



BANK OF CANADA  
BANQUE DU CANADA

Working Paper/Document de travail  
2007-55

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Bank of Canada Working Paper 2007-55

December 2007

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## **Acknowledgements**

The authors thank René Lalonde for his extremely helpful guidance and support. The authors also thank Robert Lafrance, Don Coletti, Michael Francis, Eric Santor, Frédérick Demers, Jocelyn Jacob, Larry Schembri, Dirk Muir, Nicolas Parent, Denise Côté, and seminar participants at the Bank of Canada, 41<sup>st</sup> Meeting of the Canadian Economics Association (Halifax, June 2007), and Asia-Pacific Economic Association Conference (Hong Kong, July 2007) for their helpful comments, and Sylvie Malette for her help with data collection. The views expressed herein and any remaining errors are those of the authors.

## **Abstract**

Over the past 5 years, real energy and non-energy commodity prices have trended sharply higher. These relative price movements have had important implications for inflation and economic activity in both Canada and the rest of the world. China has accounted for the bulk of incremental demand for oil and many base metals over this period. As rapid economic growth in China has raised the level of world demand, this has put upward pressure on commodity prices. The effect has been amplified by rising resource intensities in China's production in recent years. This paper discusses the factors driving emerging Asia's demand for commodities and assesses the impact of emerging Asia on the real prices of oil and base metals in the Bank of Canada Commodity Price Index (BCPI). Two separate single-equation models are estimated for oil and the base metals price index. We employ a structural break approach for oil prices, while metals prices are modelled with an error correction model (ECM). In both cases, we find strong evidence that oil and metals prices have historically moved with the business cycle in the developed world, but that this relationship has broken down since mid-1997. Thereafter, industrial activity in emerging Asia appears to have become a more dominant driver of oil price movements. While metal price fluctuations have also become increasingly aligned with levels of industrial activity in emerging Asia, rising intensities of metal production may have been a more important factor behind the acceleration in prices in recent years.

*JEL classification: E3, F4, O19, Q11*

*Bank classification: Business fluctuations and cycles; International topics*

## **Résumé**

Ces cinq dernières années, les cours réels des produits de base énergétiques et non énergétiques se sont orientés nettement à la hausse. Ces mouvements des prix relatifs ont eu une incidence importante sur l'inflation et l'activité économique au Canada comme dans le reste du monde. La Chine a été la principale responsable de l'augmentation de la demande enregistrée pour le pétrole et pour de nombreux métaux communs pendant cette période. La croissance rapide de l'économie chinoise a fait grimper le niveau de la demande mondiale et a exercé, par ricochet, une pression haussière sur les prix des produits de base. Depuis quelques années, cet effet se trouve davantage accentué par l'intensification de l'emploi des ressources naturelles dans les productions chinoises. Les auteures examinent les facteurs déterminants de la demande de matières premières dans les pays émergents d'Asie et évaluent l'impact de la montée en puissance de ces pays sur les cours réels du pétrole et des métaux communs mesurés par l'indice des prix des produits de base de la

Banque du Canada. Elles estiment deux modèles à équation unique, l'un pour l'indice des prix du pétrole et l'autre pour l'indice des prix des métaux communs. Elles appliquent aux cours du pétrole une approche fondée sur la détermination de ruptures structurelles, mais formalisent les prix des métaux à l'aide d'un modèle à correction d'erreurs. Dans les deux cas, des éléments probants indiquent que si les prix du pétrole et des métaux ont évolué historiquement en fonction du cycle économique des pays développés, ce lien s'est rompu au milieu de l'année 1997. Depuis lors, l'activité industrielle des économies émergentes d'Asie paraît jouer un rôle plus central dans les variations des cours pétroliers. Bien que les fluctuations des prix des métaux s'arriment elles aussi de plus en plus à l'activité industrielle des pays émergents d'Asie, il se peut que l'intensification de l'utilisation des métaux dans la production ait eu, en comparaison, une plus grande influence sur la hausse des prix de ces dernières années.

*Classification JEL : E3, F4, O19, Q11*

*Classification de la Banque : Cycles et fluctuations économiques; Questions internationales*

## 1. Introduction

Over the past 5 years, real energy and non-energy commodity prices have trended sharply higher. These relative price movements have had important implications for both inflation and economic activity in Canada and the rest of the world.<sup>1</sup> Dramatic increases have been observed primarily in oil and base metals prices, and can be justified in part by strengthening demand conditions in the industrialized world, the depreciation of the U.S. dollar, and slow supply responses. However, China has accounted for the bulk of incremental demand for oil and many base metals during this period. As rapid economic growth in China has raised the level of world demand, this has placed upward pressure on commodity prices. This effect has been further amplified by increasing resource intensities of China's production in recent years.

This paper discusses the factors driving emerging Asia's demand for commodities and uses an empirical approach to assess the impact of emerging Asia on the real prices of oil and base metals in the Bank of Canada Commodity Price Index (BCPI).<sup>2</sup> Given emerging Asia's growing prominence in the world economy, it is important to understand its impact on commodities markets and its role behind recent price movements. An enhanced understanding of these aspects would allow us to better assess the implications for commodity prices going forward, and improve the accuracy of Bank of Canada projection models for policy analysis. Study of emerging Asia's impact on commodity prices has been limited to date, given that its upsurge in demand has been relatively recent. While Lalonde and Muir (2006) are able to simulate the recent rise in commodity prices within a DSGE framework through combining a permanent productivity increase in emerging Asia with a shock to energy intensity, the literature to date has provided little empirical support for this outcome.

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<sup>1</sup> Since Canada is a net exporter for most commodities, a sustained increase in commodity prices would generate an appreciation in the exchange rate and a shift in productive resources towards commodity-producing sectors. The improved terms of trade would create wealth effects and raise consumption.

<sup>2</sup> Examination of agricultural and forestry product prices is left for future research, as increases observed thus far have been small in real terms and are likely too recent to be captured in estimations. For North American forestry markets, supplies have been heavily influenced by changes in softwood lumber agreements as well as industry restructuring and capacity closures over recent years. In food markets, crop supplies have been highly dependent on weather conditions. More recently, food prices have surged, reflecting pressures from strong demand for bio-fuel, increased demand from emerging markets, and adverse supply shocks.

Given the heterogeneity across different commodity markets, two separate single-equation models are estimated for oil and base metals prices. We employ a structural break approach for oil prices, based on previous findings of structural shifts by Lalonde, Zhu, and Demers (2003). For the base metals price index, an error correction model (ECM) is estimated. We find strong evidence that while oil and metals prices have historically moved with the business cycle in developed economies, this relationship broke down around mid-1997. Thereafter, industrial activity in emerging Asia appears to have become a more dominant determinant of oil price movements. While metals price fluctuations have also become increasingly aligned with levels of industrial activity in emerging Asia, rising metals intensities of production may have been a more important factor behind the recent acceleration in prices.

This paper is organized as follows. Section 2 summarizes recent developments in commodity price behaviour and Section 3 discusses the sources of emerging Asia's demand for commodities. A brief literature review is provided in Section 4, followed by a description of the theoretical framework and data in Section 5. The model specifications and results are discussed in Section 6, with concluding remarks in Section 7.

## **2. Recent Behaviour in Real Commodity Prices**

While real commodity prices had been on a downward trend for much of the past 25 years, they have moved persistently higher since the end of 2001.<sup>3</sup> This is illustrated in Figure 1, which plots the Bank of Canada Non-Energy Commodity Price Index in real terms and the real West Texas Intermediate (WTI) benchmark crude oil price. Figure 2 illustrates the evolution of prices of the major non-energy commodity groups from 1980 to the end of 2006.<sup>4</sup> The BCPI is constructed from the U.S. dollar spot or transaction prices of 23 key Canadian commodities produced in Canada and sold in world markets. A list of the commodities and their weights is provided in Table 1 in the Appendix.

The real price increases since the end of 2001 have been concentrated primarily in crude oil and base metals, which are now above or close to historical peaks of the last 25

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<sup>3</sup> The downward trend in real metals prices over history may be largely attributed to productivity gains in this sector and declining metals intensities in major industrialized countries. Meanwhile, advances in technology and agro-science, appear to have played a key role in driving down real agricultural prices.

<sup>4</sup> In Figures 1 and 2, all non-energy commodity price indexes are deflated using the U.S. producer price index for finished goods. The crude oil price is deflated by the U.S. GDP deflator.

years. The upward trend has been broadly based across different metals, suggesting that common factors have been responsible. As macroeconomic demand conditions in industrialized countries have traditionally been main determinants of commodity prices, some of the recent price surges can be explained by robust global economic growth, as illustrated by recent increases in year-over-year growth in OECD industrial production shown in Figure 3. A significant depreciation of the US dollar in recent years, shown in Fig. 4, may have also played a role. However, the expanding share of commodities consumption attributable to emerging Asia suggests that the region has contributed importantly to demand pressures in recent years. Due to declining investment in energy and metals extraction and refining industries since the late 1990s (see Fig. 5), production capacity has been slow to respond. As a result, spare oil production capacity has fallen to historic lows (see Fig. 6), along with many base metals inventories.

### **3. A Decomposition of Asia's Demand for Commodities**

Over the past 5 years, China has accounted for the majority of incremental demand for copper, nickel, and zinc, as well as a substantial portion of oil demand growth. The first two columns of Table 2 depict China's expanding share of world demand growth for oil and the four base metals contained in the BCPI. Because China has a low domestic endowment of natural resources relative to its needs, it has become a net importer of most commodities, as shown in Figure 7.<sup>5</sup>

China's expanding appetite for industrial materials can be decomposed into two sources: i) its rapid industrialization and infrastructure investment to meet the needs of an expanding urban population, and ii) its growing industrial integration with other East Asian countries to become a major world exporter of manufactured goods. Of course, these two factors are highly interrelated, since China's thriving export industry has been a major catalyst for rising domestic investment and urban migration in recent years. Nevertheless, it is worth distinguishing between these two sources of demand for commodities. This is because the first channel is driven by final domestic demand in

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<sup>5</sup> While China is the sixth largest crude oil producer in the world, it has been a net importer of oil since 1993. China has also recently emerged as a top producer and net exporter of aluminum. However, China's net imports of alumina (the main input for aluminum production) have surged since 2001, accompanied by steep increases in alumina prices. This suggests that China has likely impacted aluminum prices indirectly through driving up the input costs of production.

China and is expected to be a persistent source of commodities demand going forward, whereas the second is more dependent on external demand conditions, and is expected to eventually diminish in importance as growth rotates towards domestic demand. Henceforth, we refer to the first source as the *domestic demand channel*, and the second as the *export channel*.

### **3.1. Domestic Demand Channel**

Although China has continuously developed its urban infrastructure and domestic industry for quite some time, its energy and metals intensities have only advanced noticeably in recent years. As Figures 9 to 13 show, China's per GDP consumption has accelerated since 2003 for energy and zinc, and since the late 1990s for aluminum, copper and nickel. As discussed in Rosen and Houser (2007), much of this is attributable to the substantive growth in energy-intensive and capital-intensive industries - such as steel, aluminum, cement, and glass – used for road and building construction.<sup>6</sup>

Studies show that resource demands in developing countries typically begin to climb during the early phase of industrialization, and eventually stabilize and then decline as income levels advance, creating an inverted U-curve.<sup>7</sup> For example, Figure 14 plots the per capita consumption of zinc against real GDP per capita (2000 U.S. dollar terms) for China, Japan, South Korea, Malaysia, and Thailand. Similar graphs for energy and other base metals show comparable patterns, and are thus not shown. Based on the experiences of Japan in the 1960s and Korea in the 1980s, emerging Asia's energy and metals intensities could be expected to gain momentum at income levels between \$5000-\$10,000 per capita, and continue to grow rapidly before slowing at income levels of about \$15,000-\$20,000 per capita.<sup>8</sup> Indeed, for countries whose per capita income levels range between \$5000-\$10,000 (China, Thailand, and Malaysia), resource intensities have

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<sup>6</sup> China's energy elasticity of GDP growth averaged a modest 0.6 over the 1980s-1990s, leading to a substantial reduction in the amount of energy required to produce each unit of GDP. This may have been related to gains in energy efficiencies and market reforms that encouraged structural shifts away from heavy industry (e.g. steel and cement) towards labour-intensive light manufacturing (e.g. textiles). This trend has reversed in recent years, as economic incentives have favoured energy-intensive industries. Since 2001, it is estimated that this energy elasticity has almost doubled. For more details, see Lardy (2006).

<sup>7</sup> For example, see Cleveland and Ruth (1999), Park and Zhai (2006), and Garnaut and Song (2006).

<sup>8</sup> A slowing in China's resource intensities would be dependent on its industry moving away from manufacturing towards a service sector orientation.

accelerated in recent years. In contrast, little change has been observed thus far in India, Indonesia, and the Philippines, where per capita income levels remain below \$5000.

Garnaut and Song (2006) propose three key variables that drive a country's energy and metals use: investment share of output, export share of production, and rate of urbanization (defined as the fraction of population that is urban). So far, China's resource intensities have been bolstered primarily by advancing investment and export shares of output in recent years, displayed in Figure 15.<sup>9</sup> Looking ahead, consumption is expected to become the leading driver of energy and metals demand, as rising incomes of urban workers generates growing automobile ownership and consumption of household durables. The proportion of China's population living in cities - currently at 40%, compared with Japan at 66% and Korea at 81% (see Fig. 16) - should also continue to progress for some time. Together, these factors suggest that the domestic demand channel should be a persistent source of demand for commodities going forward.

### ***3.2. Export Channel***

China's expanding international trade, following its accession to the WTO in 2001, has been an important factor behind its escalating demand for industrial materials. Much of this trade growth has been associated with China's integration into the cross-border processing chain as a low-cost final assembler of manufactured goods. Adopting this role has generated a surge in China's exports of manufactured goods and increased raw material needs. Li and Song (2006) suggest that increasing bilateral trade and similar export structures between China and ASEAN countries reflect regional fragmentation of production by multinational corporations seeking economies of scale. It is estimated that a large portion of China's exports originate from Japanese and other Asian countries, for final destination in U.S. and European markets. Consequently, while China has fostered a swelling trade surplus with the West, it has also built trade deficits with Japan, Korea, and the ASEAN-4 countries, as shown in Figure 8. Furthermore, Li and Song (2006) find that the composition of Asian exports has shifted from goods that are agricultural-intensive and labour-intensive towards goods that are more capital-intensive over the last

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<sup>9</sup> The transportation sector has also become increasingly important. The number of motor vehicles on the road has doubled in the last 5 years, and transportation has accounted for 42% of China's growth in oil consumption since 1995.

decade. This change has likely boosted the metals and energy content of the region's manufacturing activity.

Because China is only one part of the manufacturing process for Asia's exported goods, it is important to also examine the role of other Asian economies in boosting commodities demand. Figure 17 illustrates that since 2000, larger shares of world manufacturing activity have been accumulated by China, the NIEs, and ASEAN-4.<sup>10</sup> Table 2 compares the shares of commodities demand growth of China with those of other Asian countries. These statistics indicate that the contributions of ASEAN-4 to demand growth in oil and base metals have increased significantly in recent years, but remain modest compared to China. India and Japan have seen little increase in their shares of world demand growth for these commodities, while the portion attributable to Asian NIE countries has diminished for all commodities examined.<sup>11</sup>

To the extent that emerging Asia is boosting the global supply of manufactured goods, higher production levels would generate a higher level of world demand for raw materials. It is worth emphasizing that it is the incremental *world* demand attributable to emerging Asia that moves commodity prices. This amount is generally difficult to isolate, as part of the observed increase in Asia's production levels could reflect manufacturing activity that has simply been outsourced from higher-cost countries, for re-export to those countries.<sup>12</sup> The declines observed in Japanese and U.S. shares of world manufacturing activity since 2000 (shown in Fig. 17) suggest that mounting exports from emerging Asia may be displacing production in the rest of the world.<sup>13</sup> Therefore, the increase in *world* demand for commodities is likely to be smaller than the incremental demand suggested

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<sup>10</sup> In particular, China's shares of global production have more than doubled since 2000 to 28% for aluminum, 35% for steel, and 48% for cement.

<sup>11</sup> Although this suggests little role for the NIEs in driving recent commodity price increases, South Korea's contribution to world nickel demand growth over 2001-2005 more than doubled to 33%, from 15% in the previous 5 years. This increase has been more than offset by a significant decline in Taiwan's share.

<sup>12</sup> Another reason emerging Asia's influence on commodity prices may be difficult to identify is that a significant portion of the region's manufactured goods are exported to the Americas and Europe. Consequently, one could arguably attribute the related raw materials usage to external demand. As concluded in a study by the Asian Development Bank (2007) on Asian intra-industry trade, growth in manufactures exports from emerging Asia remains heavily reliant on final demand from outside the region. Accordingly, the region's demand for commodities for its production of manufactures exports is arguably more driven by the business cycle in the industrialized world than in emerging Asia itself.

<sup>13</sup> The observed declines in net exports to the U.S. from Japan, Singapore, and Hong Kong since 2000 (shown in Fig. 18) may also indicate that some of the expanding Chinese exports to the U.S. have simply displaced Japanese and Asian NIE exports.

by observed increases in Asia's production levels. At the same time, the migration of manufacturing activity to Asia may also generate net gains in world commodities demand. This is particularly the case for oil, since emerging Asia tends to consume considerably more energy per unit of production than in the developed economies. According to some estimates (see Rosen and Houser, 2007), Chinese firms use 20% to 40% more energy for the same level of output compared to their OECD counterparts.<sup>14</sup>

#### **4. Review of Literature**

Research on structural models for commodity prices have traditionally found that price movements tend to be driven by world industrial activity and the U.S. exchange rate. For examples of these studies, see Hua (1998) and Lalonde, Zhu, and Demers (2003). Hua (1998) and Borensztein and Reinhart (1994) further find that oil price shocks play an important role in driving non-oil prices.

More recently, an empirical study by Pain, Koske, and Sollie (2006) suggests that emerging economies have become a more important influence on commodity price movements over the last 5 years. The authors represent growth in emerging markets using non-OECD shares of world output and trade, and find that relative strength in these economies exhibited significant and permanent effects on real oil prices, while only temporary effects on the level of real metals prices, and no effect on agricultural prices. However, specific analysis of emerging Asia's impact on commodity prices has been limited to date, given that its upsurge in demand has been relatively recent. Given that many major emerging markets actually lowered their shares of world demand growth in commodities over the 2002-2005 period (see IMF, 2006), such as Brazil, India, Mexico and Russia, a focus on emerging Asia could lead to different results from the Pain et. al (2006) study. Within a DSGE framework, Lalonde and Muir (2006) are able to explain the recent rise in oil prices through simulating a permanent increase in productivity in emerging Asia, combined with a further shock to energy intensity. However, empirical support for this outcome has been limited thus far in the literature.

Since commodity prices respond to both demand and supply movements, it is also important to consider supply conditions. Borensztein and Reinhart (1994) argue that

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<sup>14</sup> This may be due to economic incentives that have favoured energy-intensive industries in China.

traditional “demand-driven” structural models that ignore supply have tended to persistently over-predict real commodity prices by wide margins from the latter half of the 1980s into the early 1990s.<sup>15</sup> In practice, data on world commodity supply, demand, and inventories face limitations in terms of low quality, timeliness, and prohibitive cost.<sup>16</sup> Consequently, lack of data availability is a standard restriction in much of the commodity price literature, and price predictions are commonly derived from statistical inference based solely on the observed prices.

The specification of the commodity price equation also depends to a great extent on whether the series are stationary. While many commodity prices do not appear to be stationary over history, there is no clear consensus in the literature on whether this arises from deterministic trends, stochastic trends, or structural breaks. While earlier studies commonly assumed commodity prices to follow a random walk, much of the recent financial literature has argued in favour of modelling them as mean-reverting processes (see for example, Pindyck [2001], Schwartz and Smith [2000]). Intuitively, if a positive demand shock pushes the price of a commodity above its equilibrium level, producers would respond by increasing supply, thus pressuring prices down towards equilibrium. Non-stationarity can nonetheless arise because demand and supply adjustments are often slow, and shocks to commodity prices tend to be long-lasting, as shown by Cashin et al. (2000). The equilibrium price could also shift in response to changing expectations of the reserve base, political and regulatory climates, or production technologies.

Perron (1990) demonstrated that the existence of structural shifts in the mean of a series may also give rise to the appearance of an integrated process, when in fact the series may be stationary within each regime. Lalonde et al. (2003) find this behaviour is consistent with real oil prices between 1974 and 2001. Using the methodology of Bai and Perron (1998), the authors find evidence of two structural breaks over this sample period, each coinciding with a major exogenous shock that dramatically shifted supply

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<sup>15</sup> The authors suggest that this was due to the sharp increase in commodities exports from economies in transition in the former Soviet Union, which were not accounted for in most models.

<sup>16</sup> Frequency and units of measure also vary markedly across different countries and different types of commodities, making aggregation difficult. Furthermore, even if reliable production data can be obtained for a given commodity, it is arguably productive *capacity* which drives longer-term price behaviour. While supply capacity can be estimated from indicators such as reserves and investment in mining and resource sectors, such data remains difficult to obtain globally. Yet more difficult to capture are *expected* supply shortages, which can be important in influencing prices even in the absence of actual disruptions.

expectations: the Iran-Iraq war in 1980 and the collapse of OPEC discipline in the mid-1980s. Upon accounting for these structural shifts, real oil prices are found to be stationary within each regime.

## 5. Theoretical Framework

The approach used to estimate the impact of emerging Asia on commodity prices begins with a simple partial equilibrium framework of price formation in a storable commodity market. The market comprises of consumption demand, inventory demand, and supply:

$$\begin{aligned} D_t &= D\{(L)P_t, (L)Y_t, (L)X_t\} \\ Q_t &= Q\{(L)P_t, P^e_t, (L)Z_t\} \\ I_t &= I\{(P^e_{t+1}-P_t), r_t\} \end{aligned}$$

With  $(L)$  denoting the lag operator, commodities demand  $(D_t)$  is a function of current and past levels of the price  $(P_t)$ , income  $(Y_t)$ , and other exogenous variables  $(X_t)$ . Supply  $(Q_t)$  is also determined by current and past commodity prices, expected future prices, and some exogenous variables  $(Z_t)$ . Inventory demand  $(I_t)$  is dependent on the cost of storage as defined by the interest rate  $(r_t)$ , and the expected profit from holding the stock, as defined by the expected change in price. Because commodities are storable, expectations about future market conditions can have immediate impacts on the demand for storage, and thus affect current prices. Finally, the market clearing price is that which equates consumption demand and inventory demand with supply:

$$Q_t = D_t + \Delta I_t$$

The lack of data precludes estimating this system of equations for world commodities supply, demand, and inventories. Consequently, the commodity price is typically represented by a reduced-form single-equation model, and is a function of income, lagged prices, price expectations, interest rates, and other exogenous variables:

$$P_t = P\{(L)Y_t, (L)P_{t-1}, (L)X_t, \Delta P^e_{t+1}, (L)r_t\} \quad (5.1)$$

From this equation, it would not be possible to identify the parameters in the structural system, nor disentangle effects of supply and demand adjustments. Variables

such as expected future prices are also unobservable. The dependent and independent variables considered for equation (5.1) are described in the following section. To estimate the impact of emerging Asia on commodity prices, we consider a number of different variables to represent the region's growth in demand and intensity of resource use from both domestic demand and export channels. While it would be interesting to identify and distinguish between effects from domestic demand and export demand as described in Section 3, this is difficult in practice given that the two channels are highly correlated.

### ***5.1. Data***

All data series are quarterly and expressed as logarithms, with the exception of real world interest rates and variables in ratio form. More detailed sources and definitions of the data used are given in the Appendix. The commodity price series used are the benchmark WTI crude oil price and the base metals price index of the BCPI. To obtain real prices, the oil price is deflated using the U.S. GDP deflator, while the metals price index is deflated with the U.S. producer price index for finished goods.

To represent demand from industrialized countries, the income variables considered are the OECD index of industrial production and the OECD output gap. These variables are expected to bear a positive relationship with prices, as increased production in major industrialized countries would raise input demand for commodities. Other important determinants of commodities demand are the U.S. real effective exchange rate and real world interest rates. Since most commodities are traded and priced in U.S. dollars, a depreciation of the U.S. dollar would allow other countries to purchase commodities more cheaply, and would thus be expected to generate higher demand levels and higher prices. The exchange rate variable is represented as the price of foreign currency, with an increase signifying a real depreciation of the U.S. dollar. The relationship between commodity prices and real interest rates, however, is less clear. An increase in interest rates could lower commodity demand by raising the costs of storage as well as slowing future aggregate demand, putting downward pressure on prices. Conversely, rising interest rates could discourage investment activity by producers, thus lowering expected future supplies and driving commodity prices higher. Since commodities are also

considered a financial asset class whose price can be influenced by investment demand, we also consider the Standard and Poors 500 stock index as a substitute good price.

On the supply side, variables considered for the oil equation include data on world oil production capacity. For metals, an investment indicator was constructed from data on OECD real investment in metals and mining industries. This data provides a fairly rough measure of investment since it is only available to 2003, it is missing data for many of the OECD countries, and it also excludes many major metals producing countries such as Mexico, Chile, and China. Real oil prices are also considered in the equation for metals prices to represent costs of extraction and production.

Various variables are considered to represent demand growth in emerging Asia and rising resource intensities in the region. Emerging Asia is defined to include the 10 countries of China, India, ASEAN-4, and the Asian NIEs. A major limitation faced is the availability and reliability of Chinese data, with many of the desired series available only since the mid-1990s, or else only at annual frequencies, or in nominal or growth rate form. Given these constraints, we construct an emerging Asia industrial production index using time-varying GDP weights on the individual industrial production indexes of the 10 emerging Asia countries.<sup>17</sup>

Figure 19 shows the resulting de-trended emerging Asia industrial production index, compared with the similarly de-trended OECD industrial production index. Both series are de-trended using a Hodrick-Prescott (HP) filter, and Figure 20 illustrates the estimated trends in both series. Several observations are worth noting in these graphs. The first is that the trend in emerging Asia's industrial production has increased considerably more rapidly than that of the OECD over time. The second is that the production cycle in emerging Asia has become more closely correlated with that in the OECD since about 1997. The correlation coefficient between the two series from 1997Q3-2006Q2 is 0.58, compared with 0.29 from 1982Q1-1997Q2. This may be a reflection of either increasing globalization that has led to converging business cycles worldwide, or that the economies of emerging Asia have become more linked to those in the developed world via export demand. Another notable item in Figure 19 is that the

<sup>17</sup> While this measure overlaps somewhat with the OECD industrial production index, with South Korea included in both, the implications are expected to be minor given that its weight in OECD output is relatively small.

increase in emerging Asia's industrial cycle since 2001 looks fairly modest relative to evidence of strong demand growth in the region for commodities over the last 5 years, and relative to increases in industrial production observed in the early 1990s. This observation could be a sign that the variable does not convey the rising resource intensities of production associated with expanding urban infrastructure and recent shifts in Chinese manufacturing from labour-intensive goods towards more capital-intensive goods.

Other variables are used to capture the increasing resource intensities in emerging Asia through the domestic demand channel, including China's urbanization rate, China's investment share of output, as well as a constructed metals intensity index for emerging Asia (displayed in Fig. 21). No energy intensity measure was constructed, since increases observed thus far have been modest (as shown in Fig. 9) and likely too recent to be captured in any estimations. To reflect rising resource intensities through the export channel, variables used include emerging Asia's share of world trade, China's net exports of manufactured goods, China's exports of manufactured goods as a share of the country's GDP, Chinese exports of manufactured goods to the U.S., and Chinese exports of machinery and equipment to the U.S.<sup>18</sup>

## 6. Equation Specifications

As our interest in commodity prices stems primarily from their importance for the Canadian economy, our analysis is centred on the commodities in the BCPI basket. Since the most pronounced increases have been observed in the real prices for oil and base metals over recent years, we focus on these commodities. Two separate equations are estimated for the real oil price and the real base metals price index from the BCPI, given the heterogeneity across different commodity markets.<sup>19</sup> In particular, Lalonde et al. (2003) find that past oil price movements have been characterized by deterministic shifts that can be linked to specific events, which render prices to be nonstationary over history, but stationary within each estimated regime. This presence of stationarity in real oil prices may be the result of a tendency for supply and demand to grow at roughly the

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<sup>18</sup> Data on Chinese exports to Europe of manufactured goods and machinery and equipment were not available.

<sup>19</sup> For example, oil prices tend to be subject to idiosyncratic shocks related to geopolitical conflicts, because of the fact that the majority of world oil supplies are located in regions with political instability.

same pace over time, or to adjust fairly rapidly to shocks. Meanwhile, real metals prices have exhibited a fairly cyclical nature over history (see Fig. 2), but unit root test results are not able to reject nonstationarity. In the absence of any structural shift, this nonstationarity may indicate that metals demand and supply have typically adjusted more slowly to shocks over time.

### 6.1. Real Oil Prices

Based on the findings of Lalonde et al. (2003), we begin with an examination of the behaviour of real oil prices since the authors' last estimated break point of 1985Q3. It can be seen that the series no longer appears stationary once the sample is extended to the end of 2006. Indeed, an ADF test on real oil prices over the 1985Q4-2006Q4 interval yields a t-statistic of -1.66, confirming a failure to reject the presence of a unit root. This suggests the influence of some factors that may have generated yet another structural change, or else a stochastic shift in oil prices.<sup>20</sup> Since it is difficult to know the cause of such a change, we first test for the presence of a structural shift.

We begin by estimating the same equation as Lalonde et al. (2003) for the level of oil prices using the Bai-Perron (BP) methodology for the 1985Q4-2006Q2 sample. Given the relatively short sample size, we allow for a maximum of one unknown break point, with all parameters free to shift at the point. As described in Lalonde et al. (2003), real oil prices are characterized by the following equation in each regime  $i$ :<sup>21</sup>

$$RWTI_t = C_i + \mathbf{b}_{1i}RWTI_{t-1} + \mathbf{b}_{2i}RWTI_{t-2} + \mathbf{b}_{3i}WLYGAP_{t-1} + \mathbf{b}_{4i}\Delta USREER_{t-2} \quad (6.1)$$

where  $WLYGAP$  is a world output gap (in logged form) and  $USREER$  is the logged U.S. real effective exchange rate.<sup>22</sup>

The test detects the presence of a structural break in 1997Q2 at a 1% significance level. The resulting parameter estimates over each regime are shown under the column labelled Y1 of Table 3, which indicate that the  $WLYGAP$  variable is not statistically

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<sup>20</sup> The breakdown in stationarity over the extended sample may also indicate a divergence in the pace of demand growth relative to supply growth in recent years, or increasing marginal costs of oil production.

<sup>21</sup> This equation uses the first difference of the U.S. exchange rate, whereas Lalonde et al. (2003) had employed an exchange rate "gap" variable constructed using a HP filter. This does not affect the results materially.

<sup>22</sup> The world output gap is a production-weighted average of the gaps of the U.S., Canada, Mexico, the U.K., Europe, and Asia.

significant in either of the estimated regimes. Consequently, we modified equation (6.1) by replacing the world output gap variable with the OECD output gap, *OECD\_GAP*. This moved the estimated break date slightly to 1997Q3, while improving the fit of the equation. The results from this estimation are shown in the column entitled Y2 of Table 3.<sup>23</sup> While the OECD output gap was found to bear a significant, positive impact on oil prices in the first regime of 1985Q4-1997Q3, it appears to have lost its statistical significance since mid-1997. Meanwhile, the U.S. exchange rate is only significant with the correct sign in the second regime.

The estimated break date in mid-1997 coincides well with the Asian currency crisis, which had considerably reduced demand for commodities from this region over this period. The fact that the OECD output gap became insignificant in the period after 1997Q3 may suggest that oil prices became dominated by developments in emerging Asia's demand around that time. To test this hypothesis, we included the emerging Asia industrial production index (*ASIA\_IPdt*), de-trended using a HP filter, into the modified equation (2) along with the OECD output gap. As shown in column Y3 of Table 3, including the emerging Asia variable contemporaneously into the equation generated roughly the same break date (1997Q4) as specification Y2, and improved the adjusted  $R^2$ . While the variable was found to be insignificant in the first regime, since 1998Q1 it has produced a significant and positive impact on oil prices. These results point to a larger influence from emerging Asia on oil prices since 1997.<sup>24</sup> Alternative variables were also considered to capture the effect of emerging Asia on oil prices through both domestic demand and export channels, but these variables were found to either worsen the overall fit of the equation, or to be statistically insignificant.<sup>25</sup>

In order to account for possible endogeneity between the contemporaneous emerging Asia variable and oil prices, we also estimated the equation over the second

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<sup>23</sup> Alternative specifications were also tested with varying lag lengths and additional variables suspected to influence oil prices, such as the real world interest rate and oil production capacity. These variables were found either to be insignificant or to worsen the fit of the equation.

<sup>24</sup> Of course, emerging Asia may have also been a key source of demand for commodities even over the early 1990s (see Novin and Stuber, 1999). However, it is likely that its importance became more apparent when oil prices dropped in the wake of the Asian crisis, without any major change in the OECD output gap.

<sup>25</sup> Alternative variables include China's investment share of output, China's urbanization rate, emerging Asia's share of world trade, China's net exports of manufactured goods, China's exports of manufactured goods as a share of GDP, Chinese exports of manufactured goods to the U.S., and Chinese exports of machinery and equipment to US.

regime using generalized method of moments (GMM), with four lags of each regressor used as instruments and the standard errors adjusted using a five-lag Newey-West correction. The resulting parameter estimates were not significantly different from those produced by the BP methodology.

While the OECD gap variable remains significant and positive in the earlier regime, Table 2 shows that the inclusion of the emerging Asia industrial production variable now produces a significantly negative coefficient on the OECD gap since 1998Q1. This may reflect some multicollinearity associated with increasing correlation that has emerged between the business cycles of the developed economies with emerging Asia since mid-1997, discussed in section 5.1. Nevertheless, given that the OECD output gap was found to be insignificant since 1997 in the absence of the emerging Asia variable (equation Y2), it is desirable to remove it from the estimation when the emerging Asia variable is included. In order to do so, we estimate the oil equation using ordinary least squares (OLS) only over the latter 1998Q1-2006Q2 period, while removing the OECD output gap variable. The resulting estimates are (with t-statistics in parentheses):

$$RWTI_t = 0.481 + 0.904 RWTI_{t-1} - 0.045 RWTI_{t-2} - 1.930 \Delta US\_REER_{t-2} + 5.807 ASIA\_IPdt_t$$

(2.81)    (5.34)                    (-0.28)                    (-2.35)                    (3.18)

which shows a lower coefficient on the emerging Asia variable. The cumulative AR coefficient of 0.859 on the above equation implies less persistence in oil prices when we account for emerging Asia, compared to the Y2 specification which does not. Ljung-Box Q-statistics also show no evidence of serial correlation in the residuals for up to 8 lags. These estimates imply a conditional mean price of oil that has increased in the 1998Q1-2006Q2 regime to US\$30.31 per barrel in real terms, compared to US\$17.32 per barrel over the 1985Q4-1997Q4 regime. The results also suggest that over the current regime, a 1 percent increase in Asian industrial production above trend is associated with a 5.8 percent increase in real oil prices.

The use of the de-trended industrial production index for emerging Asia in the above analysis effectively attributes oil price movements to only temporary shocks in the region's industrial activity. However, it is recognized that it may not be emerging Asia's increase in output relative to trend that is driving recent oil price increases, but rather a

permanent increase in its levels of economic activity or trend output, resulting from higher productivity growth in recent years. If so, the above analysis would not capture this channel. Given that oil prices are characterized by stationarity within regimes over most of history (Lalonde et. al [2003] estimate the last regime to span 1986Q1-2001Q4), the need to use stationary variables in the equation is a limitation of this analysis. At the same time, HP-filter estimates of the trend in Asian industrial production over the extended sample (1985Q4-2006Q2) do not reveal any visible shift relative to the trend estimated over shorter samples (neither 1985Q4-1997Q3 nor 1985Q4-2001Q4).

The fact that the emerging Asia variable seems to have dominated the positive influence from OECD demand since 1997 may indicate that the increasing share of world manufacturing activity that has migrated to emerging Asia in recent years has caused oil prices to be driven more by industrial activity in this region than in the developed economies. If this is the case, then the impact captured in the estimated parameter of the emerging Asia variable may partly reflect oil demand that has simply shifted from one part of the world to another (i.e. the export channel), in addition to any incremental demand that the region may have added to world demand. Nonetheless, this shift has likely generated net gains in world oil demand, as greater shares of world manufacturing activity have moved to a region with relatively higher trend output growth (shown in Fig. 20), and which uses more energy per unit of output, relative to the developed world.

The results point to two main findings. The first is the presence of a break detected in the equilibrium price for oil in the last half of 1997. The second is that the cyclical behaviour of oil prices since that break point appears to be linked to emerging Asia's industrial activity. Although no conclusive evidence exists to explain the cause for the break, it appears to have possibly arisen from the increasing influence of emerging Asia. This would pose an additional challenge, as it would signify that the shift is more stochastic in nature, unlike previous breaks that were related to exogenous supply shocks or changes in OPEC behaviour.<sup>26</sup> However, the number of observations available is insufficient to capture such a stochastic equilibrium shift. In this context, the emerging Asia variable may be picking up the effects on oil prices possibly coming from any other

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<sup>26</sup> While there was a 10% increase in OPEC production quotas that took place in November 1997, no remarkable shifts in behaviour are visible from the production data around that time.

trending factors not included in the equation, such as increased globalization or geopolitical factors. Such a case would create upward bias to the impact suggested by the estimated coefficient of emerging Asia. Since the oil production capacity variable was found to be insignificant over the sample, our estimated model for oil prices does not take into account developments in supply. As shown in Figure 6, the sharp decline in OPEC spare production capacity since 2002 points to an insufficient supply response to recent demand pressures, which may have contributed in part to the recent acceleration in price. The omission of this supply effect would imply an additional upward bias on emerging Asia's estimated coefficient.

## 6.2. Real Base Metals Prices

The approach used to model real base metals prices is different from that for real oil prices. Unlike the case for oil, no specific events can be identified with metals prices to justify the presence of deterministic breaks. As ADF test results on the real metals price index were not able to reject the presence of a unit root, we employ a stochastic approach to model them. Consistent with the idea that real commodity prices should revert to some equilibrium level, we therefore test for the possibility that real metals prices possess a stable long-run cointegrating relationship with some other macroeconomic activity variable or combination of variables. This was conducted using Engle and Granger (1987) residual-based tests on the estimated cointegrating equation, using the dynamic least squares method of Saikkonen (1991) to correct for endogeneity and serial correlation:

$$RMTLS_t = \beta' x_t + \sum_{j=-k}^k b'_j \Delta x_{t-j} + v_t \quad (6.2)$$

where  $x_t$  is a vector of I(1) variables cointegrated with the I(1) variable  $RMTLS_t$ , the logged real metals price index. The estimated long-run relationship between the variables is defined by the vector  $\beta$ . Given evidence of a long-run equilibrium, a dynamic error correction equation (ECM) can be estimated using OLS, to model the short-term dynamics of metals prices:

$$\Delta RMTLS_t = \lambda(RMTLS_{t-1} - \beta' x_{t-1}) + \sum_{j=0}^m \delta_j Z_{t-j} + \mu_t \quad (6.3)$$

where  $Z_t$  is a vector of  $I(0)$  exogenous variables, and  $\lambda$  is the estimated speed at which metals prices adjust back to their long-run level following a shock that pushes them away from equilibrium.

Given the commonly found relationship between commodity prices and macroeconomic activity in developed countries, cointegration was first tested between real metals prices and various combinations of the following variables: OECD industrial production, the U.S. real effective exchange rate, the real world interest rate, real oil prices, and real OECD investment in metals and mining industries.

### ***Estimation Results***

The empirical analysis is conducted using a sample beginning from the earliest available data point in 1975Q3. Results from the cointegration tests reveal the strongest support for a long-run relationship between metals prices and OECD industrial production (*OECD\_IP*), with allowance for a deterministic trend. This cointegration, however, only exists for the sample up to 1997Q3.<sup>27</sup> The column (1) of Table 4a displays the results from this estimated cointegrated system. As shown by the ADF test statistic from the Engle-Granger test, the null hypothesis of no cointegration can be rejected at a 5% significance level for the sample up to 1997Q3.<sup>28</sup> It was also found that including emerging Asia variables (such as industrial production or trade share) in the long-run equation for the sample to 1997Q3 actually weakened the support for cointegration. This is demonstrated in column (2) of Table 4a, which shows results of the equation estimated over the same sample when emerging Asia industrial production (*ASIA\_IP*) is included. Incorporating this variable lowers the ADF test statistic from the Engle-Granger test to a level that no longer supports the existence of cointegration, suggesting that emerging Asia did not influence long-run metals prices over this period.

Table 4b displays the estimated cointegrated system with *OECD\_IP* (labelled *Z1*) over the period 1975Q3-1997Q3, along with the dynamic parameter estimates from the ECM. The adjustment parameter is statistically significant at the 5% level, lending further support to the existence of an equilibrium relationship between metals prices and

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<sup>27</sup> Tests were conducted beginning with the longest sample 1975Q3-2006Q4, with observations removed from the endpoint recursively until cointegration was found.

<sup>28</sup> This result was not altered significantly when the exchange rate, interest rate, oil price, or investment variables were included in the cointegrating equation.

*OECD\_IP*. The results suggest that a 1 percent increase in OECD industrial production leads to a long-term increase of 5.8 percent in real metals prices. The negative long-run coefficient on the time trend may be representative of improving supply conditions, as productivity gains in metals extraction and refining may have contributed to the downward trend in prices over this period. Variables found to significantly influence the short-run dynamics of metals price movements were growth in *OECD\_IP* as well as the first and third lag of first-differenced metals prices. Estimation of the dynamic ECM equation was performed using OLS. Parameter estimates from a GMM estimation did not differ significantly, suggesting that endogeneity is not an issue.<sup>29</sup> Ljung-Box Q-statistics on the residuals also do not detect any serial correlation up to 8 lags out, and the Jarque-Bera statistic suggests they are normal with zero mean.

Interestingly, the long-run relationship found between metals prices and OECD industrial activity appears to break down once the sample is extended beyond 1997Q3. When the same long-run equation is estimated over the full sample 1975Q3-2006Q4, the ADF test statistic of -1.766 fails to find evidence of cointegration over this period.<sup>30</sup> Figure 22 compares the estimated long-run equilibrium from the cointegrated system in Z1 against actual metals prices, while Figure 23 plots the gap between metals prices and this equilibrium. Upon examination of the gap, it appears that the failure to find cointegration between the two variables beyond 1997Q3 stems from the fact that metals prices remained persistently below equilibrium levels suggested by OECD industrial production for several years after this point. Similar to our findings for oil prices, this may have been caused by the Asian currency crisis, which significantly reduced world demand for commodities around that time. Since 2003, however, metals prices have surged well above equilibrium levels defined by OECD activity.

### ***Assessing the Impact of Emerging Asia***

The previous results suggest that since the end of 1997, metals prices have been driven primarily by factors other than industrial activity in the developed world. Determining whether this factor is emerging Asia poses a challenge, however, given the relatively

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<sup>29</sup> Four lags of each regressor were used as instruments for the estimation, with robust standard errors of the estimated parameters calculated using Newey-West correction with 8 lags.

<sup>30</sup> Tests for cointegration with a structural shift were also conducted using the Gregory-Hansen (1996) methodology. Test results did not provide strong evidence of cointegration with a regime shift.

recent period since the region's role would have likely become significant. This makes finding any long-term relationship between metals prices and emerging Asia particularly difficult within the "cointegration" framework. We thus conduct a series of experiments in order to assess whether the collapse of the long-run relationship between real metals prices and OECD industrial production is related to a greater influence from emerging Asia on world demand for metals. This exercise consists of testing whether including various emerging Asia variables into the long-run equation (6.2) over the extended sample can explain the discrepancy between metals prices and their equilibrium since the end of 1997. The emerging Asia variables tested are listed and described in the Data Appendix.

Figure 24 compares the estimated metals price equilibrium when the emerging Asia industrial production index is included into the long-run equation along with the OECD industrial production index, a specification labelled Z2. Figure 25 compares the disequilibrium gap from Z2 with that from the original Z1 equation. The full sample now becomes 1982Q1-2006Q2, based on the data available for emerging Asia. It can be seen that accounting for *ASIA\_IP* considerably reduces the negative disequilibrium gap created by the original Z1 equation over the 1997 to 2003 interval. This could signify that weakness in emerging Asia was a factor pulling metals prices below equilibrium levels suggested by OECD industrial activity over this period.

It is useful to compare the fit of this alternative specification with the original one. The first column of Table 5 reports the results from GMM estimations of the dynamic ECM for Z1e, the original specification re-estimated over the sample 1982Q1-2006Q2<sup>31</sup>. The short-run dynamics of the equation are also modified to include  $\Delta USREER_t$ ,  $\Delta OECD\_IP_t$ , and  $\Delta ASIA\_IP_{t-1}$ . Results from similar estimations of scenario Z2 are shown in the second column of Table 5.<sup>32</sup> As mentioned earlier, the long-run relationship between metals prices and *OECD\_IP* no longer holds over this longer sample. Because the impact from emerging Asia has likely been too recent, including the *ASIA\_IP* variable

<sup>31</sup> GMM estimates are reported in Table 5 because they yielded significantly different parameter estimates for  $\Delta ASIA\_IP_{t-1}$  than those from OLS estimations, suggesting the existence of endogeneity issues.

<sup>32</sup> The results shown are from a two-stage estimation of the equations. In the first stage, the long-run equation was estimated using the dynamic OLS method of Saikkonen (1991). The long-run parameter estimates were then imposed in the GMM estimation of the dynamic equation. One-step estimations of the full system were also performed using nonlinear least squares, but these did not change the results significantly and are thus not reported.

into the equation (Z2) still does not lead to cointegration.<sup>33</sup> As a result, the long-run parameter estimates shown in Table 5 cannot be interpreted as an equilibrium relationship. Nonetheless, it is interesting to note that incorporating *ASIA\_IP* over this sample now increases (in absolute terms) the ADF test statistic from the cointegration test relative to Z1– this contrasts with the findings from the shorter sample ending in 1997Q3, shown in Table 4a. Interestingly, if we sum the long-run coefficients from the Z2 estimation, the total implied effects of the *OECD\_IP* and *ASIA\_IP* variables on metals prices roughly equals the estimated long-run impact from OECD industrial production in the shorter sample up to 1997Q3 (Z1). As discussed in section 6.1, this may reflect the shift in metals demand from the developed world to emerging Asia as multinational firms have outsourced manufacturing activity there. The relatively larger coefficient on *ASIA\_IP* also supports the notion that industrial activity in emerging Asia has been more important in driving world metals demand since 1997.

While industrial activity in emerging Asia may have contributed to the metals price weakness relative to equilibrium in the period after 1997, Figure 25 illustrates that it does not explain well the relative strength observed in metals prices since the end of 2003. A possible reason for this is that the *ASIA\_IP* variable does not capture well the rising metals intensities in Asian manufacturing sectors, as discussed in Section 5.1. To account for this possibility, we further add the metals intensity index (*INTENS*) in the equation along with *ASIA\_IP*. Since metals intensity data was only available from 1995 onwards, the index was interacted with a dummy variable (*Dum*) which assumes a value of zero up to 1997Q3, and a value of one afterwards. This specification is labelled Z3. Figure 27 compares the disequilibrium gap from this scenario with that from equation Z1. We can see that accounting for rising metals intensities in emerging Asia appears to explain the strength in metals prices quite well up to the end of 2005. Where the specifications falls short, however, is over the last two quarters of the sample, 2006Q1-2006Q2. Over this period, metals prices surged despite that emerging Asia’s metals intensities appear to have declined (see Fig. 21). While the reason for this decline is not

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<sup>33</sup> A weighted “world” industrial production index was also constructed using a GDP-weighted aggregate of OECD and emerging Asia industrial production series. This variable was also not found to be cointegrated with metals prices, and also generated a negative coefficient (while causing the coefficient on the time trend to switch signs).

clear, it is possible that the intensity data for 2006 is less reliable, given that metals consumption data tends to undergo frequent revisions. It is also possible that increased speculative investment activity has been a larger influence on metals price behaviour in 2006.

Despite that the need for a dummy variable makes it inappropriate to evaluate the equation Z3 within a cointegration framework, it is useful to consider the estimation results in column 3 of Table 5. The positive and significant coefficient on *INTENS* suggests that the increase in metals prices above levels that would be predicted by both OECD and Asian industrial activity since 2003 may be explained by rising metals intensities in emerging Asia. This is further supported by the observation that the adjustment parameter is larger and more significant when both *ASIA\_IP* and *INTENS* are incorporated into the defined “equilibrium”, relative to when it is characterized only by OECD activity in Z1e.

## **7.0. Concluding remarks**

The purpose of this paper was to assess the impact of emerging Asia on the real prices of oil and base metals in the Bank of Canada Commodity Price Index (BCPI). Although we find strong evidence that oil and metals prices have historically moved with the business cycle in developed economies, this relationship has broken down since mid-1997. Thereafter, results suggest that industrial activity in emerging Asia has become a more dominant driver of oil price movements. This may be related to the increased outsourcing of production to Asia from the developed economies, which would generate higher levels of energy demand as relatively energy-inefficient Asian firms take on greater shares of world manufacturing activity. For metals, price fluctuations also appear to have become increasingly aligned with emerging Asia’s industrial activity since mid-1997. Unlike the case for oil, incorporating Asian industrial production is not sufficient to explain the surge in metals prices since 2002, and it appears that rising metals intensities in the region have provided the additional boost to prices over recent years. Because these influences began so recently, it remains too soon to obtain precise estimates of their long-run impact. The fact that an increasing share of world manufacturing activity has relocated to emerging Asia in recent years suggests that the estimated parameter on

emerging Asia industrial production may reflect not only the incremental commodities demand from the region, but also the demand that has simply relocated from the industrialized world. There may also be some upward bias on this parameter estimate coming other excluded factors that may have been at play, such as supply shortfalls, speculative investment demand, increasing globalization, or geopolitical unrest (in the case of oil).

Rising intensities *within* emerging Asia may also play a larger role going forward, as expanding urban infrastructure and shifts in Chinese manufacturing from labour-intensive goods towards capital-intensive goods are expected to push metals and energy intensities higher going forward. Resource-intensive consumption may also become more important in the future, as rising incomes generate greater motor vehicle ownership and consumption of household durables. Our analysis suggests that emerging Asia's impact on commodity prices will likely persist for many years as rising urbanization rates continue to push up resource intensities.

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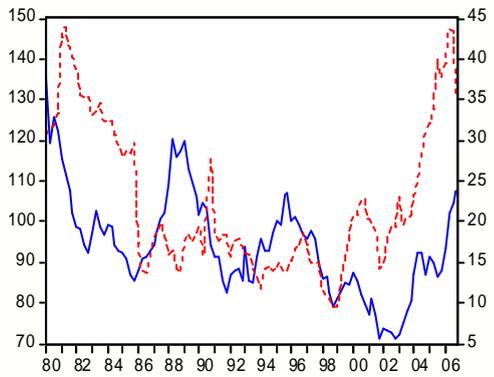
Appendix

**Table 1. Component Weights in Bank of Canada Commodity Price Index**

Weights	Canadian Production shares (1988-99)
<b>ENERGY:</b>	33.9%
Oil	21.4%
Natural Gas	10.7
Coal	1.8%
<b>NON-ENERGY:</b>	66.1%
<b>Metals</b>	14.3%
Base Metals:	11.7%
Aluminium	5.0%
Copper	2.0%
Nickel	2.4%
Zinc	2.2%
Precious Metals:	2.6%
Gold	2.3%
Silver	0.3%
<b>Minerals</b>	2.3%
Potash	1.7%
<b>Forestry</b>	33.4%
Lumber	13.6%
Pulp	12.1%
Newsprint	7.7%
<b>Food</b>	16.8%
Grains & Oilseeds:	5.9%
Wheat	3.4%
Canola	1.2%
Barley	0.7%
Corn	0.5%
Livestock:	9.7%
Cattle	7.9%
Hogs	1.8%
Fish	1.2%

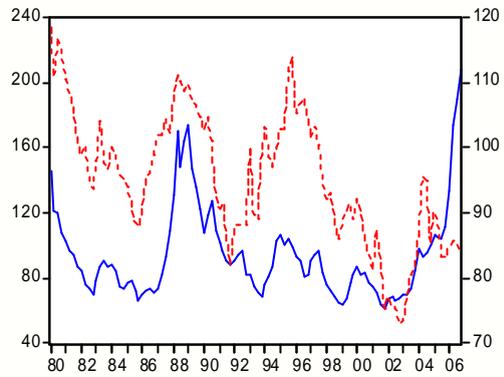
**Fig. 1: Bank of Canada Commodity Price Index**

— Real Non-Energy Commodity Price Index, 1982-90=100 (left)  
 - - - Real WTI Crude Oil Price USD/bbl, deflator base year 1982-90 (right)

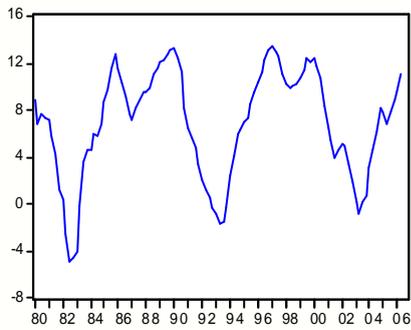


**Fig. 2: Bank of Canada Non-Energy Commodity Price Index**

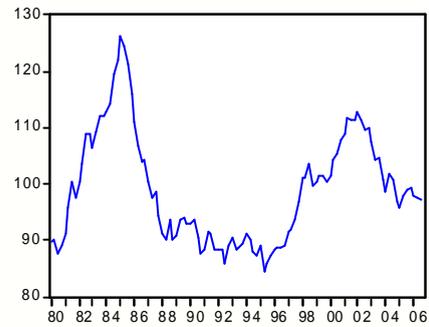
— Real Base Metals Price Index, 1982=100 (left)  
 - - - Real Agriculture and Forestry Price Index, 1982-90=100 (right)



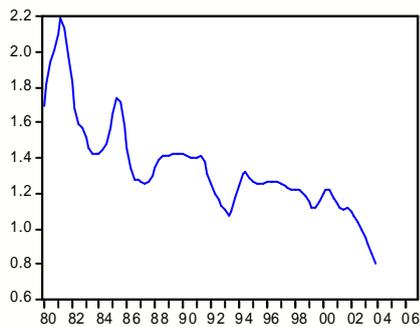
**Fig. 3: OECD Index of Industrial Production (y/y % growth)**



**Fig. 4: U.S. Real Effective Exchange Rate**

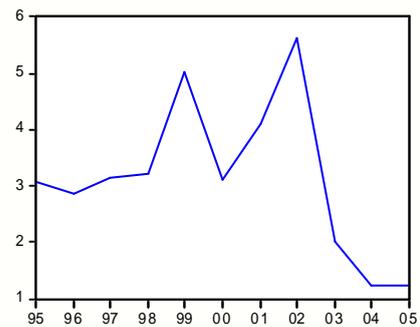


**Fig.5: OECD Real Investment in Metals and Mining Industries (Mlns USD) relative to OECD Industrial Production Index**



Source: OECD STAN Database

**Fig. 6: World Spare Oil Production Capacity (mb/d)**



Source: MF

**Table 2. Shares of World Demand Growth<sup>¥</sup>**

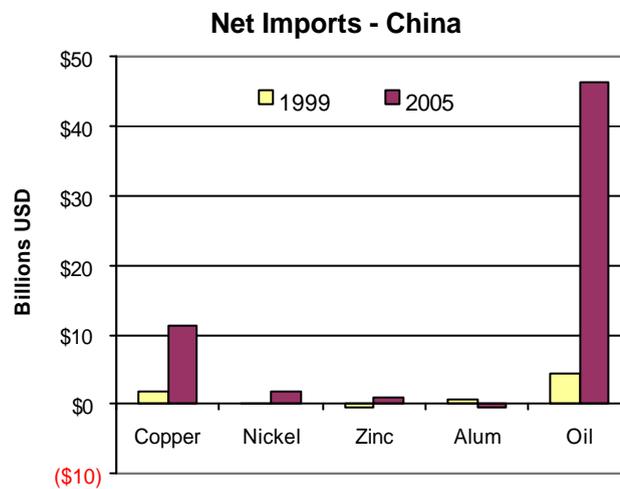
	China		Asian NIEs*		Japan		ASEAN-4**		India	
	1996-2000	2001-2005	1996-2000	2001-2005	1996-2000	2001-2005	1996-2000	2001-2005	1996-2000	2001-2005
Oil	23%	35%	6%	5%	0%	0%	3%	5%	12%	3%
Aluminium	32%	46%	7%	6%	0%	3%	0%	3%	0%	4%
Copper	26%	62%	12%	5%	0%	4%	8%	13%	4%	5%
Nickel	4%	63%	37%	28%	2%	0%	0%	4%	2%	0%
Zinc	32%	88%	13%	4%	0%	0%	2%	4%	2%	5%

<sup>¥</sup> Source: BP Statistical Review 2006, World Bureau of Metal Statistics. Demand growth is calculated as the change in units consumed over the stated period.

\* Asian NIEs include Hong Kong, Singapore, South Korea, and Taiwan.

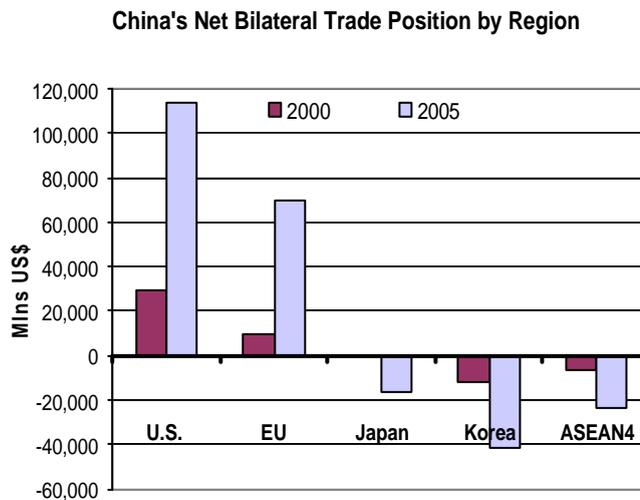
\*\* ASEAN-4 countries include Indonesia, Malaysia, Philippines, and Thailand.

**Fig. 7**



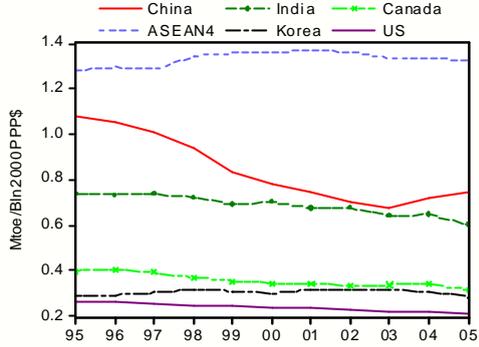
Source: UN COMTRADE

**Fig. 8**



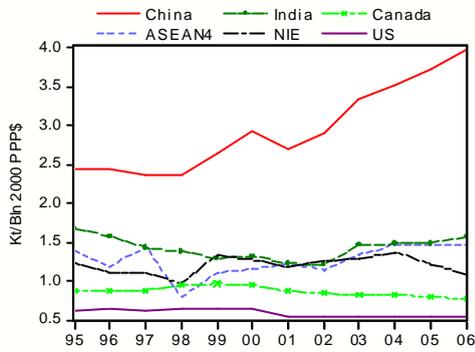
Source: IMF Direction of Trade Statistics

Fig. 9. Primary Energy Consumption per GDP



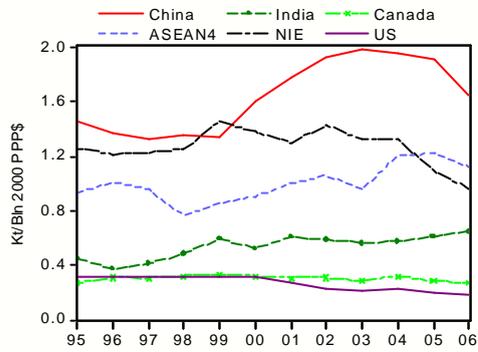
Source: BP Statistical Review 2006, World Bank, IMF

Fig. 10. Aluminium Consumption per GDP



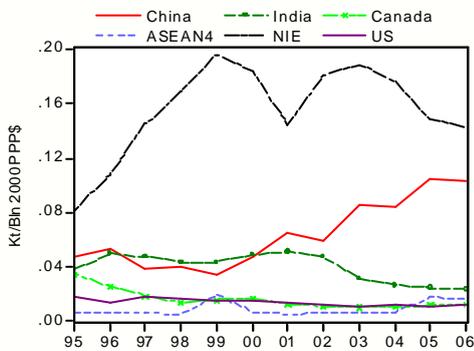
Source: World Bureau of Metals Statistics, UN Commodity Yearbook, World Bank, IMF

Fig. 11. Copper Consumption per GDP



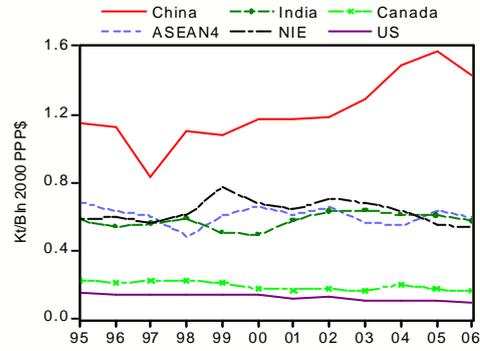
Source: World Bureau of Metals Statistics, UN Commodity Yearbook, World Bank, IMF

Fig. 12. Nickel Consumption per GDP



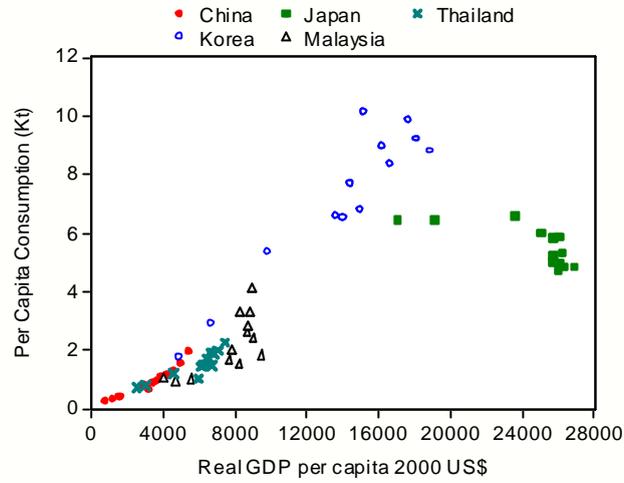
Source: World Bureau of Metals Statistics, UN Commodity Yearbook, World Bank, IMF

Fig. 13. Zinc Consumption per GDP



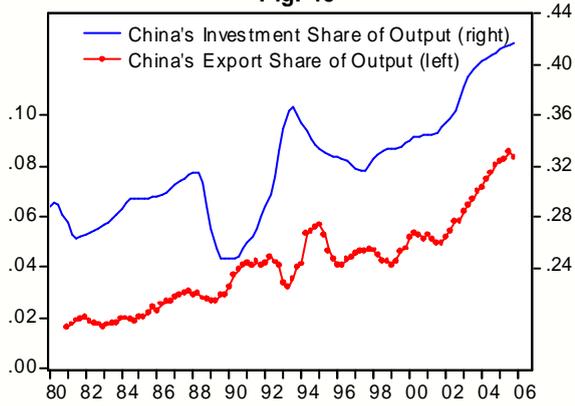
Source: World Bureau of Metals Statistics, UN Commodity Yearbook, World Bank, IMF

**Fig. 14. Zinc Consumption per Capita**



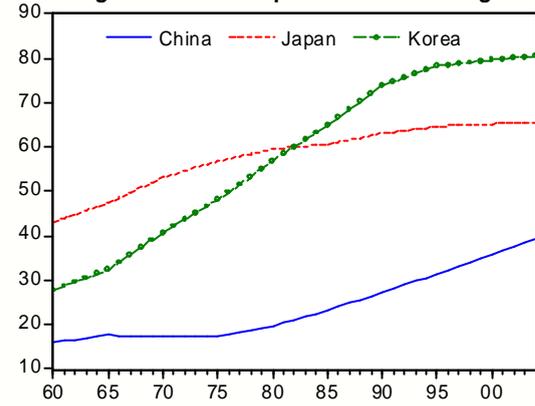
Source: World Bureau of Metals Statistics, UN Commodity Yearbook, World Bank, IMF

**Fig. 15**



Source: IMF International Financial Statistics

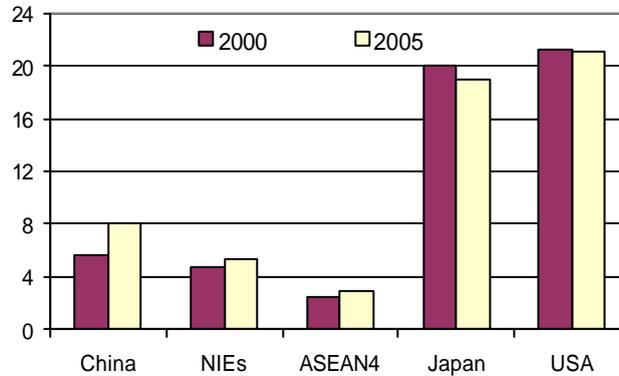
**Fig. 16: Urban Population Percentage**



Source: World Bank

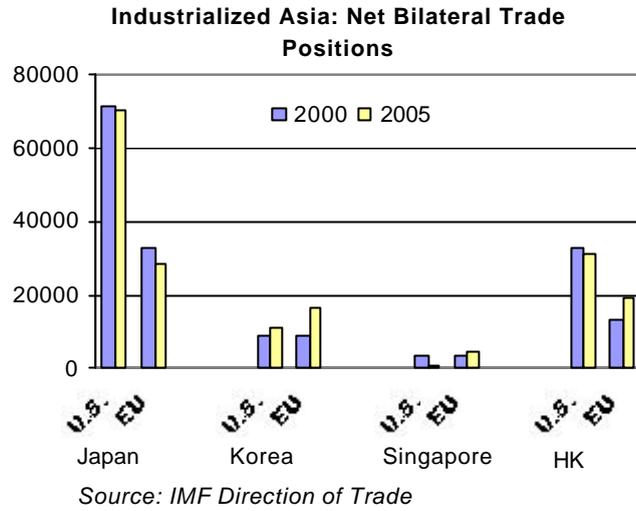
**Fig. 17**

**Share of World Manufacturing Activity**

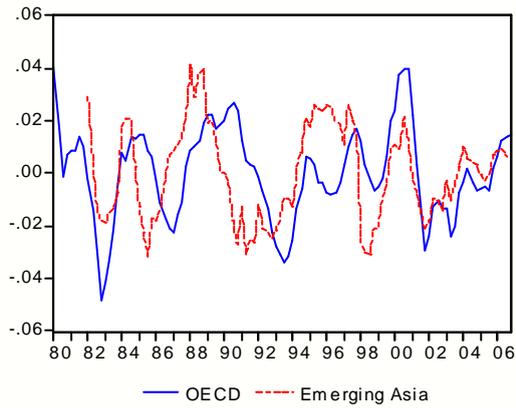


Source: UNIDO

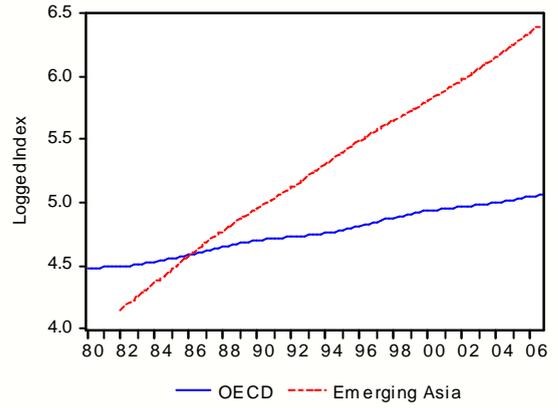
**Fig. 18**



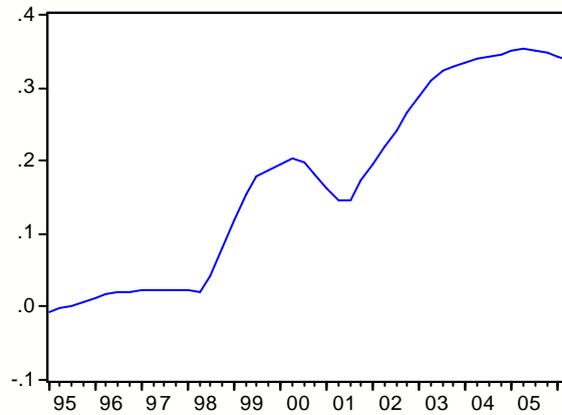
**Fig. 19. Industrial Production Cycles: OECD vs. Emerging Asia**



**Fig. 20. Industrial Production Trends: OECD vs. Emerging Asia**



**Fig. 21. Emerging Asia Logged Metals Intensity Index**



**Table 3. Real Oil Prices: Bai-Perron Estimation Results**

	Y1	Y2	Y3
<b>Regime 1:</b>	<b>1985Q4-1997Q2</b>	<b>1985Q4-1997Q3</b>	<b>1985Q4-1997Q4</b>
<i>C</i>	1.291*** (6.53)	1.386*** (7.18)	1.620*** (3.13)
<i>RWTI<sub>t-1</sub></i>	0.715*** (7.37)	0.698*** (8.22)	0.678*** (5.89)
<i>RWTI<sub>t-2</sub></i>	-0.168* (-1.86)	-0.186*** (-2.45)	-0.246** (-2.03)
<i>WLYGAP<sub>t-1</sub></i>	4.796 (1.63)		
<i>OECD_GAP<sub>t-1</sub></i>		0.033*** (2.54)	0.034*** (2.57)
$\Delta$ <i>USREER<sub>t-2</sub></i>	0.663 (1.15)	0.637 (1.22)	0.453 (0.75)
<i>ASIA_IPdt<sub>t</sub></i>			-1.550 (-1.35)
<b>Regime 2:</b>	<b>1997Q3-2006Q2</b>	<b>1997Q4-2006Q2</b>	<b>1998Q1-2006Q2</b>
<i>C</i>	0.240* (1.70)	0.156 (1.13)	0.589*** (3.67)
<i>RWTI<sub>t-1</sub></i>	1.199*** (10.12)	1.200*** (9.62)	0.825*** (5.66)
<i>RWTI<sub>t-2</sub></i>	-0.271** (-2.22)	-0.245* (-1.86)	-0.005 (-0.04)
<i>WLYGAP<sub>t-1</sub></i>	-0.034 (-0.01)		
<i>OECD_GAP<sub>t-1</sub></i>		0.010 (0.45)	-0.042** (-2.11)
$\Delta$ <i>USREER<sub>t-2</sub></i>	-2.449*** (-3.13)	-2.662*** (-3.04)	-1.257* (-1.74)
<i>ASIA_IPdt<sub>t</sub></i>			7.855*** (5.00)
<b>Adj-R<sup>2</sup></b>	0.850	0.856	0.874

Notes:

1. T-statistics in parentheses.

2. \*, \*\*, \*\*\* denote significance at the 10%, 5% and 1% level, respectively.

**Table 4a. Real Metals Prices: Cointegration Test Results**

Sample: 1975Q3-1997Q3	(1)	(2)
<i>C</i>	-20.198 (-7.40)	-24.105 (-5.38)
<i>Trend</i>	-0.033 (-9.37)	-0.083 (-3.90)
<i>OECD_IP<sub>t</sub></i>	5.791 (9.09)	4.870 (4.03)
<i>ASIA_IP<sub>t</sub></i>		2.417 (2.35)
No. Leads & Lags ( <i>k</i> )	1	1
ADF t-stat: (p-value) <sup>¥</sup>	-3.940 (0.044)	-3.547 (0.218)

Notes:

1. T-statistics are given in parenthesis, unless otherwise stated.
2. <sup>¥</sup> denotes MacKinnon (1996) critical values used.

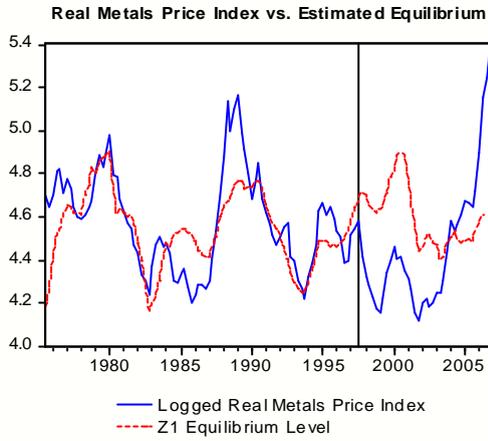
**Table 4b: Real Metals Prices: Estimated ECM (1975Q3-1997Q3)**

	Z1
<b>Long -Run Parameters</b>	
<i>C</i>	-20.198*** (-7.40)
<i>Trend</i>	-0.033*** (-9.37)
<i>OECD_IP<sub>t-1</sub></i>	5.791*** (9.09)
<b>Equilibrium Adjustment Parameter (<math>\hat{\lambda}</math>)<sup>§</sup></b>	-0.202** (-3.91)
<b>Dynamic Parameters</b>	
<i>C</i>	-0.021** (-2.13)
$\Delta RMTLS_{t-1}$	0.194** (2.05)
$\Delta RMTLS_{t-3}$	0.220*** (2.37)
$\Delta OECD_IP_t$	4.307*** (4.80)
Adj -R <sup>2</sup>	0.319
Jarque-Bera	1.835

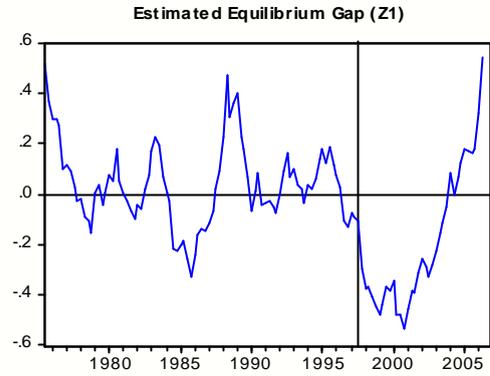
Notes:

1. T-statistics are given in parenthesis, unless otherwise stated.
2. \*, \*\*, \*\*\* denote significance at the 10%, 5% and 1% level, respectively.
3. <sup>§</sup> denotes Ericsson and MacKinnon (2002) critical values used.

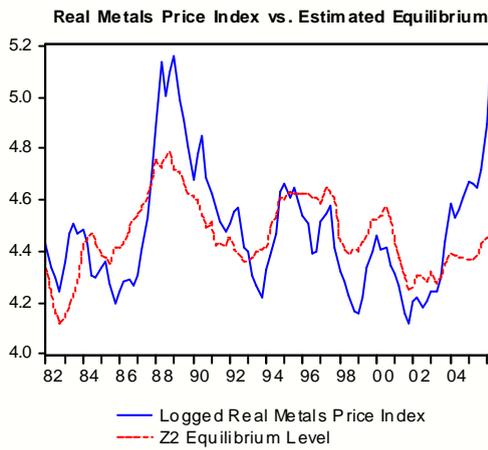
**Fig. 22**



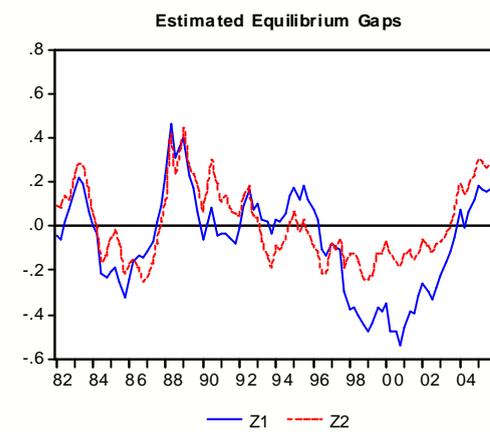
**Fig. 23**



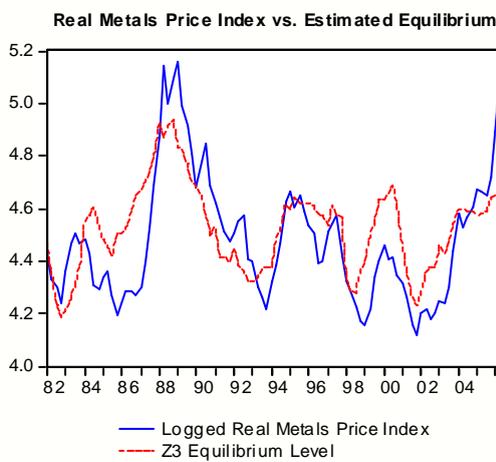
**Fig. 24**



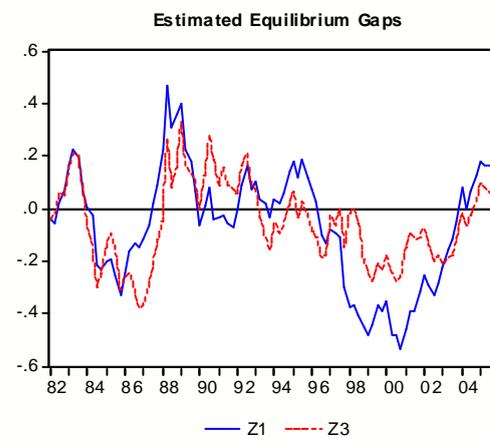
**Fig. 25**



**Fig. 26**



**Fig. 27**



**Table 5. Real Metals Prices: Estimated ECM with Emerging Asia  
(1982Q1-2006Q2)**

Variable	Z1e	Z2	Z3
<b>Long-Run Parameters</b>			
<i>C</i>	-8.26 (-2.02)	-14.848 (-3.41)	-19.263 (-5.20)
<i>Trend</i>	-0.018 (-3.17)	-0.090 (-5.72)	-0.126 (-7.11)
<i>OECD_IP<sub>t-1</sub></i>	2.997 (3.11)	1.763 (1.79)	1.818 (2.19)
<i>ASIA_IP<sub>t-1</sub></i>		3.580 (4.94)	4.960 (6.20)
<i>Dum*INTENS<sub>t-1</sub></i>			1.369 (4.40)
<b>ADF t-stat: (p-value)<sup>¥</sup></b>	-0.736 (0.99)	-1.458 (0.97)	-2.427 (0.86)
<b>Equilibrium Adjustment Parameter (<math>\hat{\lambda}</math>)<sup>§</sup></b>	-0.039 (-2.24)	-0.057 (-2.26)	-0.098 (-3.99)
<b>Dynamic Parameters</b>			
<i>C</i>	-0.061 (-4.78)	-0.060 (-4.90)	-0.058 (-4.88)
$\Delta RMTLS_{t-1}$	0.224 (3.16)	0.232 (3.17)	0.247 (2.99)
$\Delta OECD\_IP_t$	3.424 (3.90)	3.271 (3.76)	2.957 (3.35)
$\Delta USREER_t$	-0.712 (-1.91)	-0.629 (-1.67)	-0.457 (-1.07)
$\Delta ASIA\_IP_{t-1}$	2.056 (3.82)	1.964 (3.72)	1.709 (3.42)
<b>Adj-R<sup>2</sup></b>	0.274	0.276	0.298
<b>Jarque-Bera</b>	0.063	0.048	0.319

Notes:

1. T-statistics are given in parenthesis, unless otherwise stated.
2. <sup>¥</sup> denotes MacKinnon (1996) critical values used.
3. <sup>§</sup> denotes Ericsson and MacKinnon (2002) critical values used.

## Data Sources and Definitions

**Commodity prices:** Real oil price used is the West Texas Intermediate crude oil price deflated by the U.S. GDP deflator. Real metals price used is the base metals price index from the Bank of Canada Commodity Price Index (BCPI), deflated by the U.S. producer price index for finished goods. The BCPI has a base of 1982-90 =100 and is expressed in U.S. dollars.

**Commodities Consumption (Volumes):** Oil and energy consumption data are from the *BP Statistical Review 2006*. Consumption data for the metals (zinc, aluminum, nickel and copper) are from the *World Bureau of Metal Statistics* and *UN Commodity Yearbook 2003*, at an annual frequency. Metals per capita consumption data is constructed with *World Bank Development Indicators* annual population data.

### Output measures:

- *OECD Industrial Production Index:* Quarterly, from *OECD Main Economic Indicators* database
- *World output gap:* Quarterly production-weighted average of the gaps of U.S., Canada, Mexico, U.K., Europe, and Asia, constructed by the Bank of Canada.
- *OECD output gap:* Quarterly, from the *OECD Economic Outlook* database, in which potential output is estimated from a production function approach.

**US effective exchange rate:** Foreign exchange value of the U.S. dollar, U.S. Federal Reserve Board of Governors broad index, 1973=100.

**Real word interest rate:** a trade-weighted average of interest rates of Japan, U.K., the Euro zone, and U.S, deflated by trade-weighted GDP deflator.

### Supply side variables:

- *Oil Production Capacity:* constructed by summing data on world oil production with data on world spare production capacity. World oil production data is quarterly from the U.S Department of Energy's *Energy Information Administration*, while spare capacity data is annual from the *IMF World Economic Outlook* (August 2006), with quarterly values interpolated.
- *Real OECD Investment in Metals and Mining industries:* Annual data to 2003 from the *OECD STAN* database, with quarterly values interpolated.

### Emerging Asia variables:

*Country coverage:* Emerging Asia includes the following ten countries: China, India, Hong Kong, Singapore, South Korea, Taiwan, Indonesia, Malaysia, Philippines and Thailand.

- *Emerging Asia Industrial Production Index:* constructed from the 10 individual country indexes of industrial production in the manufacturing sector where available, and total industrial production otherwise. Individual country quarterly indexes are first

seasonally adjusted using the X11 method and then aggregated using GDP weights, 1990=100. China's industrial production index is constructed from National Accounts data from the Chinese Statistical Yearbook on real production in the secondary industry. Prior to 1992, this series is only available at an annual frequency, with quarterly values interpolated. Taiwan's industrial production index is constructed from National Accounts data on GDP for the manufacturing sector. For the remaining Asian countries, quarterly industrial production indexes are obtained from the *OECD Main Economic Indicators* database for Indonesia, *IMF International Financial Statistics (IFS)* for Malaysia, Philippines, Singapore, Hong Kong, Korea, and India, and the *Bank of International Settlements* for Thailand.

- *Metals intensity index*: The emerging Asia metals intensity index is constructed by first summing the units consumed of a given metal across the 10 countries and dividing by the sum of the region's real GDP to obtain an emerging Asia intensity measure for each metal. Intensity indexes are constructed for each metal with base year 1995. Each of the four intensity indexes are then weighted according to their weight in the BCPI to form the overall metals intensity index. The series begins in 1995, based on availability of consumption data for the full set of metals across all 10 countries. Since all data are annual, a quarterly index is then constructed through interpolation.
- *China's urbanization rate*: annual from the *World Bank Development Indicators*, with quarterly values interpolated. Defined as the percentage of the population living in cities.
- *China's investment share*: Annual data on nominal investment from the *IMF IFS*, with quarterly values interpolated.
- *Chinese exports of manufactured goods to the U.S. and Chinese exports of machinery and equipment to the U.S.*: monthly data from 1997- 2006 from *Datastream*. Prior to 1997, levels are constructed assuming the same growth rate as Chinese total exports of manufactured goods (an annual series from *Datastream*, with quarterly values interpolated).
- *Emerging Asia trade share*: An aggregate of 10 countries' total trade (exports and imports) as a ratio to total world trade. Quarterly nominal export and import data is obtained from the *IMF IFS*, deflated using different price indexes and seasonally adjusted using X11 methodology. For Singapore, Hong Kong and South Korea, the country's export and import price indexes from the *IFS* are used as deflators, and Taiwan trade data is deflated using an average of these countries' deflators. For the remaining emerging Asia countries, exports and imports are deflated using the Asia export and import prices from the *IFS*.