The Evolution of the Chinese Housing Market and Its Impact on Base Metal Prices

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Acknowledgements

Abstract

The Chinese housing market has grown rapidly following its liberalization in the 1990s, generating significant economic activity and demand for base metals. In this paper, we discuss the evolution of the Chinese housing market and quantify its importance for the overall Chinese economy and its linkages to base metal prices. We estimate that the housing boom was responsible for roughly a quarter of the 85 per cent increase in base metal prices from 2002 to 2010. Since 2014, however, a substantial inventory overhang has led to a steep correction in the housing market, which in turn has contributed up to a third of the 25 per cent decline in base metal prices. While the drag on metal prices should ease as the Chinese housing market stabilizes, the level of support from this sector will likely remain minimal compared with the experience of the past decade.

JEL classification: Q31, R31
Bank classification: International topics

Résumé

Le marché du logement de la Chine a connu une croissance rapide après sa libéralisation dans les années 1990, et a été à l'origine d'une activité économique importante et d'une demande massive de la demande de métaux communs. Dans cette étude, les auteurs examinent l'évolution du marché chinois du logement et quantifient son importance pour l'ensemble de l'économie chinoise ainsi que ses liens avec les prix des métaux communs. Ils estiment que la hausse de 85 % enregistrée par les prix des métaux communs entre 2002 et 2010 est attribuable pour un quart environ au boom immobilier. Depuis 2014, toutefois, un stock excédentaire considérable a donné lieu à une correction marquée du marché du logement, laquelle a contribué au recul de 25 % des prix des métaux communs dans une proportion pouvant atteindre un tiers. Bien que l'incidence restrictive sur les prix des métaux communs doive s'atténuer à la faveur de la stabilisation du marché chinois du logement, le soutien fourni par ce secteur devrait demeurer minime comparativement à son effet stimulateur au cours de la dernière décennie.

Classification JEL : Q31, R31
Classification de la Banque : Questions internationales

1. Overview

The Chinese housing market grew rapidly following its liberalization in the late 1990s. The sector is now extremely large by global standards – over six times larger than the U.S. housing market. The housing boom during the 2000s generated significant economic activity and massive demand for base metals. Our simulations suggest that the housing boom accounted for roughly a quarter of the 85 per cent increase in global real base metal prices between 2002 and 2010.

Since 2010, the unrelenting pace of housing construction and slowing demand growth has created a significant overhang of unsold inventories. As a result, the market has been correcting over the past two years. We estimate that this correction lowered Chinese GDP growth by 0.9 percentage points (ppts) in 2014 and a further 0.5 ppts in 2015. We further estimate that the Chinese housing market correction has lowered base metal prices by 5 to 10 per cent since 2014, which is up to a third of the total decline observed during this period.

While the housing market has shown signs of stabilization, we expect investment growth to remain persistently below the pace observed during the 2000s. In an environment where supply is increasingly abundant, it is unlikely that a stabilization in the Chinese housing market can sustain a new run-up in base metal prices on its own.

This paper is organized into four sections. Section 2 describes the Chinese housing market, its dynamics and near-term prospects. Section 3 discusses the impact of Chinese residential construction on base metal prices. Section 4 concludes.

2. The Evolution of the Chinese Housing Market

2.1 The Chinese housing market has become one of the most important markets in the world

Until the late 1980s, all Chinese residential real estate was essentially state-owned. Liberalization began in the 1980s, but markets remained relatively small until 1998 when the Chinese government relieved firms of the burden of providing housing for their workers (Yang and Chen 2014). The market became the primary method of obtaining housing, and new home sales increased 10-fold between 2003 and 2013 (**Chart 1**). Over this period, the Chinese housing market became extremely large by global standards. By 2015 it was over six times the size of the U.S. new home market (**Chart 2**).

Chart 1: New home sales have risen rapidly

RMB billions

Note: RMB = renminbi
Source: National Bureau of Statistics of China
Last observation: 2015
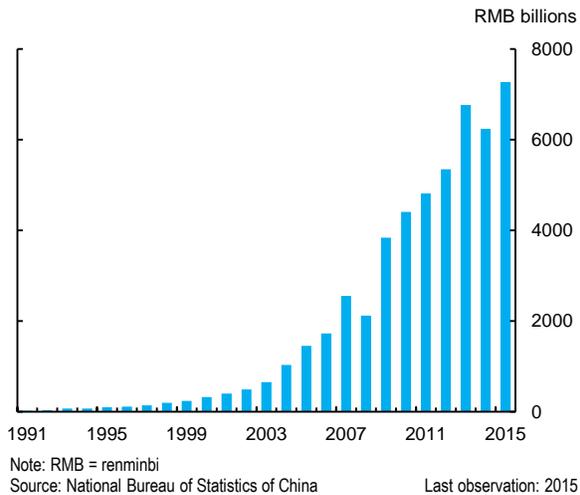
Chart 2: The Chinese housing market is large

USD billions

	USD billions
US new homes 2015	176
US new cars 2015	276
US new homes 2005	371
US food 2015	766
New Chinese housing 2015	1168

Sources: Haver Analytics and Bank of Canada calculations
Last observation: 2015
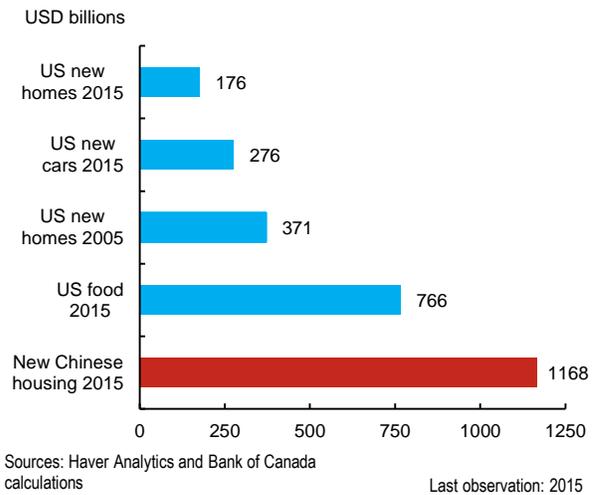
According to our estimates, real residential value-added real estate investment directly made up around 5 per cent of Chinese GDP in 2015, with non-residential real estate accounting for an additional 3 per cent (see Appendix A). The housing market also has significant linkages to other sectors of the economy through its demand for intermediate goods. Some estimates put the total direct and indirect contribution of the real estate sector as a whole to GDP as high as the 30 per cent range (Zhang et al. 2014).

2.2 The housing boom of the 2000s led to a significant inventory overhang

The unrelenting pace of housing construction and slowing demand growth in recent years likely led to a large inventory overhang. However, the various inventory measures do not tell a consistent story and

there is significant uncertainty around the true level of inventories. While official data suggest that the level of inventories only stands at 4–5 months of sales, other data point to a much more acute problem (**Chart 3**).

We collect inventory and sales data from Soufun, a private real estate information provider. These data show a much more cyclical pattern and pin the level of inventories at about 9 months of sales by the end of 2015, down from a peak of around 15 months of sales in late 2014. The advantage of this methodology is that it comes from a transparent source, and has a clear and consistent construction. However, this measure suffers from

Chart 3: Chinese housing inventories have fallen but remain high

Months of sales

Months of sales

Synthetic inventories (RHS)
Soufun inventories (LHS)
National Bureau of Statistics of China inventories (LHS)

Sources: National Bureau of Statistics of China, Soufun and Bank of Canada calculations
Last observation: December 2015

2
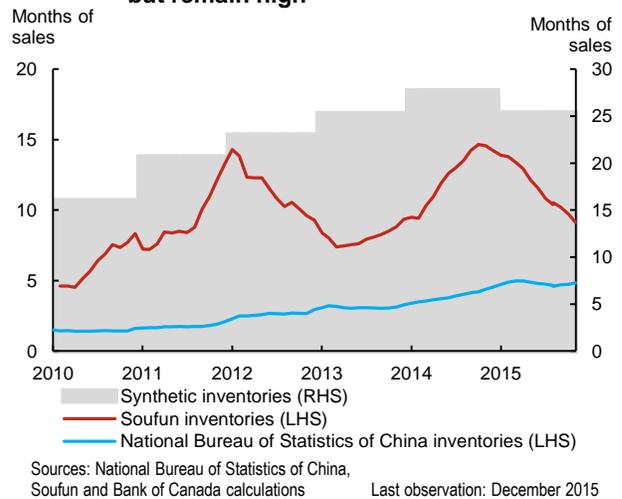
relatively limited city coverage and likely understates the true level of inventories.[1]

Despite its limited coverage, we are encouraged that the trend in our 11-city measure is fairly consistent with that exhibited by the 50-city measure used in the recent report from the People's Bank of China (PBoC 2015). These measures suggest that the inventory overhang has largely been digested. However, since the data begin only in 2010, it is difficult to gauge the equilibrium level of inventories.

Other analysts use a "synthetic" measure of inventories derived from housing starts and sales data (Chivakul et al. 2015).[2] These "synthetic" measures suggest that inventories could be in excess of two years of sales. While this measure is likely more representative than our 11-city measure, it may also overestimate the true level of inventories, since the housing starts data may not reflect the commencement of actual construction, and there does not seem to be a consistent relationship between the starts, completions and sales data (see Appendix A). While the true level of inventories remains unclear, all measures confirm a sizable accumulation of inventories in recent years.

2.3 The Chinese housing market began correcting in early 2014

In early 2014, the Chinese housing market entered its third downturn in six years. This cycle has been more pronounced than the ones in 2008 and 2011–12. The previous downturns had been largely policy-driven, as the Chinese government tightened home purchase restrictions in an attempt to improve affordability. In contrast, the current downturn has been driven primarily by market forces, in particular:

1. a significant buildup of unsold inventories;
2. slowing economic growth;
3. financial innovation that offers households alternative investment opportunities; and
4. expectations of the future implementation of a property tax.

After growth of close to 20 per cent in 2013, the volume of sales fell by 9 per cent in 2014. While they recovered by 7 per cent in 2015, they did not reattain their 2013 levels (**Chart 4**). Starts contracted sharply, in volume terms, through 2014 and 2015. Our measure of real residential fixed-asset investment growth fell from 19 per cent in 2013 to 9 per cent in 2014 and 3 per cent in 2015 (see Appendix A for calculation of this measure). Given the sharp fall in investment growth and the linkages between housing and other sectors, we estimate that the fall in housing investment growth reduced Chinese GDP growth by around 0.9 ppts in 2014 and a further 0.5 ppts in 2015 (Appendix A). Land sales have also been affected by the real estate slowdown. The volume of land sold declined by 14 per cent

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[1] In particular, our 11-city measure is heavily weighted toward Tier 1 and Tier 2 cities, which likely had a smaller buildup of inventories than what was seen in Tier 3 cities.

[2] To estimate the "synthetic" measure of inventories, we calculate excess supply as the cumulative gap between floor space starts and floor space sold (measured as average sales over the next two years, to account for the building time of housing; to estimate sales over 2016 and 2017, we grow the volume of sales forward by its 5-year average growth rate). On the assumption that this measure would be zero if developers built as much as they sold, inventories in terms of years of sales in a given year would be 1 plus the level of excess supply.

year-over-year (y/y) in 2014 and a further 32 per cent in 2015, putting considerable pressure on local government revenues.[3]

Recent data show some signs of stabilization in the market. Both sales and new home prices are increasing (**Chart 4**). Moreover, the rebound in sales has been broad-based and not limited to China's largest cities. Indeed, according to our calculations, smaller, third-tier cities contributed around 60 per cent of the increase in sales between 2014 and 2015. New home prices have also been rising in close to half of the largest 100 cities through much of 2015.

Notwithstanding these signs of stabilization, real housing investment growth continues to slow and starts continue to contract. Normally, we would expect starts to follow the rebound in sales with a lag of around four months (**Chart 5**). However, the remaining inventory overhang and concerns that the rebound in sales could be short-lived are likely weighing on developers' intentions.

Chart 4: Housing sales and prices have improved
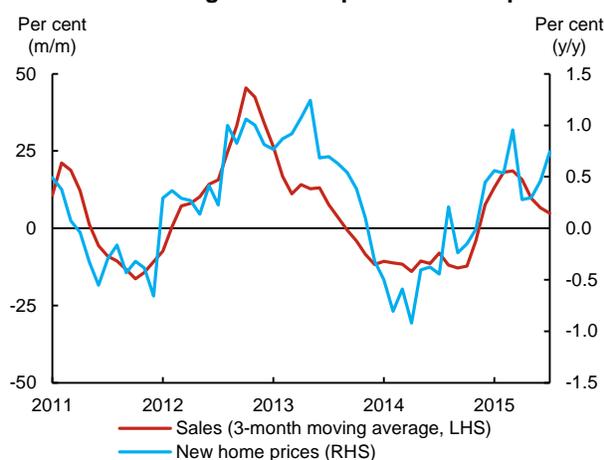
Per cent (m/m) — LHS; Per cent (y/y) — RHS

Sales (3-month moving average, LHS)
New home prices (RHS)

Sources: National Bureau of Statistics of China, Soufun and Bank of Canada calculations
Last observation: December 2015

Chart 5: Sales have tended to lead starts by around four months
3-month moving average
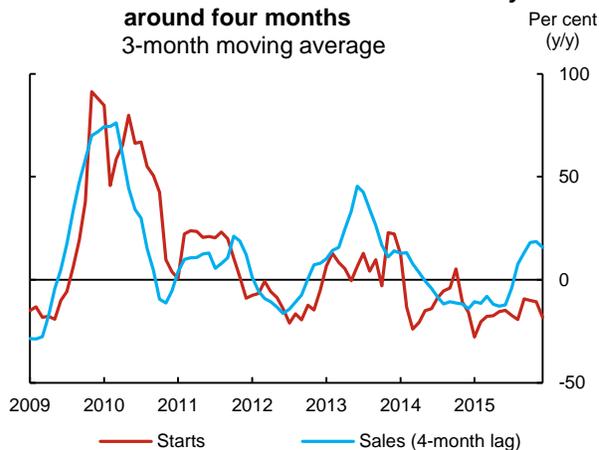
Per cent (y/y)

Starts
Sales (4-month lag)

Sources: National Bureau of Statistics of China and Bank of Canada calculations
Last observation: December 2015

2.4 We expect real estate investment growth to remain subdued

Despite stronger housing market indicators such as buoyant sales growth in 2015H2 and relatively low financing costs, we expect investment growth to remain subdued in the near term. The remaining inventory overhang likely necessitates a more prolonged adjustment in investment, while the recent strength in sales growth may have been driven by temporary factors such as payback from the recent correction, the authorities' loosening of restrictions on investment (as opposed to owner-occupied) properties, relaxation of mortgage qualification rules and stock market volatility (as investors move funds from equities back to housing).

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[3] Gross land sales proceeds accounted for nearly a quarter of local government revenues in 2014. However, around 80 per cent of land sales revenue is absorbed by associated costs of land acquisition and infrastructure development (Moody's Investors Service 2015). This mitigates much of the impact of the slowdown in land sales on local governments' ability to fund projects.

To help anchor our medium-term view of the Chinese housing market, we have constructed a bottom-up estimate of fundamental demand based on urbanization, replacement and upgrading demand (Appendix B). Based on these calculations, we estimate that fundamental demand for floor space in China has plateaued and is not expected to pick up substantially going forward (**Chart 6**). Accordingly, we do not expect any significant rebound in housing investment growth in the coming years.

An important facet of housing demand that is not captured in the above calculations is investment demand, which made up a substantial portion of

Chart 6: Fundamental demand for housing

Million square metres

■ Urbanization demand ■ Upgrading demand ■ Replacement demand
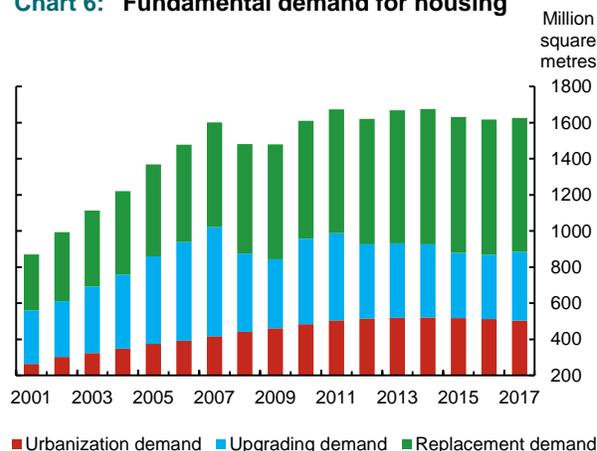
Sources: UN World Development Report 2014,
National Bureau of Statistics of China and
Bank of Canada calculations   Last data plotted: 2017

total demand during the housing market boom.[4] Despite its previous importance, we would not expect increasing investment demand to drive a substantial increase in Chinese demand for housing in the coming years. While limited alternative investment opportunities and artificially low deposit rates likely contributed substantially to strong investment demand during the boom period (Fang et al. 2015), liberalization of deposit rates, increased investment opportunities and the expected implementation of a property tax should reduce the incentive for Chinese households to use housing as an investment vehicle going forward.

3. The Impact of Chinese Housing on Global Metal Prices

3.1 Chinese real estate generates a large demand for base metals

China's demand for base metals rose at a meteoric pace over the 2000s, and in recent years China has become by far the world's largest consumer of base metals (**Chart 7**).

The high base metal content of economic growth in China reflects an economic structure that has been geared toward metal-intensive sectors such as real estate (**Table 1**). Data from the input-output tables (OECD 2015) suggest that for every dollar of housing output, roughly 16 cents' worth of base metals are used as inputs, compared to about half that for the economy overall.

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[4] As an example, survey data suggest that investment demand may have made up over 50 per cent of total housing demand in 2012 (Chen and Wen 2014; Gan 2013).

Chart 7: China's consumption of industrial metals has grown rapidly
Percentage of world consumption

%

Legend: ■ 2002 ■ 2010 ■ 2014 ■ 2015

(Aluminum, Copper, Nickel, Zinc, Iron ore)
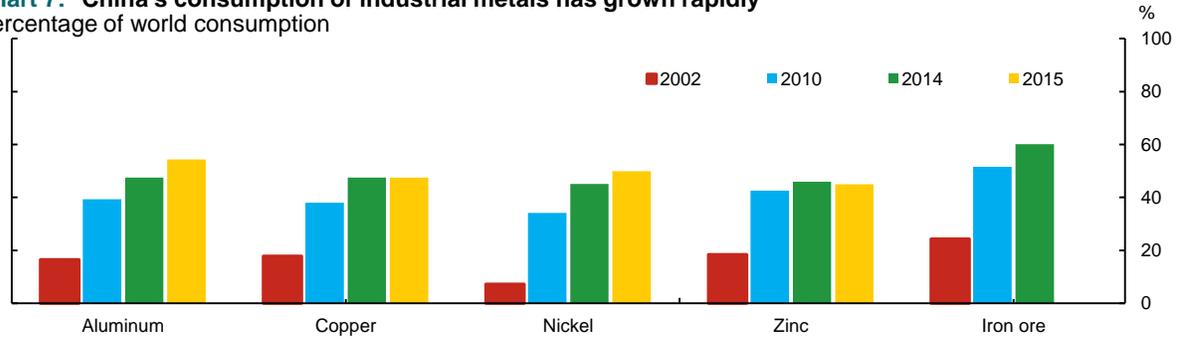
Sources: World Bureau of Metal Statistics, U.S. Geological Survey, Haver Analytics and Bank of Canada calculations

Table 1: Chinese base metal intensity across sectors (intermediate use)

	Base metal use per dollar of output (dollar worth of inputs)
Real estate/Infrastructure	0.16
Manufacturing (excluding metals/steel)	0.13
Non-manufacturing	0.02
Total economy	**0.09**

Sources: OECD input-output tables and Bank of Canada calculations

The base metal intensity of the Chinese economy is also higher than that of other countries at similar stages of economic development (**Chart 8**). One possible reason for this is that the high density of Chinese cities could have a non-linear effect on metal demand. For example, unlike housing markets in North America and Japan that involve lumber-based structures, housing units in Chinese urban areas are nearly all found in high-rise buildings. Taller buildings require much more concrete and reinforced steel to stay upright: a 32-floor building consumes twice the steel per unit of floor area as a shorter, eight-floor structure (Komesaroff 2012). Another explanation relates to China's ongoing urbanization given its still-large rural population, necessitating high levels of construction and demand for base metals. In the past, when Japan and Korea were at China's current level of real per capita income, they were largely urbanized (with urbanization rates at around 80 per cent), whereas nearly half of China's population still resides in rural areas.

Chart 8: The Chinese economy has relatively high base metal intensity given its current stage of economic development

Base metal consumption per capita (kilograms)

Legend: China, Japan, Korea, US

Real GDP per capita
(thousands of international dollars)
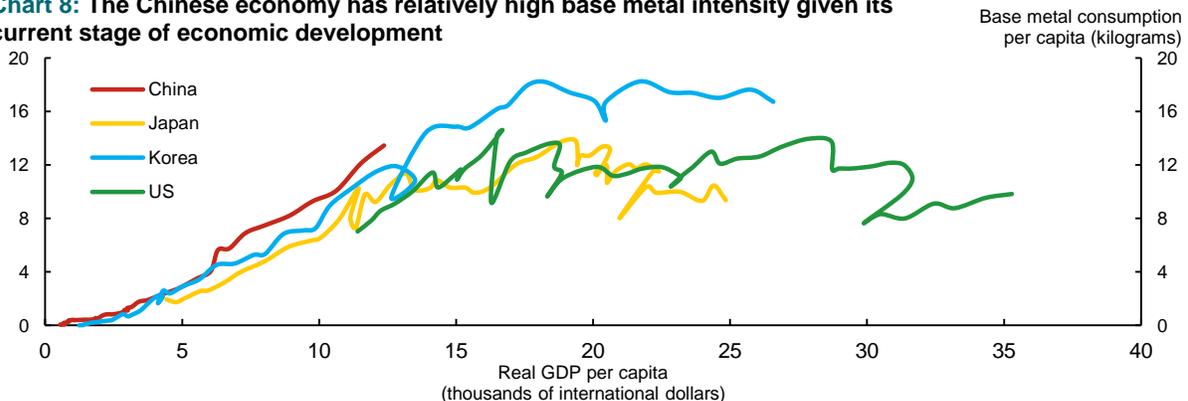
Note: Base metals include aluminum, copper, nickel, zinc and tin. Aggregation is done using weights based on the value of global trade for these metals.
Sources: World Bureau of Metal Statistics, Maddison Project and Bank of Canada calculations

Last observation: 2015

6

3.2 Housing contributed about a quarter of the increase in base metal prices during the 2000s

Previous research has generally established China's rapid economic growth as the main demand-side driver of the commodity price boom during the 2000s (Cheung and Morin 2007; Yu 2011). Importantly, the unexpected nature of the rapid demand growth in China led to sustained supply shortages and exerted substantial upward pressure on prices. Work by Bank of Canada staff suggests that repeated upward revisions to growth prospects for emerging Asia played an important role in explaining price movements for base metals between 2003 and 2008 (Arbatli and Vasishtha 2012).

While many market analysts have pointed to the importance of the Chinese housing market for global base metal prices, there has not been much quantitative analysis on the specific contribution of the housing boom to the run-up in base metal prices during the 2000s. Part of the difficulty relates to data limitations, particularly in translating housing market developments into GDP space. Using the approach discussed in Appendix A, we estimate that the level of Chinese GDP would have been about 9 per cent lower at the end of 2010 in a counterfactual scenario where the housing market did not grow after 2002.

We have developed a model to perform scenario analysis on base metal prices. The model utilizes a vector error-correction framework and comprises four main variables: real base metal prices, global economic activity, base metal production and inventories (Appendix C). Specifically, we use the model to forecast base metal prices from 2002 through 2010 based on two scenarios for global economic activity: the realized path and the counterfactual scenario where Chinese GDP is 9 per cent lower by 2010.[5]

Our model suggests that base metal prices would have been close to 20 per cent lower by the end of 2010 in the absence of the Chinese housing market boom. This represents a significant portion of the 85 per cent increase observed in base metal prices from 2002 to 2010. There are also reasons to believe that the true impact of the housing boom on prices may have been larger. In particular, the impact of stronger demand on base metal prices may become non-linear when supply constraints are tested, as was likely the case during the 2000s.

3.3 The correction in the housing market amplified downward pressure on base metal prices

The recent correction in the Chinese housing market has tempered demand growth for base metals. Indeed, Chinese base metal import volumes, which grew at a double-digit pace for most of the past decade, have essentially flatlined over the past two years (**Chart 9**). In particular, we note that the slowdown in import growth has been especially pronounced in the case of iron ore, which is the base metal that is most intensely used for construction. This unexpected slowdown in demand growth has likely amplified downward pressure on base metal prices stemming from increasingly abundant

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[5] The shock to Chinese GDP in the counterfactual is further adjusted for the fact that the shock is coming from the Chinese housing market, which is especially base metal intensive (up to two times more intensive than the economy overall).

production capacity at low-cost mines around the world.[6] Overall, base metal prices were 25 per cent below their previous peak in mid-2014 by the end of 2015 (**Chart 10**).

Chart 9: Chinese base metal imports have flatlined in recent years
3-month moving average
Index (Jan. 2013 = 100)
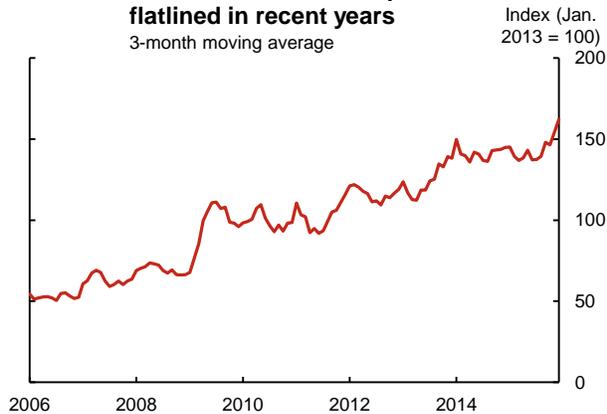
Note: Base metals covered are iron ore, copper and aluminum, weighted by their 2009 prices.
Sources: Haver Analytics and Bank of Canada calculations
Last observation: December 2015

Chart 10: Base metal prices have tumbled since mid-2014
Index (Jan. 2013 = 100)
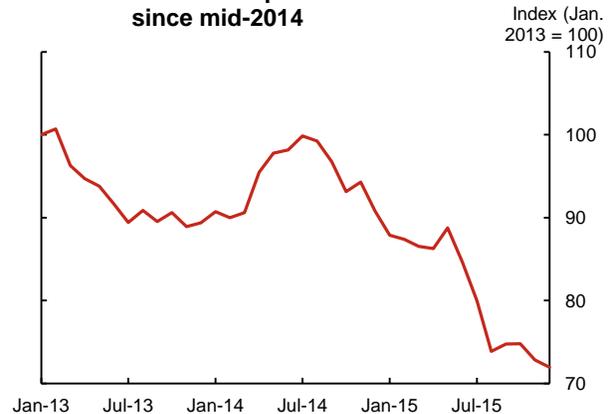
Source: Bank of Canada calculations
Last observation: December 2015

Using our model for base metal prices, we attempt to isolate the impact of the housing market correction on prices. Specifically, we assume in a counterfactual scenario that investment and activity in the Chinese housing market would have continued to expand at their previous pace, instead of declining in 2014. In such a scenario, the level of Chinese GDP would have been around 2 per cent higher by the end of 2015. After accounting for the fact that these additional economic activities are more metal intensive than the economy overall, we find that base metal prices could have been 5 to 10 per cent higher had there been no correction in the Chinese housing market.[7,8] This estimate represents up to a third of the actual decline in prices observed.

Other factors not captured by the model may have further added to the drag on base metal prices. In particular, the correction in the housing market may have eroded confidence in the Chinese economy more broadly, and given China's outsized share of global base metal consumption, this could have led to an undershoot of base metal prices.

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[6] New production capacity is the result of investments made in previous years when base metal prices were still high and expected to remain so.

[7] According to the model, base metal prices would have been about 5 per cent higher at the end of 2015 had the Chinese housing market grown at its pre-correction pace in 2014 and 2015. However, market participants are forward looking and the current weakness in prices likely also reflects the expected weakness in future demand owing to the housing correction. Under a naïve assumption that real residential investment remains stagnant over the next two years, the total impact on prices from the housing correction could be as high as 10 per cent.

[8] These results are consistent with estimates of elasticity between Chinese GDP growth and base metal prices from other studies. For example, the World Bank states that "a 1 percentage point decline in China's growth has been estimated to … reduce metals prices by 1.3-5.5 percent" (World Bank 2016).

3.4 Subdued construction growth should provide only modest support to base metal prices

The Chinese housing market is directly accountable for a sizable portion of the world's base metal consumption, so even modest growth in this sector could lead to a meaningful increase in the level of demand for base metals. As the housing market correction eases, this should reduce downward pressure on base metal prices.

That said, we do not believe the Chinese housing sector will grow fast enough to stimulate a large run-up in base metal prices, as was the case during much of the past decade. First, as discussed above, the rate of investment growth in the Chinese housing market is not expected to return to the elevated pace observed prior to the recent correction. Second, and perhaps more importantly, vast new mining production capacities have come online in recent years and supply is becoming increasingly abundant. In such an environment, the modest pace of the increase in demand will likely be absorbed by excess supply in the market, rather than lead to substantial upward pressure on prices.

4. Conclusion

Due to its large size and metal-intensive nature, the Chinese housing market has had a significant impact on global metal prices over the past decade. We estimate that the boom in the Chinese housing market added 20 per cent to base metal prices from 2002 to 2010.

Since early 2014, the Chinese housing market has gone through a very steep correction, driven by over-building and slowing fundamental demand growth. Since the Chinese housing market is one of the most metal-intensive sectors in a country that consumes half of the world's supply of base metals, the recent correction has weighed heavily on base metal prices. We estimate that the housing market correction from 2014 to 2015 reduced base metal prices by 5–10 per cent relative to a no-correction scenario.

Looking ahead, it is unlikely that growth in this sector alone can contribute to a run-up in base metal prices, as was the case during the 2000s. While there have been some recent signs of stabilization, we do not expect residential investment growth to return to the pace observed during the past decade, given the remaining inventory overhang and slower growth in fundamental demand for housing. Furthermore, unlike in the 2000s, when supply capacity was strained, substantial production capacity has come online for various base metals in recent years, which can help meet the relatively muted increase in demand expected from China's housing. Therefore, while the drag on metal prices from Chinese housing should ease as the market stabilizes, commodity markets will likely need to look to other sectors for a new source of price growth.

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Appendix A: Our Approach to Dealing with Data Limitations

Although real estate is one of the most important markets in China, a number of data limitations make it challenging to analyze:

- lack of important data (particularly for value-added investment);
- uncertainties around official data quality (for example, projects being reported as "housing starts" without real progress being made,[9] and the official inventory series widely undershooting most private sector estimates);
- lack of consistency among data (particularly for floor space data such as sales and completions, **Chart A1**);
- lack of real gross investment series or price deflators from which it can be calculated; and
- significant seasonal patterns and volatility (**Chart A2**).

Chart A1: Official sales and completions data suggest negative inventories

Million square metres

Sources: National Bureau of Statistics of China and Bank of Canada calculations
Last observation: 2015

- Implied inventory stock
- Housing sales
- Housing completions
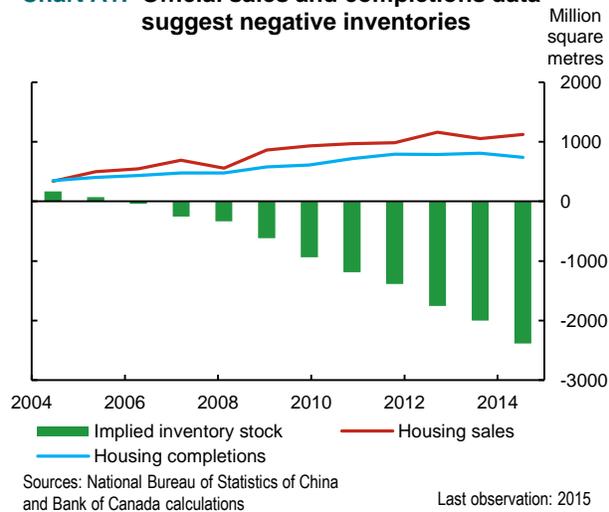
Chart A2: Chinese housing market data are highly seasonal

Thousand square metres

- Residential sales

Note: Monthly flows derived from published year-to-date data
Sources: National Bureau of Statistics of China and Bank of Canada calculations
Last observation: December 2015
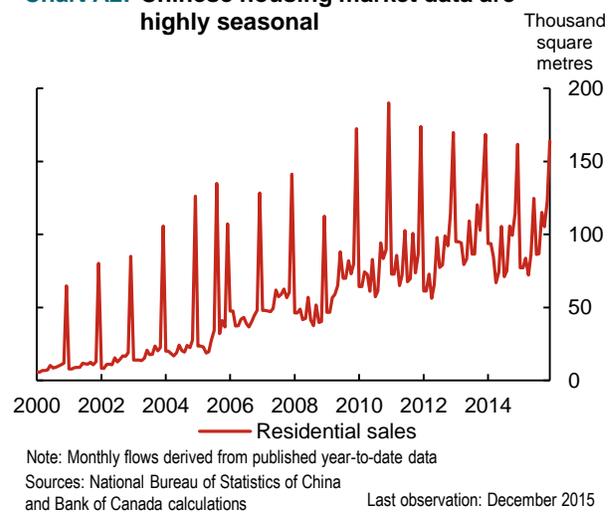
Due to these limitations, there is considerable uncertainty surrounding both the current state of the market and its expected evolution. Depending on how analysts choose to deal with the limitations, views on the housing market can differ widely.

We devise a number of different methods to address the data limitations, including seasonal adjustment and the use of private sector data where possible. Furthermore, we use the fixed-asset investment deflator for construction and installation to deflate residential fixed-asset investment, which allows us to assess gross housing investment in real terms. The use of a deflator is essential, since recent falls in commodity prices have led to a sharp decline in the price of construction. As a consequence, we estimate that nominal residential real estate fixed-asset investment growth now undershoots real investment growth by around 3 percentage points.

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[9] In return for purchasing land, developers often have an incentive to indicate that construction has started even though only the most rudimentary preparations have been made to build.

The lack of value-added data on housing investment adds a further challenge to analysis of the housing market, since it is not immediately clear how changes in real fixed-asset investment affect GDP growth. In this paper we estimate a real value-added level of real estate investment by applying the share of residential real estate in fixed-asset investment to value-added investment from the national accounts.[10]

The development of a value-added series for housing investment allows us to map developments in the housing market directly into Chinese GDP, which is necessary for further modelling exercises. For example, we estimate the impact of the housing market slowdown on GDP growth as the change in the contribution from residential real estate investment using our estimated real value-added series, and scale the decline in the contribution to account for its indirect impact on GDP. We do this by multiplying the change in the contribution to growth from residential real estate investment by two, based on People's Bank of China research suggesting that accounting for the indirect effects could double the total impact of a slowdown in real estate investment on GDP (PBoC 2014).

Our estimated series for value-added housing investment is also used for our commodity price scenarios. For the no-boom scenario, we assume that there is no growth in housing investment between 2002 and 2010, and strip out all growth in this series from total GDP to calculate a percentage shock to the level. As described above, we then double this percentage shock to account for the indirect effects. For the no-correction scenario, we assume that value-added housing investment grows at the same rate going forward as it did in 2013. We again calculate a percentage shock to the level of GDP, and double it to account for the indirect effects.

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[10] We apply the share of residential fixed-asset investment in total fixed-asset investment to nominal value-added investment to estimate the share of housing investment in nominal GDP, in line with methodology used by Chivakul et al. (2015). We further assume that this share also holds for real GDP, allowing us to back out a series of real value-added housing investment.

Appendix B: Estimating the Fundamental Demand for Chinese Housing

To get a better sense of where the Chinese housing market is headed, we have constructed an estimate of the fundamental demand for Chinese housing (measured in terms of floor space) through 2017. This fundamental demand measure is the sum of urbanization demand, upgrading demand and replacement demand. It is based in part on an estimate of the floor space demanded per person at a given level of per capita income.

Estimate of floor space demanded per person

To get an idea of the demand for floor space at a given level of income, we estimate the floor space demanded per person as a function of GDP per capita for a cross-section of countries from the 1990s to the 2000s.[11] There is a strong positive relationship between GDP per capita and floor space per capita, which gives us some confidence in using this estimate (**Chart B1**).

At first glance, the measure of urban residential floor space per capita published by the National Bureau of Statistics of China is significantly higher than our estimate predicts. However, this measure is believed to be overstated due to the use of the urban hukou population as the denominator, rather than the true urban population of hukou holders and migrant workers (Berkelmans and Wang 2012). We deflate the officially published urban floor space data by the ratio of urban hukou holders to the total urban population, in line with methodology developed by Berkelmans and Wang (2012).

After making this adjustment, the most recent data for Chinese floor space per capita are broadly in line with our estimated results, suggesting that our income-based estimate is appropriate to use in the Chinese context. Not only can we use this methodology to estimate a "fundamental" demand for floor space per person based on Chinese GDP per capita over history, but we can also forecast it.[12]

Chart B1: Chinese floor space is in line with international experience

Square metres of floor space per capita

In(GDP/Capita)

◆ International housing stock   ■ China housing stock
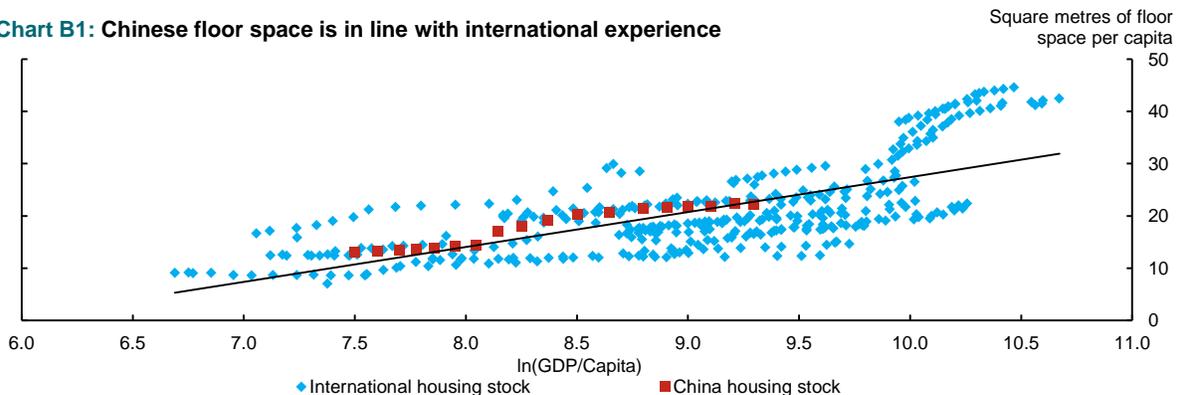
Note: GDP per capita measured in international dollars
Sources: National Bureau of Statistics of China, International Monetary Fund, Helgi Library and Bank of Canada calculations

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[11] GDP per capita measured in logged international dollars.

[12] Using our estimate of floor space demanded per capita over history strips out the potential distortionary impacts of investment demand on actual floor space per capita, and also prevents any discontinuities or inconsistencies resulting from a transition between realized data (which extends only until 2012) and estimates.

Constructing the demand add-up

To estimate urbanization demand, we multiply the change in urban population in each period by the average floor space per capita demanded in that period, using urban population figures and forecasts from the United Nations World Urbanization Prospects report (UN 2014).[13]

To estimate upgrading demand, we multiply the previous period's population by the change in floor space demanded per capita.

Finally, replacement demand is calculated as between 3 and 5 per cent of the Chinese housing stock per year, consistent with the demolition rate used by Berkelmans and Wang (2012).[14,15]

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[13] United Nations (UN) and official National Bureau of Statistics of China numbers for the urban population are broadly consistent over history, but we use the UN numbers for our estimation to prevent any discontinuities from arising in the transition between historical National Bureau of Statistics of China numbers and UN forecasts.

[14] Berkelmans and Wang (2012) estimate an average demolition rate of 4.5 per cent over 2008–10, and assume that the demolition rate falls to 3 per cent by 2020 and 2 per cent by 2030 as the stock of older residential buildings declines. We therefore apply a replacement rate of 4.5 per cent over 2000–10, followed by a cubic spline interpolation toward 3 per cent in 2020 and 2 per cent in 2030.

[15] Over history, we calculate the Chinese housing stock by multiplying the realized adjusted floor space per capita by the urban population, and after 2012 we use our estimate of floor space demanded per capita. For this calculation, we use realized floor space per capita over history rather than our estimated series, since it is a more appropriate measure for capturing the true stock of housing.

Appendix C: Our Base Metal Price Model

The main goal of this model is to supplement our understanding of base metal price movements and help determine the most likely future path for prices given a specific scenario of global macroeconomic demand conditions.

Key variables

The variable of interest is the base metal price index, which is constructed using prices for copper, nickel, zinc, aluminum, and iron ore, and a Fisher chain indexing methodology.[16] Inspired by previous work by Bank of Canada staff on the modelling of oil prices, we construct three key economic determinants of base metal prices: global base metal production, changes in global base metal inventory levels, and global economic activity (**Chart C1**).[17,18]

Chart C1: Key variables for the base metal price model

a. Real base metal prices — Index (2002 = 100). Last observation: 2015Q3

b. Base metal production — Index (2002 = 100). Last observation: 2015Q3

c. Base metal inventory — Index (2002 = 100). Last observation: 2015Q3

d. Global economic activity — Index (2002 = 100). Metals consumption-weighted GDP; PPP Global GDP. Last observation: 2015Q3
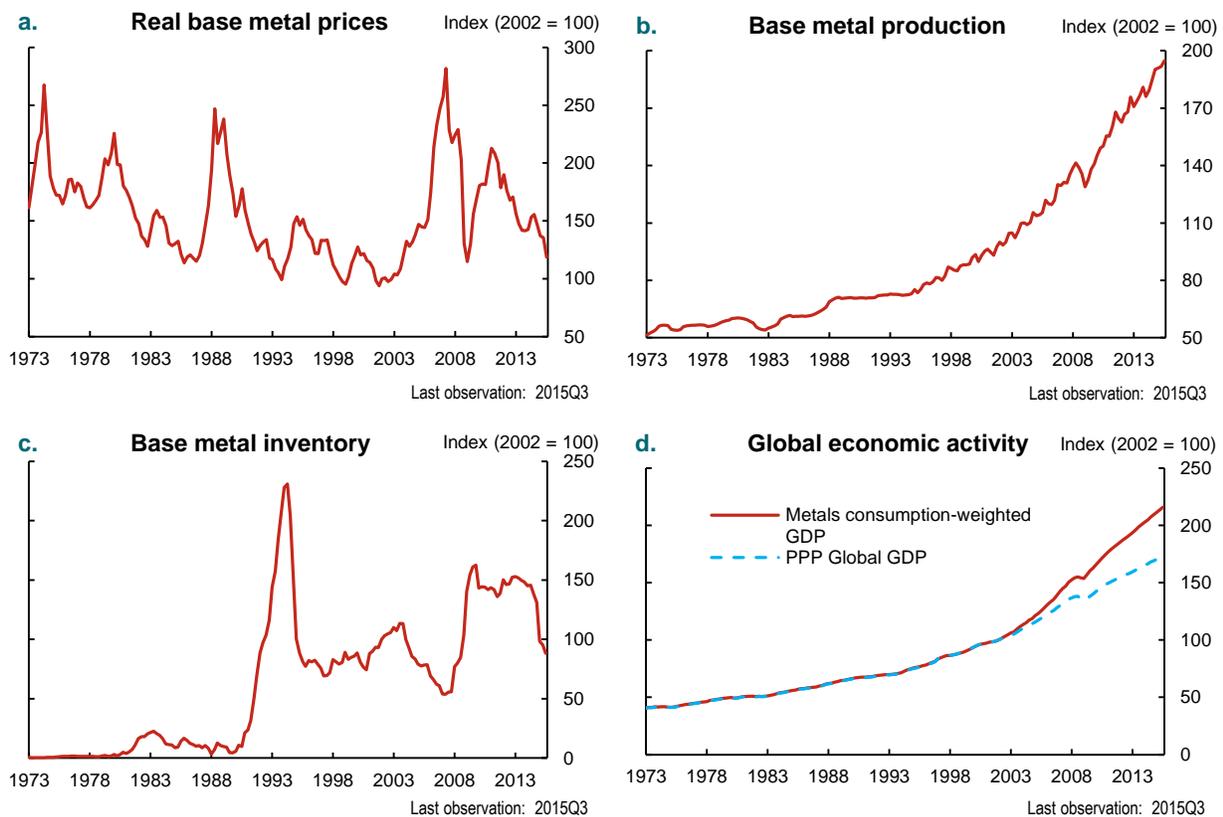
Sources: World Bureau of Metal Statistics, London Metal Exchange, International Monetary Fund and Bank of Canada calculations

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[16] The Fisher chain index is also used to construct the Bank of Canada commodity price index (Kolet and Macdonald 2010). The weight of each commodity is determined by its production value in Canada.

[17] Various methodologies for forecasting oil prices are summarized in Baumeister (2014).

[18] The base metal production volume index is a weighted-average index of production for individual base metals obtained from the World Bureau of Metal Statistics. The inventory volume index is constructed in a similar manner with data for individual base metals from the World Bureau of Metal Statistics and the London Metal Exchange.

The indicator for global economic activity is constructed such that it captures the outsized presence of China in the global base metal markets since the early 2000s. China's consumption of base metals was less than 20 per cent of the world's supply in 2002, but it is now accounting for about half of the world's output. In contrast, China's share of the world in purchasing-power-parity (PPP) GDP terms is only around 15 per cent (**Table C1**). As such, global GDP is aggregated using weights based on each region's recent consumption share of base metals, rather than their PPP GDP shares, starting in 2002 (the year China joined the World Trade Organization).

Table C1: Share of the world by region: base metal consumption vs. PPP GDP (per cent)

	China	Japan	U.S.	Oil-importing EMEs	Euro area	Rest of world
Base metal consumption	45	6	9	19	13	9
PPP GDP	17	4	16	33	12	18

Note: Base metal consumption weights reflect the average consumption share of each region between 2010 and 2014. Consumption shares across different base metals are aggregated using their weights in the Bank of Canada commodity price index. Regions are defined according to the standard Bank of Canada methodology (Bank of Canada 2015).
Sources: World Bureau of Metal Statistics, International Monetary Fund and Bank of Canada calculations

The U.S. dollar is also included as an exogenous and contemporaneous variable because of its negative correlation with base metal prices.[19]

Modelling approach

The four key variables are non-stationary and integrated of order 1 in levels. Further inspection using the Johansen technique reveals that they are cointegrated. As such, we find it appropriate to model these variables using a vector error-correction model (VECM), which takes the following form and is estimated with five lags:

$$\Delta y_t = c + \alpha(\beta' y_{t-1} + \mu + trend) + \sum_{i=1} \Delta y_{t-i} + \Delta er + \varepsilon_t,$$

y_t: matrix containing, in logs, the real base metal prices, base metal production index, indicator of economic activity and global base metal inventory;
Δer: changes in the trade-weighted U.S. exchange rate;
α: error-correction coefficient.

The estimated coefficients for the cointegration term normalized with respect to prices are as follows (numbers in square brackets denote the *t*-statistics):

$$prices = 12.44 + 6.52 * gdp - 4.67 * production + 0.09 * inv - 0.02 * trend.$$
$$\qquad\qquad\quad [-4.89] \qquad\quad [3.73] \qquad\qquad [1.35] \qquad\quad [3.19]$$

According to this cointegration equation, a 1 per cent increase in global GDP increases the long-run equilibrium of base metal prices by about 7 per cent. Our interpretation of the negative trend is that it

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[19] There is the numeraire effect, since base metals are priced in U.S. dollars. In the event of an exogenous shock to the U.S. dollar unrelated to the metals market, base metal prices in U.S. dollars should adjust in the opposite direction. This simply offsets the shock to the relative price of base metals across different currencies.

captures the base metal intensity of the global economy, which is generally falling outside of periods of exuberant industrialization of a large economy.

Real-time out-of-sample forecast ability

In line with the previous literature, we compare the model's dynamic out-of-sample forecasts to the random walk (RW) benchmark and predictions from a vector autoregression (VAR) model with the same variable and lag specifications. A root-mean-squared-error (RMSE) ratio under 1 represents greater forecast accuracy for the VECM relative to the other benchmark models. The evaluation period covers 1998 to 2015.

The "Pure Model Dynamics" column of Table C2 shows that forecasts from the model only outperform the RW within the first year, although they outperform the unrestricted VAR benchmark up to three years. The lack of forecast power beyond one year may be because the VECM has a hard time forecasting global economic activity given the limited number of variables.

We then proceed with a second exercise in which we suppose that the model is supplemented with perfect foresight for shocks to global economic activity that it cannot itself predict. Specifically, for each of the forecasts of economic activity that the model makes, we allow the model perfect foresight with respect to global GDP growth. We can justify "cheating" in this way because our model is designed to be used in scenario analysis or in combination with other models that are specifically designed to forecast GDP growth. In this scenario, the dynamic out-of-sample forecast from the VECM can reduce forecasting errors by nearly 25 per cent relative to the RW forecast and VAR forecast (in which the path of realized GDP growth was also made exogenous), even for periods of up to three years. Results from the Diebold-Mariano test suggest that the improvement in forecasting ability is statistically significant at the 5 per cent confidence level at three quarters and beyond.

Table C2: RMSE ratios (dynamic out-of-sample evaluation from 1998Q1–2015Q4)

Quarters Ahead	Pure Model Dynamics		Making Realized GDP Exogenous	
	VECM/RW	VECM/VAR	VECM/RW	VECM/VAR
T+1	0.92	0.99	0.92	0.99
T+2	0.93	0.99	0.87**	0.96*
T+3	0.96	0.96	0.82***	0.90***
T+4	0.98	0.95	0.80***	0.86***
T+5	0.99	0.95*	0.80***	0.85***
T+6	1.01	0.93**	0.79***	0.82***
T+7	1.02	0.91***	0.77***	0.79***
T+8	1.02	0.89***	0.77***	0.77***
T+9	1.03	0.88***	0.78***	0.77***
T+10	1.03	0.88***	0.79***	0.77***
T+11	1.03	0.88***	0.79***	0.76***
T+12	1.04	0.88***	0.80***	0.76***

*, **, and *** denote statistically significant improvement in forecast accuracy based on the Diebold-Mariano test at the 15, 10, and 5 per cent confidence level, respectively.
Source: Bank of Canada calculations