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China: Credit, Collateral, and Commodity Prices

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Abstract

We review how China has become a dominant influence in global commodity markets due to the economy's size and commodity intensity. We then focus on the emergence of China's credit market as a new influence on commodity prices using a vector autoregression model and recursive identification. We find that a 1 percentage point (ppt) surprise increase in China's bank lending results in statistically significant price increases of 10-12 percent for some base metals, including copper. This contrasts with a 1 ppt shock to China's industrial production which leads to a statistically significant change of 7-9 percent of aluminum, copper, and crude oil. We suggest that one reason for the large influence of China's credit aggregates may be the important role that some commodities play as collateral for lending in a financial system still bedeviled by information asymmetries, particularly for private sector borrowers.

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1. Introduction

China has emerged as a dominant influence on world commodity markets. During 2013, China accounted, on average, for about one-third of global consumption of a basket of important commodities. Its share of global trade varies by commodity but is high, and rising, for many food, metal, and energy products.[1] These facts suggest that any cogent analysis of global commodity markets must rest on a solid understanding of supply and demand spillovers from China. But the story may not end here. In this paper, we suggest that credit shocks—specifically, unexpected changes in lending by banks—may now be an important and underappreciated source of Chinese influence on commodity markets.

Why might credit shocks in China be important for commodity markets? One reason may simply be that changes in credit predict changes in economic activity and real commodity demand. It is certainly true that China's economic growth since 2008 has become more reliant on credit—in other words, a given level of GDP growth now requires a higher level of credit growth. Credit intensity may decline as China rebalances away from investment towards consumption, but it will surely take time to transition to an economic growth model that is less reliant on borrowing. In the meantime, an unexpected pick-up in economic growth will require more borrowing, higher investment, and increased commodity consumption.

A second related but more direct channel through which credit shocks may impact commodity prices is through collateral demand. Collateral assumes a pivotal role in China's banking system. As we explain in section 2, the domestic credit market in China is bedeviled by informational asymmetry problems between the lender and borrower, particularly for private sector borrowers. These problems can be partially overcome by borrowers posting collateral as security against the loans. Banks had long preferred, and even required, property or land as collateral. However, a watershed moment for the financial sector came with the 2007 Property Rights Law. This law made it much easier for firms to

[1] Simple average across key commodities (consumption shares in parentheses): crude oil (12), natural gas (5), coal (50), aluminum (47), copper (47), lead (42), nickel (51), tin (48), zinc (46), corn (22), cotton (31), beef (12), pork (51), soybeans (29), chicken (16), rice (31), and wheat (17).

use “movable assets” as collateral and some commodities are ideally suited for this purpose. Our hypothesis in this paper is that a positive credit supply shock will increase the demand for collateral and commodities and cause prices to rise. In this case, the commodities are purchased, imported, and stored as security for borrowing but not consumed. The financing for these imports is often structured as part of a commodity financing deal (CFD), the mechanics of which we describe in section 2.3.

We define credit shocks as changes that are unanticipated by an econometric model. More fundamentally, we interpret credit shocks mainly as unanticipated changes in the supply of, rather than the demand for, loans. Like Bernanke and Blinder (1988), “we find it difficult to think of or identify major shocks to credit demand, that is, sharp increases or decreases in the demand for loans at given interest rates and GNP.” It seems more reasonable to see such shocks as either monetary and financial sector policy innovations or a sudden change in the willingness of creditors to extend loans at a given interest due to a change in credit or liquidity risks. In turn, this would change the cost of firms’ external financing and influence the level of their desired capital stock, thereby altering investment plans, and affecting economic activity, especially industrial production, and commodity consumption.

This paper follows Kilian (2009) and Roache (2012) and uses vector autoregressions which focus on the short-run spillovers from credit and activity shocks. Of course, another part of the China story is the secular convergence of income levels to developed economy levels and the likely rebalancing in China’s demand, away from investment and towards consumption. Over the long run, these developments will likely prove more important for trade patterns and equilibrium real prices of major global commodities. At the same time, along this path, China’s economy will likely experience cyclical fluctuations, particularly as markets play a more decisive role. It is the impact of these unanticipated fluctuations on commodity prices that interest us here.

The plan of the paper is as follows. In section 2 we provide an overview of the literature describing China’s role in global commodity markets, including the demand for collateral. In section 3 we outline the econometric methodology. We describe the data used in the estimations in section 4. In section 5 we summarize the results and present a battery of robustness tests. We provide our main conclusions in section 6.

2. China's Role in World Commodity Markets—Overview and Literature

2.1 China's current status as dominant consumer

China dominates the demand side of many of the world's most important commodity markets. Farooki and Kaplinsky (2013) note that in 2008 at the start of the Global Financial Crisis "China was the world's largest consumer of tin, iron ore, coal, steel, zinc, aluminum, copper, and nickel. It was the second largest consumer of oil and its market accounted for half of the world's demand for pork." Since then, remarkably, China's dominance has grown. Figure 1 illustrates China's share of global markets and summarizing these data, we find that China's share of global consumption has reached 22 percent of primary energy, 26 percent of agricultural crops, and 47 percent of base metals. [2]

China's share of global trade is jointly determined by demand but also its own supply capacity. In turn, this reflects China's natural endowments but also public governance and strategic policy decisions—including environmental standards and the allocation of scarce resources—to ensure self-reliance. For example, energy economists such as Aden and Sinton (2006) posit that lower mine safety and environmental standards resulting from decentralization may have allowed China to more fully exploit its large endowment of coal and reduce its reliance on energy imports. Agricultural economists including Ray and Schaffer (2015) suggest that China used public stockbuilding and trade protection measures to favor the domestic production of corn while relying on imports for its close supply-side substitute – soybeans.

[2] Primary energy comprises commercially traded fuels including modern renewables used to generate electricity. Based on BP data for 2013. Agricultural crops: simple average across cotton, rice, wheat, corn, and soybeans in 2014, ranging from 18 percent for wheat and 32 percent for cotton (USDA). Base metals: simple average across aluminum, copper, tin, nickel, zinc, and lead in 2014, ranging from 41 percent for lead to 51 percent for tin (World Bureau of Metal Statistics). China's consumption share of unprocessed mineral ores and concentrates is estimated to be even larger than that of refined metals.

It is no surprise then that China's large share of global commodity markets translates into material contributions to changes in global demand. Figure 2 shows that between 1996 and 2014, China's contribution to changes in global demand are consistently positive for crude oil, and are particularly sizable for base metals, accounting for nearly all the growth in refined copper, nickel and tin.

2.2 China's path to dominant global consumer

China started to open up its economy in the 1980s but its presence in global commodity markets began to take off only around the time of its World Trade Organization (WTO) accession in the early 2000s. Three related structural shifts have been important.

First, China began to emerge as a large exporter of commodity-intensive manufactured products. Recent studies indicate this has been an important driver of China's commodity demand (Roberts and Rush, 2012). During the early 2000s, only a few sectors explain the growth in China's U.S. dollar exports: machinery; textiles, apparel, and furniture; and metals (Amiti and Freund, 2010 and Berger and Martin, 2013). Although light and less commodity-intensive manufacturing, such as cell phones and laptops, accounted for a large share of the rise in export values, falling output prices in industries such as steel and shipbuilding likely understate the contribution of commodity-intensive heavy manufacturing. Shipbuilding is a good example: Tsai (2011) finds that China's share of global production by volume rose from less than 1 percent in 1985 to about 5 percent and almost 20 percent by 2000 and 2005, respectively. Construction investment accounts for over a third of base metal end-use, while nearly a third is attributable to foreign demand for Chinese output, mainly embodied in the exports of other industries that use manufactured-metals products as inputs (Kelly, 2014).

Second, faster economic growth and a widening urban-rural income gap has increased the pace of China's urbanization as rural workers flood into the factories located in or near cities (Zhang and Song, 2003). During the 1990s, China's urban population increased each year by an average 15 million people but there was a sudden and persistent jump in 2001-02 which lifted the average increase to 20 million people where it has remained. This migration had to be accommodated by a large and sustained rise in commodity-intensive infrastructure and real estate. Third, the income levels of China's urban workforce have risen to the point where consumption patterns have changed with large implications for global commodity trade. Data show that household consumption share of GDP has trended higher in recent years, suggesting that the process of rebalancing away from investment-led growth may already have begun (Kelly, 2014). For example, higher demand for meat and cooking oil has triggered a sustained rise in China's soybean imports.

Figure 3 shows how China's share of global commodity imports rose in the early 1990s and accelerated and broadened in the 2000s. Demand outstripped domestic supply for a number of key commodities. For example, China turned from being a small net exporter of soybeans to account for over 60 percent of world imports in two decades. China also became a net importer of such commodities as base metals – for use in construction and manufacturing, cotton – an important input in its textile production, and soybeans – used primarily as animal feed.

China's commodity consumption growth may slow but consumption is unlikely to have peaked (Farooki and Kaplinsky, 2012). As countries become richer, their commodity demand increases at a rising rate until eventually stabilizing at a much higher level—sometimes described as the S-curve. China's commodity intensity of demand has been growing very fast but not unusually so when compared to other countries' industrialization patterns. Figure 4 shows that China is outpaced only by Brazil among a small sample of G-20 economies. The metal intensity of China's demand is nearly identical to that of Korea, which stabilized at a much higher consumption level and an income level more than twice as high as China's income today.

China will likely play an even larger role in international commodity trade but this only matters if it affects the relative distribution of supply and demand of different commodities across countries. A changing pattern of growth will also affect the pattern of commodity consumption. Norrish et al (2015) suggest that for some commodities, demand growth has contracted fast and intensity of use is in a structural decline (including coal, refined oil products, and some staple crops) but for others there continues to be rapid increases in intensity of use (including soft commodities and natural gas). Canuto (2014) documents changes in demand intensity across commodities and concludes that

China's changing growth patterns may lead to less intensive demand for metals, but this is not necessarily true for foodstuffs. Kelly (2014) concludes that "while growth in Chinese demand is expected to slow from the rapid rates seen over the past decade, this growth will be from a much higher base, and the overall volume of Chinese imports is likely to expand further."

Thus China's new growth path in the medium to long run could imply less volatile but still robust commodity demand (IMF 2012a). Although likely to be constrained by growing environmental concerns, China's commodity demand along with that of other emerging-market economies is likely to remain the determining factor for global commodity prices in the foreseeable future. Farooki and Kaplinsky attribute China's continuing dominance in commodity markets to the following factors: high and stable demand for crops (although of varying composition), growth and structure of China's manufacturing sector (dominant sub-sectors are also relatively commodity-intensive), low saturation of consumer durables for rural households (nearly half the population), sizable growth potential for the auto sector, and steady demand for improvements in infrastructure.

As evidence of China's steady appetite for crops and extractable resources, Chinese firms are increasingly present as producers of commodities outside of their domestic economy. Implications of such presence are widely discussed in literature, and are outside the scope of this paper[3]. Instead, we focus on the extent domestic activity in China affects global commodity prices.

2.3 Commodities as collateral in China

Previous literature has focused almost exclusively on real demand spillovers from China to commodities. Much less attention has been paid to the role that commodities play as collateral in the domestic financial system. This reflects the relatively recent emergence of this activity and the paucity of hard data. In this section, we briefly survey research on collateral constraints in China, including some recent work touching on the link with commodities.

[3] See Ferchen et al (2013), Gallagher and Porzecanski (2009) on Latin America, Gruss (2014) on Latin America and the Caribbean, Deutsche Bank report (2006) on Latin America and Africa, several articles by Sautman and Hairong (2007-2009), Jiang (2009) on Africa, among others.

Information asymmetries in China's banking system

The asymmetric information problem for the lender-borrower relationship in China's formal financial sector remains acute. Banks have for a long time directed a substantial proportion of credit to state-owned enterprises (SOEs) and therefore lack a long and reliable credit history for private sector borrowers. This has reflected, inter alia, the historical role of banks in policy lending (Cull and Xu, 2003) but also more relaxed lending conditions for SOEs (Firth, Lin, and Wong, 2009; Chen, Chen, Lobo, and Wang, 2010). In China this information problem is compounded by a predominance of small and medium enterprises (SMEs) among private borrowers as the accounting practices, internal control, and governance of these firms is often informal and difficult to audit (Firth, Lin, Liu, and Wong, 2009). Lacking credible signals of creditworthiness, which for larger SOEs can include links with the government, private borrowers typically rely on collateral when accessing credit from the formal financial sector. The World Bank's 2012 enterprise survey for China shows that for a sample of 2,700 firms, about 80 percent of loans required some form of collateral which, on average, was valued at twice the loan amount. While close to the Asia-Pacific average, these figures are substantially higher than for OECD economies where collateral is required for about 64 percent of loans with an average collateral-loan value ratio of about 150 percent. The challenge for many private borrowers has been to find acceptable collateral to use as security for bank loans. Surveys have found that lack of collateral is often the main constraint for firms' access to bank loans, particularly for private SMEs (Gregory and Tenev, 2001; OECD, 2005; Ayyagari, Demirgüç-Kunt, and Maksimovic, 2010; and Boao, 2013).

Before 2007, the only type of collateral acceptable to most banks was either land or buildings. The existing patchwork of laws then allowed only two other types of collateral, equipment and motor vehicles, and just 4 percent of loans were secured by these so-called "movable assets," considerably lower than in the United States (World Bank-PBC, 2006). In March 2007, the Chinese government passed the landmark Property Rights Law which came into effect on October 1 that year. This law brought a number of changes including: equal protection of state, collective and individual property; a detailed framework for the protection of real (immovable) and movable properties; and an expansion of the scope of movable collateral that can be used by borrowers to secure a loan, encompassing equipment, inventory, accounts receivable and other tangible, movable assets. At the same time, the law provided creditors with more control over defaults by allowing events in default to be defined by contract (Marechal, Tekin, and Guliyeva, 2009). Before the passing of the Property Rights Law, China scored only 4 out of 10 on the Doing Business *Legal Rights Index*. After the law was implemented, the score rose to 6.

Commodities as collateral after 2007

Comprehensive data on the use of commodities as collateral since 2007 is not available. Circumstantial and partial evidence is the best we can do but this does paint a picture of a structural change in demand. For example, if the use of commodities as collateral did rise after 2007, we should expect to see a structural break in inventory-use (IU) ratios as a greater quantity of a commodity is imported but not consumed and instead held in a warehouse as security against loans. There are other possible explanations for a change in IU ratios, such as precautionary demand, but these would typically have a transient impact.

Inventory data covering aluminum and copper stocks in China's bonded warehouses suggest it is indeed possible to identify structural breaks soon after the new law's introduction. Unfortunately, the onset of the global financial crisis and the post-crisis fiscal stimulus are also likely to have had an effect, but as Figure 5 shows, these ratios increased and remained higher until the Qingdao port scandal in mid-2014.

Chinese banks provide only a partial picture of their collateral exposures. One of China's largest banks, the Industrial and Commercial Bank of China (ICBC), discloses relatively more information but even these disclosures are limited to the amount of lending secured by pledged assets (which exclude mortgaged property and land). Figure 6 shows that ICBC's pledged lending rose strongly from 2008 and, as a share of total lending, started to rise strongly between 2010 and 2013. The share subsequently dipped soon after the uncovering of the scandal at China's Qingdao port in June 2014. Investigations discovered that a large but unspecified quantity of aluminum and copper had been pledged as collateral for multiple loans (*Wall Street Journal*, June 18 2014). Banks subsequently reported that they had tightened conditions for commodity-backed lending to Chinese firms, including requiring an additional cash pledge (*Reuters*, January 15 2015).

Importing commodity collateral—commodity financing deals (CFDs)

China’s endowment of some basic resources is limited and domestic firms often need to import commodities to use as collateral. A popular way for firms to finance these imports is by borrowing offshore and arranging a commodity financing deal (CFD). A simplified structure for a financing deal starts with a Chinese firm drawing a U.S. dollar-denominated letter of credit (LC) from the offshore subsidiary of a domestic bank. The firm then exchanges the LC for the commodity with a trading house—in practice, the firm acquires a warrant or certificate of ownership for a physical commodity that is either being shipped to, or is already located in, a bonded duty-free warehouse in China. At this point, the firm has a short-term dollar liability which is financing a commodity asset that can now be used as security for domestic borrowing. The LC may be rolled over a number of times to allow the firm to maintain ownership of the commodity. These deals have become popular because they allow firms to relax their domestic collateral constraints, arbitrage the difference between onshore-offshore collateral (or margin) requirements and interest rates, or take a long (carry trade) position in the domestic currency.[4] Why do these arbitrage opportunities exist?

In terms of collateral or margin arbitrage, there are a number of reasons why a domestic bank may accept a lower level of security for an offshore LC compared to an onshore loan.[5] First, LCs are regarded as a lower risk credit exposure than a regular loan as they are shorter in maturity and potentially self-liquidating if the commodity is held as inventory. This lower risk status is reflected in a credit conversion factor of just 20 percent for the purposes of calculating capital ratios under Basel. Second, the underlying asset financed by the LC can be easily marked-to-market with the level of security adjusted with a maintenance margin. Third, borrowing firms may place the margin for the CFD as an onshore renminbi (CNY) deposit with the parent bank which then issues an off-balance sheet LC through its offshore subsidiary—this can help some banks with binding liquidity constraints, including loan-to-deposit ratios. In terms of interest rate arbitrage, the firm can now use the

[4] Firms may also use a CFD to take a carry-trade position that pays off in the event of renminbi appreciation versus the dollar. In this case, the firm “re-exports” the commodity by selling the warrant for dollars and uses the repatriated proceeds to fund a renminbi-denominated investment. This may allow the firm to evade capital account restrictions by classifying their cross-border transactions as trade flows.

[5] For example, Tang and Zhu (2013) suggest that an importer is required to pay a margin of just 20-30 percent of the LC nominal amount.

warehouse warrant as collateral in a domestic repurchase agreement or another type of loan, thereby allowing the firm to earn a domestic rate of return. At the same time, the firm can hedge the risks of its commodity exposure by selling forward contracts. A simplified example of this structure is shown in Figure 7.

Comprehensive data quantifying CFD activity is limited because banks typically do not report this business separately in their accounts. Market participants, notably the bank Goldman Sachs, have estimated that CFDs arranged by Chinese firms may have accounted for as much as $160 billion or 31 percent of China's total short-term foreign-exchange loans and 30 million tons of iron ore and 1 million metric tons of copper or about 1 percent and 5 percent of annual production, respectively (Yuan et al, 2014).[6] Unfortunately, in this paper we again need to rely on circumstantial evidence such as the volume of LCs issued by Chinese banks and the correlation with commodity imports. Figure 8 shows that LC issuance and copper imports are positively correlated but this does not suggest causality and may reflect a common factor, such as the global trade cycle.

Evidence of a collateral demand – commodity price relationship

One of the only attempts to uncover an empirical relationship between China's collateral demand and commodity prices is by Tang and Zhu (2015). They find evidence consistent with a significant impact of CFDs on commodity prices. They estimate a regression in which the dependent variable is the change in the commodity price and the independent variables include a proxy for the incentive for carry-trades and collateral demand (deviations from covered interest rate parity) and other controls. Their results indicate that higher collateral demand increases the price for some base metals and gold with this effect accounting for about 12-15 percent of the rise in the price of major base metals between 2007 and 2014.

[6] According to the U.S. Geological Survey data.

3. Econometric Methodology: VARs with Recursive Identification

We use vector autoregressions (VARs) because their atheoretical properties are an advantage in this exercise given our lack of knowledge and data on the specificities of how shocks in China spill over to commodity markets. Limited data covering inventory holdings in China, the use of commodities as collateral for bank loans, and the scale and terms of offshore commodity financing deals all hamper our ability to directly test our hypotheses. VARs abstract from these problems by allowing us to focus on the overall impact of unanticipated changes in large aggregate credit and activity indicators.

3.1 Basic specification

We estimate a reduced-form VAR with recursive shock identification based largely on Kilian (2009) and Roache (2012). The baseline VAR estimating the impact of aggregate activity and credit shocks includes seven endogenous variables: world primary production of commodity (supply denoted Q_W), world excluding China industrial production (X_{RoW}), China's aggregate credit (CR_{CH}), China's industrial production (X_{CH}), a real U.S. dollar short-term interest rate (RR_{US}), the U.S. dollar real effective exchange rate ($REER_{US}$), and the real price of the commodity (P/P_{US}). There is no economic reason to expect these variables to be cointegrated and this is indeed confirmed by Johansen cointegration tests (not shown). As a result, the first difference of the log of these variables is used in this specification model with the exception of real interest rates which is simply first differenced (see section 4 for details). The vector of endogenous variables Z can then be written as:

$$Z' = \left[\Delta ln\left(Q_{W,t}\right) \quad \Delta ln\left(X_{ROW,t}\right) \quad \Delta ln\left(CR_{i,t}\right) \quad \Delta ln\left(X_{i,t}\right) \quad ln\left(RR_{US,t}\right) \quad \Delta ln\left(REER_{US,t}\right) \quad \Delta ln\left(P_t/P_t^{US}\right)\right] \tag{1}$$

A recursive ordering will provide sufficient restrictions on the contemporaneous relationships between the variables to exactly identify the structural shocks from the residuals of the reduced-form equations. We interpret these shocks as: supply; world excluding-China aggregate activity; China aggregate credit; China aggregate activity; a real exchange rate; and a commodity-specific precautionary shock, consistent Kilian (2009). The ordering of these shocks is described by (1).

This ordering rests on intuitive and reasonable short-run restrictions. The first restriction is that the commodity supply curve is vertical in the very short run. In other words, shifts in the demand curve elicit no changes in supply during the same month. This can be justified by appealing to non-negligible adjustment costs and uncertainty related to the persistence of the demand shock, both of which are likely to mean that the supply response will lag by at least a month. The second restriction assumes that industrial output in the rest of the world is unaffected in the same month by a shock to either credit growth or output growth in China. The third restriction rules out a shock to China's real activity affecting credit growth in the same month. The fourth restriction assumes that changes in the U.S. dollar's real effective exchange rate do not affect the real policy rate in the same month, consistent with some lag in monetary policy decisions. Finally, the real effective U.S. dollar exchange rate is assumed to impact all other variables, except the real commodity price, with a lag of at least one month. The sensitivity of the results to these recursive orderings will depend on the contemporaneous correlations of the reduced-form residuals from the estimated VAR and these are presented in section 5.4. Robustness tests on different ordering are presented in section 5.4.

3.2 Choice of variables

The inclusion of most of these variables in a reduced-form supply-demand model is intuitive. Using industrial production as a measure of real aggregate demand is common in the literature (Baumeister and Peersman, 2013), although alternatives have also been used, such as Kilian's (2009) index of freight costs. The inclusion of the U.S. dollar exchange rate is to control for changes in purchasing power and currency hedging. The U.S. dollar interest rate which is used in some specifications can affect inventory demand. We discuss our motivation for including China's credit aggregates in the model in section 2.3.

4. Data

We sample the data at a monthly frequency. Oil supply is world crude oil production (excluding natural gas liquids) as reported by the United States Energy Information Agency. Base metal supply refers to the output of refined products and is sourced from World Bureau of Metal Statistics. Rest of the world industrial production data are PPP GDP-weighted aggregates based on nationally reported seasonally-adjusted indexes. China's industrial production is seasonally adjusted using the U.S. Census Bureau's X-12 procedure. We use four separate series to measure credit in China. The first is total social financing (TSF), a broad measure of financing for the non-financial private sector which includes bank loans, trust loans, lending by firms, bankers' acceptances, and net bond and equity issuance. We also use bank loans and non-bank credit separately. We complement this with the use of the M2 monetary aggregate which, although not a credit aggregate, has been widely used since the early 2000s by market analysts as a gauge of financial conditions. We deflate the credit series using the non-food consumer price index to remove the influence of highly volatile food prices, which are unlikely to influence real credit conditions. The ex-post real U.S. interest rate is the consumer price index-deflated average Federal Funds effective interest rate. The monthly average real effective U.S. dollar exchange rate is sourced from the International Monetary Fund (IMF). Commodity prices are U.S. dollar spot prices as reported by the IMF Primary Commodity Price System, deflated by the U.S. consumer price index.

Our sample period starts in January 2002 and ends in May 2015 with the start date dictated by the availability of China's TSF data. This start date is also close to China's WTO entry and corresponds approximately to the point at which GDP growth began to increase following the Asian crisis of the late 1990s. Shorter sample periods may provide a more up-to-date perspective on China's role in global commodity markets, but at the expense of degrees of freedom, an important consideration for over-parameterized VAR models. Table 1 shows the summary statistics for the variables used in the estimations. Over the sample period, it is not possible to reject the null hypothesis that the log of each variable is non-stationary. Some variables, including tin and zinc supply, appear trend stationary but there is no clear economic reason for this result. In contrast, the first differences of the logs of all variables show clear evidence of stationarity and this is the transformation we use for all of our estimations.

We choose the lag length for the estimations based on the results from information criteria (IC) which are not shown. In most cases, likelihood ratio tests and the Akaike criteria indicate lag lengths of up to 12 months, but this tended to produce unstable dynamics and non-intuitive results, particularly as the impulse response horizon lengthened. In almost all cases, ICs that favor greater parsimony, including the Schwarz-Bayes criterion, selected a lag length of between 3 and 6 months. All the results that follow are based on models with a lag of 4 months and we present a robustness tests with varying lag lengths in section 5.4.

Table 2 shows the correlations of the residuals from the reduced-form VARs for selected commodities and for a specification including bank lending as the credit aggregate (the results are broadly similar for commodities and credit aggregates not shown). These indicate how important our choice of recursive ordering is for the results that follow. For most bivariate relationships, correlation coefficients (r) are low and statistically insignificant at the 5 percent level. The correlation between the residuals from the China bank lending equation and the China industrial production equation are positive and statistically significant and we test the robustness of our ordering assumption for these two variables in section 5.

5. Results

All of the results that follow come from estimates of the reduced-form VAR using the vector Z described in (1) with 4 lags and identification using the recursive ordering described in section 3.

5.1 Granger causality tests

We find mixed evidence that past values of China's credit aggregates help to predict commodity prices over the full sample period. We test this by dropping all of the lagged values of China's credit aggregates from each of the other equations in the system, with the exception of its own equation. For 7 variables and equations (N=7), each with 4 lags (P=4), this imposed a total of 24 ((N-1) x P) restrictions on (1). The null hypothesis that lagged values of the excluded credit indicator variable do not Granger cause other variables in the system was tested using a log likelihood test, for which the critical values are distributed as χ^2 ~ (24).

Table 3 presents the p-values from these tests for each credit aggregate/ commodity combination along with comparable values for China's industrial production. Over the full sample period, lagged values of China's industrial production have been a better in-sample predictor of commodity price changes than credit aggregates. At the same time, the results change when using a sample that starts in November 2007 at the time the property law came into effect. In this case, using the small-sample adjusted log-likelihood test, we can reject the null hypothesis that credit does not Granger cause other variables in (1) at the 5 percent level.

5.2 Impact of a China credit shock on commodity prices

Impulse responses from the estimated VAR suggest that a shock to China's real credit aggregates has a large and statistically significant impact at the 5 percent level after 4-8 quarters on most base metals, including copper, lead, nickel, and tin. Table 4 and Figure 9 show that a one-time unanticipated 1 percentage point (unit) change to the real month-on-month growth rate of bank lending leads to an increase in the real price of these commodities that ranges from about 10 percent to over 13 percent after 4 quarters. This impulse to bank lending growth is equivalent to a 1.6 standard deviation shock. The impact on commodity prices typically peaks after 4 quarters and moderates slightly thereafter. Bank loans have the largest impact on commodity prices, followed by M2 money supply. TSF and non-bank credit have smaller and less significant impacts. We show only the results for bank lending.

5.3 Impact of a China industrial production shock on commodity prices

Impulse responses show that industrial production in China exerts an important influence on commodity prices with a large and statistically significant impact on oil, aluminum, and copper. This contrasts with the credit shock which had an even larger impact across base metals that are more likely to be used as collateral for loans. Table 5 and Figure 10 show that a one-time 1 ppt (unit) shock to the real month-on-month growth rate of China's industrial production leads to an increase in the real price of these commodities that ranges from about 6½ percent to almost 9 percent after 4 quarters, again with some slight moderation thereafter. As with bank lending, this 1 ppt impulse to industrial production is equivalent to a 1.6 standard deviation shock. These estimates are higher than in Roache (2012) who finds that an identical shock in a similar model for a 2000-2011 sample period causes a change in commodity prices of between 1 and 2 percent for these commodities after 4 quarters.

5.4 Robustness tests

In this section, we present robustness tests of the sensitivity of the results to some of the assumptions we have made, including the ordering of the endogenous variables, lag length, and sample period.

Identification ordering

Our baseline model assumes that the quantity of credit responds to an unexpected change in industrial production only with a lag of one month or more. This assumption seems reasonable given the typical lags involved in the financing and investment decisions of firms (Nickell, 1977). It also appears to have little impact on the empirical results. Figure 11 compares the 12-month cumulative impulse response of real commodity prices to a credit shock in our baseline model and an alternative model in which the ordering of China's bank lending and industrial production is reversed (the ordering of all other variables is kept unchanged). For the alternative model, we find that the results are somewhat weaker. Specifically, the mean 12-month impact across commodities is lower by about 1.5 ppts on average while confidence intervals are little changed.

Lag length

Our baseline model is estimated with a lag length of 4 months and is open to two criticisms. First, this is relatively short for a commodity price VAR with other approaches in the literature considering a lag of at least 12 months. Second, given our short sample period, the lag length is perhaps too long, consumes degrees of freedom, and could allow outliers to influence our results. Figure 12 shows that impulse responses estimated using a model with 2 lags instead of 4 lags produces broadly similar results with the impact of a credit shock on commodity prices on average 1.3 ppts larger and statistically significant for two additional commodities, oil and aluminum.

Figure 13 shows that impulse responses estimated using a model with 6 lags instead of 4 lags produces broadly similar results. In this case, the impact of a credit shock on commodity prices is on average 0.3 ppts larger. The impact on aluminum gains statistical significance while the impact on nickel loses statistical significance.

Sample period

We checked the sensitivity of our results to the sample period by re-estimating the VAR and comparing impulse responses for two separate periods with a breakpoint of October 2007. This is a natural breakpoint in our sample for two reasons: it is the month during which China's Property Rights Law came into effect; and it is the eve of the global financial crisis after which China's growth came to rely more on credit. Figure 14 shows the cumulative 4 quarter impulse responses from the baseline model for sample 1 (Jan-2002 to Oct-2007) and sample 2 (Nov-2007 to May-2015). In most cases, we find that the 4 quarter impact appears to rise for the later sample (consistent with China's growing presence in commodity markets and a positive effect from the new law) and it becomes statistically significant for copper, lead, and nickel. At the same time, reflecting fewer usable observations, the confidence interval ranges tend to increase compared to the estimates for the full sample period.

The risk of the abovementioned robustness test is that the baseline VAR may be severely over-parameterized in each sub-sample with 29 parameters in each equation. We therefore estimated the VAR with just 2 lags and 15 parameters in each equation over the same two sample periods. This confirms the earlier result—that the impulse response tends to rise, in this case by an average of 9 ppts to 11.5 percent—but also produces much narrower confidence intervals. The impact in a model with 2 lags over the later 2007-2015 sample period is now statistically significant at the 5 percent level for all base metals and borderline significant for oil (see Figure 15).

6. Conclusion

China remains a dominant consumer, importer, and price-setter in global commodity markets. Its rebalancing away from investment-led growth towards consumption will likely have implications for the level and pattern of global commodity trade. At the same time, historical cross-country experience suggests that China will remain a very large source of demand in a broad range of important global commodity markets – spanning energy, metals, agricultural raw materials, and some foodstuffs – in the medium term.

Unsurprisingly then, and confirming earlier findings in Roache (2012), we find that shocks to China's industrial activity have a statistically significant and economically meaningful impact on the real U.S. dollar price of some commodities, namely crude oil, aluminum, and copper. We find that a 1 percentage point (1.6 standard deviation) shock to the monthly growth rate of China's industrial production causes the prices of these commodities to rise by an average of 7.4 percent after 4 quarters. This impact is somewhat larger in magnitude than in Roache (2012), likely reflecting China's growing share of global consumption in many markets.

More interesting – and perhaps surprising – is our finding that shocks to China's credit aggregates—especially bank lending--have a significant impact on some industrial commodity prices. This seems to capture more than the indirect impact that changes in credit may exert through their effects on investment, industrial production, and ultimately the real demand for commodities. We find two important differences between the impact of a credit shock and an industrial production shock. First, credit shocks tend to affect different commodities, specifically base metals rather than oil and aluminum. Second, the impact when statistically significant is larger, averaging almost 12 percent for copper, lead, nickel, and tin. We find that bank lending is more important for commodity prices than other indicators of credit, including the broader concept of total social financing. Our results are robust to changes in the ordering of Chinese variables in the baseline model, changes in lag length, and estimation of two shorter sub-samples.

We find these results to be supportive of the hypothesis that China exerts a direct financial influence, as well as a real demand influence, on global commodity markets. Specifically, our results are consistent with the story that commodities play an important role as collateral in the domestic financial system. An easing in financial conditions which is perhaps best measured by assessing financial quantities rather than prices (or interest rates) in China should increase the demand for commodities which can serve as collateral and raise commodity prices. We recognize, however, that the evidence is circumstantial, as it must be given the paucity of hard data describing the actual mechanism through which commodities are imported into China for the purposes of accessing domestic credit.

Will these relationships remain stable? Looking ahead, China's dominance as a consumer and importer of commodities is likely to persist given its economic size and development prospects. We expect China's industrial activity to remain an important determinant of commodity price trends in the medium term. As for the impact of Chinese credit shocks, its importance for global commodity prices may diminish over time as China develops its domestic financial system to overcome the information asymmetries that give such prominence to collateral. Additionally, further integration into the global financial system which should give domestic private borrowers greater financing flexibility.

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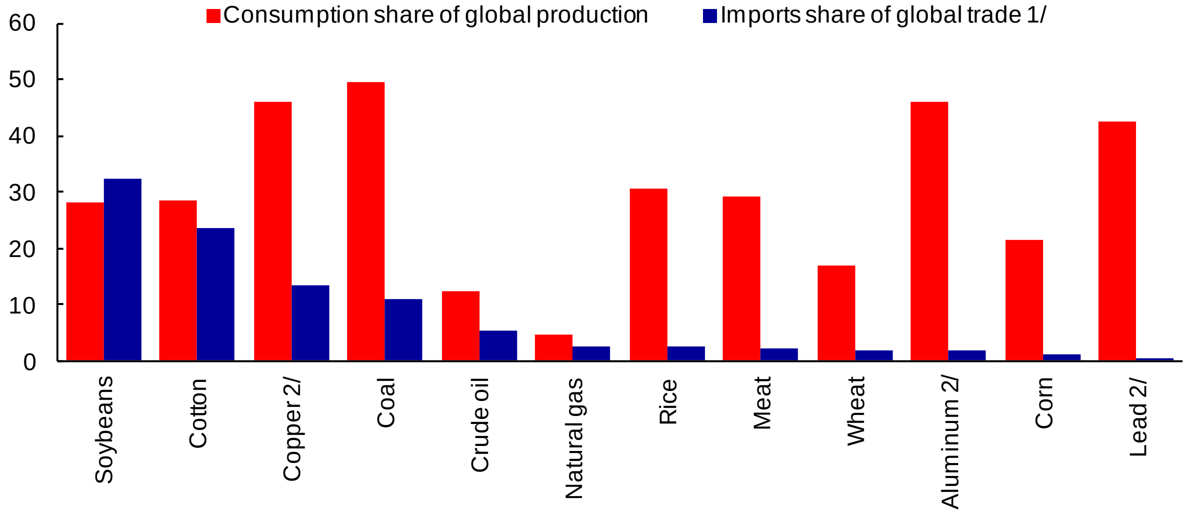
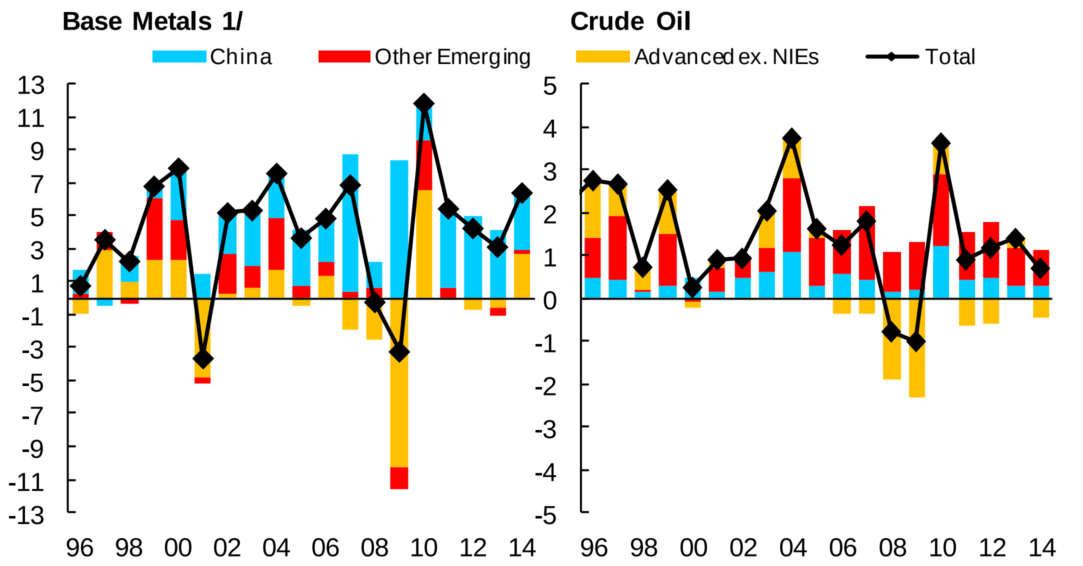
Figure 1. China's Share of Selected Global Commodity Markets, 2013
(percent)



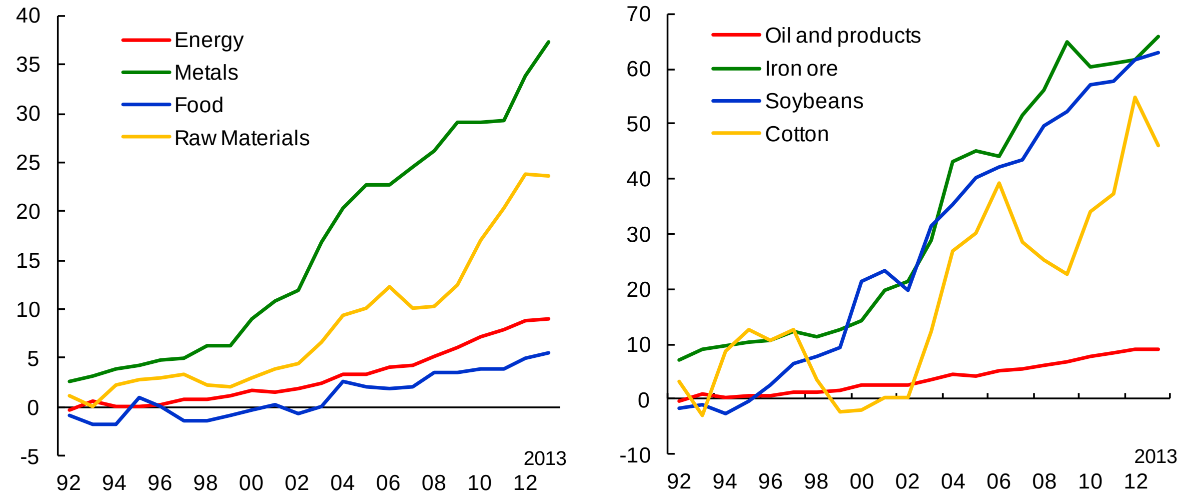
Sources: United Nations COMTRADE database, BP *Statistical Review of World Energy*, United States Department of Agriculture, World Bureau of Metal Statistics, and authors' calculations.
1/ Sum of global imports and exports.
2/ Refined metals only.

Figure 2. Oil and Base Metals Demand Growth Contributions, 1996-2014
(percentage points)



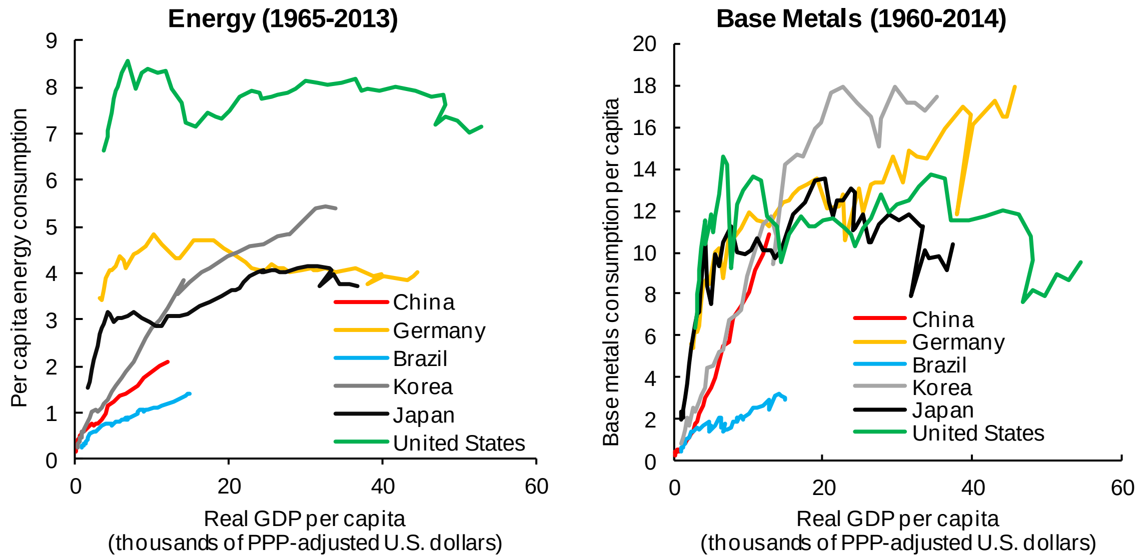
Sources: International Energy Agency, World Bureau of Metal Statistics, and authors' calculations.
1/ IMF trade-weighted average of aluminum, copper, lead, nickel, tin, and zinc.

Figure 3. China's Share of Global Commodity Trade
(net imports in percent of world imports) 1/



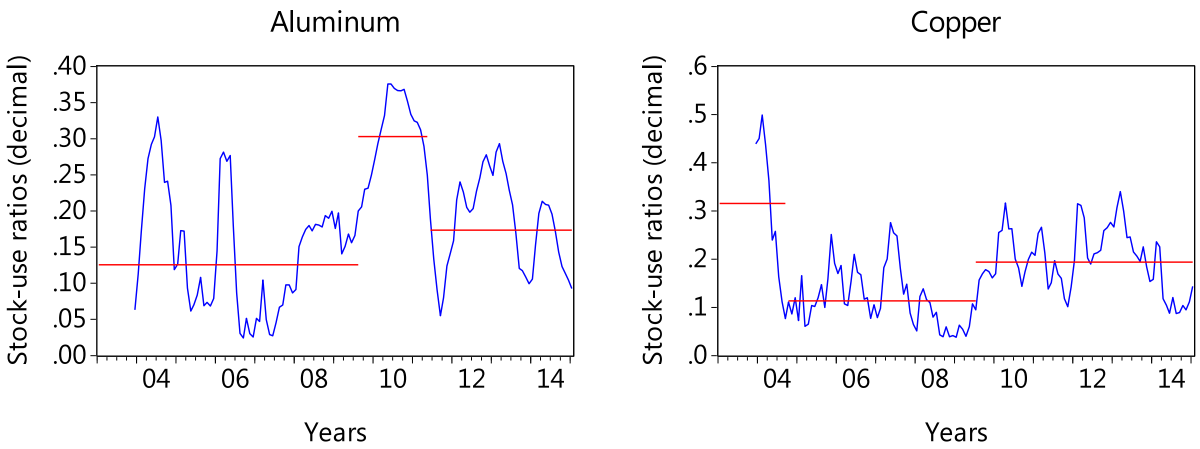
Sources: United Nations COMTRADE database, and authors' calculations.
1/ Commodity groups are IMF Primary Commodity Price Index- weighted. Net imports are calculated as commodity *i* imports less commodity *i* exports in percent of world commodity *i* imports. A positive (negative) number indicates that China is a net importer (exporter).

Figure 4. Energy and Base Metal Intensity



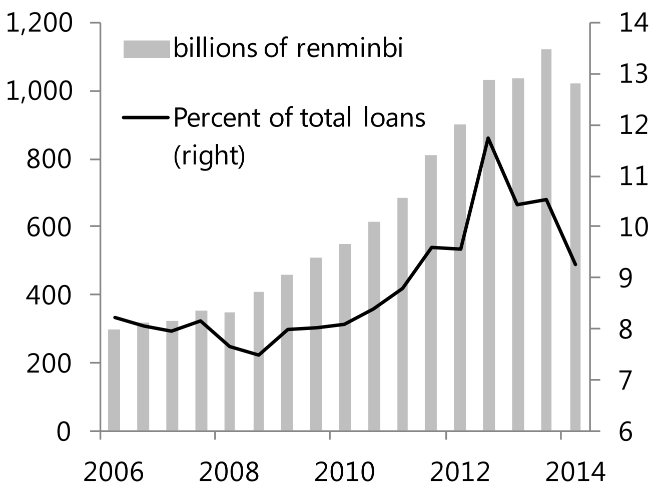
Sources: International Energy Agency, World Bank Development Indicators, author's calculations.
1/ Energy consumption in millions of British thermal units. Metals consumption is an IMF trade-weighted average of aluminum, copper, lead, nickel, tin, and zinc in kilograms.

Figure 5. China's Domestic Inventory-use Ratios 1/



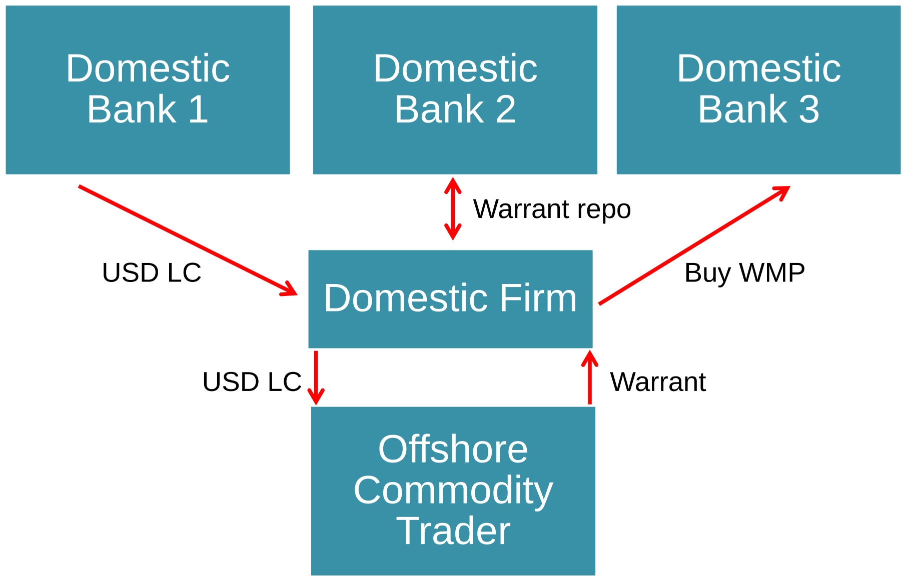
Source: Shanghai Metals Exchange; World Bureau of Metals Statistics; and authors' calculations.
1/ Month-end inventories in Shanghai bonded warehouses divided by monthly consumption of refined product.

Figure 6. Industrial and Commercial Bank of China: Pledged Loans 1/



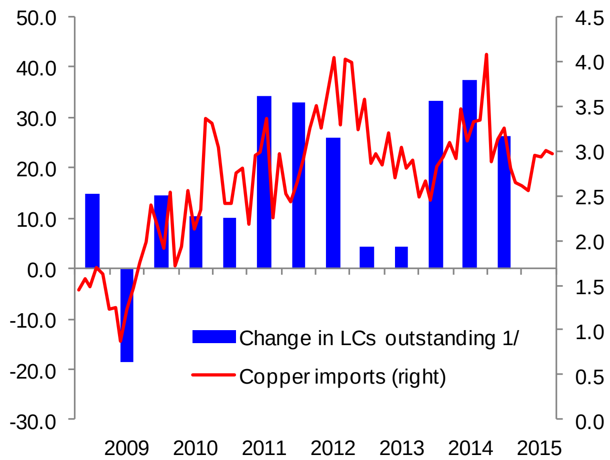
Source: Company reports; and authors' calculations.
1/ Pledged loans excluding discounted bills.

Figure 7. A Simplified Chinese Commodity Financial Deal 1/



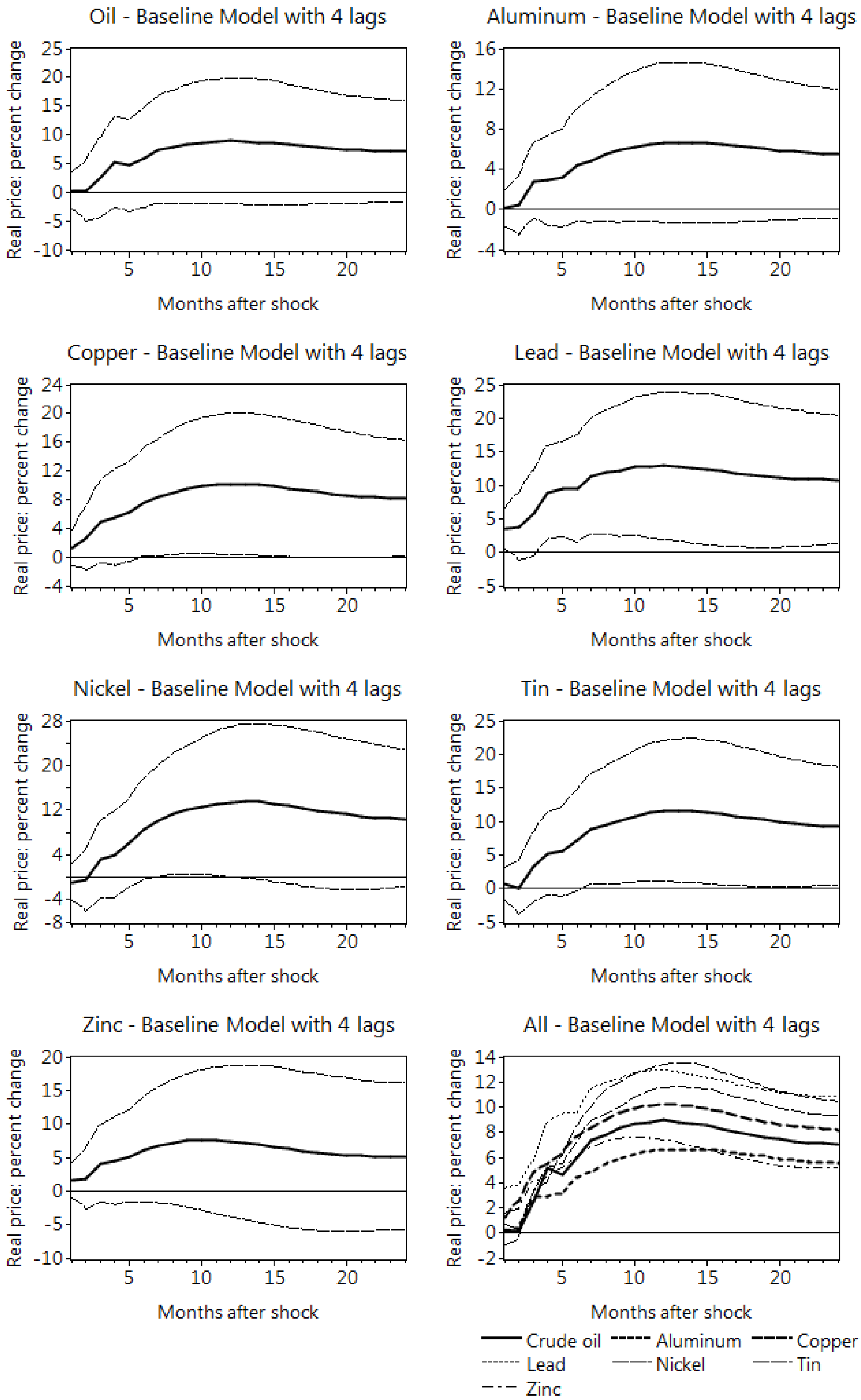
Source: Goldman Sachs (2012), Tang and Zhu (2015), authors' estimates.
1/ U.S. dollar denoted by USD. Letter of credit denoted by LC. WMP stands for wealth management product.

Figure 8. Chinese Banks Letter Issuance and Copper Imports, 2008-2014
(billions of U.S. dollars)



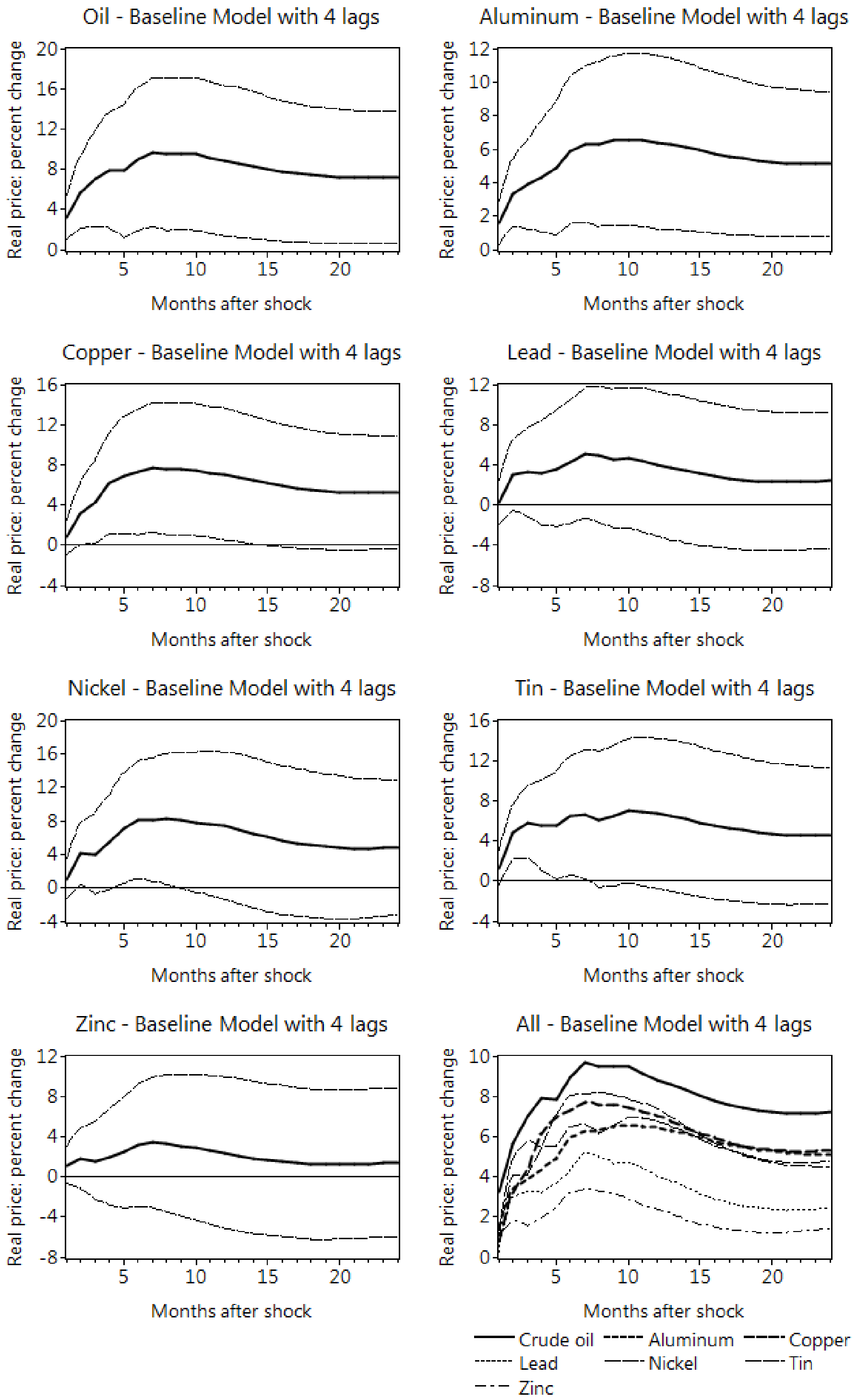
Source: Bank interim reports, Thomson Datastream.
1/ Change in letters of credit outstanding for the largest [six] Chinese banks.

Figure 9. Impulse Responses for Real Commodity Prices 1/
(cumulative responses to a 1 ppt shock to the growth rate of China's bank lending)



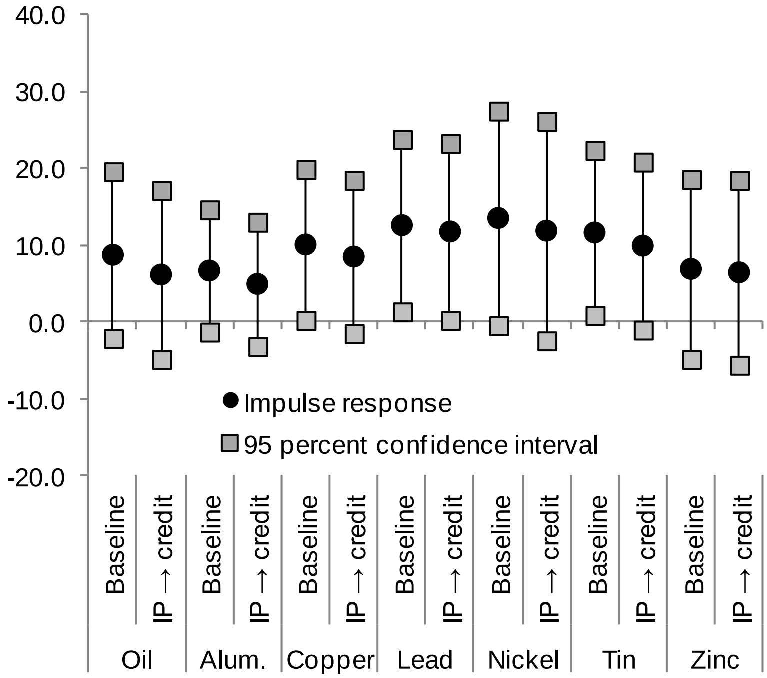
Source: Authors' calculations.
1/ Impulse response with 95 percent confidence intervals.

Figure 10. Impulse Responses for Real Commodity Prices 1/
(Cumulative responses to a 1 ppt shock to the growth rate of China's industrial production)



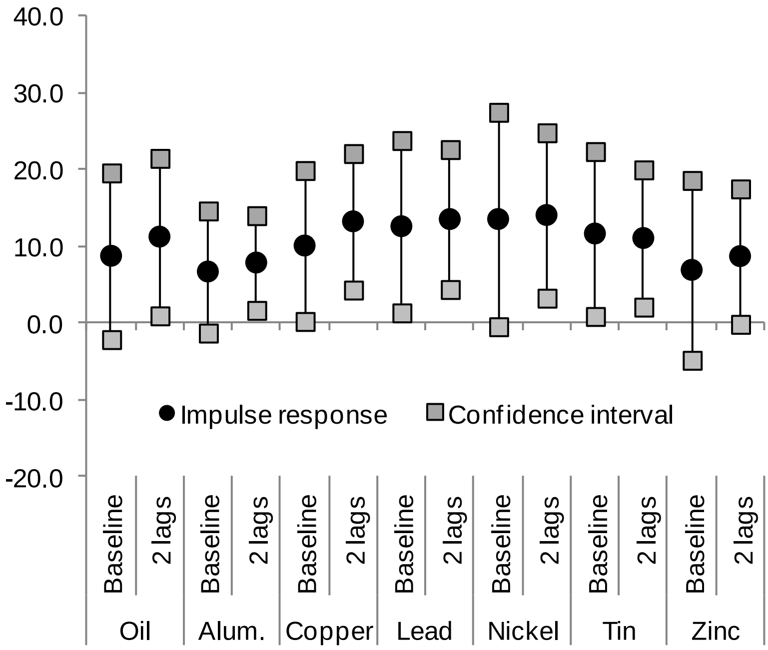
Source: Authors' calculations.
1/ Impulse response with 95 percent confidence intervals.

Figure 11. Alternative VAR Specifications: Reverse Ordering of Credit and IP
(4 quarter responses to 1 ppt shocks to the growth rate of bank lending) 1/



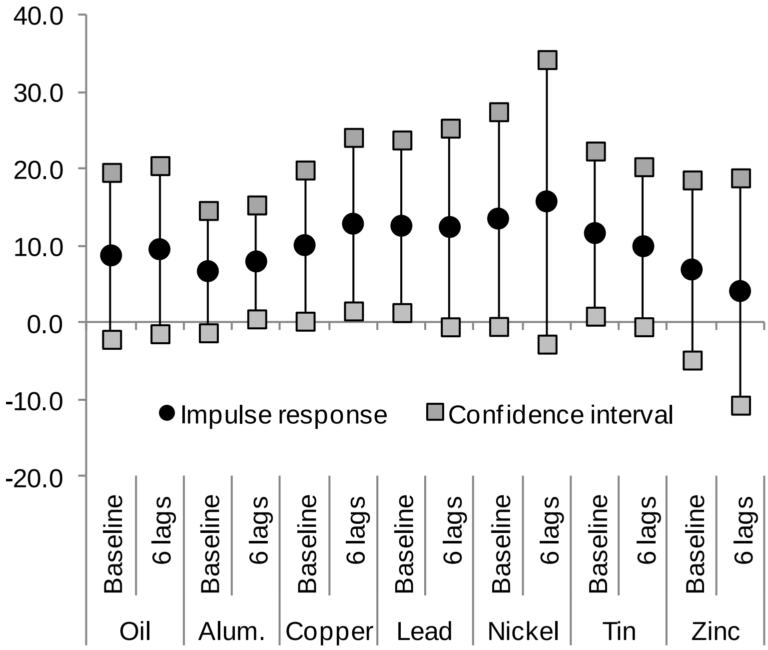
Source: Authors' calculations.
1/ Two responses are shown for each commodity: the baseline model which orders bank lending before industrial production in the Cholesky identification (and vice versa), respectively.

Figure 12. Alternative VAR Specifications: Shorter Lag Length
(4 quarter responses to 1 ppt shocks to the growth rate of bank lending) 1/



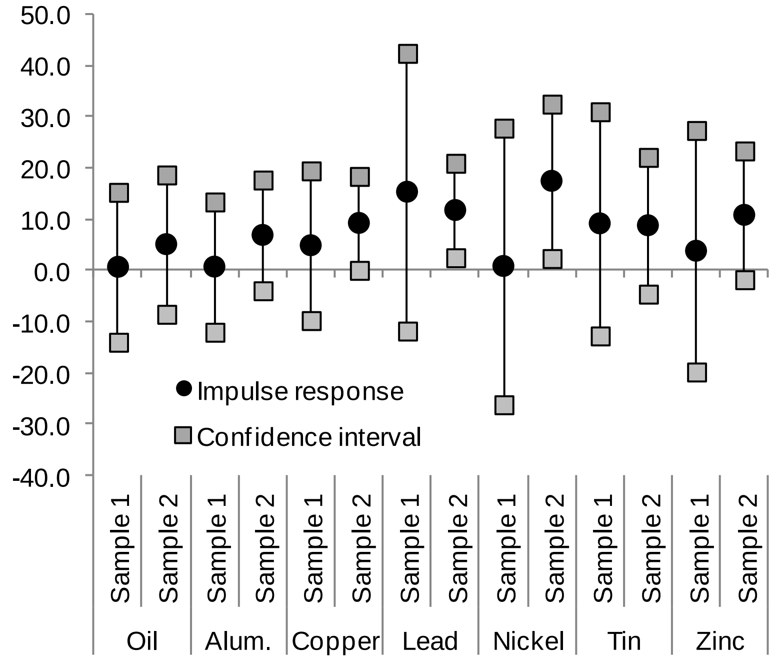
Source: Authors' calculations.
1/ Two responses are shown for each commodity: the baseline model using 4 lags and an alternative model using 2 lags, respectively.

Figure 13. Alternative VAR Specifications: Longer Lag Length
(4 quarter responses to 1 ppt shocks to the growth rate of bank lending) 1/



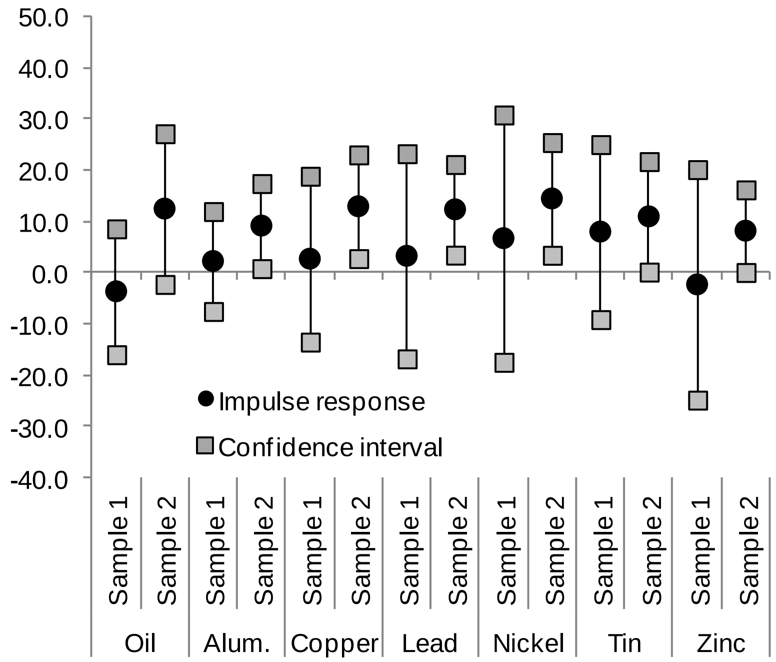
Source: Authors' calculations.
1/ Two responses are shown for each commodity: the baseline model using 4 lags and an alternative model using 6 lags, respectively.

Figure 14. Alternative VAR Specifications: Sub-Sample Periods and 4 Lags
(4 quarter responses to 1 ppt shocks to the growth rate of bank lending) 1/



Source: Authors' calculations.
1/ Sample 1 is from January 2002 to October 2007 (67 observations) and sample 2 is from November 2007 to May 2015 (91 observations).

Figure 15. Alternative VAR Specifications: Sub-Sample Periods and 2 Lags
(4 quarter responses to 1 ppt shocks to the growth rate of bank lending) 1/



Source: Authors' calculations.
1/ Sample 1 is from January 2002 to October 2007 (67 observations) and sample 2 is from November 2007 to May 2015 (91 observations).

Table 1. Variables Used in the VARs: Summary Statistics, January 2002 to May 2015
(100x monthly first differences of logs, unless otherwise specified)

				Unit root test p-values		
	Mean	Standard deviation	Skew	Log level	Log level with trend	Log difference
Activity/ financial variables						
World excl. China Industrial Production	0.3	0.7	-2.7	0.68	0.05	0.00
China Industrial Production	1.0	0.7	0.3	0.21	0.83	0.00
China total social financing	1.4	0.6	1.5	0.78	0.45	0.04
China non-bank credit	4.3	14.9	0.8	0.00	0.70	0.00
China M2 money supply	1.2	0.8	0.6	0.80	0.72	0.00
China bank lending	1.2	0.6	2.7	0.79	0.57	0.04
U.S. dollar real effective exchange rate	-0.1	1.3	0.4	0.29	0.00	0.00
U.S. real Fed Funds interest rate 1/	0.0	0.5	0.0	0.34	0.76	0.00
Commodity supply						
Oil	0.1	0.8	0.0	0.68	0.03	0.00
Aluminum	0.5	3.3	0.1	0.98	0.13	0.00
Copper	0.2	3.3	-0.4	0.89	0.35	0.00
Lead	0.2	5.0	0.0	0.70	0.73	0.00
Nickel	0.3	4.8	-0.2	0.83	0.23	0.00
Tin	0.1	8.3	-0.1	0.53	0.00	0.00
Zinc	0.2	4.9	-1.2	0.76	0.02	0.00
Real commodity prices						
Oil	0.8	8.4	-1.2	0.15	0.19	0.00
Aluminum	0.2	5.3	-0.7	0.26	0.20	0.00
Copper	0.9	7.3	-0.9	0.54	0.16	0.00
Lead	0.9	8.3	-0.7	0.65	0.25	0.00
Nickel	0.6	9.2	-0.4	0.27	0.05	0.00
Tin	0.8	6.9	-0.3	0.43	0.63	0.00
Zinc	0.7	7.0	-0.5	0.40	0.10	0.00

Sources: Haver Analytics, CEIC, World Bureau of Metal Statistics, U.S. Energy Information Agency, authors' calculations.
1/ First difference of the level.

Table 2. Correlations of Residuals from Reduced-Form VAR Equations
January 2002 to May 2015 1/

	Refined commodity production	World excl. China industrial production	China bank lending	China industrial production	U.S. dollar exchange rate	Real U.S. interest rate
Aluminium						
World excl. China IP	0.21 *					
China credit	0.05	0.03				
China IP	0.17 *	0.31 *	0.24 *			
U.S. dollar exchange rate	-0.15	-0.13	0.19 *	-0.38 *		
Real U.S. interest rate	0.08	0.13	-0.06	-0.23 *	0.33 *	
Real commodity price	-0.01	0.11	0.05	0.22 *	-0.24 *	-0.60 *
Copper						
World excl. China IP	-0.09					
China credit	-0.09	-0.02				
China IP	-0.11	0.26 *	0.19 *			
U.S. dollar exchange rate	0.12	-0.19 *	0.19 *	-0.34 *		
Real U.S. interest rate	0.03	0.14	-0.03	-0.18 *	0.34 *	
Real commodity price	-0.12	0.30 *	0.16	0.26 *	-0.30 *	-0.49 *
Crude oil						
World excl. China IP	0.32 *					
China credit	-0.05	0.06				
China IP	0.03	0.24 *	0.30 *			
U.S. dollar exchange rate	0.02	-0.17	0.13	-0.33 *		
Real U.S. interest rate	0.16	0.09	-0.05	-0.31 *	0.33 *	
Real commodity price	-0.01	0.07	0.17 *	0.31 *	-0.38 *	-0.46 *

Source: Authors' calculations.
1/ * denotes statistical significance at the 5 percent level.

Table 3. Granger Causality Tests for Chinese Credit and Industrial Production: p-values 1/

Sample: January 2002 - January 2015 (157 observations)

	Credit aggregates				Industrial production			
	Baseline 4-lag model estimated with:				Baseline 4-lag model estimated with:			
	TSF	Non-bank	M2	Bank	TSF	Non-bank	M2	Bank
Aluminum	0.268	0.067	0.093	0.429	0.092	0.049	0.034	0.045
Copper	0.880	0.012	0.016	0.663	0.108	0.025	0.087	0.029
Lead	0.679	0.000	0.213	0.237	0.076	0.006	0.160	0.050
Nickel	0.884	0.076	0.197	0.513	0.013	0.009	0.035	0.007
Tin	0.535	0.033	0.010	0.034	0.000	0.001	0.000	0.000
Zinc	0.961	0.039	0.650	0.694	0.184	0.138	0.244	0.062
Oil	0.629	0.001	0.062	0.165	0.149	0.098	0.059	0.017
	Baseline 2-lag model estimated with:				Baseline 2-lag model estimated with:			
	TSF	Non-bank	M2	Bank	TSF	Non-bank	M2	Bank
Aluminum	0.000	0.146	0.114	0.000	0.011	0.001	0.003	0.030
Copper	0.000	0.030	0.047	0.000	0.080	0.007	0.019	0.151
Lead	0.000	0.000	0.114	0.000	0.012	0.000	0.006	0.043
Nickel	0.000	0.095	0.114	0.000	0.020	0.001	0.004	0.035
Tin	0.000	0.050	0.056	0.000	0.000	0.000	0.000	0.001
Zinc	0.000	0.097	0.295	0.000	0.040	0.002	0.007	0.092
Oil	0.000	0.016	0.024	0.000	0.061	0.020	0.026	0.228

Sample: November 2007 - May 2015 (87 observations)

	Credit aggregates				Industrial production			
	Baseline 4-lag model estimated with:				Baseline 4-lag model estimated with:			
	TSF	Non-bank	M2	Bank	TSF	Non-bank	M2	Bank
Aluminum	0.047	0.000	0.054	0.035	0.075	0.000	0.112	0.006
Copper	0.216	0.056	0.005	0.041	0.000	0.000	0.003	0.000
Lead	0.277	0.064	0.437	0.068	0.003	0.000	0.053	0.001
Nickel	0.294	0.002	0.054	0.001	0.001	0.000	0.009	0.000
Tin	0.234	0.588	0.027	0.020	0.000	0.000	0.002	0.000
Zinc	0.003	0.003	0.261	0.000	0.000	0.000	0.014	0.000
Oil	0.068	0.051	0.131	0.022	0.027	0.006	0.104	0.008
	Credit aggregates				Industrial production			
	Baseline 2-lag model estimated with:				Baseline 2-lag model estimated with:			
	TSF	Non-bank	M2	Bank	TSF	Non-bank	M2	Bank
Aluminum	0.000	0.005	0.106	0.000	0.005	0.000	0.006	0.002
Copper	0.001	0.151	0.048	0.000	0.003	0.000	0.001	0.000
Lead	0.001	0.029	0.097	0.000	0.000	0.000	0.000	0.000
Nickel	0.001	0.050	0.180	0.000	0.005	0.000	0.006	0.002
Tin	0.000	0.018	0.131	0.000	0.001	0.000	0.002	0.000
Zinc	0.000	0.011	0.025	0.000	0.000	0.000	0.002	0.000
Oil	0.000	0.001	0.014	0.000	0.010	0.000	0.026	0.002

Source: Authors' calculations.
1/ p-values for the null hypothesis that lagged values of the specified variable do not Granger cause other variables in the system (1). A value below 0.05 indicates that the null hypothesis can be rejected at the 5 percent level; p-values for the shorter sample period are calculated using small sample-adjusted log-likelihood ratio hypothesis tests.

Table 4. Impulse Responses for Real Commodity Prices 1/
(Cumulative responses to a 1 ppt shock to the growth rate of China's bank lending)

	Jan-2002 to May-2015 sample. Real price level response of:						
	Oil	Aluminum	Copper	Lead	Nickel	Tin	Zinc
1 quarter	2.53	2.81	4.88	5.76	3.29	3.28	4.05
	(3.46)	(1.88)	(2.90)	(3.16)	(3.47)	(2.61)	(2.89)
2 quarters	6.03	4.37	7.67	9.52	8.62	7.23	6.22
	(4.33)	(2.80)	(3.80)	(3.98)	(4.51)	(3.77)	(3.94)
4 quarters	8.98	6.61	10.17	12.90	13.37	11.52	7.35
	(5.47)	(3.95)	(4.91)	(5.49)	(6.70)	(5.27)	(5.66)
8 quarters	7.08	5.52	8.15	10.80	10.44	9.25	5.14
	(4.36)	(3.18)	(4.03)	(4.80)	(6.14)	(4.39)	(5.43)

Source: Authors' calculations.
1/ Standard errors in parentheses.

Table 5. Cumulative Impulse Responses for Real Commodity Prices 1/
(responses to 1 percentage point shocks to the growth rate of China's industrial production)

	Jan-2002 to May-2015 sample. Real price level response of:						
	Oil	Aluminum	Copper	Lead	Nickel	Tin	Zinc
1 quarter	7.02	3.87	4.30	3.27	4.05	5.82	1.57
	(2.38)	(1.34)	(2.05)	(2.22)	(2.40)	(1.82)	(1.96)
2 quarters	8.91	5.92	7.29	4.27	8.07	6.48	3.16
	(3.56)	(2.20)	(3.11)	(3.10)	(3.52)	(2.96)	(3.05)
4 quarters	8.81	6.39	7.02	4.03	7.37	6.73	2.34
	(3.74)	(2.58)	(3.26)	(3.61)	(4.40)	(3.73)	(3.76)
8 quarters	7.21	5.13	5.28	2.42	4.79	4.51	1.43
	(3.27)	(2.16)	(2.80)	(3.37)	(4.05)	(3.37)	(3.69)

Source: Authors' calculations.