Determinants of Chinese Economic Growth and Trade: an ARDL Approach

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Abstract

In 2014 the IMF reported that China became the largest economy in the world according to Purchasing Power Parity (PPP) rates. This study aims to analyze and explain the Chinese miracle growth story. It focuses on the most frequently suggested explanations of China's growth, such as export promotion, exchange rate policy, labor productivity and comparative advantage due to low wages.

The paper employs the Autoregressive Distributed Lags (ARDL) model, the bounds test, and the Johansen cointegration technique to test for evidence of long-run equilibrium relations among pertinent variables. Once cointegration is established for an ARDL model, Granger Causality tests are performed using the Vector Autoregressive (VAR) model following the Toda Yamamoto (1995) method. In the case that cointegration is established using the Johansen methodology, Granger causality tests are performed within the framework of an estimated Vector Error Correction Model (VECM). The above models were employed to test for factors Granger-causing real Chinese GDP growth. Real GDP in this paper was used as a proxy for GDP growth. It was found that exports, imports, and the exchange rate Granger-cause real Chinese GDP growth. It was also found that world GDP, Chinese imports, and the exchange rate Granger-cause Chinese exports. The paper found asymmetry regarding the relationship of the exchange rate. We found that a weaker Renminbi was associated with increased exports, but a reduced GDP.

Section 1 – Introduction

For almost four decades China has experienced phenomenal economic growth, as demonstrated by the twenty-eight fold increase in real Chinese GDP from 1978 to 2014. The growth period began in 1978, only two years after the death of the long time communist leader Mao Zedong. The successful transformation of China from a closed planned agrarian economy to an open market is mainly attributed to the Deng Xiaoping-led government, which by 1978 adopted and launched many economic reforms. These reforms marked a benchmark in the history of China and the global economy.

China and Germany are presently the two world leading export economies. The vast majority of economists are convinced that economic growth in the two countries is based mainly on their booming foreign sectors. This study aims to investigate the determinants of Chinese economic growth. Specifically, the study examines particular policies and variables that contributed to economic growth.

Although real Chinese real exports increased by an average annual growth rate of approximately 11 percent from 1978-2014, during the period 2007-2014 they contracted by an average annual rate of 1.5 percent. This sharp decline in exports could be a major source of concern if the world economy continues to slow down. This is very important because most analysts are convinced that exports are the main driver of Chinese economic growth.

Another factor which has been widely cited as a source of Chinese economic growth is Foreign Direct Investment (FDI). After the opening of the Chinese economy to the world in 1978, many foreign companies invested heavily in China. Such companies took advantage of the exceptionally low Chinese labor costs, and thus gained a comparative advantage by exporting their goods from China. Real FDI increased at an average annual rate of approximately 40 percent from 1980 to 2014. Besides providing physical and financial capital, FDI also facilitated growth of exports by providing the know-how of international business.

Since the opening of the Chinese economy, continuous labor migration from rural to urban areas has been credited as a major contributing factor to the high economic growth of China. Such migration provided cheap labor and supported large gains in labor productivity, as workers kept moving from farming to manufacturing. As a result real labor productivity increased by an average annual growth rate of 3.4 percent. This constituted a total increase of approximately 220 percent during the period of 1978-2014.

Another factor that is considered to have played a crucial role in the growth of the Chinese exports is the real exchange rate (ER). In the past, China received fierce criticism for controlling (manipulating) the value of its currency, the Renminbi (Yuan), in order to boost its exports. The study also examines the validity of this claim.

More recently, the global financial crisis has had an acute negative impact on the Chinese economy. Starting with the financial crisis in 2007, the Chinese economy began experiencing negative real export growth and a slower growth in its real GDP. A few analysts have expressed concern that a slowdown of the Chinese economy would also have a negative impact on the global economy. Such analysts expect the Chinese economy to shift to a slower pace of economic growth if unfavorable external and/or domestic conditions continue to develop. The possibility of such negative developments raises concerns regarding the ability of China to continue its rapid economic growth in the future. One major reason for such concern is the possibility that the supply of migrant workers from rural to urban areas may dry up in the future. Such an event would cause labor shortages in the manufacturing sector. This concern holds particular weight because China no longer exclusively exports low-skilled labor-intensive products. China is now producing a variety of high-tech products, such as consumer electronics, weapons, and transportation equipment.

Another reason of concern about China's economic future is the environmental degradation which was an unintended negative side effect of the intensive development of manufacturing. Environmental degradation could be a growth deterrent factor for China. In addition, the state of the financial and banking sectors of China, particularly the high level of debt held by state banks and state-owned enterprises, is a major factor of concern regarding the sustainability of economic growth.

The study investigates and performs several empirical tests to reveal which policies and variables cause Chinese export growth. In this paper real Gross Domestic product is employed as a proxy for economic growth, in order to comply with the requirements of the econometric ARDL model.

In Section 2 the literature on Chinese economic growth is reviewed and discussed. In Section 3 the methodology of the paper is presented. Section 4 describes the sources and definitions of the variables. Section 5 presents and discusses the empirical results based on the estimated models. Finally Section 6 provides concluding comments.

Section 2 – Literature Review

For several centuries, most economists have been in agreement on the relationship between trade and economic growth. Starting with Adam Smith and David Ricardo, numerous economists have supported the beneficial effects of trade on economic growth and development. Some, however, have opposed free trade. These opponents to free trade are known as mercantilists.

Long ago, economists were divided into two groups regarding international trade policy. In one camp were those who supported the view that an open economy and the export-led growth model was the best way to economic development and growth. Many authors, such as Balassa (1978, 1985), Kruger (1980), Bhagwati and Shrinivasan (1978), support the export-led economic growth model. These authors believe free trade promotes efficiency in the domestic industries, which helps countries become internationally competitive. A successful export sector enables a country to earn foreign exchange which makes it possible to support a sustained level of imports. As a result exporting countries can develop advanced technologies through the importation of technologically-rich capital equipment. A few South East Asian countries, including China, experienced phenomenal economic growth following the export-led growth model.

A trade theory which is diametrically opposed to the export-led model is the import-substitution theory. According to this model a country can promote economic growth via protectionism by producing those goods that under free trade would normally have been imported. Raul Prebish (1962) was a strong proponent of the import-substitution model that was widely adopted in South America, as well as in a few other countries. It turned out that the import-substitution model was not successful in promoting economic growth. Protectionism leads to inefficiency, due to dependency on continuous subsidization of the domestic firms from their government.

Many empirical studies investigated the causal relations between international trade and economic growth. Most of the earlier studies employed the Vector Autoregression (VAR) model, as well as the method of cointegration in conjunction with the Vector Error Correction (VEC) model. Such studies employed either cross section or time series data. The majority of these studies found evidence that trade (exports and imports) cause economic growth, while other studies found evidence that economic growth causes trade. See for example Dutt and Ghost (1996), Ahmad and Harnhirun, Zestos and Tao (2002), and Tao and Zestos (1999). These studies have investigated Granger causality relations between trade and GDP in both developing and developed countries. Some studies support causality from trade to GDP growth whereas others support causality from growth to trade. A few empirical studies, however, have found bidirectional Granger causality between GDP and trade.[1]

Several authors examined the relation between Chinese economic growth and FDI. One of the earliest studies, by Liu, Burridge, and Sinclair (2002), reported that China's real exports and real GDP during the period 1979-1997 grew at the exceptionally high rates of 15 and 9 percent respectively. The aforementioned authors

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[1] Zestos and Tau (2002)

found that export-promotion policies were successful in China boosting economic growth. Rapid increases in exports were mainly carried out by Foreign Invested Enterprises (FIE), which were offered many incentives to invest in China. Indeed, FIE were given the privilege to carry their businesses with minimum restrictions from the government. As far back as the early 1990's, according to these authors, FIE were responsible for 41% of the total Chinese exports. The Liu, Burridge, and Sinclaire study employed the cointegration technique as well as the weak exogeneity Granger Causality tests and found two-way, direct and reverse causality between exports and FDI, in relation to Chinese economic growth.

A study by Yao (2006) also examined the relationship between economic growth on one hand, and FDI and exports on the other. This study also found that FIE were crucial in boosting Chinese exports. To attract FIE, China launched major economic reforms in its economy. For example China also drastically devalued its currency, the "Rein Ming Bi", which is more commonly known as the Renminbi or Yuan. Using a large panel data set of 28 Chinese provinces, Yao found that exports and FDI positively affected real GDP growth. In addition, Yao was possibly one of the first authors to point out some problems China was facing back in 2006 and before. China presently is confronted with the same problems, even a decade later. Such problems pertain to corruption, inefficient state industries, environmental degradation, over-indebted financial institutions, and income inequality.

Narayan (2006) examines the "nexus" between the Chinese trade balance and the Renminbi/US dollar exchange rate. He employed the relatively new Bound Test using the Autoregressive Distributed Lags (ARDL) model in order to establish evidence of cointegration among the two variables. Estimates based on the ARDL model provided evidence that a Renminbi devaluation improves the trade balance. Such empirical finding suggests that Chinese government policies aiming to affect the trade balance have been effective in generating trade surpluses and boosting economic growth.

The ARDL model and the Bounds Test were also employed by Narayan (2005a) to test the hypothesis: whether Chinese saving and investment were more closely correlated during the period when China maintained a fixed exchange rate regime (1952-1994) in relation to another period that included years after China had adopted a managed floating exchange rate regime (1952-1998). According to the Bounds Test, Chinese saving and investment to GDP ratios are related in both periods, but the relationship is much stronger during the fixed exchange rate regime when capital flows were not as important. Such results provide evidence against the Feldstein-Horioka Paradox, which had found strong correlation between national saving and national investment. This suggests that capital flows became more important in more recent years, during which the managed floating exchange rate regime was adopted.

Several other authors examine causal-relations between real GDP growth and economic variables which they consider to be important in affecting real GDP growth. For example, Jalin, Feridun, and Ma (2010) found a strong and positive causal relationship between finance and growth. These authors employed both the principal component method as well as the ARDL model to examine a possible nexus between financial development and economic growth in China. They concluded that financial development and international trade have both played a positive role in affecting real

Chinese economic growth. Qiren (2013) claimed the miraculous economic growth of China is explained by institutional reforms and the "redefinition of property rights." Such reforms were triggered by emancipation of human capital, and reduced the operational cost in China. According to Qiren, these reforms gave China a comparative advantage in the global economy.

A few other authors paid much attention to the relation of environmental degradation and Chinese economic growth. Salami, Dada, and Kareem (2012) employed the Johansen Cointegration method and the VEC model to study causal relations between carbon dioxide emissions, energy consumption, and economic growth for the period 1971-2008. The authors found that the economic growth of China depends on carbon dioxide production. Therefore the authors recommend that Chinese authorities ought to search for alternative sources of energy. For example they could create a market for pollution rights, or employ taxation and subsidization incentive policies to reduce environmental degradation.

Popescu (2013) attributes the rapid Chinese economic growth to the development of the urban "non-agricultural" sector, which was caused by migration from rural to urban areas. Chinese economic growth, according to Popescu, was also positively affected by fiscal decentralization.

Yizhong, Jian, and Min (2014) support the view that Chinese economic growth is based on the growth of all inputs of production except that of capital. According to the authors, the marginal product of capital is recently very low, implying that overinvestment is an issue in China. Consequently, the authors found that excessive capital investment would render the Chinese rate of growth unsustainable. Such an approach, however, ignores the fact that new FDI is crucial because it brings advanced technology along with the physical capital.

A few more recent studies raise concerns regarding the long-term sustainability of Chinese economic growth. Zhang (2015) identifies the determinants of the miraculous economic growth. These are factors mentioned in many previous studies: export promotion, FDI, and the flow of rural workers to urban areas. In addition Zhang (2015) points out that since the global recession, growth of both Chinese exports and GDP began to slow down. In response to these global challenges, the Chinese government began to promote domestic consumption. Because the domestic Chinese market is exceptionally large, a shift towards promoting domestic consumption could be a long run solution for China. In addition such an approach could be very beneficial for countries that have been negatively affected by the large Chinese trade balances.

Chen, Funke, and Tao (2015) claim that China would be able to maintain a high rate of growth if it undergoes major reforms of its financial and banking system. According to the authors, there exists strong evidence that the government favors the State-Owned Enterprises (SOE) in relation to private firms, consequently, state enterprises were protected and as a result many became inefficient. China has recently put forward some initiatives to liberalize its economy and thus remove misallocation of resources by relying on the market pricing mechanism. However, there are counterforces within the government and the Chinese Communist Party that push in the opposite direction supporting and promoting SOEs.

Lastly, since China became such a great economic power, it is plausible for one to ask the pertinent question: what is the effect of China's economic growth on the world GDP growth? This question was addressed by Arora and Vamvakides (2011). Employing Vector Error Correction (VEC) and Vector Autoregressive (VAR) models the study found that Chinese economic growth is sustainable.

Section 3 – Methodology

The paper employs three different models to investigate causal relations between real GDP growth of China and a few pertinent variables that are considered likely to affect economic growth[1]. The first model is the Autoregressive Distributed Lags (ARDL) model developed by Pesaran, Shin, and Smith (2001). The second model is the Vector Autoregression (VAR) model which is employed to test for Granger non-causality using the Toda Yamamoto method (2005), and serves as a complement to the estimated ARDL model. Lastly, the third model is the Johansen (1991, 1995) cointegration technique used in conjunction with the Vector Error Correction (VEC) model. The latter model is often employed to test for short and long-run Granger non-causality once cointegration is established among the variables.

The ARDL model tests for cointegration at the levels of variables by employing the Bounds Test within the framework of the estimated ARDL model. The ARDL-Bounds Test procedure is considered superior to the previously employed models, such as the two step procedure of Engle and Granger (1987) and the Johansen (1991, 1995) technique.

The superiority of the ARDL model and the Bounds Test lies in the fact that the ARDL model can be employed whether each of the time series variables are integrated of order zero I(0), of order one I(1), or are mutually cointegrated. So long as the variables are not of order I(2) or higher, the ARDL-Bounds Test procedure can be employed. Such features allow researchers to incorporate many variables in their research that could not have been included with other methodologies. In using the ARDL model, researchers have the option to include lagged differences of varying orders in their variables. The optimal lag length of each variable of the ARDL model is found by estimating: $(p+1)^k$ regressions, where k is the number of right-hand side variables in the equation and p is the maximum number of lags included for a variable in the single equation of the ARDL model. The test statistic of the Bounds Test is a Wald F-statistic, which tests for joint-significance of all the one-period lagged levels of all variables in a conditional or unrestricted Error Correction Model (ECM) (Pesaran et al, 2001).

The two critical values of the lower and upper limits of the Bounds Test are derived for the case when all variables are stationary in levels I(0) and when all variables are stationary in first differences I(1). The first ARDL model is denoted as model A, and uses the variables: Y = real GDP, X = real total exports, ER = real exchange rate of the Renminbi vs. the US dollar, M = real total imports. Equation (1) below represents the unrestricted or conditional ARDL model for the variables Y, X, ER, and M. All variables in this model are real and in natural logarithms, and all except ER are divided by population and thus expressed in per capita terms.

(1) $$\Delta lnY = \alpha_0 + \sum_{i=1}^{r} \alpha_{1i} \Delta lnY_{t-1} + \sum_{i=0}^{s} \alpha_{2i} \Delta lnX_{t-1} + \sum_{i=0}^{k} \alpha_{3i} \Delta lnER_{t-1} + \sum_{i=0}^{p} \alpha_{4i} \Delta lnM_{t-1}$$
$$+\alpha_5 lnY_{t-1} + \alpha_6 lnX_{t-1} + \alpha_7 lnER_{t-1} + \alpha_8 lnM_{t-1} + \varepsilon_t$$

where α_0, α_{1i}, α_{2i}, α_{3i}, α_{4i}, α_5, α_6 , α_7, and $\alpha_8$are parameters to be estimated and ε_t is assumed to be a white noise error.

The null and alternative hypotheses (H_o and H_a) regarding the Bounds Test for evidence of cointegration are:

$$H_o: \alpha_5 = \alpha_6 = \alpha_7 = \alpha_8 = 0$$
$$H_a: \alpha_5 \neq \alpha_6 \neq \alpha_7 \neq \alpha_8 \neq 0$$

We estimated a second ARDL model, denoted as model B, which includes exactly the same variables as model A. All the variables in model B, however, are expressed in nominal terms. These variables are: nominal GDP (NY), nominal exports (NX), nominal exchange rate (ER), and nominal imports (NM). Equation (2) presents the unrestricted or conditional ARDL Error Correction Model (ECM) for the four variables described above. All variables in this model are nominal and in natural logarithms, and all except ER are divided by population and thus expressed in per capita terms.

(2) $$\Delta lnY = \beta_0 + \sum_{i=1}^{r} \beta_{1i} \Delta lnY_{t-1} + \sum_{i=0}^{s} \beta_{2i} \Delta lnX_{t-1} + \sum_{i=0}^{k} \beta_{3i} \Delta lnER_{t-1} \sum_{i=0}^{p} \beta_{4i} \Delta lnW_{t-1}$$
$$+\beta_5 lnY_{t-1} + \beta_6 lnX_{t-1} + \beta_7 lnER_{t-1} + \beta_8 lnW_{t-1} + \varepsilon_t$$

where β_0, β_{1i}, β_{2i}, β_{3i}, β_{4i}, β_5, β_6 , β_7, and β_8 are parameters to be estimated and ε_t is a white noise error.

The Bounds Test is performed with Model B as well. The null hypothesis and alternative hypothesis for the bounds test are shown below respectively:

$$H_o: \beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$$

$$H_a: \beta_5 \neq \beta_6 \neq \beta_7 \neq \beta_8 \neq 0$$

Section 4 – Definitions and Data Sources of Variables

Two sets of data were used in this study. The first data set is for the period 1978-2014, a total of 37 annual observations. For the first data set of 1978-2014 all of the variables were expressed in per capita terms, with the exception of wages (W) and the exchange rate (ER). Real total manufacturing wages (W) are divided by the total manufacturing labor force, thus making W real wage per worker. All of the variables in the first data set are expressed in terms of Renminbi. The second data set is for the period 1981-2014, a total of 34 annual observations. All of the variables in the second data set are expressed in terms of US Dollars, and are not expressed in per capita terms. In both sets of data, the natural logarithms of the levels of the time series variables are employed. Finally, the exchange rate is expressed in terms of Renminbi per Dollar in both data sets.

Definition of Variables from the First Data Set (Models A, B, and the VEC):

lnY: Natural logarithm of Real Gross Domestic Product (Y) per capita. The real GDP is equal to nominal GDP divided by the GDP deflator, which is equal to 100 in 2010[2]. Nominal GDP and real GDP are expressed in billions of national currency units, i.e., Renminbis (RMBs). The nominal GDP of China is from the China Yearbook. GDP deflator index of China (2010=100) is from the International Monetary Fund (IMF).

lnX: Natural logarithm of Real Total Exports (X) per capita, expressed in 100 million RMB. Source: the China Yearbook.

lnM: Natural logarithm of Real Total Imports (M) per capita, expressed in 100 million RMB. Source: the China Yearbook.

lnER: Natural logarithm of the Real Exchange Rate (ER) versus the US dollar expressed in terms of the number of Renminbis per 1 US dollar. Real exchange rate is calculated using the following formula:

$$ER_{\frac{\#RMB}{\$1}} = NER_{\frac{\#RMB}{\$1}} \bullet \frac{P_{US}}{P_{PRC}}$$

NER refers to the nominal exchange rate of the country expressed in number of Renminbi per US dollar. P_{US} and P_{PRC} refer to the GDP Price deflators of the respective countries, the United States and the People's Republic of China (PRC). Source: Organization of Economic Cooperation and Development (OECD).

lnW: Natural logarithm of the total wage bill of employed manufacturing workers per laborer in urban areas expressed in 100 million RMB. Thus, it is total wages in manufacturing divided by the labor force in manufacturing. Source: China Yearbook.

Nominal Variables in the First Data Set:

For the estimation of Model B we employed exactly the same variables as in Model A, described above, however these variables were nominal instead of real. These variables are: lnNY (Nominal GDP), lnNX (Nominal Exports), lnNER (Nominal Exchange Rate), and lnNM (Nominal Imports).

Definition of Variables from the Second Data Set (Models C and D):

The second data set spans from 1981-2014, and includes the variables:

lnWY: Natural logarithm of Real World GDP (WY), excluding Chinese GDP. The real GDP is equal to nominal world GDP divided by the GDP deflator, which is equal to 100 in 2010. Nominal GDP and real GDP are expressed in billions of US Dollars. Sources: The nominal world GDP is from the World Bank. The US GDP deflator index (2010=100) is from the IMF's International Financial Statistics.

lnX: Natural logarithm of Real Total Exports (X). Source: the China Yearbook.

lnM: Natural logarithm of Real Total Imports (M). Source: the China Yearbook.

lnER: Natural logarithm of the Real Exchange Rate (ER) versus the US dollar expressed in terms of the number of Renminbis per 1 US dollar. Real exchange rate is calculated in the same way as in the first data set (see above).

Nominal Variables in the Second Data Set:

Nominal data from the second data set is defined identically to the real data, as above. This includes the following variables: lnNX (Nominal Exports), lnNWY (Nominal World GDP), lnNER (Nominal Exchange Rate), and lnNM (Nominal Imports).

Section 5 – Empirical Results

Before proceeding with the estimation of the models, we first investigate the dynamic properties of the time series variables. For this purpose, unit root tests were performed for all variables. The most common unit root tests used in time series econometric studies, the Augmented Dickey-Fuller (1979) and the Phillips-Perron (1988) tests, have recently been criticized for being unreliable for small sized samples. This is because these tests too frequently tend to reject the null hypothesis when it is actually correct, and accept it when it is false (DeJong et al., 1992, Alimi, 2014). Consequently, in this study, we utilize two relatively new unit root tests, the Dickey-Fuller Generalized Least Squares (DF-GLS) test, developed by Elliot et al. in 1996, and the Ng-Perron test (2001). The results of these two tests are reported below in Table 1.

According to DF-GLS and Ng-Perron unit root tests below, the vast majority of the test results of all variables in levels are either non-stationary or mixed, whereas all of the variables in the first differences are stationary. Upon examining the Augmented Dickey-Fuller and Phillips-Perron test results, it was observed that they generally convey the same information regarding the dynamic stability of the variables. However, the test results tend to be less convincing in revealing the correct level of integration.

Since all of the variables are stationary at the first differences, and none of the variables are integrated of order two I(2) or above, it is appropriate to proceed with the estimation of the ARDL model and perform the Bounds Test for cointegration. Two such models were estimated using the first data set spanning from 1978-2014. Both Model A and Model B utilize exactly the same variables; however Model A includes all real variables whereas Model B includes only nominal variables. The two models will be presented simultaneously side by side in each table.

Table 1 – Unit Root Tests for Variables Used In Model A and Model B

Variables	DF-GLS test							
	Level				1st Difference			
	constant	lags	c & trend	lags	constant	lags	c & trend	lags
lnY	-.81	3	-1.78	0	-2.73***	3	-3.51**	3
lnX	.01	0	-1.04	0	-5.37***	0	-6.06***	0
lnER	-1.08	0	-.65	0	-4.17***	0	-5.42***	0
lnM	-.73	0	-1.28	0	-4.57***	0	-5.05***	0
lnW	.52	1	-2.07	1	-3.65***	0	-3.99***	0

Variables	Ng-Perron test at Level									
	constant					constant & trend				
	MZa	MZt	MSB	MPT	lags	MZa	MZt	MSB	MPT	lags
lnY	-154.37***	-8.37***	.06***	.25***	3	-11.04	-2.34	.21	8.28	4
lnX	.66	.80	1.20	90.99	0	-2.67	-.85	.32	24.93	0
lnER	-.76	-.62	.81	31.92	0	-.40	-.22	.56	68.32	0
lnM	.55	.59	1.08	78.04	0	-3.66	-1.06	.29	22.77	0
lnW	1.75	.73	.42	19.67	1	-14.46*	-2.46	.17*	7.57	1

Variables	Ng-Perron test at 1st Difference									
	constant					constant & trend				
	MZa	MZt	MSB	MPT	lags	MZa	MZt	MSB	MPT	lags
lnY	-38.53***	-4.39***	.11***	.64***	3	-1760***	-29.66***	.02***	.06***	3
lnX	-17.35***	-2.91***	.17***	1.53***	0	-17.47*	-2.95**	.17*	5.23**	0
lnER	-15.61**	-2.79***	.18**	1.57***	0	-16.84*	-2.89*	.17*	5.47**	0
lnM	-16.52***	-2.81***	.17***	1.71***	0	-17.16*	-2.92*	.17*	5.36**	0
lnW	-14.16***	-2.66***	.19**	1.73***	0	-15.16*	-2.74*	.18*	6.10*	0

- All unit roots reported are of the Schwarz Information Criterion (SIC) to determine the optimal number of lags to be included in the test equation
- *, **, and *** represent the significance levels of .10, .05, and .01 respectively
- Unit roots for nominal data, as well as for Philips Perron and Augmented Dickey Fuller tests, can be obtained by contacting the authors

Below in Table 2, the estimated ARDL unrestricted or conditional models of equations (1) and (2) are presented respectively. Model A has the natural logarithm of Real GDP per capita (lnY) as its dependent variable, whereas Model B has the natural logarithm Nominal GDP per capita (lnNY) as its dependent variable. The independent variables for the two models appear in the second row. Specific information[3] about the estimated models appears in the bottom of the table. The models were estimated using EViews. The Schwarz Information Criterion (SIC) was used to determine the number of lags. The SIC is known to select fewer lagged differences in the model than any of the other criterion and as a result, it selects the most parsimonious model. This is desirable for this study, as our two sample sizes are relatively small.

Several of the coefficients are statistically significant in each model, as denoted by the number of asterisks. Both models have Durbin-Watson statistics relatively close to 2, indicating that the models are free of serial correlation. In order to ensure each model was free from serial correlation, we performed a Lagrange Multiplier (LM) Test for each of the two models. The results of the LM Test for the two estimated models are shown below in Table 3. According to the Breusch Godfrey Serial Correlation test, both models pass at the 5 percent level of significance as all p-values are above the 5 percent level of significance.

Besides the lagged differences, each model includes all the one period lagged variables. This is the main characteristic of the unrestricted ARDL model.

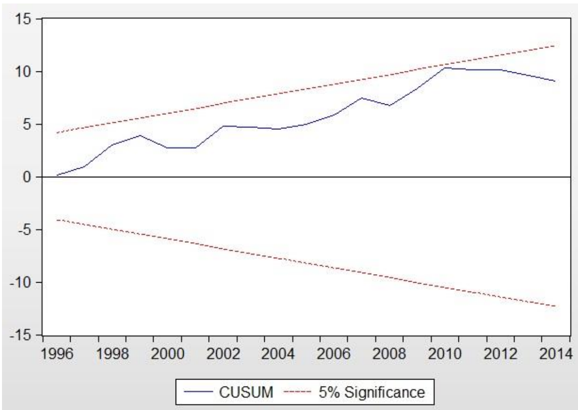
Table 2 – Estimated Unrestricted ARDL Model A and B 1978-2014

Model A		Model AB	
Dependent Variable	ΔlnY	Dependent Variable	ΔlnNY
Independent Variables	ΔlnX, ΔlnER, ΔlnM	Independent Variables	ΔlnNX, ΔlnNER, ΔlnNM
C	.1542	C	.5884***
ΔlnX	-.0203	ΔlnNY(-1)	.3704**
ΔlnX(-1)	-.0547	ΔlnNY(-2)	.0294
ΔlnX(-2)	-.0820**	ΔlnNY(-3)	.1478
ΔlnER	.0465	ΔlnNX	.0119
ΔlnER(-1)	.2224***	ΔlnNM	.2442***
ΔlnER(-2)	.2598***	ΔlnNER	-.2520*
ΔlnER(-3)	.1521***	Break94	.1313**
ΔlnM	.1206***		
ΔlnM(-1)	-.0722*		
lnX(-1)	.0984***	lnNX(-1)	.1078*
lnER(-1)	-.0156***	lnNM(-1)	.0180
lnM(-1)	.1319**	lnNER(-1)	-.0704***
lnY(-1)	-.1734***	lnNY(-1)	-.1521***
R^2	.8238	R^2	.8666
Adjusted R^2	.7031	Adjusted R^2	.7967
S.E.	.0132	S.E.	.0268
D.W.	2.1034	D.W.	2.0043
F	6.8311	F	12.3984
SIC	-4.8817	SIC	-3.5801

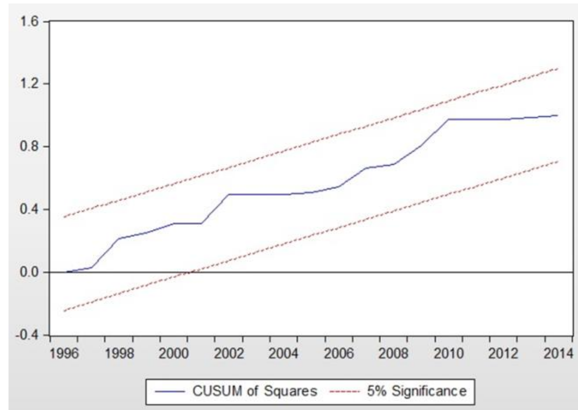
Table 3 – Breusch-Godfrey Serial Correlation LM Test

Lag	Prob. Chi-square	
	Model A	Model B
1	.5837	.8865
2	.6641	.3602
3	.8231	.4023
4	.8949	.1996

Figure 1 – Structural Stability Tests – Model A

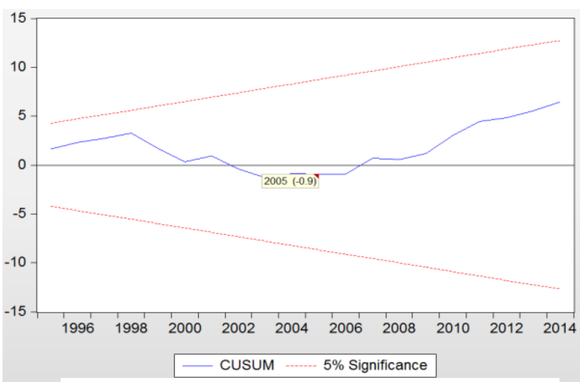


CUSUM Graph

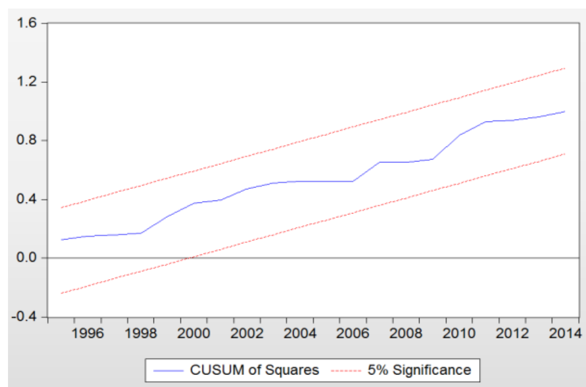


CUSUM of Squares Graph

Figure 2 – Structural Stability Tests – Model B



CUSUM Graph



CUSUM of Squares Graph

Figures 1 and 2 above show the graphs of two structural stability tests: Cumulative Sum (CUSUM) and CUSUM of Squares, which were suggested by Pesaran and Shin (1997) to test the stability of the coefficients of the ARDL model. The two tests were developed by Brown, Durbin, and Evans (1975), and their test statistic is based on the recursive residuals method.

Table 4 – Bounds Test – Testing for Cointegration

Model A F-statistic: 14.59355

Model B F-statistic: 4.265793 k = 3 df = 36

Significance Level	Pesaran		Narayan	
	I(0) Bound	I(1) Bound	I(0) Bound	I(1)Bound
10%	2.72	3.77	2.96	4.10
5%	3.23	4.35	3.62	4.91
2.5%	3.69	4.89	-	-
1%	4.29	5.61	5.20	6.85

Table 4 above lists the critical values of the Bounds Test calculated by Pesaran et al. (2001)[4] and Narayan (2005a)[5]. Because our sample size is relatively small (n=37), we decided to report the critical values of the Bounds Test that were calculated specifically for small sample sizes $30 \leq n \leq 80$ by Narayan (2005a). The calculated F-statistics for Models A and B are 14.59355 and 4.265793 respectively. The F-value for Model A is very large and above the I(1) critical values of both the Pesaran and Narayan bounds at the 1 percent level of significance. The F-value for Model B is above the I(1) critical values at the 10 percent level of significance. Therefore it is concluded that the null hypothesis of no cointegration can be rejected for both cases. The Bounds Test allows us to test for the significance of the one period lagged dependent variable Y(-1) for both of the models. The estimated t-values of these variables are -4.84083 and -3.159795 for the Models A and B respectively. Since the value of Model A is above the 1 percent I(1) value of the t-limiting distribution in table C11(iii) case iii unrestricted intercept and no trend, this provides further evidence for cointegration for Model A.

Table 5 – Estimated Conditional Long Run ARDL Model

Model	Model A1	Model	Model A2
Dependent Variable	ΔlnY	Dependent Variable	ΔlnNY
Independent Variables	ΔlnX, ΔlnER, ΔlnM	Independent Variables	ΔlnNX, ΔlnNER, ΔlnNM
C	.1542***	C	.6162***
ΔlnX	-.0203	ΔlnNY(-1)	.3553**
ΔlnX(-1)	-.0547*	ΔlnNY(-2)	.0219
ΔlnX(-2)	-.0820***	ΔlnNY(-3)	.1554
ΔlnER	.0465	ΔlnNX	.0132
ΔlnER(-1)	.2224***	ΔlnNM	.2434***
ΔlnER(-2)	.2598***	ΔlnNER	-.2402***
ΔlnER(-3)	.1521***	ΔBreak94	.1230***
ΔlnM	.1206***		
ΔlnM(-1)	-.0722***		
EC_{t-1}	-.1734***	EC_{t-1}	-.1593***

Cointegrating Equations

Model A – Equation (3):

lnY = 0.5676(lnX) – 0.8974(lnER) + 0.7608(lnM)

	lnX	lnER	lnM
SE	.2523	.0854	.2346
t	2.2492	-10.5094	3.2437
p	(.0365)	(.0000)	(.0043)

Model B – Equation (4):

lnNY = 0.7089(lnNX) – 0.4627(lnNER) + 0.1184(lnNM) + 0.8631(Break94)

	lnNX	lnNER	lnNM	Break94
SE	.4027	.1624	.4090	.4177
t	1.7606	.-2.8496	.2895	2.0663
p	(.0929)	(.0096)	(.7751)	(.0514)

In Table 5 above, the estimated long run conditional ARDL models are presented. The main feature of this model is the inclusion of the one period lagged error term EC_{t-1}. As displayed above, the coefficient of EC_{t-1} is highly significant and negative in both models. This indicates that if the variables are not at their long run equilibrium values, there will be a quick adjustment for these variables to return to their long-run equilibrium values.

Equations 3 and 4 are the cointegrating equations of the ARDL Models A and B. In equation (3) for Model A, all three independent variables are statistically significant. Both exports and imports have a positive coefficient, indicating that an increase in exports or imports will increase the real GDP of China. The coefficient of the exchange rate however, is negative, implying that as the Renminbi becomes stronger versus the dollar, the Chinese real GDP increases. One possibility for the unexpected incorrect sign of the ER variable is that this variable should not have been included in linear logarithmic form, but instead should have been included as a nonlinear quadratic variable. Another possible explanation for this unexpected result is that Chinese GDP has been increasing since 1978, even during periods of Renminbi appreciation, as there were such periods in the exchange rate history of China.

The cointegration equation (4) for Model B also shows that an increase in real exports positively affects real GDP. The exchange rate in equation (4) is also negatively related to the nominal GDP (lnNY). This is the same relationship as in equation (3), suggesting that both Models A and B should be further investigated regarding the sign of the exchange rate.

Granger Causality Tests for Models A and B

Although the empirical work of the study established cointegration among the variables in each of the two models, no test for Granger causality has been carried out yet. It seems that the breakthrough work by Pesaran et al. (2001) for cointegration of time series variables of differing integrating orders was complemented by Toda and Yamamoto (1995). As indicated by the year of the major contribution, it preceded the introduction of the ARDL model and the Bounds Test. Toda and Yamamoto showed that even if a set of level variables are of different order of integration, the standard asymptotic theory is still valid, provided the order of integration does not exceed the lag length of the VAR model. Thus, a VAR model can be estimated in the levels of the variables and within the framework of the estimated VAR model, Granger noncausality tests can be performed.

The data used to estimate ARDL Models A and B was also used to estimate two VAR models for A and B respectively. The usual procedure for the lag length selection was followed. In Tables 7 and 9 we report the VAR Granger Causality test results that were produced in EViews, where they are referred to as: Granger Causality/Block Exogeniety tests. The estimated VAR models are reported in the Appendix 1. Prior to choosing the number of included lagged difference in the models, we performed the Lagrange Multiplier LM Test to test for serial correlation.

The “VAR lag order selection criteria” of EViews, suggested to use 5 lags for Model A, so we report the Granger Causality test results for 5 lags. The “VAR lag order selection criteria” of EViews, suggested to use 5 lags for Model B, however through trial and error we determined 3 lags to be the optimal number of lags, and thus we report Granger Causality Test results for 3 lags.

Table 6 – VAR Residual Serial Correlation LM Test Model A

Lags	LM-Stat	Probability
1	21.3781	.1644
2	7.6444	.9588
3	23.5454	.0999
4	9.2892	.9010
5	25.1150	.0678

Table 7 – Granger Causality Tests for Model A

Dependent Variable		lnY	
Excluded	Chi-square	df	Probability
lnX	9.7688	5	.0821
lnER	4.6426	5	.4610
lnM	8.8679	5	.1145
All	**31.0937**	**15**	**.0085**

Dependent Variable		lnX	
Excluded	Chi-square	df	Probability
lnY	14.8370	5	.0111
lnER	9.5483	5	.0891
lnM	19.6998	5	.0014
All	**55.5561**	**15**	**.0000**

Dependent Variable		lnER	
Excluded	Chi-square	df	Probability
lnY	66.2903	5	.0000
lnX	47.3042	5	.0000
lnM	55.2381	5	.0000
All	**233.4931**	**15**	**.0000**

Dependent Variable		lnM	
Excluded	Chi-square	df	Probability
lnY	33.7613	5	.0000
lnX	10.7838	5	.0558
lnER	5.6368	5	.3432
All	**60.7330**	**15**	**.0000**

Table 8 – VAR Residual Serial Correlation LM Test Model B

Lags	LM-Stat	Probability
1	21.1740	.1719
2	16.2802	.4336
3	9.2659	.9021
4	11.8369	.7551
5	20.1826	.2121

Table 9 – Granger Causality Tests for Model B

Dependent Variable		lnNY	
Excluded	Chi-square	df	Probability
lnNX	3.8515	3	.2780
lnNER	1.8536	3	.6071
lnNM	1.5618	3	.6681
All	**15.7032**	**9**	**.0733**

Dependent Variable		lnNX	
Excluded	Chi-square	df	Probability
lnNY	3.1010	3	.3763
lnNER	1.6344	3	.6516
lnNM	7.8136	3	.0500
All	**11.3655**	**9**	**.2515**

Dependent Variable		lnNER	
Excluded	Chi-square	df	Probability
lnNY	.5922	3	.8982
lnNX	3.6697	3	.2994
lnNM	1.8034	3	.6142
All	**6.1987**	**9**	**.7199**

Dependent Variable		lnNM	
Excluded	Chi-square	df	Probability
lnNY	7.2506	3	.0643
lnNX	1.8307	3	.6083
lnNER	1.6292	3	.6528
All	**9.7714**	**9**	**.3693**

As can be seen from the results above, there is evidence of Granger causality from the independent variables to the dependent variable of GDP. The real data support Granger causality at the 1 percent level and the nominal data support causality at the 10 percent level.

Model C and Model D - Estimation of Exports 1981-2014

Two more ARDL models were estimated, and are reported as Model C and Model D. Model C includes four variables: lnX, lnWY, lnER, and lnM. The dependent variable of this model is the natural logarithm of exports, whereas the independent variables are the natural logarithms of real world GDP, real exchange rate (ER), and real imports. All variables are expressed in terms of the levels of the variables, rather than in per capita terms as they were in Models A and B. lnER is defined as it was for Model A. Model D includes exactly the same variables as Model A, but the variables are all in nominal terms. Both Models C and D include a break for the year 1993.

Prior to the estimation of the ARDL model, we investigated the stability properties of the variables by performing unit root tests.[7] According to the unit root results, none of the variables are integrated of order I(2) or above, making an ARDL model estimation suitable.

Table 10 below reports the results of the estimated unrestricted Models C and D. Both models have a DW statistic which is very close to the ideal value of 2, indicating that there is most likely an absence of serial correlation. This is also shown by the Bresuch-Godfrey Serial Correlation LM test results in Table 11, which show the p-values of both models are above .05 for all lags. In Figure 3 and Figure 4, the graphs of the CUSUM and CUSUM of Squares clearly indicate that there is no statistical evidence of change in the stability of the coefficients. Such evidence is supported as the graph of the test statistics remain within the 95% confidence interval boundaries for both Model C and Model D.

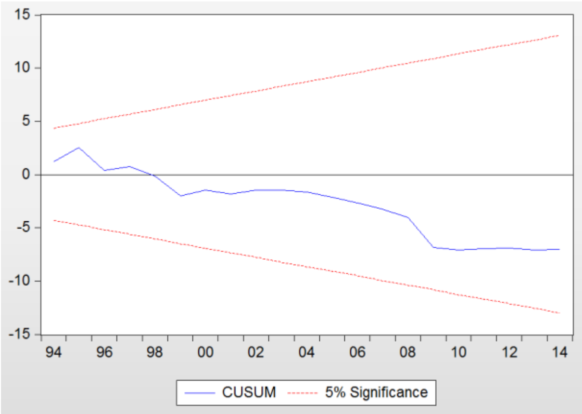
Table 10 Estimated Unrestricted ARDL Model C and D

Model C		Model D	
Dependent Variable	ΔlnX	Dependent Variable	ΔlnNX
Independent Variables	ΔlnWY, ΔlnER, ΔlnM	Independent Variables	ΔlnNWY, ΔlnNER, ΔlnNM
Variable	Coefficient	Variable	Coefficient
C	-4.1236***	C	-2.3218*
ΔlnX(-1)	-.0792	ΔlnNX(-1)	-.0863
ΔlnWY	1.1125***	ΔlnNX(-2)	-.0670
ΔlnM	.4272***	ΔlnNWY	1.2562***
ΔlnER	.2400	ΔlnNM	.3940***
Break93	-.0735	ΔlnNER	1.3021***
		Break93	-.0887
lnWY(-1)	.4493**	lnNWY(-1)	.2896
lnM(-1)	.1839	lnNM(-1)	.2373*
lnER(-1)	.1584**	lnNER(-1)	.3101***
lnX(-1)	-.2939**	lnNX(-1)	-.3398**
R^2	.8188	R^2	.9652
Adjusted R^2	.7447	Adjusted R^2	.9479
S.E.	.0611	S.E.	.0554
D.W.	1.9072	D.W.	2.0358
F	11.0447	F	55.5477
SIC	-2.0442	SIC	-2.1696

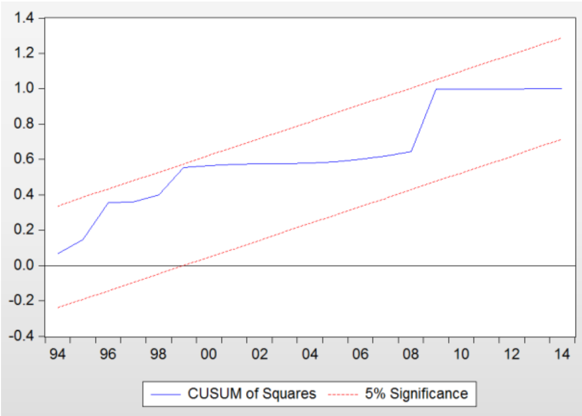
Table 11 Breusch-Godfrey Serial Correlation LM Test C and D

	Model C	Model D
Lag	Prob. Chi-square	Prob. Chi-square
1	.9030	.4286
2	.1451	.2280
3	.2759	.3984
4	.1596	.3443

Figure 3 – Structural Stability Tests – Model C

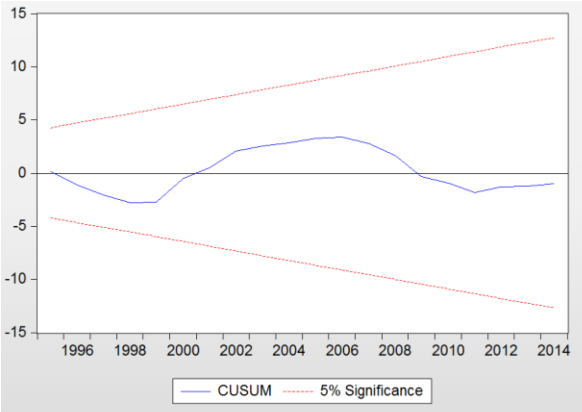


CUSUM Graph

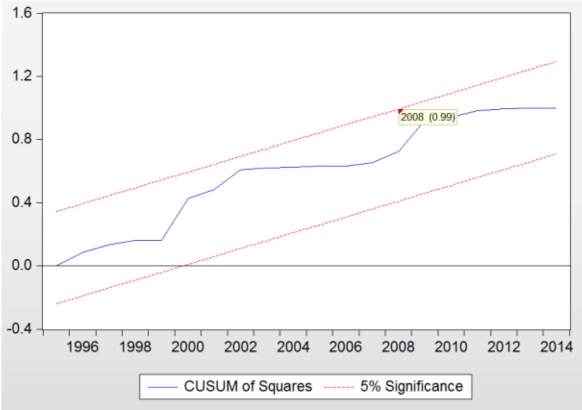


CUSUM Graph

Figure 4 – Structural Stability Tests – Model D



CUSUM Graph



CUSUM of Squares Graph

Table 12 reports the Bounds Test by indicating the Pesaran and Narayan critical values. The null hypothesis of no cointegration is rejected for Model C at the 2.5 percent significance level according to Peseran, and 10 percent according to Narayan. The null hypothesis of no cointegration is rejected for the nominal data (Model D), at the 5 percent significance level according to both Peseran and the 10 percent significance level according to Narayan. Therefore we conclude that there is evidence for cointegration for both Models C and D.

Table 12 – Bounds Test – Testing for Cointegration

Model C1 F-statistic: 4.937176

Model C2 F-statistic: 4.371775 k = 3 df = 33

Significance Level	Pesaran		Narayan	
	I0 Bound	I1 Bound	I0 Bound	I1Bound
10%	2.72	3.77	3.008	4.150
5%	3.23	4.35	3.710	5.018
2.5%	3.69	4.89	-	-
1%	4.29	5.61	5.33	7.063

Table 13 reports the long run conditional ARDL model. As it can be seen from this table, the one period lagged error term (EC_{t-1}) of the cointegrating equation are highly significant and negative as is required for cointegrated variables. The coefficient of the lagged error terms for Models C and D indicate that 27 and 33 percent of the deviation of the variables from their long run equilibrium values will be corrected within one year respectively.

Table 13 – Estimated Long Run Conditional ARDL Model C and D

Model C		Model D	
Dependent Variable	ΔlnX	Dependent Variable	ΔlnNX
Independent Variables	ΔlnWY, ΔlnER, ΔlnMUS	Independent Variables	ΔlnNWY, ΔlnNER, ΔlnNM
Variable	Coefficient	Variable	Coefficient
C	-3.7802***	C	-2.2526***
ΔlnX(-1)	-.0751	ΔlnNX(-1)	-.0840*
ΔlnWY	1.0952***	ΔlnNX(-2)	-.0648
ΔlnM	.4271***	ΔlnNWY	1.2509***
ΔlnER	.1621	ΔlnNM	.3942***
ΔBreak93	-.1201**	ΔlnNER	1.2863***
		ΔBreak93	-.0979**
EC_{t-1}	-.2696***	EC_{t-1}	-.3298***

Model C – Equation (5):

lnX = 1.5287(lnWY) + 0.6255(lnM) + 0.5390(lnER) – 0.2500(Break93)

	lnWY	lnM	lnER	Break93
SE	.7946	.2613	.2674	.2330
t	1.9240	2.3936	2.0159	-1.0729
p	(.0674)	(.0256)	(.0562)	(.2949)

Model D – Equation (6):

lnNX = 0.8523(lnNWY) + 0.6984(lnNM) +0.9127(lnNER) – 0.2611(Break93)

	lnNWY	lnNM	lnNER	Break93
SE	.4334	.1482	.3295	.1873
t	1.9664	4.7137	2.7701	-1.3941
p	(.0633)	(.0001)	(.0118)	(.1786)

Below Table 13, the cointegrating equations are reported. According to equation (5), there exists a positive long run relationship between all of the independent variables and real exports. Equation (6) shows similar results for the nominal data. This provides statistical evidence that as world GDP increases, China's exports likewise increase. This is plausible, because as world income increases other countries would increase imports from China. Similarly as the Renminbi becomes weaker, other countries would increase their imports from China. Finally, we found that Chinese exports increase with an increase in imports. The explanation for this is that Chinese imports are important in enhancing productivity and efficiency.

Granger Causality Tests for Models C and D

Tables 15 and 17 report Granger Causality test results for Models C and D, following the Toda-Yamamoto procedure. According to the Granger Causality tests of Block Exogeneity, there exists statistical evidence for Granger Causality. For both the real and nominal data, Granger causality is supported from the independent variables to the dependent variable exports.

Table 14 – VAR Residual Serial Correlation LM Test Model C

Lags	LM-Stat	Probability
1	7.5344	.9615
2	12.0424	.7411
3	20.3235	.2060
4	19.3576	.2506
5	20.7342	.2890

Table 15 – Granger Causality Tests for Model C

Dependent Variable		lnX	
Excluded	Chi-square	df	Probability
lnWY	.0148	1	.9033
lnER	2.8381	1	.0921
lnM	5.0460	1	.0247
All	**7.0766**	**3**	**.0695**

Dependent Variable		lnWY	
Excluded	Chi-square	df	Probability
lnX	7.0838	1	.0078
lnER	4.1849	1	.0408
lnM	9.7576	1	.0018
All	**13.2270**	**3**	**.0042**

Dependent Variable		lnER	
Excluded	Chi-square	df	Probability
lnX	2.4992	1	.1139
lnWY	5.0624	1	.0245
lnM	3.1771	1	.0747
All	**7.0279**	**3**	**.0710**

Dependent Variable		lnM	
Excluded	Chi-square	df	Probability
lnX	.7172	1	.3971
lnWY	.0456	1	.8308
lnER	1.5396	1	.2147
All	**2.4955**	**3**	**.4761**

Table 16 – VAR Residual Serial Correlation LM Test Model D

Lags	LM-Stat	Probability
1	7.7769	.9552
2	12.2234	.7285
3	21.0082	.1782
4	17.6604	.3442
5	20.9498	.1804

Table 17 – Granger Causality Tests for Model D

Dependent Variable		lnNX	
Excluded	Chi-square	df	Probability
lnNWY	.2591	1	.6107
lnNER	.0077	1	.9303
lnNM	7.9478	1	.0048
All	**8.8415**	**3**	**.0315**

Dependent Variable		lnNWY	
Excluded	Chi-square	df	Probability
lnNX	.8960	1	.3439
lnNER	.3021	1	.5826
lnNM	3.4946	1	.0616
All	**6.9430**	**3**	**.0737**

Dependent Variable		lnNER	
Excluded	Chi-square	df	Probability
lnNX	2.0763	1	.1496
lnNWY	.4843	1	.4865
lnNM	9.0757	1	.0026
All	**9.8021**	**3**	**.0203**

Dependent Variable		lnNM	
Excluded	Chi-square	df	Probability
lnNX	.4775	1	.4896
lnNWY	.2770	1	.5987
lnNER	.0052	1	.9425
All	**2.1865**	**3**	**.5346**

Johansen Cointegration Test and Estimation of a VEC Model

Lastly, a Vector Error Correction (VEC) model was estimated to test for short-run and long-run Granger causality among four variables that were found to be cointegrated. All variables within the model, lnY, lnX, lnM, and lnW, are expressed in per capita terms, with the exception of lnW, which is divided by the manufacturing labor force. Evidence of cointegration was obtained through the Johansen (1991, 1995) methodology. According to the Johansen test, there is only one cointegrating vector based on the maximum likelihood tests λ_{trace} and λ_{max}, as shown in Table 18 below.

Table 18 – Johansen Cointegration Test

H_0: Rank = r	Eigenvalue	Trace			Maximum Eigenvalue		
		λ_{trace}	.05 CV	p-value	λ_{max}	.05 CV	p-value
= 0	.61	57.83	55.24	.03	32.57	30.81	.03
≤ 1	.38	25.26	35.01	.37	17.00	24.25	.34
≤ 2	.19	8.26	18.39	.66	7.57	17.15	.65

Cointegrating Equation

lnY = 9.903152 + .107687(trend) + .089919(lnX) - .325965(lnM) - .121692(lnW) (7)
SE (.09782) (.10317) (.10394)
t [.91919] [-3.15963] [-1.17081]

According to the cointegrating equation (7) above a positive relation exists between real GDP and real exports. This relationship is plausible, but lnX is not statistically significant. A negative relationship exists between real imports and real GDP, as well as between the wage rate and real GDP. The relationship between the wage rate and real GDP is plausible, but lnW is also not statistically significant. Statistical evidence of cointegration allows us to estimate the VEC model for the four variables. The complete model is shown below in Equations (8), (9, (10,) and (11) in general form for variables X, Y, Z, and W.

$$\Delta X_t = \alpha_1 + \alpha_t t + \alpha_X \theta_{t-1} + \sum_{i=1}^{r_1} \alpha_{1i} \Delta X_{t-i} + \sum_{i=1}^{s_1} \beta_{1i} \Delta Y_{t-i} + \sum_{i=1}^{k_1} \gamma_{1i} \Delta Z_{t-i} + \sum_{i=1}^{p_1} \delta_{1i} \Delta W_{t-i} + \varepsilon_{1t} \quad (8)$$

$$\Delta Y_t = \beta_2 + \beta_t t + \beta_Y \theta_{t-1} + \sum_{i=1}^{r_2} \alpha_{2i} \Delta X_{t-i} + \sum_{i=1}^{s_2} \beta_{2i} \Delta Y_{t-i} + \sum_{i=1}^{k_2} \gamma_{2i} \Delta Z_{t-i} + \sum_{i=1}^{p_2} \delta_{2i} \Delta W_{t-i} + \varepsilon_{2t} \quad (9)$$

(10) $$\Delta Z_t = \gamma_3 + \gamma_t t + \gamma_Z \theta_{t-1} + \sum_{i=1}^{r_3} \alpha_{3i} \Delta X_{t-i} + \sum_{i=1}^{s_3} \beta_{3i} \Delta Y_{t-i} + \sum_{i=1}^{k_3} \gamma_{3i} \Delta Z_{t-i} + \sum_{i=1}^{p_3} \delta_{3i} \Delta W_{t-i} + \varepsilon_{3t}$$

(11) $$\Delta W_t = \delta_4 + \delta_t t + \delta_W \theta_{t-1} + \sum_{i=1}^{r_4} \alpha_{4i} \Delta X_{t-i} + \sum_{i=1}^{s_4} \beta_{4i} \Delta Y_{t-i} + \sum_{i=1}^{k_4} \gamma_{4i} \Delta Z_{t-i} + \sum_{i=1}^{p_4} \delta_{4i} \Delta W_{t-i} + \varepsilon_{4t}$$

The estimated VEC model includes only one lagged difference for each variable, therefore the presentation of the model is simple. It is also simple to perform the Granger Causality tests with this model. In general, two Granger Causality tests are performed within the framework of the VEC model. The first test is a t test on the coefficient of the one period lagged error term, Θ_{t-1}, for long-run causality. This test is performed by setting $\Theta_{t-1} = 0$ as the null hypothesis versus $\Theta_{t-1} \neq 0$, the alternative hypothesis. The second test is a test for short-run causality performed by setting all coefficients of the lagged differences for each relevant right-hand side variable equal to 0. By doing so, we are testing whether the variable is significantly different than 0 and therefore belongs in the equation. However, since there is one lagged difference for each right-hand side variable in this model, a t test is performed because an F and t test are equivalent in such case.

Table 19 – Estimated VEC Model

Dependent Variable	c	trend	Θ_{t-1}	ΔlnY	ΔlnX	ΔlnM	ΔlnW
ΔlnY	.0127	.0001	-.1678	.8158	.0571	-.0359	-.0506
	.0131	.0004	.0597	.1471	.0316	.0315	.0662
	.9749	.3298	-2.8102	5.5448	1.8089	-1.1418	-.7636
ΔlnX	.2169	-.0047	-.2034	-.7392	-.3632	.4678	.3294
	.1003	.0029	.4588	1.1303	.2424	.2416	.5088
	2.1636	-1.6141	-.4433	-.6539	-1.4981	1.9364	.6474
ΔlnM	-.0271	-.0056	-1.3205	2.3935	-.2315	.3163	.1063
	.0858	.0025	.3925	.9668	.2074	.2066	.4352
	-.3164	-2.2496	-3.3647	2.4756	-1.1165	1.5308	.2444
ΔlnW	-.0816	.0016	-.1010	.8303	-.0362	.1242	.2678
	.0378	.0011	.1729	.4258	.0913	.0910	.1917
	-2.1606	1.4371	-.5845	1.9498	-.3958	1.3643	1.3970

According to the estimated VEC model seen above in Table 14, real GDP, represented by lnY, is Granger-caused by the right-hand side variables, lnX, lnM, and lnW as the error term Θ_{t-1} is statistically significant. In the same equation, there exists evidence for short-run causality from lnX to lnY. As for the other equations, the lnM has a long-run relationship with the other three variables and thus, is caused by them. Furthermore, real imports are Granger-caused real GDP in the short-run. These results support the view that trade and GDP are strongly linked to each other through short and long-run Granger Causality.

Section 7 – Conclusions

The study examines causal relations between real GDP growth and a few macroeconomic variables, such as: exports, imports, and the real exchange rate. The first two ARDL models were estimated using the same real and nominal variables. Both models support Granger causality from exports, imports, and the exchange rate to GDP. Exports and imports were positively related with GDP according to the cointegrating equations. The exchange rate, however, was found to be negatively related with GDP in both models. This result comes as a surprise to what used to be suspected; that China maintained an undervalued currency in order to promote exports and increase its GDP. Both real and nominal data were utilized in order to test for robustness of these results, particularly due to concerns regarding the quality of Chinese macroeconomic data.

Two other ARDLs were estimated to determine the causes of Chinese export growth, again using both real and nominal variables. There is evidence that world GDP, Chinese imports, and the exchange rate Granger cause Chinese exports. According to the cointegrating equations there exists a positive long run relationship between each of the three right hand side variables and exports. According to these results, as the Renminbi devalues against the US Dollar, Chinese exports increase.

At first it appears that the relationship between the exchange rate and GDP is incompatible with the relationship between the exchange rate and exports. This may not the case, however, because the relation between the exchange rate and GDP is indirect. In other words, the exchange rate directly affects other macroeconomic variables before GDP. During the sample period of this study the Chinese government intervened in the foreign exchange markets to achieve certain economic goals. This may be a factor in why the true relationship between the exchange rate and GDP is unclear.

Furthermore by reviewing the literature regarding the exchange rate policy in China, it is clear that the exchange rate is an ambiguous policy variable. Yingseng Xu (1999) reported that even during period of RMB appreciation, exports were rising. One explanation for this is that as the Chinese economy was opening up to the world economy, and Chinese prices were converging to the global prices, thus the exchange rate became less relevant in affecting Chinese trade balances. Other studies found that the exchange rate for certain periods was positively affecting exports and a weaker Renminbi caused both export and GDP growth.

Finally similar results regarding causal relations between real GDP, real exports, real imports, and real wages were obtained by utilizing the Johansen methodology to test for cointegration and performing short and long-run Granger Causality tests within the framework of an estimated VEC model. These methodologies provide statistical evidence that real Chinese GDP has a long-run relationship with real exports, real imports, and real manufacturing wage. This means that a long-run causality exists between the three variables and real GDP.

Endnotes

[1] Real GDP is used as a proxy for real GDP growth in this study

[2] The equation for Real GDP is:

$$Real\ GDP = \frac{Nominal\ GDP}{GDP\ Deflator}\ x\ 100$$

[3] Such information includes: number of observations (37 for both models), the coefficient of determination (R^2), the standard error of regression (SER), the Durbin-Watson statistic (DW), and the Schwarz Information Criterion (SIC).

[4] Table C1 – Asymptotic Critical Value bound for the F-statistic – Testing for the existence of a levels relationship. We used C1(iii) Case iii unrestricted intercept and no trend as both Models A and B fit this scenario.

[5] Narayan(2005) see Appendix page 1988 for the case III unrestricted interval and no trend for degrees of freedom n = 35.

[7]The results of these unit root tests can be obtained by contacting the authors.

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Appendix 1

Table 1A VAR Model A

		lnY	lnX	lnER	lnM
lnY(-1)	VAR	1.2932	-1.5741	-3.3051	4.2652
	St. Error	(.4336)	(2.4947)	(.9520)	(2.3888)
	t-statistic	[2.9827]	[-.6310]	[-3.4719]	[1.7855]
lnY(-2)	VAR	-.6431	-6.7706	1.9192	-10.3626
	St. Error	(.6593)	(3.7932)	(1.4475)	(3.6322)
	t-statistic	[-.9755]	[-1.7849]	[1.3259]	[-2.8530]
lnY(-3)	VAR	.3040	12.0963	2.3163	12.8433
	St. Error	(.8939)	(5.1433)	(1.9627)	(4.9250)
	t-statistic	[.3401]	[2.3519]	[1.1802]	[2.6078]
lnY(-4)	VAR	-.2800	-13.5075	-3.9560	.12.2452
	St. Error	(.8765)	(5.0434)	(1.9245)	(4.8293)
	t-statistic	[-.3194]	[-2.6783]	[-2.0555]	[-2.5356]
lnY(-5)	VAR	.2459	8.1127	2.5148	5.8118
	St. Error	(.4937)	(2.8407)	(1.0840)	(2.7201)
	t-statistic	[.4981]	[2.8559]	[2.3199]	[2.1366]
lnX(-1)	VAR	-.0116	-.9994	-.4604	-.6289
	St. Error	(.1055)	(.6068)	(.2315)	(.5810)
	t-statistic	[-.1097]	[-.1647]	[-1.9884]	[-1.0824]
lnX(-2)	VAR	.0169	.1188	.4223	.3064
	St. Error	(.0803)	(.4622)	(.1764)	(.4426)
	t-statistic	[.2106]	[.2571]	[2.3939]	[.6923]
lnX(-3)	VAR	.0306	-.3146	-.1813	-.2720
	St. Error	(.0806)	(.4635)	(.1769)	(.4439)
	t-statistic	[.3796]	[-.6787]	[-1.0247]	[-.6128]
lnX(-4)	VAR	.0744	.3722	.4331	-.0090
	St. Error	(.0695)	(.3997)	(.1525)	(.3827)
	t-statistic	[1.0718]	[.9312]	[2.8396]	[-.0234]
lnX(-5)	VAR	-.0681	.3286	-.1039	.0803
	St. Error	(.0792)	(.4557)	(.1739)	(.4364)
	t-statistic	[-.8602]	[.7211]	[-.5977]	[.1838]
lnER(-1)	VAR	.1154	-.2946	.6497	-.2505
	St. Error	(.1175)	(.6762)	(.2580)	(.6475)
	t-statistic	[.9823]	[-.4356]	[2.5180]	[-.3869]
lnER(-2)	VAR	.0223	.4425	.2399	7.263
	St. Error	(.1137)	(.6539)	(.2495)	(.6261)
	t-statistic	[.1959]	[.6768]	[.9614]	[1.1599]
lnER(-3)	VAR	-.0723	-.5951	.0372	-.2313
	St. Error	(.1076)	(.6193)	(.2363)	(.5930)
	t-statistic	[-.6714]	[-.9609]	[.1573]	[-.3900]

lnER(-4)	VAR	-.1259	-.1670	-.01389	.2635
	St. Error	(.1080)	(.6215)	(.2372)	(.5952)
	t-statistic	[-1.1653]	[-.2687]	[-.0586]	[.4427]
lnER(-5)	VAR	-.0065	-.2891	-.3610	-.0350
	St. Error	(.1358)	(.7811)	(.2981)	(.7480)
	t-statistic	[-.0478]	[-.3702]	[-1.211]	[-.0468]
lnM(-1)	VAR	.0278	2.1433	.6193	1.2906
	St. Error	(.1410)	(.8110)	(.3095)	(.7766)
	t-statistic	[.1976]	[2.6427]	[2.0009]	[1.6619]
lnM(-2)	VAR	.0269	-.2583	-.4127	-.7904
	St. Error	(.0905)	(.5206)	(.1986)	(.4985)
	t-statistic	[.2978]	[-.4962]	[-2.0777]	[-1.5858]
lnM(-3)	VAR	.0449	1.3015	.3441	.4687
	St. Error	(.1296)	(.7459)	(.2846)	(.7142)
	t-statistic	[.3460]	[1.7449]	[1.2090]	[.6563]
lnM(-4)	VAR	-.0790	.3723	-.1610	.0791
	St. Error	(.0900)	(.5177)	(.1975)	(.4957)
	t-statistic	[-.8784]	[.7193]	[-.8152]	[.1596]
lnM(-5)	VAR	.0589	-.1139	.0523	.0537
	St. Error	(.0594)	(.3416)	(.1303)	(.3271)
	t-statistic	[.9922]	[-.3334]	[.4015]	[.1641]
C	VAR	-.0069	2.6956	1.6787	-.1665
	St. Error	(.3474)	(1.9987)	(.7627)	(1.9139)
	t-statistic	[-.0198]	[1.3487]	[2.2011]	[-.0870]

Table 2a VAR Model B

		lnNY	lnNX	lnNER	lnNM
lnNY(-1)	VAR	1.3623	-.4911	.1714	-.2918
	St. Error	(.2203)	(.6498)	(.3844)	(.7496)
	t-statistic	[6.1835]	[-.7558]	[.4461]	[-.3893]
lnNY(-2)	VAR	-.5385	.3434	-.2350	.1465
	St. Error	(.1831)	(.5399)	(.3193)	(.6228)
	t-statistic	[-2.9418]	[.6361]	[-.7360]	[.2352]
lnNX(-1)	VAR	.0083	.2400	-.5191	-.3927
	St. Error	(.1052)	(.3104)	(.1836)	(.3581)
	t-statistic	[.0788]	[.7731]	[-2.8274]	[-1.0967]
lnNX(-2)	VAR	.1599	.3691	.4314	.7300
	St. Error	(.1028)	(.3032)	(.1793)	(.3497)
	t-statistic	[1.5555]	[1.218]	[2.4058]	[2.0873]
lnNER(-1)	VAR	.1079	.2493	1.2888	.37431
	St. Error	(.1133)	(.3341)	(.1977)	(.3855)
	t-statistic	[.9521]	[.7459]	[6.5206]	[.9710]
lnNER(-2)	VAR	-.1474	-.1748	-.3031	-.3579
	St. Error	(.1162)	(.3427)	(.2027)	(.3953)
	t-statistic	[-1.2683]	[-.5102]	[-1.4954]	[-.9052]
lnNM(-1)	VAR	.0255	.7064	.2696	1.3842
	St. Error	(.0949)	(.2798)	(.1655)	(.3227)
	t-statistic	[.2684]	[2.5250]	[1.6292]	[4.2891]
lnNM(-2)	VAR	-.0554	-.2234	-.1526	-.6492
	St. Error	(.0898)	(.2649)	(.1567)	(.3056)
	t-statistic	[-.6163]	[-.8435]	[-.9740]	[-2.1244]
C	VAR	.7040	.7771	.4163	.8935
	St. Error	(.2867)	(.8456)	(.5002)	(.9756)
	t-statistic	[2.4554]	[.9190]	[.8322]	[.9159]

Table 3A VAR Model C

		lnXUS	lnMUS	lnWY	lnER
lnXUS(-1)	VAR	.5826	.1143	-.1879	-.1038
	St. Error	(.1567)	(.22498)	(.0609)	(.1116)
	t-statistic	[3.7173]	[.5078]	[-3.0835]	[-.9305]
lnMUS(-1)	VAR	.3917	.9174	.2462	.0758
	St. Error	(.1550)	(.2225)	(.0603)	(.1103)
	t-statistic	[2.5276]	[4.1240]	[4.0856]	[.6871]
lnWY(-1)	VAR	.1602	-.1524	.8763	-.0648
	St. Error	(.2939)	(.4218)	(.1143)	(.2092)
	t-statistic	[.5451]	[-.3613]	[7.6698]	[-.3096]
lnER(-1)	VAR	.2396	.1942	.0862	.8984
	St. Error	(.0763)	(.1095)	(.0297)	(.0543)
	t-statistic	[3.1410]	[1.7729]	[2.9060]	[16.5426]
C	VAR	-1.8748	.9967	.6787	1.1508
	St. Error	(2.2030)	3.1625	(.8567)	(1.5681)
	t-statistic	[-.8510]	[.3152]	[.7924]	[.7339]
Break93	VAR	-.0642	.1425	-.0364	-.0868
	St. Error	(.1117)	(.1604)	(.0434)	(.0795)
	t-statistic	[-.5746]	[.8886]	[-.8377]	[-1.0918]

Table 4A VAR Model D

		lnNXUS	lnNWY	lnNER	lnNMUS
lnNXUS(-1)	VAR	.1572	-.1746	-.3077	-.2268
	St. Error	(.3213)	(.0697)	(.1273)	(.3592)
	t-statistic	[.4892]	[-2.5037]	[-2.417]	[-.6313]
lnNWY(-1)	VAR	.3032	.8353	.2763	-.1452
	St. Error	(.5285)	(.1147)	(.2094)	(.5908)
	t-statistic	[.5737]	[7.2828]	[1.3198]	[-.2458]
lnNER(-1)	VAR	.2913	-.0428	1.1285	.03171
	St. Error	(.2828)	(.0614)	(.1120)	(.3161)
	t-statistic	[1.0301]	[-.6977]	[10.0727]	[.1003]
lnNMUS(-1)	VAR	.6975	.2271	.2002	1.2139
	St. Error	(.2812)	(.0610)	(.1114)	(.3144)
	t-statistic	[2.4800]	[3.7215]	[1.7968]	[3.8610]
C	VAR	-1.7511	1.2567	-1.8251	1.8025
	St. Error	(3.9943)	(.8668)	(1.5824)	(4.4653)
	t-statistic	[-.4384]	[1.4498]	[-1.1534]	[.4037]
Break93	VAR	-.1375	-.02164	-.04550	.0973
	St. Error	(.2141)	(.0465)	(.0848)	(.2394)
	t-statistic	[-.6421]	[-.4657]	[-.5364]	[.4067]