \delta^- oim_{t-1}^- + \\ &\sum_{i=1}^{p} \eta_i \Delta ms_{t-i} + \sum_{i=0}^{r} \theta_i^+ \Delta oim_{t-i}^+ + \sum_{i=0}^{s} \theta_i^- \Delta oim_{t-i}^- + u_t \end{aligned} \qquad (3)$$

Where *d* is a constant, ρ is the coefficient of the non-linear error correction term that should be negative, $\phi^+ = -\delta^+ / \rho \; and \; \phi^- = -\delta^- / \rho$ are the long-run coefficients, $\theta_i^+ \; and \; \theta_i^-$ are for short-run estimates, and u_t is a residual term. The robustness of our results is checked with tests for normality, heteroskedasticity, and serial correlation. Moreover, short- and long-run asymmetries are validated by the Wald test. For long-run asymmetry, the null hypothesis is $\phi^+ = \phi^-$, and for short-run asymmetry, we can use the null hypothesis $\sum_{i=0}^{r} \theta_i^+ = \sum_{i=0}^{s} \theta_i^-$.

Our NARDL estimates are gathered in Table 4. We can see that the Fisher statistic is quite significant, the error correction term (ECT) is negative and statistically significant, and long-run coefficients are significant. However, short-run contemporaneous coefficients are not significant. In addition, we don’t have a problem of serial correlation nor that of heteroscedasticity. However, our residues are not normally distributed but the absence of normality is not a necessary condition for the validity of ARDL models. Finally, the Wald tests reject the null hypothesis of equating short-run coefficients and the same thing for long-run coefficients.

Table 4. NARDL estimates with ms as a dependent variable

Conditional Error Correction Regression

Independent variables	Coefficient	Prob.
c	4.043[a]	0.001
ms_{t-1}	-0.450[a]	0.001
oim^{+}_{t-1}	0.384[a]	0.002
oim^{-}_{t-1}	0.660[b]	0.031
Δoim^{+}	-0.053	0.525
Δoim^{+}_{t-1}	-0.270[c]	0.058
Δoim^{-}	0.009	0.966
Δoim^{-}_{t-1}	-0.683[a]	0.004
Δoim^{-}_{t-2}	-0.601[b]	0.019
Δoim^{-}_{t-3}	-0.396[b]	0.043

Levels Equation (Restricted Constant and No Trend)

Independent Variables	Coefficient	Prob.
oim^{+}	0.853[a]	0.000
oim^{-}	1.467[a]	0.001
c	8.990[a]	0.000
Optimal lags : (1,2,4)	Normality test: 0.000[a]	Cointegration: yes
Fisher statistics: 17.932[a]	LM test: 0.561	$W_{LR=}$ 4.958(0.044)[b]
$ECT_{t-1=}$ -0.450[a]	BPG test: 0.997	$W_{SR=}$ 8.263(0.013)[b]

The Fisher statistic is calculated for the case of restricted constant. We obtain critical values from Pesaran et al. (2001) for a finite sample n=30. The maximum number of lags selected for the dependent and independent variables is 4. Optimal lags are fixed by AIC. Diagnostic tests comprise serial correlation LM test (Breusch-Godfrey), heteroscedasticity test (Breusch-Pagan-Godfrey(BPG)), and normality test (Jarque-Bera); the probability of rejecting the null hypothesis are provided. The LM test is computed with lag=2. W_{LR} and W_{SR} are the Wald statistics for long- and short-run asymmetries, respectively.

1%, 5%, and 10% statistical significance levels are denoted by [a], [b], and [c], respectively.

NARDL models contain three general forms of asymmetry, which are long-run or reaction asymmetry ($\phi^{+} \neq \phi^{-}$), impact asymmetry related to the coefficients on the contemporaneous first differences ($\Delta oim^{+} \neq \Delta oim^{-}$), and adjustment asymmetry. This latter derives from the interaction of reaction and impact asymmetries at the same time with the error correction coefficient. The cumulative dynamic multipliers capture the patterns of adjustment from the initial equilibrium to the new equilibrium. The cumulative dynamic multipliers impacts of oim_t^{+} and oim_t^{-} on ms_t can be estimated by:

$$m_h^{+} = \sum_{i=0}^{h} \frac{\partial ms_{t+i}}{\partial oim_t^{+}} \quad , \quad m_h^{-} = \sum_{i=0}^{h} \frac{\partial ms_{t+i}}{\partial oim_t^{-}} \quad , \quad h = 0, 1, 2, ... \qquad (4)$$

We recall that when $h \rightarrow +\infty$, then $m_h^{+} \rightarrow \phi^{+}$ and $m_h^{-} \rightarrow \phi^{-}$. These dynamic multipliers are represented graphically in Fig. 2.

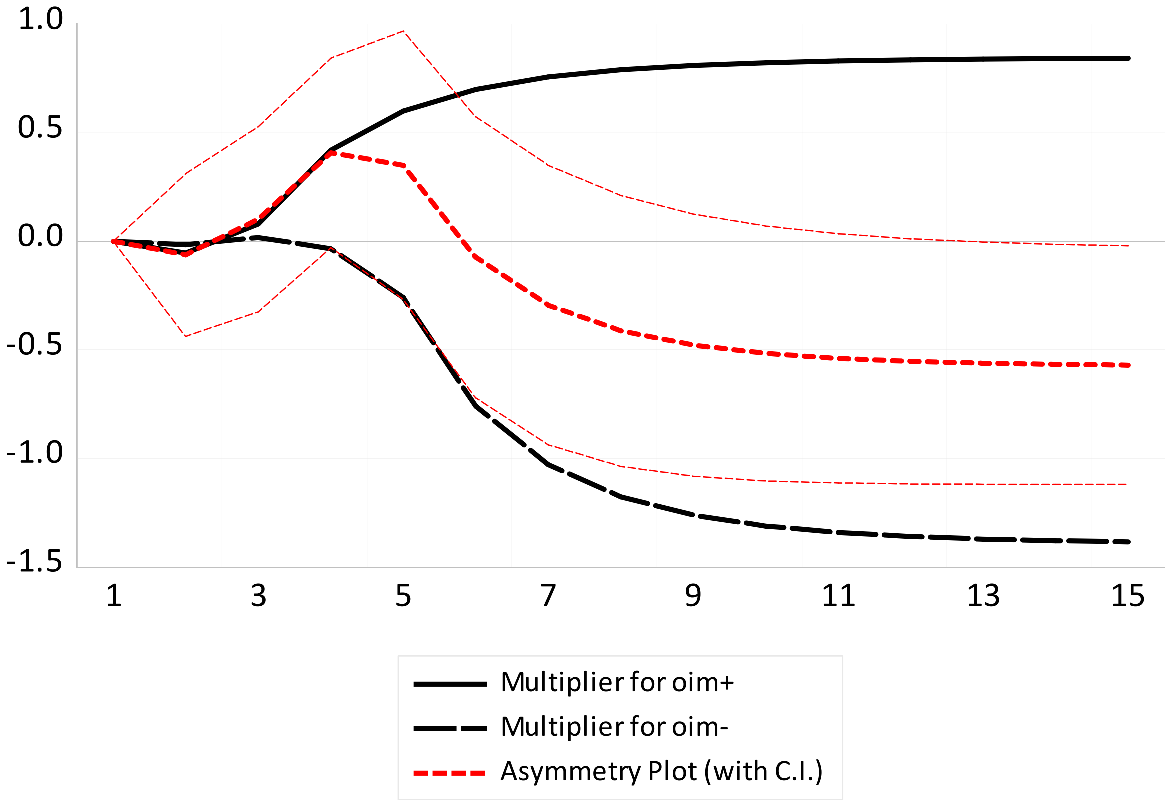


Fig. 2. Dynamic multipliers

For both our ARDL and NARDL models, the stability of our long-run estimated coefficients is checked through the statistics cumulative sum (CUSUM) and cumulative sum of squares (CUSUMS) developed by Brown et al. (1975). The estimated parameters of our regressions can be considered stable when the plots of these statistics are within the 5% critical bounds. Our statistical tests results are shown in Figures 3-8. We can see that these statistics are well within the critical values of the 5% significance level. Thus, all our long-run ARDL and NARDL estimated coefficients are stable.

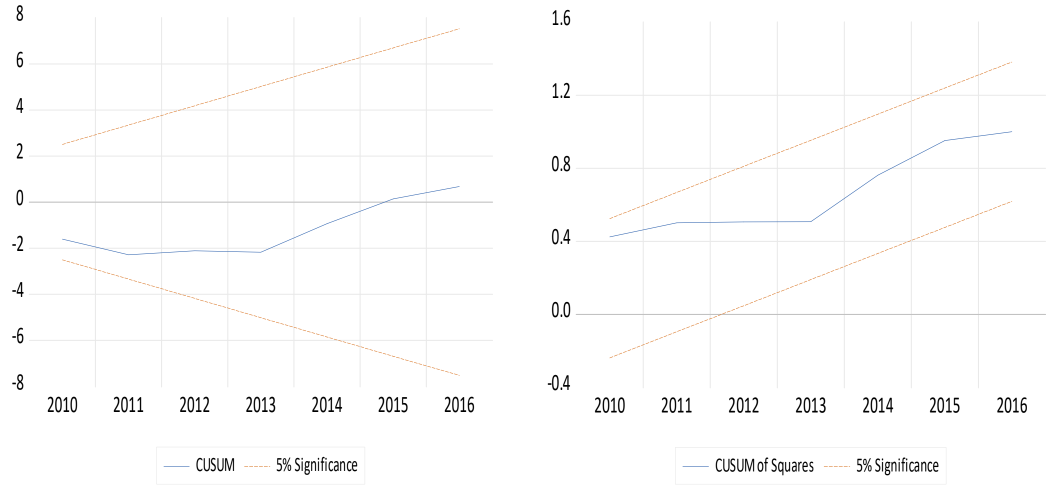


Fig. 3. CUSUM and CUSUMS of recursive residuals for oim (Model 1)

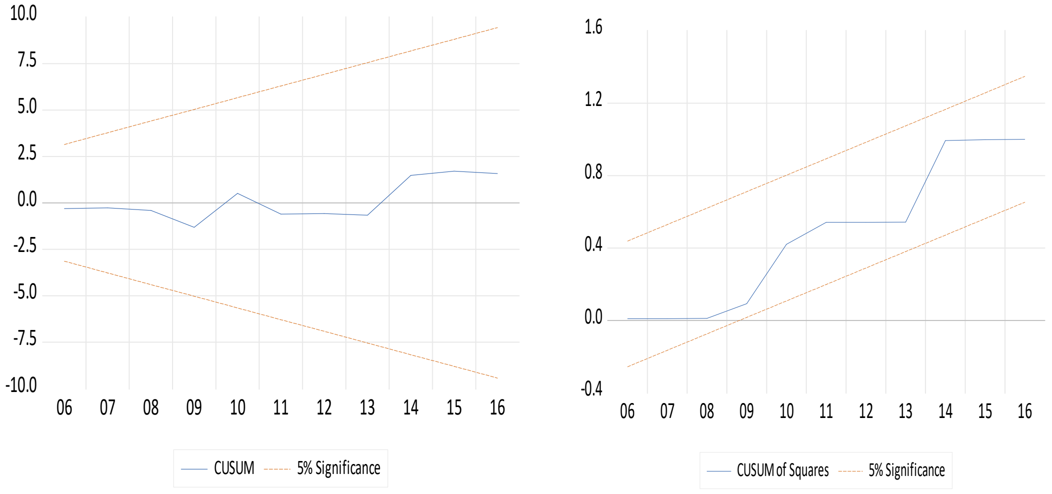


Fig. 4. CUSUM and CUSUMS of recursive residuals for re (Model 2)

Fig. 5. CUSUM and CUSUMS of recursive residuals for ae (Model 3)

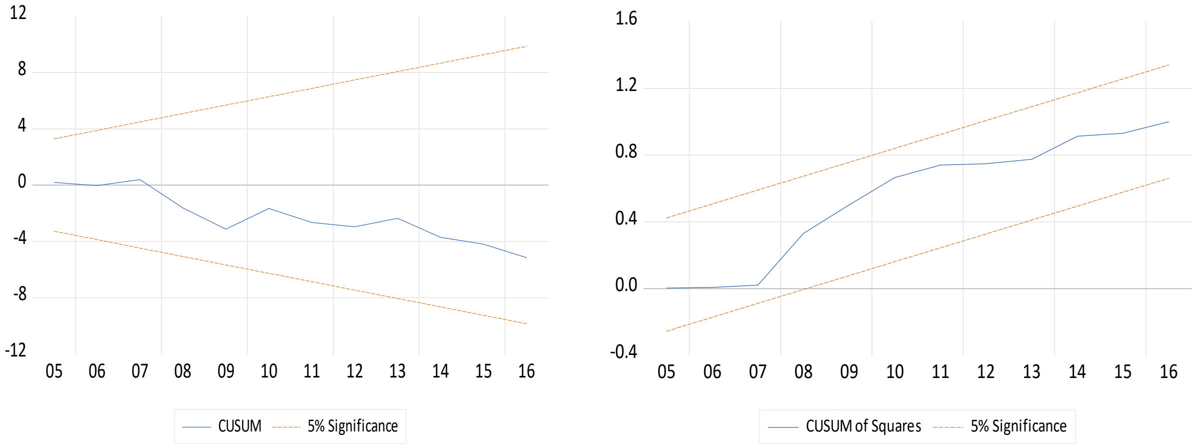


Fig. 6. CUSUM and CUSUMS of recursive residuals for y (Model 4)

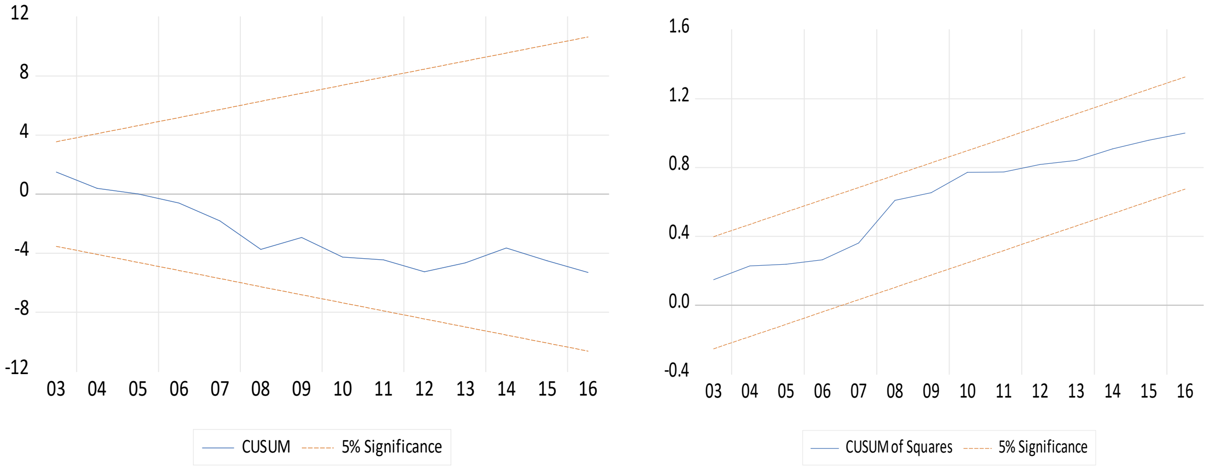


Fig.7. CUSUM and CUSUMS of recursive residuals for ms (Model 5)

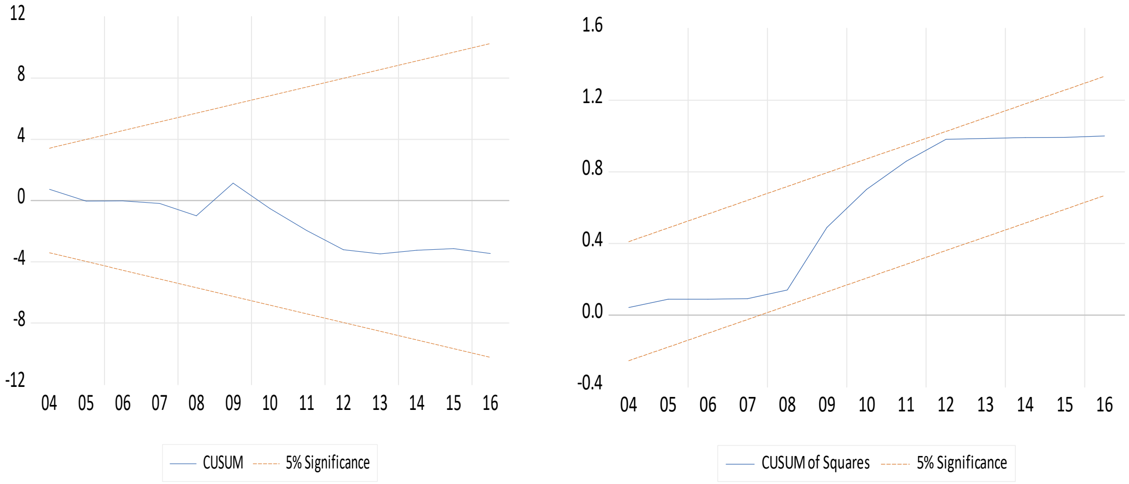


Fig. 8. CUSUM and CUSUMS of recursive residuals for ms (Model 6)

4. Results discussion

Table 3 contains all our ARDL long-run estimates. As we remarked in the previous section, Model 5 will not be considered because of the problem of serial correlation and most estimated coefficients are not significant. Thus, we have twelve statistically significant elasticities, but our discussion will focus only on the most novel and interesting ones. Renewable energy consumption increase reduces oil imports by China and the contrary occurs because these two energy sources are substitutes in the case of this country. This result is similar to that reached by Ben Youssef (2020) for the case of the USA showing that RE increase reduces net energy imports. Military spending has a positive impact on energy imports by China. This may be explained by two things. First, the military sector is a big consumer of energy, and an increase in the military budget is expected to increase oil imports and consumption. Second, the high investments of China in defense and its imposing army are dissuasive and constitute a message for belligerent countries that it is ready to defend its needs in oil. This constitutes a new and interesting result not reached before by the literature. However, arms exports have no impact on oil imports in China because these exports are not sufficiently important for the moment due to, among other things, their technological backwardness compared to their competitors like the USA. As expected, an increase in economic growth increases oil imports because growth needs energy.

Military spending has a positive long-run impact on renewable energy consumption due to the combination of at least two phenomena. Firstly, an important increase in MS increases the need for less costly and more secured renewable energy resources. Secondly, as pointed out by Samaras et al. (2019), civil renewable energy technology may have already benefited from military renewable energy technology improvements, causing an increase in renewable energy production and consumption in China. These technology improvements in the military sector may be due to the increase of China's military budget dedicated to R&D. Again, this is a new worth considering result to reach before by the literature. Arms exports don’t have any impact on RE consumption in China because they are not high enough to impact either OIM or to procure sufficient money to invest in renewable energy projects. Economic growth has a long-run impact on RE consumption because it needs more energy. In addition, economic growth enables to get the necessary funds to invest in R&D and renewable energy projects. This result is similar to that obtained by Lin and Moubarak (2014)’s study on China.

In the long-run, an increase in oil imports reduces arms exports by China. This may be explained by the fact that China considers the export of arms as threatening peace in the world and in particular in oil-exporting countries, thus threatening its provision in oil. This result is contrary to that found by Bove et al. (2018) study on 149 countries showing that net energy imports have a positive impact on arms exports. On contrary, for the same reasons, when renewable energy consumption is increased, so does arms exports because China's dependency on imported oil is reduced. This constitutes a new and interesting result.

Both renewable energy consumption and oil imports increase economic growth in China because energy is a necessary input for production. These findings are following those of Long et al. (2015)'s research on China. Military spending seems to be beneficial for China's economic growth. Indeed, a consistent force army is needed for the stability of the regime and deters thinking about compromising China's oil supply. Moreover, more defense expenditures imply more R&D, used labor, consumption of local goods, involvement in civil projects,…etc, and all these seem to have a positive impact on economic growth. Our result is different from that of Menla Ali and Dimitraki (2014) showing that military expenditures changes impact economic growth negatively during the state of slower growth–higher variance, and positively during the state of faster growth–lower variance. Lastly and surprisingly, arms exports reduce economic growth in China. One explanation is that more arms exports signify more political and eventually military conflicts in the world which hurt international goods and services exchanges and thus harming China's economic growth. This constitutes a new result not reached before by the literature.

Table 4 contains our NARDL estimates. The long-run elasticities for increases and decreases in oil imports are positive and statistically significant at the 1% level. The Wald tests show that they are statistically different confirming the asymmetric effect of oil imports on military spending. While a 1% increase in oil imports, increases military spending by 0.85%, a 1% decrease in oil imports decreases military spending by 1.47%. Securing its oil supply appears to be a critical determinant of China's military efforts. This is a worth considering result as this is the first econometric study explaining military spending as a function of oil imports.

Short-run impacts are also asymmetric as shown by the Wald test. Both increases or decreases in contemporaneous oil imports don't have an impact on military spending as the estimated coefficients are not significant. However, any increase in oil imports reduces military spending in the next period. Perhaps because this increase reassures. On contrary, a reduction in oil imports increases military efforts for the next three periods. For the same reason, perhaps China feels its oil supply is threatened.

The cumulative dynamic multipliers impacts of increases and decreases in oil imports reported in Fig. 2. show that chocks in oil imports reductions have no impact on military spending in the upcoming three years. Thereafter, there is a rapid move to the long-run equilibrium. However, chocks in oil imports increase cause a reduction in military spending for the next year, then there is a rapid move to the long-run equilibrium. Interestingly, positive innovation chocks dominate negative ones for short-run impacts (nearly 6 years), but negative innovation chocks dominate as the system moves to the long-run equilibrium. These interesting results show that China is very careful in reducing its military efforts in case of a negative chock on its oil imports, but it responds relatively very quickly to positive chocks.

5. Conclusion and policy implications

This study evaluates the relationships between renewable energy consumption, crude oil imports, arms exports, military spending, and gross domestic product for China by using annual data ranging from 1989 to 2016. The ARDL bounds testing approach is used where at each time one variable is chosen as a dependent. Since the relationship between military spending and oil imports seems to be asymmetric, the non-linear ARDL approach is used to capture the asymmetric impact of oil imports on military spending.

Renewable energy and oil are substitute goods in China because an increase in the consumption of one reduces the consumption of the other in the long-run. Military expenditures impact positively oil imports in the long-run because firstly the military sector is an important consumer of energy. Secondly, high investments in defense and an imposing army dissuade belligerent countries from compromising the provision of China in oil. This interesting result has not been reached before by the literature.

Military spending impacts positively renewable energy consumption in the long-run as an important increase in MS increases the need for less costly and more secured renewable energy resources. Moreover, as raised by Samaras et al. (2019), civil renewable energy technology may have already benefited from military renewable energy technology improvements, leading to an increase in China's renewable energy production and consumption. These technological advances in the military sector may be caused by the increase in the Chinese military budget dedicated to R&D. This is a new result to be considered.

In the long-run, an increase in oil imports reduces arms exports by China because it considers the export of arms as a threat to peace in the world and in particular in oil-exporting countries, thus compromising its oil's provision. However, and for the same reasons, an increase in renewable energy consumption increases arms exports because China's dependency on imported oil will be reduced due to the substitutability between these two energy sources. Again, this non-obvious result has not been reached before by the literature.

Interestingly, while military spending is good for economic growth, arms exports hurt economic growth in China. Indeed, more arms exports could mean both more political and even military conflicts in the world negatively impacting international trade in goods and services, thus reducing China's economic growth.

Short- and long-run estimated coefficients of increases and decreases in oil imports are statistically different confirming the asymmetric relationship between military spending and oil imports. In the long-run, increasing oil imports by 1% increases military spending by 0.85%, and decreasing oil imports by 1% decreases military spending by 1.47%. Securing its oil supply appears to be a determining factor in Chinese military efforts.

The cumulative dynamic multipliers effects of increases and decreases in oil imports indicate that innovation chocks in oil imports short-cuts do not affect military expenditures in the following three years. After this, we observe a quick move to the long-run equilibrium. On the contrary, innovation chocks in oil imports increase imply a decrease in military spending the next year, then we observe a relatively quick move to the long-run equilibrium. It appears that China is very cautious about reducing its military efforts in the event of a negative shock to its oil imports, but it reacts very quickly to positive shocks. This worth considering result has not been reached before by the literature.

Given our econometric results, several policy recommendations may be driven. China should continue encouraging renewable energy use through fiscal policies as pollution taxes, subsidies for innovation and R&D, investment credits, ecological legislation, …etc. But it can also increase the R&D budget of the defense department dedicated to innovations in renewable energy as this may impact positively civil renewable energy projects. A sustainable renewable energy increase could reduce both oil imports and arms spending, ending in a cleaner environment and a peaceful world.

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