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## China's Factor in Recent Global Commodity Price and Shipping Freight Volatilities

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**Abstract:** This paper attempts an investigation on the impact of China's factor on the global commodity and ocean shipping freight volatilities in recent years. It measures China's contribution to the incremental demand growth for selected bulk commodities and ocean shipping in the world. China's impact on the price volatilities is statistically analyzed through a conventional econometric framework.

**Key words:** the world commodity markets, global ocean shipping freights, China's factor in the global commodity markets.

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The world commodity and ocean shipping markets have witnessed remarkable growth and large fluctuation since the beginning of the new century. The commodity boom, identified in a World Bank study as “the largest and longest of any boom since 1900” (World Bank, 2008), presents profound challenges to the global economy. Huge swings in the relative prices for the commodities have produced world-wide distribution effects for the income and wealth. The market developments have re-generated active discussion about the sustainable supply of the raw materials and energy, and revived the concerns among the central bankers and academic circles over the so-called “imported inflations”.

China figures prominently in the new round of the world commodity price volatility. As the largest emerging economy undergoing the process of rapid urbanization and industrialization, the unprecedented growth in consumption of bulk commodities and energies tips the balance of supply and demand equations for various commodities in the global landscape. Through surging imports of the primary commodities over the last decade or so, China’s factor has contributed a crucial driving force, perhaps the single most important one, behind the world commodity boom. On the other hand, commodity price volatility also presents crucial challenges for the Chinese economic growth through changes in terms of trade, pressure of domestic inflation, coordinating and managing relationships with the supply countries in the rapidly changed environment.

Though China’s impact in the context has been wildly acknowledged and commented, systematic study on this emerging issue is still lacking and rare. This paper attempts an empirical investigation on China’s factor in recent commodity price volatility mainly with two steps. Initially, the issue will be approached by measuring and observing China’s contribution to the incremental growth of global consumption in several major commodities. The impact of China’s factor will then be investigated more rigorously in conventional econometric model of commodity price determination.

The paper is organized as follows. Section 1 observes the recent commodity price and ocean shipping freight volatilities with the relevant descriptive data. Section 2 discusses the general causes for the commodity price and ocean shipping freight volatilities. Section 3 provides measures for China’s contribution to the global consumption growth in several major metals and the petroleum oil. Section 4 attempts an empirical investigation on China’s impact on recent commodity price volatility using the conventional econometric framework. Section 5 presents concluding remarks.

## **1. Recent global commodity price and ocean freight volatilities**

Since the turn of the century, commodity markets have undergone a new period

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of remarkable volatility. A World Bank report summarized the recent exceptional commodity boom to be “the largest and longest of any boom since 1900” (World Bank, 2008). As shown in Figure 1, the apparent declining trend in real CRB non-oil bulk commodity price index during 1980s and 90s changed after 2002. It increased from less than 50 in the early this century to about 77 in the early 2008. Due to the recent global financial and economic crisis, it plummeted to 55 in the early 2009, but bounced back rapidly to near 70 by the mid-2009.

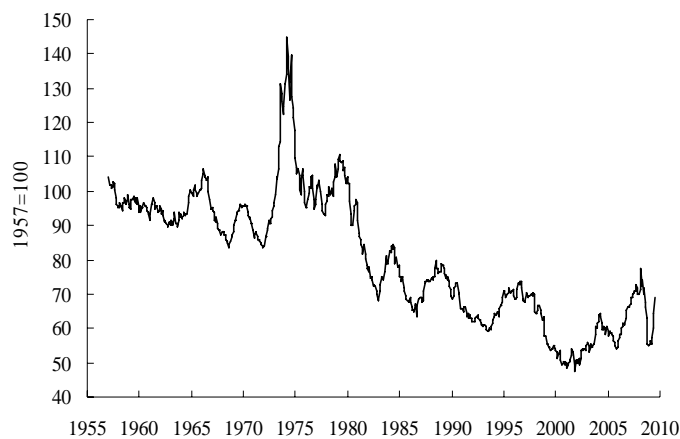


Figure 1. Real CRB commodity index (1960M1-2009M6)

Notes and source: CRB index is from Commodity Research Bureau. Real CRB index is deflated by U.S. PPI from U.S. Bureau of Labor Statistics.

Extends of price swing differ substantially among the CRB sub-indices. As indicated by figures 2 and 3, the peaks and troughs of different commodity prices covered by CRB index vary greatly, and the metal index underwent the most spectacular spike. The soaring index reached its 1970s' record in real terms and then more than halved in just a few months by the end of 2008. Nominal price of metals peaked more than 5 times its lowest level since 2000 while CRB spot index as a whole peaked just over 2 times its lowest level during the same period.

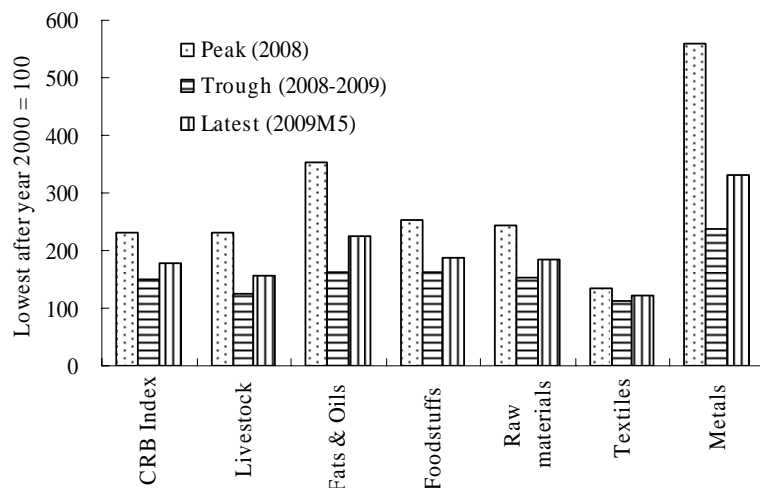


Figure 2. Peaks and troughs of CRB sub-indices (2000M1-2009M5)

Notes and source: Calculations are based on CRB indices from Commodity Research Bureau.

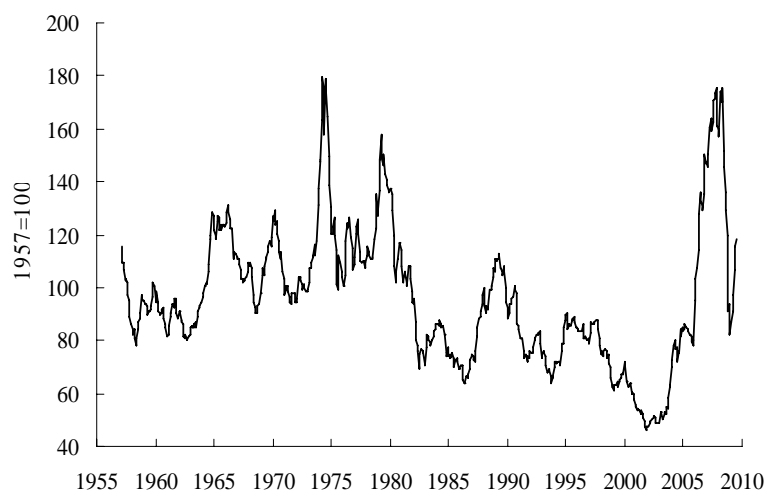


Figure 3. Real CRB metal sub-index (1957M1-2009M6)

Source: CRB metal sub-index is from Commodity Research Bureau. Real CRB metal sub-index is deflated by U.S. PPI from U.S. Bureau of Labor Statistics.

A closer inspection by category reveals that the general pattern in CRB metal index dominates the price development of major metal materials like copper, aluminum and iron ore (Figure 4). Both in nominal and real terms, their prices experienced evident rises after 2002 and peaked around 2007 to 2008. Similar development can be also seen in crude oil price in the new century.

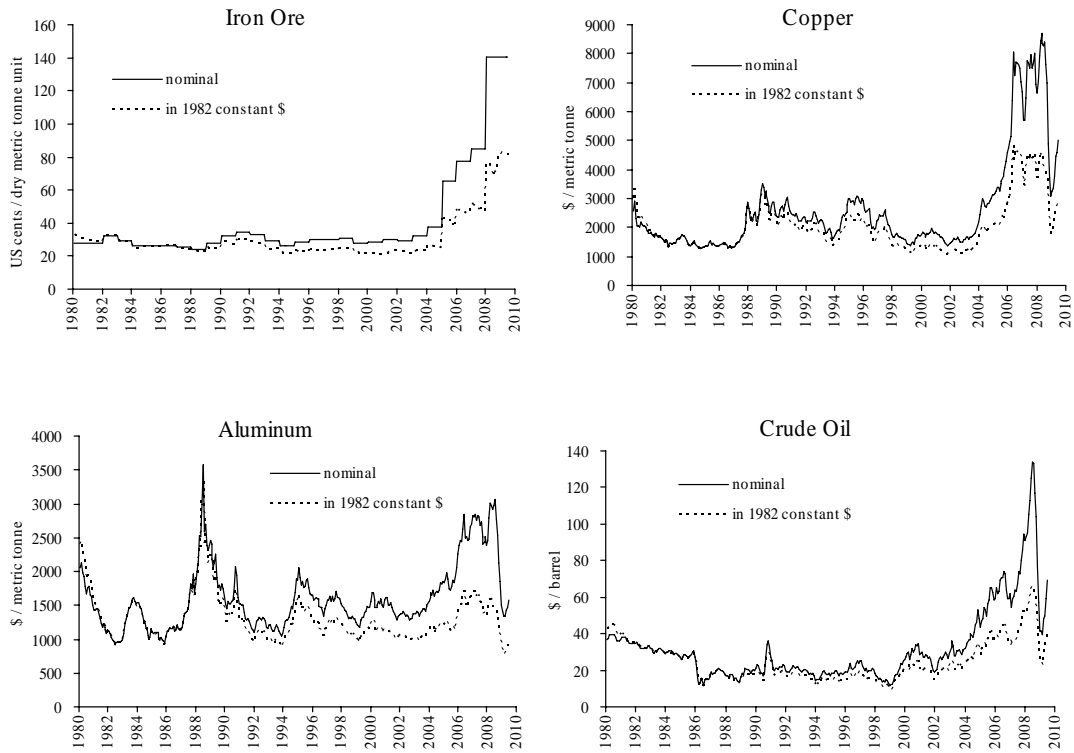


Figure 4. Price development of metal materials and crude oil (1980M1-2009M6)

Source: Nominal prices are from International Monetary Fund. Real prices are deflated by U.S. PPI from U.S. Bureau of Labor Statistics.

Commodity and oil prices swings went hand in hand with the world shipping freight rates. As indicated by Figure 5, the tanker voyage freight rate also fluctuated widely in recent years. Dry bulk shipping market has even recorded by far the highest real freight rate for nearly 50 years.

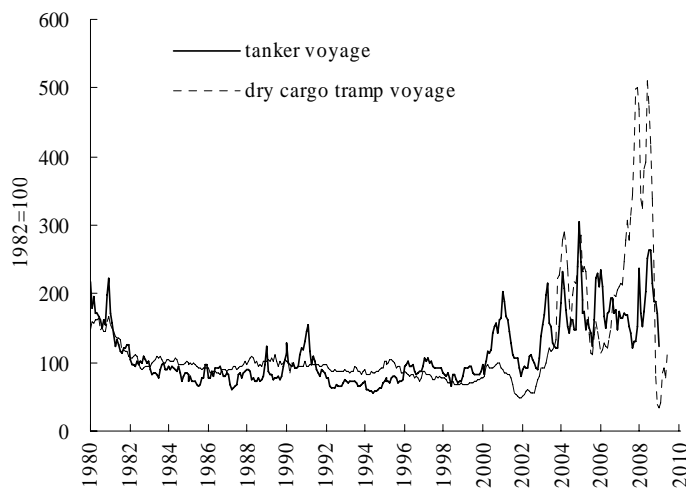


Figure 5. Real ocean shipping freight index (1980M1-2009M6)

Source: Freight index of tanker voyage between Jan 1952 and Dec 1958 is from Zannetos (1966); freight index of

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tanker voyage between Jan 1959 and Nov 2003 is from *Review of Maritime Transport* (various issues); freight index of tanker voyage between Dec 2003 and Dec 2008 is from *Lloyd's Shipping Economist* (various issues). Freight index of dry cargo tramp voyage between Jan 1952 and Nov 1999 is from *Review of Maritime Transport* (various issues); freight index of dry cargo tramp voyage between Dec 1999 and May 2009 is from the website of *China Daily News Shipping* (Zhonghua Ribao Hangyun Dianzibao, <http://www.cdns.com.tw/box/bdi.htm>, Accessible on Dec 1st, 2009).

## 2. Overview on causes for price volatilities

What are the driving forces behind the recent tremendous price volatilities in the world commodity and ocean shipping markets? The causes are discussed mainly through three perspectives.

The first explanation focuses on some key macroeconomic variables underlying the surge in major commodity prices during 2002-2008. The apparent co-movement of metals and oil prices in recent years suggests significant common factors at play. Thus it is natural to examine the recent commodity price volatility in a macroeconomic framework. Some important aggregate variables suggested in literature for explaining variation in commodity price are the real interest rate, US Dollar real effective exchange rate, and the relative strength of world's industrial activities<sup>†</sup> (Frankel, 1986; Gilbert, 1989; Reinhart and Borensztein, 1994; Hua, 1997; Krichene, 2008). Together they form a macroeconomic "demand-driven" model.

The industrial production growth will raise the demand for raw materials and energy, while the real interest rate affects the opportunity cost of holding commodity stock as well as the economy's investment activities both in commodity sector and manufacturing sector. The real effective exchange rate works its effect into the real commodity prices denominated in U.S. dollar through the law of one price.

As indicated in Figure 6, the real interest rate calculated on the basis of US Federal Funds Rate dipped below zero bound during 2001-2005. The previous experience of negative real interest rate in US went back to 1970s; it fueled the most serious inflation in the country after the second world war. The relative oversupply of dollar liquidity injected by loose monetary policy could cause investors to redistribute their portfolio towards more commodities stockholding. This increased demand for commodities could then have an immediate positive effect on commodity prices. Krichene(2008) identified a monetary shock to be underlying soaring commodity prices during 2003-2007.

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<sup>†</sup> The state of business cycle in industrial countries is often used as a proxy.

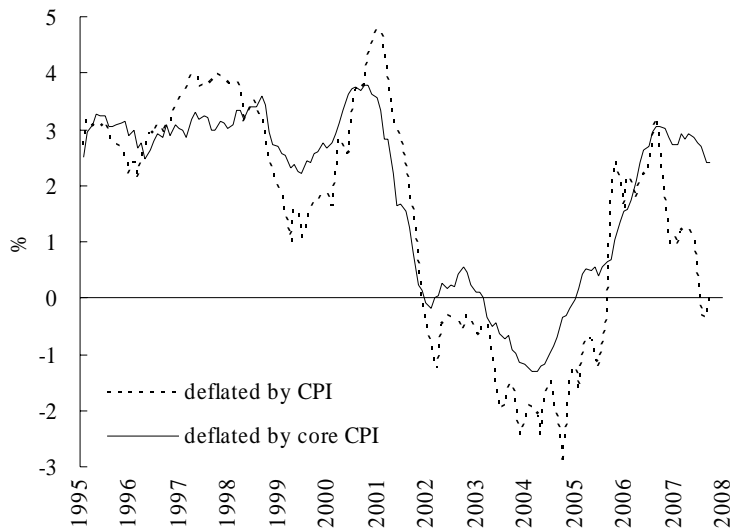


Figure 6. Real U.S. federal funds overnight rate (1995M1-2007M9)

Notes and source: U.S. federal funds overnight rates are from Board of Governors of the Federal Reserve System. CPI and core CPI are from U.S. Bureau of Labor Statistics

Closely related to U.S. loose monetary policy is the development of US Dollar real effective exchange rate. Shown in Figure 7, its index depreciated more than 20% during 2002Q1-2008Q2, from 114.4 to 76.5. Since primary commodities are quoted in US Dollar, market arbitrage exerts inflationary pressure on dollar prices of these commodities.

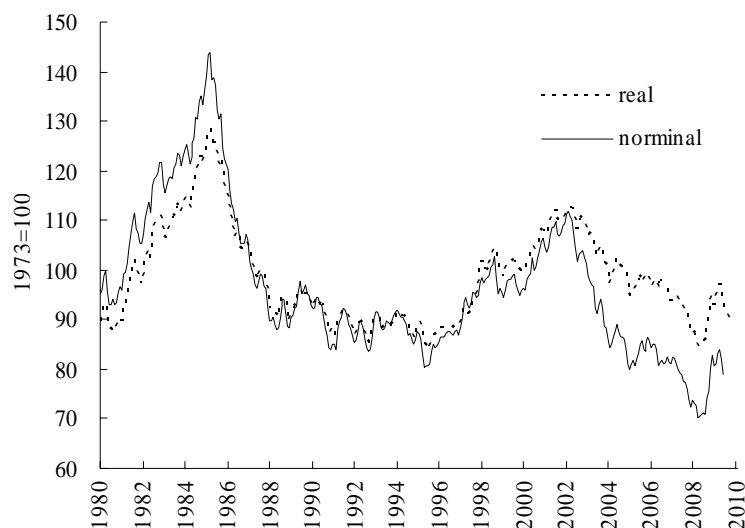


Figure 7. U.S. real and nominal effective exchange rate (1980M1-2009M9)

Source: Board of Governors of the Federal Reserve System.

US dollar depreciation relative to major trading partners, world's low real interest rates, and general favorable conditions of world economy during the time, have all boosted commodities markets. However, the vigor varied across different

category. To account for the strongest base metals and oil price development for nearly three decades, the unprecedented demand growth proves worthy of our notice.

Hence follows the second explanation based on the conventional supply and demand analytical framework. Giving the expansion and adjustments of long-term production capacity are lagged and slow, unexpected change in demand for consumption for the commodities and ocean shipping services may cause drastic changes in the market prices.

Table 1 compares the growth of consumption for 3 metal raw materials and petroleum oil during the periods of 2001-2007 and the previous three decades. The world economy had undergone robust growth before the most recent economic crisis. As a result, world consumption of primary commodities accelerated during 2001-2007. Take iron ore for example: it took the world 30 years to increase the annual consumption of iron ore by 3 billion tons, but only 6 years passed when the number grew from 10.7 in 2001 to 18 billion tons in 2007. It follows that the annual growth in world iron ore consumption during 2001-2007 was 10 times that of 1970-2001. Annual consumption of copper, aluminum and crude oil also accelerated recently.

Table 1. World Consumption Growth in 4 Commodities (1970-2007)

	Iron ore	Copper	Aluminum	Crude oil
Annual consumption	(billion ton)	(million ton)	(million ton)	(billion ton)
1970	7.7	7.3	10	17.1
2001	10.7	15.1	24.9	28.1
2007	18	18.2	37.8	30.9
Annual growth rate	(%)	(%)	(%)	(%)
1970-2001	1.1	2.4	3	1.6
2001-2007	11.1	3.1	7.2	2

Notes and source: World iron ore consumption is substituted by world iron ore production due to lack of consumption data. World iron ore production is from U.S. Geological Survey. World consumptions on copper and aluminum before 2007 are from *World Metal Statistics Yearbook* (various issues) and data in 2007 and 2008 are from Shanghai Nonferrous Metal (2009). World crude oil consumption is from U.S. Energy Information Administration.

Strong demand growth for metal materials and petroleum oil over the recent period has mobilized the expansion of international trade. In turn, it has generated an accelerating growth in seaborne shipping activities. As Figure 8 shows, seaborne trade volume for major commodity categories all moved along steeper trends since 2002. Among them, 5 major dry bulks displayed the most conspicuous growth, averaging 9.5% annually, Iron ore, as the largest single item of dry cargo in seaborne trade, increased its share in world seaborne trade from 11% in 2002 to 15% in 2007 (UNCTAD, 2008), a record never reached ever since iron ore became a major ocean shipping item.



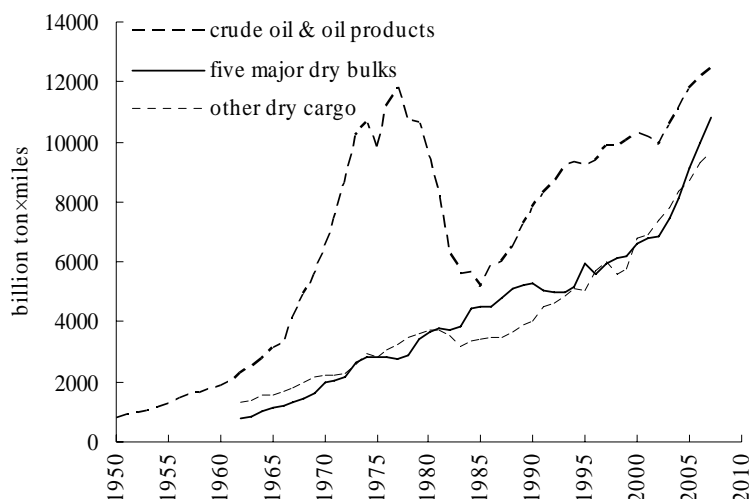


Figure 8. Seaborne trade volume by cargo (1950-2007)

Notes and Source: The five major dry bulks are iron ore, coal, grain, bauxite/alumina and phosphate. Data are from *Review of Maritime Transport* (various issues).

With the positive demand shock as given, changes in the equilibrium prices are largely determined by the supply responses. It is widely acknowledged that it takes relatively lengthy periods for bulk commodity sectors to substantially expand their potential supply capacities. The factor of lagged response may contribute to long periods of under- and over- supply (ODI, 1995). In fact, relatively low commodity prices during 1980s and 1990s depressed the investment in exploration and mining (World Bank, 2008) As the idle capacity comes back into use and production gradually reaches the technical upper bound, further expansion of short-term supply will be subject to more constraints and therefore result in rapid increase in marginal cost. Then the demand shocks turn to be the dominating cause of short-term price volatility. The story underlies recent surge of commodity prices, and shipping freight rates as well.

Although there are difficulties in quantifying the variation in supply capacity for bulk commodities, observation of data regarding the laid-up capacity for the global shipping sector helps illustrate the point. Hardly to be substituted by other modes of transport, the demand for shipping service, derived from rather inelastic demand for primary commodities, is often assumed to be zero within a wide price range in maritime literature. Empirical studies also confirmed the hypothesis (Stopford, 1988; Beenstock and Vergottis, 1993). Besides, shipping market is characterized by long construction lag. When most laid-up tonnage has been drawn out for service, the short-term shipping supply can only be expanded through faster steaming, with fuel consumption increasing at cubic or even higher power. If shipping demand meets supply at this range, sea freight rates tend to respond with extreme sensitivity to demand shocks. This is what happened in the recent shipping market. In recent years, laid-up tonnage of both oil tankers and dry bulkers has been gradually depleted (Figure 9). With one to three years of construction lag in shipbuilding, short-term

supply of shipping has been inelastic. It resulted in huge price spikes as shown in Figure 8. Consistent with the story of soaring iron ore demand, dry bulk shipping market has registered the highest real freight rate for nearly 50 years.

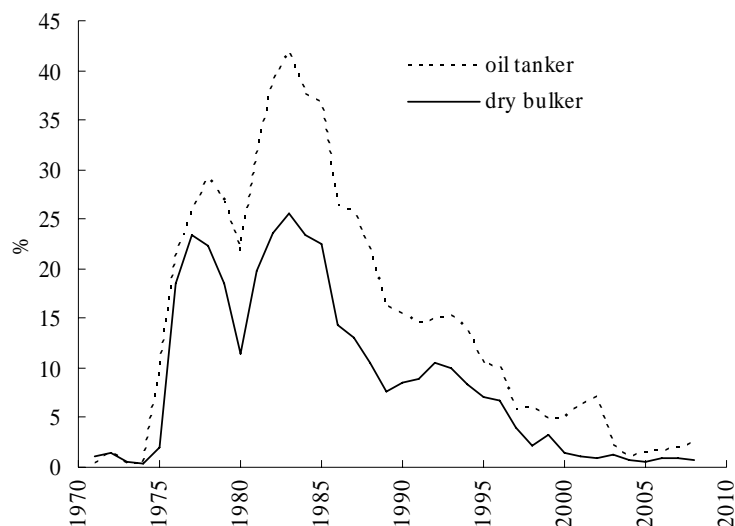


Figure 9. Laid-up tonnage as percentage of respective fleet (1970-2008)

Source: *Review of Maritime Transport* (various issues).

As for the general situation of supply side factors, the crude oil sector may presents a more special case. It has been observed that some major oil fields of the world are suffering production drain due to gradual aging (Hamilton, 2008). It has become a strenuous task for them to make ends meet, maintaining existing capacity on the one hand and keeping up with rising demand on the other. In summary, sluggish response in supply side factors and strong surge of demand for the commodities underpinned the price volatilities in the markets.

The third explanation relates to the role played by the financial investors in the derivative markets for commodities such as copper, petroleum oil, cereals etc. One special feature with this round commodity price volatility is that the drastic swings of the prices correlated with the huge funds totaling hundreds of billions of USD pouring in and out the markets. There are debates regarding how to interpret the relationship between the investor's behavior and the market structure for the derivative instruments on the one hand and the price swings on the other hand. For example, as argued by Masters (2008), the speculative behavior of the financial investors plays an important role in facilitating and even creating the price swings, so he strongly advocates that the conduct of financial investors should be more rigorously regulated. On the other hand, Greely and Currie (2008) holds the view that financial speculative investors did not cause the commodity price swings but help reveal changes in underlying forces of supply and demand in the markets.

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### 3. Role of China's factor: Some descriptive evidences

China's influence on the recent world commodity market development has been widely commented. There are studies assessing China's impact in this context as part of emerging economies (Cheung and Morin, 2007; Lalonde *et al.* 2009). Researches focusing primarily on China's impact are nevertheless still rare. The paper attempts an investigation on China's factor incorporating the most recent relevant statistical data. We explore the issue through two steps of investigation in section 3 and 4 respectively. China's contribution to the demand growth for several commodities and ocean shipping is observed in this section. The relationship is also discussed through observing the most recent development in CRB prices and growth in China's steel sector that shaped the V-typed recovery in the late 2008 and early 2009.

As the widely held hypothesis of environmental Kuznets curve (EKC) suggests, intensity of material use demanded by an economy varies through successive stages of development. During the early stages of industrialization, material use would normally intensify, until the economy converges to a higher income level and the economic structure shifts to the more service-oriented type. Then, some sort of "dematerialization" would occur and this will produce an inverted U-shaped curve of material use as a function of income (Cleveland and Ruth, 1999). In addition, empirical study shows, though income elasticities for most non-energy primary commodities are less than 1 (ODI, 1995), those for metals are exceptionally elastic (Pei and Tilton, 1999).

With rapid urbanization, industrialization and income growth in recent years, China is expanding its consumption of bulk commodities at an amazing speed. Garnaut and Song (2006) claim that some structural aspects of China's economic growth in the new century have changed from 1980s and 1990s, as the Chinese economy is becoming more and more capital-intensive. The pattern of development experienced by the Western Europe, the United States, Japan and other economies in East Asia, will be seen in China again. It means, China is bound to exert greater impact on commodity markets through its intensified demand for metals and energy.

In addition to the expansion in final domestic demand for primary commodities as a result of sweeping industrialization and urbanization over the country, Cheung and Morin (2007) distinguish yet another source of China's growing appetite for resources, namely the export channel. As China has been increasingly integrated into the world production chain, a large volume of manufacturing activities have been outsourced from developed countries to China and other emerging economies. Apparently the outsourcing activities should not produce much variation in the world total demand for primary commodities, because it only looks like the relocation of production activities. However, the relative labor cost plus other competitiveness in China puts a downward pressure on manufactured goods prices (Gagnon *et al.*, 2004; Pain *et al.*, 2006; Kaplinsky, 2006). It induces increased volume of manufactured

goods consumed and therefore more resources input. Moreover, production in emerging economies tends to demand more resources input than their developed counterparts due to technological restrictions. As a result, relocation of world production of manufactured goods may also enlarge the world demand for primary commodities.

As Figure 10 shows, annual consumption of crude oil in China nearly doubled in recent 10 years. During the same period, copper and iron ore consumption tripled, while aluminum consumption quadrupled. Given the size of Chinese economy, the consumption growth has significantly raised its shares in world commodity consumption. As shown in Figure 11, upon the turn of the century, China accounted for 6.3%, 12.7%, 14.0% and 27.3% in world consumption of crude oil, copper, aluminum and iron ore respectively. In 2008, the shares reached 9.2%, 29.9%, 32.7% and 57.6% for the commodities listed above.

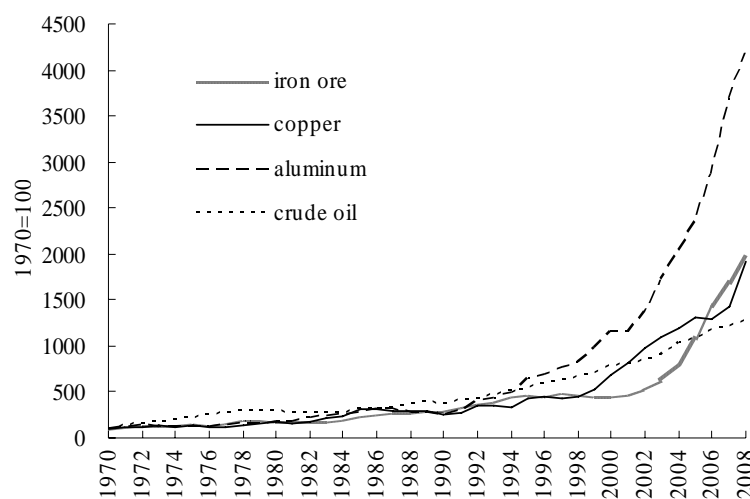


Figure 10. China's consumption of selected commodities (1970-2008)

Notes and source: Copper and aluminum consumptions before 2007 are from State Bureau of Nonferrous Metal Industry (1999), data in 2007 and 2008 are from China's Ministry of Land and Resources (2007) and China's Ministry of Land and Resources (2008). Iron ore consumption of China is calculated as China's iron ore production plus imports, data before 2007 are from Editorial Committee of Comprehensive Historical Statistics on Fifty Years of China Steel and Iron Industry (2003) and Editorial office of China Steel Yearbook (various years), data in 2007 and 2008 are from China's Ministry of Land and Resources (2007) and China's Ministry of Land and Resources (2008). Crude oil consumptions are from U.S. Energy Information Administration.

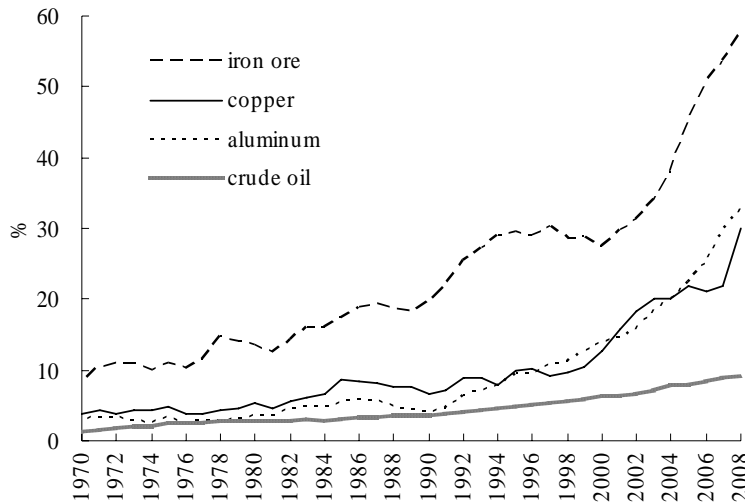


Figure 11. Share of China's consumption in the world on selected commodities (1970-2008)

Notes and source: Shares are calculated with China's consumption and world consumption on the four commodities. Source of China's consumptions refer to Figure 10. Source of world consumptions refer to Table 1.

Rapid changes in the profile of the global steel production in last decade or so highlight the growing importance of China's factor in the world commodity markets. Figure 12 compares China's annual steel production with other countries. During 2000-2007, steel production in China rose from 127 to 489 million tons, topping the world. Its growth accounts for 72% of world's incremental steel production. As shown in the figure, China's exponential growth pattern contrasts sharply with the moderate growth in other major steel-producing countries. It also stages the background for the controversies arising in recent international iron ore price negotiations.

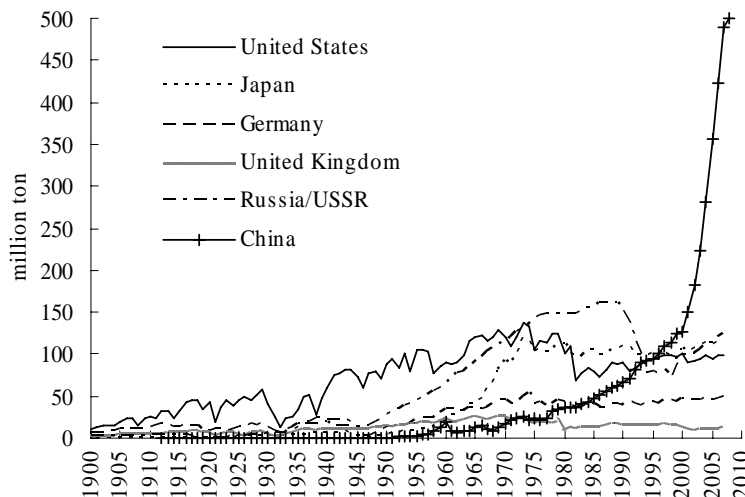


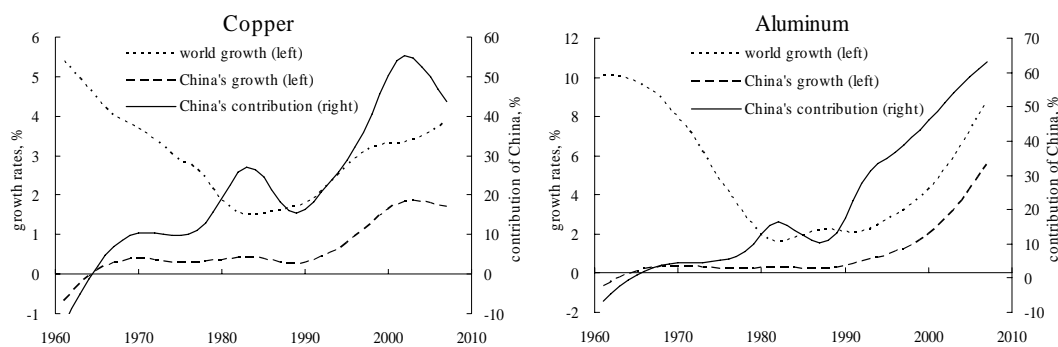
Figure 12. Steel Production of Major Countries (1900-2008)

Source and notes: Productions between 1900 and 1979 are from Mitchell (2003) and productions between 1980 and 2008 are from World Steel Association. Russia/USSR's production refers to production of Russian Empire

excluding Finland before 1913, refers to production of USSR between 1914 and 1991, and refers to production of the Commonwealth of Independent States after 1993. Its production in 1992 is estimated as the average of production in 1991 and 1993.

Thus, world demand for bulk commodities has been increasingly affected by China. An intuitional measure of China's impact is to quantify its marginal contribution to world consumption growth, that is, the share China accounts for in the world incremental consumption. However, this measurement will not be appropriately defined if the world incremental change is negative. To provide a consistent evaluation, the growth rate of world consumption and its growth rate due to China, are filtered with standard Hodrick-Prescott filter so as to smoothing out the occasional negative growth rates in recent decades<sup>‡</sup>. Then with the filtered series, we divide the latter by the former to give the smoothed and unified measure of China's marginal contribution. If China's contribution calculated as such exceeds 100 per cent, we simply use the figure of 100 per cent instead.

Figure 13 presents data on the trends of the global consumption growth and China's contribution in four bulk commodities during 1960-2007. As it shows, China made substantial contribution to the world's incremental consumption in copper, aluminum, iron ore and crude oil in recent years. The average ratio of China's contribution to world incremental consumption for the three metals of copper, aluminum and iron ore during the period of 2001-2007 was estimated at 51%, 56% and 89% respectively. The similar ratio for crude oil was 33% during the same period.



<sup>‡</sup> World consumption growth rates for commodities as a whole are all positive during the recent decade over which this study is primarily focused upon.

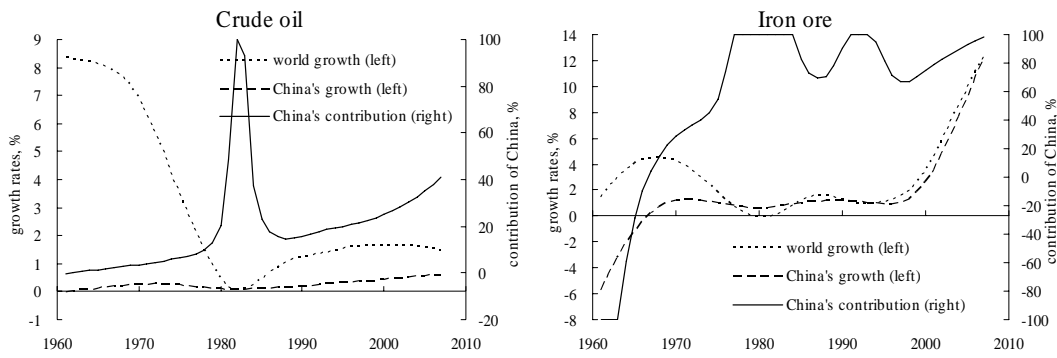


Figure 13. China's Contribution to World Consumption by Category 1960-2007 (%)

Source: Calculations are based on China's and World consumption on the four commodities. Source of China's and World consumptions refers to Figure 10 and Table 1.

China's significant consumption growth in these commodities would hardly materialize without its integration into the world economy. In the recent decade, import structure of the country has altered substantially. Considerable growth occurred in the share of primary commodities. The rapid increase in China's commodities import has generated immediate demand for ocean shipping. As a result, China extends its impact upon commodities market right unto shipping market. As reflected in Figure 14, growth in China's import shipping volume accounts for 43% of world's incremental seaborne trade volume during 2002-2007.

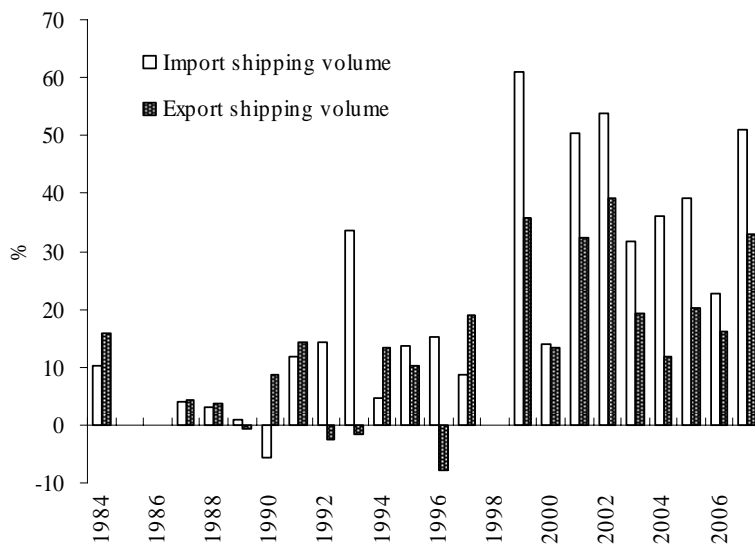


Figure 14. China's Contribution to World Seaborne Trade (1984-2007)

Notes and source: World seaborne trade volumes are from *Review of Maritime Transport* (various issues). China's seaborne trade volumes between 1984 and 1996 are from *Monthly Bulletin of Statistics* (various issues). China's seaborne trade volumes between 1997 and 2007 are from *Year Book of China Transportation & Communications* (various issues). China's seaborne trade volumes in *Year Book of China Transportation & Communications* are

different from those in *Monthly Bulletin of Statistics*. Data in this figure is based on *Monthly Bulletin of Statistics* and is extend to 2007 using growth rates inferred from *Year Book of China Transportation & Communications*.

Traditionally, industrial countries generate the bulk of world demand for primary commodities. Their state of business cycle, as a consequence, shows explanatory value for variation in commodity prices. However, in the most recent recovery of commodity prices, casual observation reveals some different sign. The recovery of industrial activities in China has distinctly led that of world commodity prices. Figure 15 presents China's recovery against that of CRB metal index. Steel production in China, as it shows, fell consecutively from 50.8 million tons in the May of 2008 to 42.8 million tons in October. But then it rebounded and resumed the peak level in the early spring of 2009. The growing trend continued to the most recent observation. CRB price index started recovery after December 2008. Turning point of China's steel industry in the recovery obviously took the lead over CRB metal index. The apparent relationship between recovery of CRB index and China's heavy industrial sector during the recent crisis may be suggestive of the special influence that China casts on the world commodity markets.

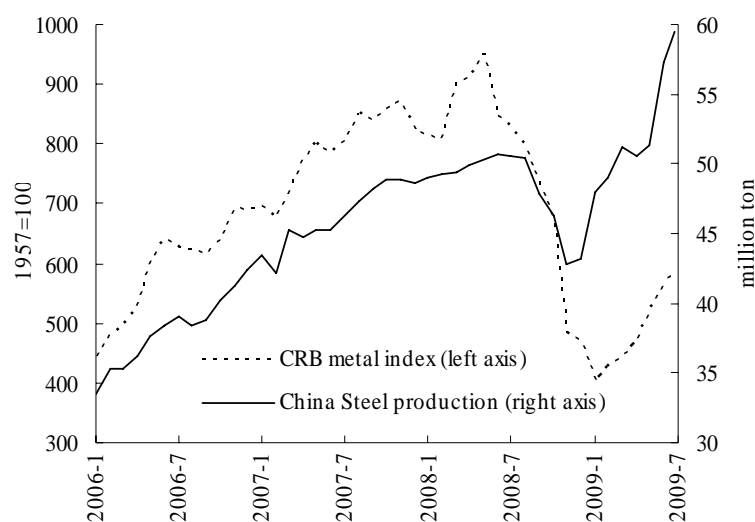


Figure 15. China's Steel Production vs CRB metal index (2006M1-2009M6)

Source: CRB metal index is from Commodity Research Bureau. Steel production of China is from *China Month Economic Indicators* (various issues).

#### 4. Role of China's factor: An econometric analysis

Given the changed composition of world commodity demand, China has been exerting increasingly evident influence over the commodity market. In this section, an econometric analysis of China's impact on the metal prices is developed. China's factor is highlighted by examining whether incorporating appropriate measures of China's factor can contribute to the explanation of the observed metal price



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volatilities.

Conventional structural analysis of commodity prices is largely “demand-driven”, where OECD countries’ industrial production provided a convenient proxy for the world commodity demand. However, newly emerging economies like China significantly alters the landscape of the commodity market in recent decade. As a result, OECD industrial production alone would gradually lose track of the long-run relationship between commodity prices and the world industrial activities as predicted by the partial equilibrium theory. Furthermore, short-run fluctuations in commodity prices would be better captured by more comprehensive measures that take China’s information into account.

The econometric analysis below comprises of four subsections. Literature review and the methodology adopted are introduced in the first subsection. Long-term relationships among variables of interest are examined in the next. The third part presents the conventional model that focuses on the impact of OECD countries’ industrial production over short-run dynamics of the commodity price. Its deteriorating forecast performance since the late 1990s is observed. Then, the econometric models incorporating China’s factor are set out in the last part, together with a comparison in the forecast efficiency of the three models introduced.

#### **4.1 Review on the related studies and the methodology**

Although direct examination of China’s impact on commodity prices has been rare in recent literature, there are a few studies discussing the influence of emerging economies in the world commodity markets. Pain, *et al.* (2006) estimated the impact of non-OECD output growth on five groups of commodity prices with reduced-form error correction models<sup>§</sup>. They found real oil and metals prices have been amplified by non-OECD output growth, whereas three agricultural commodity prices were not significantly influenced by the variables mentioned. More specifically, the impact of emerging Asia on real oil and base metal prices was examined by Cheung and Morin (2007), with different empirical strategies. For the real oil price, they detected a structural break in the sample over 1985Q4-2006Q2, located around the time of the Asian financial crisis. OECD output gap was no longer significant in the regime after 1997Q3, while the emerging Asia’s industrial production gap became significant only in the latter regime. The authors then explored the emerging Asia’s impact on the real metal prices in a co-integration framework. The findings are suggestive, but not conclusive. Based on a DSGE global economic model, Lalonde *et al.* (2009) generated a medium-term outlook for commodity prices under the influence of emerging Asia. However, their goal was to construct scenarios rather than explain the commodity price volatility.

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<sup>§</sup> To measure the demand-related pressures brought by the changing composition of world output and trade, three alternative measures are considered: the non-OECD share of world trade, the non-OECD share of world GDP, and the differential between the rates of GDP growth in the non-OECD and the OECD.

Our empirical study differs from the above literature in three aspects. First, we focus on the impact of China's demand on commodity prices. Second, rather than direct inclusion of China's output or industrial production variables, we developed aggregate measures for the strength of world commodity demand, to circumvent the issue of the changing impact of China's demand variables that direct inclusion of these variables incurs. Thirdly, our strategy of assessing China's impact is to compare models based on different hypothesis, rather than evaluation of the corresponding coefficients.

We derive the theoretical relationship between the demand variable and the commodity price in a simple partial equilibrium model of the world's competitive commodity market, expressed in formula (4.1)-(4.4). As mentioned above, the commodity demand, including both consumption demand and inventory demand, is a function of the real commodity price denoted in US dollar ( $p$ ), the dollar real effective exchange rate ( $reer^{us}$ ), world industrial activities ( $Y$ ), the real interest rate ( $r$ ), expected future price ( $p^e$ ) and the storage expenses ( $c$ ). On the other hand, the commodity supply depends on the production capacity ( $K$ ), the trade policies of commodity exporting countries ( $T$ ) in addition to the current market price and expected future price. Under the market clearing condition, commodity price should equate the supply and demand.

$$\text{Consumption demand: } Q^d = Q^d(p, reer^{us}, Y) \quad (4.1)$$

$$\text{Inventory: } S = S(r, p^e, p, c, Y) \quad (4.2)$$

$$\text{Commodity supply: } Q^s = Q^s(p, p^e, K, T) \quad (4.3)$$

$$\text{Market clearing condition: } Q^s = Q^d + \Delta S \quad (4.4)$$

However, due to lack of data on supply-side variables like  $K$  and  $T$ , as well as the unobservable  $p^e$ , endogenizing supply for a group of commodities still poses serious difficulties for this line of research. Thus, exogenous supply assumption has been made in lots of studies (e.g. Chu and Morrison, 1984; Dornbusch, 1985; Reinhart and Borenzstein, 1994), and reduced-form single-equation model is employed widely. Besides, the industrial production of OECD countries is widely used as the income variable  $Y$  for the demand function in practice. Thus, the conventional reduced form price equation is represented by:

$$a_0(L)p_t^c = f(a_1(L)reer_t^{us}, a_2(L)ip_t, a_3(L)r_t, X_t) \quad (4.5)$$

$p_t^c$ : real commodity price deflated by U.S. GDP deflator in period  $t$ ;

$reer_t^{us}$ : real effective exchange rate of U.S. dollar in period  $t$

$ip_t$ : OECD industrial production in period  $t$

$r_t$ : real interest rate in period  $t$

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$X_t$ : other exogenous variables

$a_i(L)$ : lag polynomials of finite orders

The above conventional representation of commodity prices is a “demand-driven” one. It forms the basis of our empirical study. As noted above, the income variable  $ip_t$  is represented by the industrial production of the OECD countries in most studies. Considering that industrial countries dominate most commodity demand, the ups and downs in their industrial activities can exert huge influence on commodity prices. However, when emerging economies like China begin to reshape the composition of world demand by margin, the extent of industrial countries’ influence on commodity prices is also subject to change. Irrespective of the estimation approach adopted, OECD countries’ industrial production could gradually lose its efficiency as the measure for strength of commodity demand, if China is rapidly enlarging its contribution share. In this case, the measures including China would outperform the one excluding it, on account of predicting efficiency.

Thus the price equation will be evaluated with different measures for  $ip_t$ . However, there are three issues worth noting while estimating the price equation (4. 5). Firstly, the variables listed above are all in level forms, and most of them are non-stationary. Secondly, in general equilibrium setting, real commodity price also comes into the determination of the RHS variables, so the endogeneity issue may be present. Thirdly, unobserved supply-side variables can cause significant misspecification problems during certain periods (Reinhart and Borenzstein, 1994)

Different estimation strategies were developed in the literature concerning equation (4. 5). The traditional one involves dealing with the non-stationarity issue by differencing, despite the loss of long-run information during the process. Then, instrumental variable estimation (IVE) is applied to correct the simultaneity bias introduced by certain RHS variables. The more recent practice estimates equation (4. 5) in an error-correction framework, but it hinges on the existence of co-integration among the variables in level form, which we will examine in the next subsection.

If OECD industrial production has lost track of the metal prices in long-run terms during recent years, then equation (4. 5) should be estimated with first-differenced data. In this case, even if more comprehensive measures including China may track the metal prices well, equation (4. 5) based on these new measures will be also estimated with first-differencing technique, for the sake of comparing with the basic model based on OECD countries’ industrial production. If the measures including China still perform better in this situation, we can conclude that incorporating China’s factor helps in predicting the long-run as well as the short-run dynamics of the metal prices.

## 4.2 Different demand measures and their long-run relationship with the metal price

Figure 16 gives the broad picture concerning China's relative size against OECD countries by different measures across years. As to the industrial production, China's size relative to OECD countries rose spectacularly in recent years. In 2000, industrial production of China was only 6.7% of OECD countries. Eight years later, the ratio became 28.6%. The volume of mineral ores imported by China was even more remarkable, rising from 12.4% in 2000 to 41.0% in 2007, relative to that of OECD countries. In terms of total primary commodities import, a similar trend can be observed but at a lower scale.

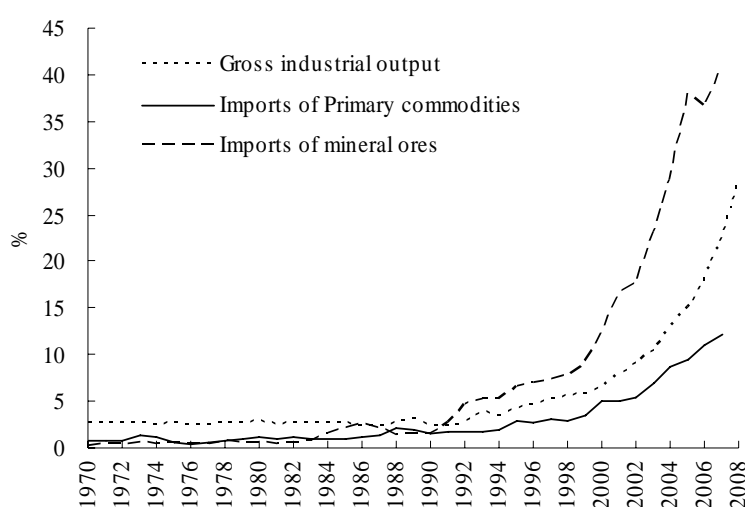


Figure 16. China's industrial production and commodity imports as percentage of OECD (1970-2008)

Source: China's gross industrial output is from Department of Comprehensive Statistics of National Bureau of Statistics (1999) and *China Statistical Yearbook* (various issues). OECD countries gross industrial output are from OECD.Stat Extracts Database. Commodity import figures are from BvD, Chelem Database.

We construct two new measures by combining industrial production indices of both OECD countries and China. The first one is constructed according to their relative size of industrial production in terms of \$ value, denoted by  $ip_t^*$ . Nevertheless, there is still some important information the new measure could fail to capture, for China's industrialization has been driving towards more capital-intensive production in recent years. Consequently, the unit growth of China's industrial production demands higher intensity of metals and energy input than that of industrialized countries. To deal with the possible underrating issue, a second measure is constructed by combining the two industrial production indices, according to the relative size of the mineral ores imports by OECD countries and China. It will be designated as  $ip_t^c$ .

The subsequent proxies for the commodity demand are plotted against OECD

industrial production index in Figure 17. As expected, since 1990s,  $ip_t^*$  and  $ip_t^c$  begin to depart markedly away from the original  $ip_t$  series, whereas the close co-movement between  $ip_t^*$  and  $ip_t^c$  weakens after 2001, with  $ip_t^c$  displaying stronger up-trending than  $ip_t^*$ .

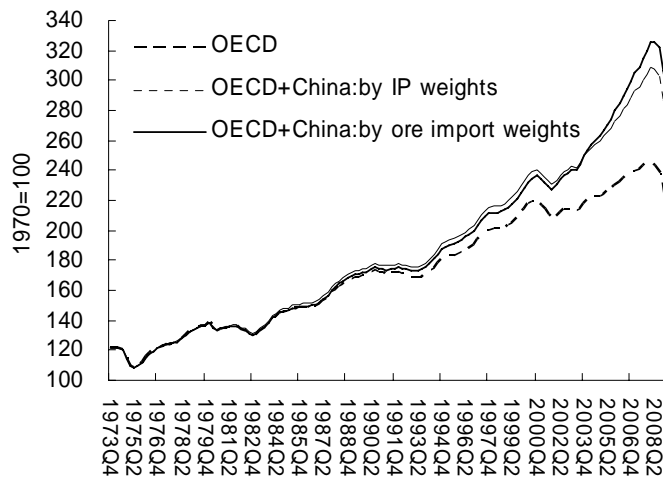


Figure 17. Three Proxies for the Aggregate Demand Factor (1973Q4-2008Q2)

Notes and source: OECD industrial production index is from the OECD.Stat Extracts database. China's industrial activities are proxied by the index of the value-added of industry. The composite industrial production index of OECD and China by IP weights is weighted by their relative size of industrial output in \$ value, not ppp-adjusted. The composite industrial production index of OECD and China by ore import weights is weighted by their relative size of mineral ore import volume.

To illustrate China's role in long-run commodity price movement during recent years, we will conduct empirical analysis on the cointegration relation embedded in equation (4. 5). Though lack of supply-side variables could distort the equilibrium relationship we aim to discover, it may be partly remedied by plugging a deterministic time trend into the equation. As shown in Figure 3, there is a downward trend in the real metal price before 2000, which is most likely the consequence of bettering supply conditions.

When we use the Engle-Granger cointegration test to confirm the existence of long-term co-movement of the macroeconomic variables and the real metal price, we find aggregate demand measures with or without China's factor can make a significant difference. To test the long-run relationship, the real metal price index is regressed on the US dollar real effective exchange rate, the real interest rate, a time trend and industrial production by different measures. Then, unit root tests are then performed on the residual series derived from these regressions. ADF test without the constant term is chosen here and critical values suggested by Davidson and Mackinnon (1993) are used. With the full sample coverage over 1973Q1-2009Q1, cointegration only significantly exists for the measure of  $ip_t^c$ , as shown in Figure 18.

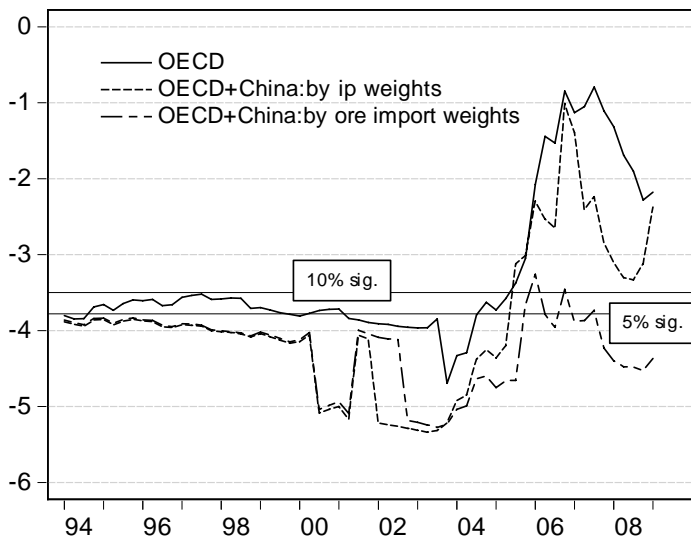


Figure 18.  $t$ -statistic of ADF tests on residuals from different rolling regressions

To get a clearer picture, rolling regressions are performed among the real metal price and other macroeconomic variables plus a time trend. It is interesting to note that the OECD industrial production series has lost the long-run co-movement with the real metal price since 2004Q4, while the composite measure  $ip_t^*$  lost it since 2005Q3. By contrast, with only three exceptions (2006q1, 2006Q4 and 2007Q3), the cointegration relation is detected for  $ip_t^c$  and the real metal price at 5% significance level when the sample widens from 1994Q1 to 2009Q1.

This information indicates the weakening of the long-run relationship between OECD industrial production and the real metal price in recent years. In other words, the long-run movement of the real metal price must take China's information into account. Moreover, China's impact on the real metal price cannot be fully traced by the size of its industrial activities. The intensity of its resource input proves to be of significant role in producing the price pattern we saw, from a long-term perspective.

#### 4.3 Conventional analysis focusing on impact of OECD economies.

Based on (4. 5), the basic reduced-form single-equation model goes like:

$$\Delta \log p_t^c = \beta_0 + \beta_1 \Delta \log reer_t^{us} + \beta_2 \Delta \log ip_t + \beta_1 \Delta r_t + \varepsilon_t \quad (4. 6)$$

where all variables except the real interest rate are expressed as logarithms, and  $\Delta$  indicates first differencing. As the real interest rate must reflect the opportunity cost of holding commodity inventory, the four-quarter US consumer price inflation is subtracted from the annualized market yield of the 3-month U.S. treasury-bill to generate  $r_t^{**}$ . Right now, the strength of the world industrial activities is proxied by

\*\* The nominal series for 3-month U.S. treasury-bill annualized market yield is from the U.S. Federal Reserve Board.

the OECD industrial production series, denoted by  $ip_t$ .

Table 1 gives the OLS coefficients for equation (4. 6). To account for the dynamics in the price series, lagged first difference of real metal price is inserted in the regression. We also allow demand variables to affect the price series with lags. Lagged effects of other RHS variables are also considered, but only significant ones are kept. To confirm the appropriateness of this dynamic specification, the presence of serial correlation in residuals must be tested. We run the regression with the lagged residual included in the regressor and testing the  $t$ -statistic on the lagged residual. This procedure gives a heteroskedasticity-robust  $t$ -statistic of -0.25. Hence, the hypothesis of no serial correlation in the disturbance can be held.

The extreme volatility of commodity prices observed in certain periods also reveals some presence of heteroskedasticity or conditional heteroskedasticity. With serial correlation undetected in the error term, the usual tests for them can be applied. The white test and ARCH test confirm the presence of heteroskedasticity and the conditional one respectively. As a result, the heteroskedasticity-robust  $t$ -statistic is reported in Table 1 instead of the normal one.

A further issue arises when co-movement between the crude oil price and real metal price is brought into consideration. It seems feasible to include oil price in the equation. Nevertheless, regression including oil price improves the Adjusted- $R^2$  by a tiny 0.01, without noteworthy changes in the values of other coefficients. In light of this, we use the equation without oil price as the basic model for the real metal price to focus on its macroeconomic determinants.

Table 1. Real Metal price: Model-1(full sample:1973Q1-2009Q1)

Constant term	$\Delta \log ip_t$	$\Delta \log ip_{t-1}$	$\Delta \log ip_{t-2}$	$\Delta \log reer_t^{us}$	$\Delta r_{t-1}$	$\Delta \log p_{t-1}^c$	Adj- $R^2$	D.W. statistic
-0.0099	3.51	-2.35	1.20	-0.54	-0.009	0.29	0.43	1.91
(-1.57)	(3.58)	(-2.23)	(1.89)	(-2.20)	(-1.32)	(2.63)		

Note: The numbers in parentheses below estimated coefficients are heteroskedasticity-robust  $t$ -statistics.

To check the possible simultaneity bias embedded in equation (4. 6), the Davidson and MacKinnon (1989) version of Hausman test is applied. Contemporaneous industrial production and the real effective exchange rate are the main suspects. As for the industrial production, four of its own lags and the U.S. unemployment rate ( $ur_t$ ) are used to construct an instrument, while the instrumental variables for the REER include U.S. fiscal deficit as a percentage of U.S. GDP ( $fs_t$ ), and four of its own lags. The residuals from the auxiliary regressions are then added to the structural equation. To test the the joint significance of the two residuals, we apply the  $F$ -test. The  $F$ -statistic generated is 1.07, with a  $p$  value at 0.35. Thus, the endogeneity issue does not prove to be serious enough to deserve special treatment. In

fact, 2SLS estimation of the above model only shows only minor revision on OLS estimation<sup>††</sup>.

The estimated coefficients are largely consistent with previous studies. However, information contained in recursive residuals reveals certain signs of misspecification and structural break.

Figure 19 plots the cumulative sum (CUSUM, the top one) and cumulative sum of squares (CUSUMSQ, the bottom one) of recursive residuals. CUSUM tends to show a definite movement in one direction while CUSUMSQ is likely to cross the significance line, if the model is incorrectly specified or a structural break occurs.

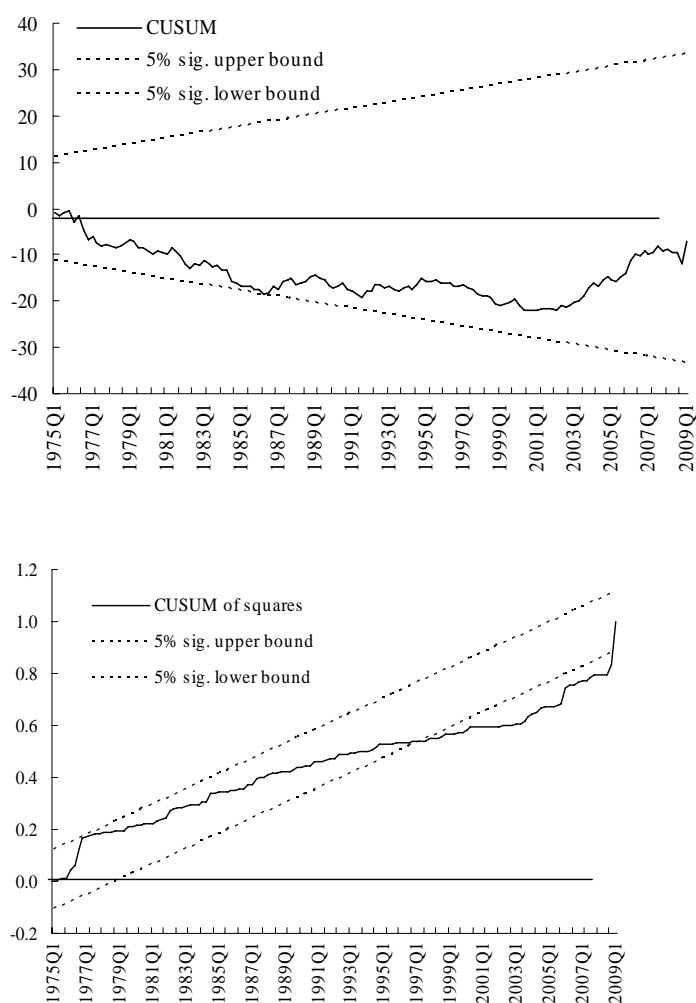


Figure 19. Tests of Recursive Residuals for the Real Metal Prices

As shown in the CUSUM plot, the sum of recursive residuals moves continuously downward before mid-1980s. It means that Model-1 persistently over-predicts the real metal price during this period. This pattern corresponds to the issue that Reinhart and Borenzstein (1994) have dealt with: the positive supply

<sup>††</sup> The results can be offered on the reader's demand.



shock<sup>††</sup>, unspecified in the demand-driven model, lies at the root of over-prediction during this period. However, some different pattern emerges around 2000: CUSUM begins to show definite upward movement. It indicates the model continually under-predicts after 2000, and the under-prediction is rather phenomenal compared to past experiences.

The plot of CUSUMSQ provides some complementary information. It crosses the 5% significance line at year 1998, close to the timing of trend reverse in CUSUM. Moreover, its movement persistently falls out of the “normal” path until recently. This pattern suggests that the one-step-ahead prediction errors of our basic model grow large in absolute term in recent years.

CUSUM and CUSUMSQ of recursive residuals for Model-1 all point to sometime around the turn of century when certain structural break occurs. Since then, systematic bias is introduced into the one-step-ahead prediction of Model-1. We re-estimate it with the sample over 1973Q1-1997Q4 to examine the out-of-sample forecasting performance of Model-1 after the break occurs. The dynamic forecast generated by Model-1 is plotted against the actual development of real CRB metal index in Figure 17, together with the two standard error bounds. It shows, the dynamic forecast by Model-1 gradually loses track of the real metal price since 2002 or 2003. The actual price series even shoots out of the plus-two-standard-error bound after 2005.

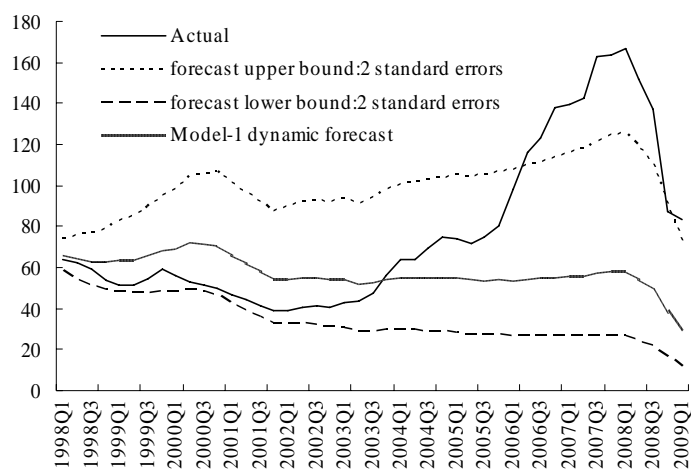


Figure 20. Real Metal Prices: Actual v.s. Forecast (1998Q1-2009Q1)

#### 4.4 An econometric modeling incorporation China’s factor

The systematic under-prediction casts doubts over the specification of Model-1. Thus, with new measures incorporating China’s information, Equation (4. 6) is

<sup>††</sup> There was a sharp increase in the commodity exports of commodity exporting countries during the debt crisis of the 1980s.

re-estimated.

The estimation results with  $ip_t^*$  and  $ip_t^c$  are presented in Table 2 and Table 3. Compared with Model-1, they show some improvement in overall fitting efficiency. Adjusted- $R^2$  increases from 0.43 to 0.46 and 0.47 respectively. Though the overall improvement appears to be minor, the coefficients for the aggregate demand factor in the new models grow in significance as well as magnitude. Model-1 predicts that one percent increase in OECD industrial production results in 3.5 percent immediate rise in real metal price, other things being equal. This elasticity grows to 4.15 in Model-2 with  $ip_t^*$ , and 4.22 in Model-3 with  $ip_t^c$ . The long term impact of one percent increase in aggregate demand factor on real price is 3.32, 4.01 and 4.11 for Model-1 to Model-3.

Table 1. Real Metal price: Model-2 with  $ip_t^*$  (1973Q1-2009Q1)

Constant term	$\Delta \log ip_t^*$	$\Delta \log ip_{t-1}^*$	$\Delta \log ip_{t-2}^*$	$\Delta \log reer_t^{us}$	$\Delta r_{t-1}$	$\Delta \log p_{t-1}^c$	Adj- $R^2$	D.W. statistic
-0.018 (-2.74)	4.13 (4.39)	-2.44 (-2.29)	1.28 (2.02)	-0.54 (-2.21)	-0.007 (-1.09)	0.26 (2.34)	0.46	1.95

The numbers in parentheses below estimated coefficients are heteroskedasticity-robust  $t$ -statistics.

Table 2. Real Metal price: Model-3 with  $ip_t^c$  (1973Q1-2009Q1)

Constant term	$\Delta \log ip_t^c$	$\Delta \log ip_{t-1}^c$	$\Delta \log ip_{t-2}^c$	$\Delta \log reer_t^{us}$	$\Delta r_{t-1}$	$\Delta \log p_{t-1}^c$	Adj- $R^2$	D.W. statistic
-0.021 (-3.15)	4.22 (4.52)	-2.31 (-2.17)	1.21 (1.99)	-0.53 (-2.17)	-0.0063 (-1.03)	0.24 (2.19)	0.47	1.96

The numbers in parentheses below estimated coefficients are heteroskedasticity-robust  $t$ -statistics.

On the other hand, different from most other coefficients, the significance and magnitude of the coefficient on the short-term real interest rate decreases in the new models. It seems to suggest after incorporating China's demand factor into the equation, the short-term real interest rate loses some of its power in explaining variation of real metal prices. Given that only the aggregate demand variable is replaced in the new models, it is likely some part of variation explained by short-term real interest rate formerly is now explained by the newly-added portion of China's industrial production. As the short-term real interest rate is proxied by U.S. 3-month treasury bills' real yield, it relates to China's industrial production most likely through the demand channel for China's export.

The limited improvement in  $R^2$  indicates the performance of one-step ahead forecasts by the above three models can not vary to any notable extent. However,

when the forecast horizon is prolonged, the difference among three models will emerge more clearly. Figure 20 compares the dynamic forecasts generated by the above models with the actual development of the real CRB metals index. Although all of them under-predict the upward trending of the index in recent years, Model-3 is the one that follows most closely among them, and Model-1 behaves the most poorly in this regard.

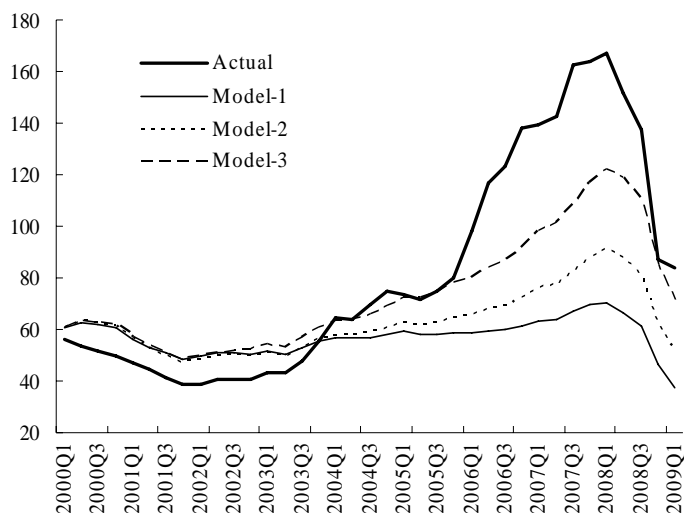


Figure 21. Dynamic Forecasts of Three Models over 2000Q1-2009Q1

The persistent under-forecast of the metal price in recent years may be accounted partly by the fact that other emerging economies apart from China are not reflected in our new measures. In addition, the demand-driven formulation ignores the rising inelasticity of commodity supply when the commodity demand expands at a spectacular rate.

Some descriptive and evaluation statistics for the forecasts generated by these models are presented in Table 4. As it shows, the forecast mean of model-3 is the closest one to the actual mean. The last column computes one form of Theil's  $u$  statistic that compares the model forecast with the dynamic forecast generated by a random walk model. This statistic is 0.95 for Model-1, which means the model improves very little from the RW one. With the lowest  $u$  statistic, Model-3 outperforms the other two in terms of forecasting.

Table 3. Some Descriptive and Forecast Evaluation Statistics: 2000q1-2009q1

	Max	Min	Mean	S.D.	Theil's U1	Theil's U2
Model-1	70.3	37.4	57.1	6.7	0.30	0.95
Model-2	96.3	47.9	65.2	13.5	0.21	0.71
Model-3	122.3	48.2	73.6	21.8	0.13	0.48
Actual	167.1	38.7	81.6	42.2		

Although it is difficult to separate China's exact contribution to the real metal

price volatility from other factors in Model-2 and Model-3, we have found some indirect evidence of China's impact by comparing the forecasting performance of different reduced-form models. However, there is yet another way to test whether the model with China's information significantly improves the model specification. Since the three models illustrated above are non-nested, we can apply the Davidson-Mackinnon test (1989) to test against non-nested alternatives. The resulting *t* statistics are presented in Table 5. It shows, at 5% significance level Model-1 is rejected in favor of Model-2 and Model-3. But between Model-2 and Model-3, there is no clear-cut winner, for the *t* statistics are not significant in both cases. Nevertheless, the models incorporating China's demand factor prove to be better specification than the one without it.

Table 4. Non-nested Tests for the Three Models

	H <sub>0</sub> : Model-1 is True	H <sub>0</sub> : Model-2 is True	H <sub>0</sub> : Model-3 is True
H <sub>1</sub> : Model-1 is True		1.16	0.56
H <sub>1</sub> : Model-2 is True	2.09**		-0.55
H <sub>1</sub> : Model-3 is True	2.25**	1.20	

\*, \*\*, \*\*\* indicates *p*-value less than 0.01, 0.05 and 0.1 respectively.

## 5. Concluding Remarks

One special feature of the global economy in the new century is wide price volatilities for bulk commodity prices and ocean shipping markets. The large price fluctuations have deeply influenced the function of the world economy and the international economic and political relationship. Differing from the previous episodes of the world commodity price hikes in history, strong consumption growth for commodities in the emerging economy especially China plays an important role in facilitating the recent market developments.

Bearing in mind the multiple and complicated factors behind the recent commodity price volatilities, this paper focuses the impact of China's factor in this context. We approach the issue mainly through two steps of investigations. First, China's impact is examined through observing China's contribution to the global incremental consumption growth for the commodities and ocean shipping services. The results suggest that the average ratio of China's contribution to world incremental consumption for the three metals of copper, aluminum and iron ore during 2001-2007 was estimated at 51%, 56% and 89% respectively. The similar ratio for crude oil was 33% during the same period.

The significance of China's factor is further analyzed using the conventional "demand driven" econometric model in which industrial activity of OECD countries is normally used to capture the effects of demand change. It fails in projecting the recent commodity price hike. Through incorporating China's factor, the model

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significantly improves its performance in simulating the recent commodity price growth. The empirical evidence confirms that the international commodity prices fluctuation is no longer independent of China's own industrial activities.

The finding of this paper is of policy implications in various areas, including the conduct of China's macro-economic policies. The special impact of China's factor in the global commodity and ocean shipping markets highlights the importance of China's macro-economic policy. Through improving the adjustment of the aggregate demand and therefore the derived demand for bulk commodities by the Chinese macro-economic policy makers, the commodity price volatility due to unexpected rises in demand plus inelastic supply responses, may be somehow moderated. To achieve this goal, China needs to reform her macro-economic management regime through allowing a more flexible exchange rate system and a more liberalized interest rate policy instruments.

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