Modeling Fluctuations in the Global Demand for Commodities

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Lutz Kilian
University of Michigan
CEPR

Xiaoqing Zhou
Bank of Canada

Abstract: It is widely understood that the real price of globally traded commodities is determined by the forces of demand and supply. One of the main determinants of the real price of commodities is shifts in the demand for commodities associated with unexpected fluctuations in global real economic activity. There have been numerous proposals for quantifying global real economic activity. We discuss which criteria a measure of global real activity must satisfy to be useful for modeling industrial commodity prices, we examine which of the many alternative measures in the literature are most suitable for applied work, and we explain why some popular measures are inappropriate for modeling commodity prices. Given these insights, we re-examine in detail whether global real economic activity has declined since 2011 and by how much. Drawing on a range of new evidence, we show that the global commodity price boom of the 2000s appears to have been largely transitory. Our analysis has important implications for the design of structural models of commodity markets, for the analysis of the transmission of commodity price shocks to commodity-importing and -exporting economies, and for commodity price forecasting.

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Correspondence to: Lutz Kilian, Department of Economics, 611 Tappan Street, Ann Arbor, MI 48109-1220, USA. Email: lkilian@umich.edu.

Non-Technical Summary

Although this question arises frequently in applied work, there is no universal agreement on how to quantify cyclical variation in global real economic activity. We show how such a measure must be constructed in order to be useful for modeling industrial commodity prices. We compare a wide range of alternative measures discussed in the literature and assess their merits for applied work on commodity prices. Among these indicators, we stress the advantages of the widely used Kilian (2009) index of global real economic activity, of indices based on real commodity prices and, to a lesser extent, of proxies for global industrial production.

We show that, regardless of the measure used, there is robust evidence for a major global economic slowdown since 2011, the extent of which has not been documented previously or widely recognized. Our evidence suggests, first, that the demand boom in emerging Asia in the 2000s has been a persistent, but ultimately transitory phenomenon, much like the persistent demand booms in the early 1970s and in the late 1970s and early 1980s. Second, our analysis suggests that the role of increased supply in commodity markets has been overemphasized in popular accounts. Third, we conclude that, all else equal, low real commodity prices are likely to persist, which constrains the policy options available to commodity producers and exporters.

This is not to say that global real economic activity could not recover in the future. In fact, if the history of commodity markets since the 1970s is any guide, commodity busts are sooner or later followed by commodity booms. An interesting question for future research will be to identify in more detail the deeper determinants of the boom in global real economic activity in the 2000s. Research along these lines will also help researchers pinpoint the conditions that may presage the next global economic boom.

1. Introduction

There has been growing interest in the determination of the real price of globally traded commodities, especially after the surge in global commodity prices in 2003–08. It is widely accepted that commodity price booms and busts are primarily driven by fluctuations in global demand that are associated with unexpected shifts in global real economic activity. This view is supported by a range of evidence based on monthly and quarterly data since the early 1970s (see, e.g., Barsky and Kilian 2002, Kilian 2009a, Kilian and Hicks 2013, Baumeister and Kilian 2016a) as well as annual data since the 1870s (see, e.g., Jacks and Stürmer 2016; Stürmer 2018). Identifying such shifts in global demand requires reliable measures of fluctuations in global real economic activity. Some researchers have viewed changes in the prices of individual industrial commodities such as copper or iron ore (or changes in broad indices of industrial commodity prices) as indicators of changes in global real economic activity (see, e.g., Barsky and Kilian 2002; Alquist, Kilian and Vigfusson 2013; Alquist and Coibion 2014; Delle Chiaie, Ferrara and Giannone 2016; Newell, Prest, and Vissing 2016). Other researchers have proposed various measures of changes in global real output or in the volume of shipping of industrial raw materials (see, e.g., Kilian 2009a; Baumeister and Peersman 2013; Ravazzolo and Vespignani 2015).

Indicators of global real economic activity are of central importance in macroeconomics as well as in microeconomics. In macroeconomics, they are used in nowcasting and forecasting world trade as well as domestic economic growth and inflation (see, e.g. Stratford 2013). They also play a central role in forecasting the prices of oil and other commodities (see, e.g., Baumeister and Kilian 2014a; Alquist and Coibion 2014), in designing fiscal policies in commodity-exporting economies (see, e.g., Kilian 2017), in modeling the determinants of commodity prices (see, e.g., Kilian 2009a; Kilian and Murphy 2014; Khalil 2017; Stürmer 2018), in studying the effects of commodity price shocks on commodity-importing and exporting economies (see, e.g., Kilian 2009b, 2017), in studying agricultural commodity markets (see, e.g., Baumeister and Kilian 2014b; Jacks and Stürmer 2016; Bruno, Büyüksahin, and Robe 2017), and in studying financial market integration and the role of speculation (see, e.g., Kilian and Murphy 2014; Büyüksahin, and Robe (2014; Büyüksahin, Haigh, Harris, Overdahl, and Robe 2017). In applied microeconomics, they have also been used in identifying the short-run price elasticity of supply in commodity markets (see Newell et al. 2016).

The objective of this paper is to compare alternative indicators of global real economic activity and to assess their suitability for modeling industrial commodity markets. Our focus is not on quantifying the statistical relationships between these indicators, but on highlighting their conceptual differences and merits.[1] In section 2, we outline several criteria that help in choosing among alternative measures of global real economic activity. Section 3 reviews the commonly used measure of global real economic activity proposed by Kilian (2009a) and addresses several potential objections to the latter index that have been raised in the literature, including the role of changes in bunker fuel prices and of the shipbuilding cycle. We also investigate the determinants of the sharp decline in this index in early 2016. In section 4, we discuss the merits of proxies for global real output such as indices of world real gross domestic product (GDP) or industrial production as well as global steel production. In section 5, we discuss the use of indices of real commodity prices as proxies for fluctuations in global real economic activity. In section 6, we draw on a range of additional evidence including qualitative indicators to support the conclusion that there has been a sustained global economic slowdown in commodity markets since 2011.

[1] A number of studies have examined the contemporaneous correlation and lead-lag patterns among alternative indicators of global real economic activity and their relative predictive accuracy (see, e.g., Bakshi, Pamayotov, and Skoulakis 2011; Alquist and Coibion (2014); Baumeister and Kilian (2014a); Ravazzolo and Vespignani (2015); Tapia (2016)). These results, while of independent interest, are not immediately relevant for our analysis because they do not address the question of how to choose among these indicators.

The concluding remarks are in section 7. Although many of the qualitative results in the literature are robust to the choice of the indicator of global real economic activity, there are at times important differences in the timing and amplitude of global business cycle fluctuations. We stress the advantages of the Kilian (2009a) index of global real economic activity, of indices of real commodity prices and, to a lesser extent, of proxies for global industrial production compared with alternative indicators. Regardless of the measure chosen, there is broad-based evidence of a slowdown in global real economic activity since 2011.

2. How to Measure Global Real Economic Activity When Modeling Commodity Prices?

It is widely understood that the real prices of most commodities are determined in global markets subject to the forces of demand and supply.[2] The demand side of commodity markets tends to be competitive. One of the main determinants of the real price of commodities is shifts in the demand for commodities associated with unexpected fluctuations in global real economic activity. A global business cycle boom tends to lift all real commodity prices, whereas a slowdown of the global business cycle tends to lower them. Kilian (2009a) refers to demand shifts associated with unexpected fluctuations in the global demand for all industrial commodities as aggregate demand shocks (not to be confused with the notion of a shift in the domestic aggregate demand curve in macroeconomic models).[3]

This is not to say that aggregate demand shocks are the only demand shocks affecting real commodity prices. Demand may also shift over time, as consumer preferences or technologies change. For example, the demand for rare earths was stimulated by advances in

[2] This has not always been the case. For some commodities, global markets did not exist until recently; in other commodity markets prices were regulated or constrained by contractual agreements (see, e.g., Alquist et al. 2013, Jacks and Stürmer 2016).
[3] The extent to which a shift in the aggregate demand for global commodities results in shifts in the domestic aggregate demand curve and the domestic aggregate supply curve (and, conversely, the extent to which shifts in these curves shift the global demand for commodities) is a question that continues to be studied (see, e.g., Baumeister and Kilian 2017).

computer technology, while the demand for pork bellies and whale oil has greatly diminished, as consumer tastes have evolved. Moreover, storage demand may fluctuate in response to shifts in expected real commodity prices or in response to shifts in the uncertainty about future real commodity prices (see Alquist and Kilian 2010; Kilian 2009a; Kilian and Murphy 2014; Kilian and Lee 2014; Knitel and Pindyck 2016). The latter channel also allows nonfundamental beliefs to affect the real price of commodities. Nevertheless, a large body of literature based on a range of different models and data has concluded that the bulk of commodity-price fluctuations not only since the 1970s, but for the last 150 years has been driven by shifts in aggregate demand (see, e.g., Barsky and Kilian 2002; Kilian 2009a; Lippi and Nobili 2012; Baumeister and Peersman 2013; Kilian and Hicks 2013; Kilian and Murphy 2014; Alquist and Coibion 2014; Delle Chiaie, Ferrara and Giannone 2016; Knittel and Pindyck 2016; Jacks and Stürmer 2016; Stürmer 2018). This conclusion, of course, hinges on our ability to accurately measure fluctuations in the global business cycle. Thus, the question of how to measure cyclical variation in global real economic activity is paramount in modeling global commodity markets.

2.1. Global Real Activity Is Not Global Demand

Indicators of global real economic activity are sometimes incorrectly referred to as proxies for global demand. This practice is common in government reports, but also in academic papers. It is important to understand why this terminology is misleading. In the standard model of demand and supply, demand shifts by construction are not directly observable. One can observe only equilibrium prices and quantities. Measuring aggregate demand shifts requires both data on global real economic activity and a structural model of demand and supply in the commodity market that takes account of the fact that each of the variables in the model responds to all demand and supply shocks, not only to aggregate demand shocks. Moreover, each model variable, including global real economic activity, endogenously depends on lagged values of all model variables. These facts must be taken into account in modeling the determination of real prices in global commodity markets and in interpreting fluctuations in global real economic activity.

2.2. How to Measure Global Real Activity

Although this question arises frequently in applied work, there is no universal agreement on how to measure cyclical variation in global real economic activity. A popular approach has been the use of an index of global real activity constructed with the help of ocean dry bulk cargo freight rates, as proposed by Kilian (2009a). This index is related to a broader literature, originating in the 1930s, on using indices of ocean shipping rates such as the Baltic Dry Index (BDI) as proxies for fluctuations in real economic activity.[4] Some macroeconomists instead lean toward using proxies for global real GDP, while others favor using measures of global industrial production (see, e.g., Manescu and van Robays 2014, Baumeister and Peersman 2013). An alternative approach has been to focus on global steel production (see Ravazzolo and Vespignani 2015). Yet another proposal has been to rely on qualitative indicators of the state of the global economy constructed from business surveys. Examples include the J.P. Morgan Global Manufacturing PMI and the CESifo Index of the Global Economic Climate. There has also been increased interest in recent years in extracting measure of the global business cycle from the real prices of selected commodities, building on insights in Barsky and Kilian (2002). Prominent examples include Kilian (2009a), Alquist et al. (2013), Alquist and Coibion (2014), Delle Chiaie et al. (2016), and Newell et al. (2016). Finally, in closely related work, some researchers have proposed to measure the component of the price of commodities associated with fluctuations in

[4] Examples include Isserlis (1938), Tinbergen (1959), and Stopford (1997).

global economic activity based on regressions of the change in the nominal commodity price on contemporaneous changes in nominal copper prices, changes in the nominal dollar exchange rate, and possibly other variables (see Hamilton 2014; Bernanke 2016).

Table 1 provides a systematic overview and comparison of the indicators of global real economic activity discussed in the literature. There are important differences between these alternative indices, not only in the span of time covered by each index, in their geographic coverage, and in whether the data are available at monthly or only at quarterly frequency, but in how suitable these proxies are for modeling shifts in the aggregate demand for industrial commodities in particular. There are six criteria, in particular, that an index of global real economic activity used in modeling global industrial commodity prices should satisfy:

a. The coverage of the index must be global. Of particular importance is the inclusion of emerging Asia starting in the 2000s, without which the surge in global demand for commodities since 2003 cannot be understood. The same concern with global coverage also arises when constructing an index for the 1950s and 1960s because even many of the industrialized countries lack reliable data at monthly and quarterly frequency prior to the 1970s.

b. The index should account for structural changes in the composition of global real output. Of particular concern is that in many countries, over time, the weight of the service sector in real GDP has greatly increased at the expense of the industrial sector. Because the industrial sector is more intensive in the use of raw materials than the service sector, the correlation between traditional measures of global output such as world real GDP and the real prices of commodities tends to be unstable over time. Similarly, the introduction of new technologies in the industrial sector may undermine the stability of the correlation between global real output and the real prices of commodities.

c. Industrial production requires raw materials as an input in the production process. Many of these raw materials are industrial commodities that must be ordered and shipped well in advance of the start of the production process because shipping takes time. Thus, in modeling commodity prices, we need a leading indicator for global industrial production rather than a coincident indicator. The amplitude of this leading indicator may be far greater than the amplitude of fluctuations in industrial output because the demand for commodities, at the time when the commodity is shipped, reflects firms' expectations of future production.

d. The index must span a long enough time period to facilitate the estimation of structural models. This is not only a question of the precision of the estimates. Being able to study commodity markets across many different episodes also helps isolate the distinct effects of each demand and supply shock. If there is not enough variation in the data, as is likely to be the case when working with short samples, it will not be possible to reliably estimate these effects. In modeling the global market for crude oil, for example, one typically requires data back to 1973.

e. Monthly indices are preferred over quarterly or annual indices because the use of monthly data facilitates the imposition of identifying assumptions in structural models of commodity markets.

f. If the index is to be used for forecasting, it must also be available in real time.

As the next sections show, some measures of global real economic activity proposed in the literature come closer to meeting these requirements than others. Section 3 examines the perhaps most widely used measure of global real economic activity, due to Kilian (2009a). A number of alternative empirical measures of global real economic activity that have been proposed in the literature are reviewed in sections 4 and 5.

3. Kilian's (2009a) Index of Global Real Economic Activity

The global real economic activity index of Kilian (2009a), shown in Figure 1, is an index of cyclical variation in global real economic activity based on percentage changes in representative single-voyage ocean shipping freight rates available for various bulk dry cargoes, consisting of grain, oilseeds, coal, iron ore, fertilizer, and scrap metal, further differentiated by the size of the vessel and the shipping route. These rates of growth are averaged and adjusted for inflation and for the long-run trend in the cost of the shipping, which reflects mainly the increased size of ships.

3.1. Interpretation

The Kilian index in Figure 1 is constructed as a business cycle index and, hence, must not be differenced or otherwise transformed. It is important to stress that the level of the Kilian index has no intrinsic meaning. Rather, the presumption is that variation in the volume of shipping of industrial commodities is proportionate to variation in this index.[5] Note that Kilian (2009a) does not propose to use the price of the commodity of interest as a measure of its quantity, but rather takes changes in the cost of shipping of that commodity as a proxy for shifts in the volume of shipping of industrial raw materials.[6] This idea has a long history in economics and is commonly used in measuring historical business cycles (see, e.g., Isserlis 1938; Tinbergen 1959). As documented by Stopford (1997), at low levels of freight volumes the supply curve of shipping is relatively flat in the short and intermediate run, as idle ships may be reactivated or active ships may simply cut short layovers and run faster. As the demand schedule for shipping services shifts due to increased economic activity, the slope of the supply curve becomes increasingly steep and freight rates increase. At full capacity the supply curve becomes effectively vertical, as all available ships are operational and running at full speed. Thus, sustained increases in bulk

[5] Although there are some data for the volume of global trade in recent years, these data cannot be used to assess the empirical plausibility of the Kilian index because they include mainly manufactured goods rather than industrial raw materials.

[6] This shipping is in turn linked to the production of manufacturing goods and manufacturing trade, as stressed by Kilian (2008), Baumeister and Kilian (2017) and Khalil (2017), among others.

dry cargo shipping rates are commonly viewed as being indicative of aggregate demand pressures in global commodity markets. Likewise, a drop in global aggregate demand for commodities would be expected to lower bulk dry cargo shipping rates.

This is not to say that all fluctuations in this index of global economic activity reflect shifts in aggregate demand. Obviously, additional shipbuilding may shift the supply of ships and lower freight rates. In practice, much of this shipbuilding is triggered by higher global aggregate demand, with new ships often arriving at a time when the initial high levels of economic activity have already subsided.[7] Such dynamics are best viewed as part of the propagation of an aggregate demand shock rather than as exogenous shocks to the supply of shipping. Following a global business cycle upswing, there is likely to be a rather drawn-out trough in the shipping market, as new ships are still being launched and excess capacity of shipping persists, long after the business cycle peak has passed. Only gradually over time, the scrapping of older ships and rising demand, as the business cycle recovers, offset this depression in the shipping market. This shipbuilding cycle serves to accentuate the upswing in the Kilian index caused by a commodity boom and to exaggerate the downswing caused by a commodity bust. Kilian (2009a), nevertheless, shows that the business cycle fluctuations implied by this index are consistent with anecdotal accounts of how the global business cycle affected commodity markets in the 1970s and 1980s, and Baumeister and Kilian (2012), among others, document that this index is useful in forecasting the price of oil.

One of the advantages of the Kilian index is that it may be constructed as far back as January 1968, although it is likely to be reliable only starting in the mid-1970s due to the limited availability of disaggregate bulk dry cargo ocean shipping freight rates in the late 1960s and early 1970s. The primary data source underlying the Kilian index is the monthly report on

[7] For a formal analysis of this point see also Greenwood and Hanson (2015).

Shipping Statistics and Economics published by Drewry Shipping Consultants Ltd.[8] Construction of the index is complicated by the fact that the raw data from this source must be recorded manually. Since 2007, the Kilian index has therefore been updated by the author based on the growth rate of the BDI rather than the average growth rates of the nominal bulk dry cargo rates in Drewry's Shipping Monthly. The BDI is a commercially available average of nominal global bulk dry cargo shipping freight rates, which tends to track the data constructed in Kilian (2009a) closely, when both are available. Unlike the Kilian (2009a) data, however, the BDI is only available starting in 1985.[9]

Kilian's (2009a) index of global real economic activity has four important advantages over alternative measures of global real economic activity such as global real GDP and global industrial production. First, it gives proper weight to emerging economies; it does not require exchange-rate or purchasing-power-parity (PPP) weighting; and it automatically incorporates shifting country weights, changes in the composition of real output, and changes in the propensity to import industrial commodities for a given unit of real output. It also avoids the use of inadequate data from emerging economies.

Second, the Kilian index is a coincident indicator with respect to the volume of shipping in global commodity markets and responds instantaneously to shifts in the aggregate demand of industrial commodities, which facilitates the identification of such demand shifts. This makes the

[8] These data are more appropriate than related shipping price indices such as the Harpex index provided by Harper Peterson and Co., which focuses on the cost of leasing container ships and which – after being deflated and suitably detrended – may be considered an indicator for the global consumption of finished goods. Because the latter type of index is not directly related to the shipping of industrial raw materials, because container shipping rates are typically contracted forward rather than in spot markets, and because this index is not available prior to 1986, we do not consider it.

[9] Whereas Kilian (2009a) averaged the growth rates of single voyage dry bulk cargo freight rates by vessel size, cargo, and destination, the BDI is constructed as the unweighted average of average time charter rates for ocean-going dry bulk cargo vessels of certain vessel sizes (Capesize, Panamax, Supramax and Handysize), adjusted by a multiplier that changes when shipping routes or vessel sizes are added or removed from the calculation of the BDI. Unlike the Kilian index, the BDI makes no allowance for U.S. CPI inflation or trends in U.S. dollar- denominated shipping rates. Hence, it is not an index of global real economic activity.

Kilian index a leading indicator with respect to global real output, unlike global industrial production, which is a coincident indicator. Coincident indicators for global real output (such as global industrial production) by construction tend to misidentify the timing of shifts in aggregate demand in commodity markets. Moreover, changes in the stock of raw materials held by governments and firms may further weaken the link between the volume of shipping in global commodity markets and changes in global industrial production.

Third, the Kilian index also recognizes that the amplitude of fluctuations in the volume of shipping in commodity markets may be far higher in some episodes than the amplitude of the fluctuations in global real GDP or industrial production. The reason is that, unlike measures of real output, the volume of commodity shipping may respond to shifts in expectations about future levels of industrial production. For example, following the outbreak of the financial crisis, the volume of iron ore shipping on the Great Lakes dropped dramatically, consistent with a sharp drop in the Kilian index, while U.S. real output remained comparatively stable. Finally, it should be noted that the Kilian index, unlike measures of global industrial production or global real GDP, may also be constructed in real time (see, e.g., Baumeister and Kilian 2014a).

3.2 Potential Objections to the Kilian Index of Global Real Economic Activity

Notwithstanding the many advantages of the Kilian index, as reviewed in section 3.1, there are a number of drawbacks. Notably, the index does not allow for changes in the size of the active fleet as ships are taken out of service and laid up, and it does not allow for changes in the utilization rate of active vessels (which may vary their speed of operation). In addition, a number of authors have criticized the Kilian index for allegedly failing to take into account the dependence of bulk dry cargo rates on the cost of bunker fuel (and hence on the price of oil) and on the shipbuilding cycle, arguing that this index is no longer relevant after 2011 and that its implication of a global economic slowdown after 2011 is counterfactual. The remainder of this section provides a detailed analysis of the merits of these critiques.

3.2.1. The Role of Bunker Fuel Prices

One objection has been that the BDI (and by implication the Kilian index) by construction depends on the price of oil because ships run on bunker fuel, the price of which depends on the price of crude oil (see, e.g., Odom 2010; Manescu and Van Robays 2014; Ravazzolo and Vespignani 2015). It has been pointed out that changes in the real price of oil have predictive power for the index of real economic activity, a fact that is readily apparent from the original analysis in Kilian (2009a). This fact is sometimes misinterpreted as evidence that changes in the price of oil cause changes in bulk dry cargo shipping rates. Critics suggest that this result constitutes evidence of reverse causality from the change in the real price of oil to global real economic activity, invalidating the construction of structural VAR models of the commodity markets. In other words, they are concerned with the lack of exogeneity of the Kilian index. Usually, this argument is followed by the recommendation to replace the Kilian index by a measure of global real GDP or global industrial production.

Closer examination reveals that this argument is flawed. Not only does predictive evidence not necessarily imply that there is a causal relationship, as discussed in Kilian and Lütkepohl (2017), but no indicator of global real economic activity (including world real GDP and industrial production) is exogenous with respect to the real price of oil. All of these indicators can be predicted based on past changes in the real price of oil. In fact, there is nothing wrong with measures of global real activity being predictable based on changes in the real price of oil, given that exogeneity is not required for structural modeling, and there is nothing to choose between alternative measures of global real economic activity in this regard.

More importantly, framing this problem as one of reverse causality is misleading. The link between global real economic activity and the real price of oil cannot be understood without recognizing that these variables are simultaneously determined in a structural model. For example, a positive shock to the aggregate demand for all industrial commodities raises both real economic activity and the real price of oil at the same time, inducing precisely the type of positive co-movement that causes changes in the real price of oil to predict global real economic activity as well as global real economic activity to predict changes in the real price of oil. Yet, there is no causal link from changes in the real price of oil to global real economic activity in that case. Thus, evidence of Granger causality from changes in the real price of oil to the Kilian index of global real economic activity does not undermine the validity of the index.

If one wants to make the case for a causal link from changes in the real price of oil to the price of bunker fuel, from there to the BDI, and ultimately to the Kilian index of real activity, one must identify exogenous variation in the real price of oil caused by shocks other than aggregate demand shocks (such as oil supply shocks or shocks to storage demand driven by political turmoil in the Middle East) and show that this variation has quantitatively important effects on the Kilian index. An instructive example is provided by the episode of January 1970 to February 1974, which includes both a period of comparatively stable oil prices in the early 1970s and the quadrupling of the price of oil in late 1973 (see Kilian 2006). Figure 2 plots the Kilian index against an index of U.S. bunker fuel rates constructed from data in the *Oil and Gas Journal*. Figure 2 establishes three facts: First, there were substantial fluctuations in the Kilian index, even when the real price of oil was essentially flat during 1970–73. Second, the pass-through from the real price of oil to bunker fuel prices was extremely weak during this episode. Third, when the bunker fuel price finally rose in early 1974, the Kilian index fell.

An even better example is provided by the invasion of Kuwait in 1990, which was followed by a large spike in the real price of crude oil. This price spike was clearly driven by an exogenous political event. Figure 3 shows that both the real price of crude oil and the real price of U.S. No. 6 residual fuel oil, which is an important component of bunker fuel, jumped in late 1990, but the index of global real economic activity did not. In fact, the index fell slightly. We conclude from these two examples that there is no evidence in support of the argument that the global index of real economic activity is driven by exogenous variation in the real prices of oil and bunker fuel.

Upon reflection, this result is not surprising. Bunker fuel is a residual product. It is the residue left after more valuable fuels have been extracted from crude oil, it has few competing uses, and it is not traded globally. Thus, its price need not move one-for-one with the global price of crude oil. Moreover, the cost share of crude oil in producing bunker fuel is clearly below one, as is the cost share of bunker fuel in operating a dry bulk vessel. Few carriers provide much insight into their cost structures. Some recent studies and press reports postulate cost shares in bulk dry cargo shipping between 40% and 70%, but the source of these numbers is unclear because shipping companies rarely reveal this type of information. One credible source is data recently released by the container carrier CMA CGM for 2014–15, which shows bunker fuel cost shares of between 16% and 24%, which may be taken as a lower bound on the bunker fuel cost share for bulk dry cargo carriers, given the higher density and weight of bulk dry cargo.

Suppose the share of bunker fuel in the cost of dry bulk shipping were 25%. Then, even assuming perfect pass-through from an exogenous decline in the real price of oil to the price of bunker fuel, a 50% increase in the price of crude oil would only increase the cost of shipping by 12.5%: $0.25\times1.5+(1-0.25)\times1=1.125$. With incomplete pass-through, this effect would diminish further. The extent of the pass-through depends on the cost share of crude oil in producing bunker fuel. If this share were 50%, for example, the increase in the price of bunker fuel in the previous example would drop to 6%. While the precise numerical values of these shares may be debated, these simple back-of-the-envelope calculations provide additional intuition for why the role of exogenous shocks to the real price of oil in driving the index of global real activity is so small in the data.

The question of feedback from oil prices to freight rates becomes moot altogether to the extent that the Kilian index in recent years has been updated based on raw data for the BDI (which is constructed based on bulk dry cargo time-charter rates rather than single-voyage rates). The reason is that time charter rates by construction do not depend on bunker fuel costs. These costs are paid by the lessee of the vessel. Thus, by construction, there can be no direct feedback from the price of oil, except to the extent that both share a common demand component. Given that the original Kilian index closely tracks the evolution of the index updated based on the BDI data, when both indices are available, we may safely rule out direct feedback from oil price fluctuations caused by shocks other than aggregate demand shocks.

Finally, it is worth noting that the structural VAR methodology of Kilian (2009a) explicitly recognized the potential endogeneity of the index of global real economic activity. The only restriction placed on the model is there is no feedback from changes in the real price of oil within the current month. This identifying restriction is motivated by the fact that ocean carriers set fuel charges for single-voyage rates at the beginning of each quarter on the basis of the weekly average on each route over the preceding three months. As a result, bulk dry cargo ocean shipping rates are always responding after the fact, providing a natural delay restriction in the structural VAR model. Thus, the econometric analysis in Kilian (2009a) and related studies would remain robust even in the presence of quantitatively important feedback from exogenous changes in the real price of oil to global real economic activity, reinforcing our earlier conclusion that changes in bunker fuel prices may be ignored in the analysis of the Kilian index.

3.2.2. The Role of the Shipbuilding Cycle

A second objection to the use of the Kilian index is that changes in this index may arise from changes in the supply of bulk dry cargo carriers (see, e.g. Odom 2010). Although the supply of bulk dry carriers tends to be inelastic in the short run, high shipping rates provide an incentive for shipowners to place orders for additional bulk dry cargo vessels. Because the construction of these vessels may require two or three years to complete, they often enter service at a point in time, at which the demand for shipping services has already subsided. The resulting excess capacity in the shipping market lowers bulk dry cargo freight rates below the rate that would have prevailed if the fleet size had remained constant. This problem of excess capacity resolves itself over time, as less efficient bulk dry carriers are gradually scrapped. In the end, the fleet size adjusts. This shipbuilding cycle is well documented in the literature. It can be traced to the work of Tinbergen (1931), Stopford (1997), and Glen and Martin (2005), among others. As discussed earlier, Kilian (2006, 2009a) was fully aware of this issue, but made the case that his index of global real economic activity nevertheless provides a good approximation to the global business cycle for the purpose of modeling commodity markets.

This conclusion has been called into question, following the sustained decline in the BDI (and, hence, in the Kilian index of global real economic activity) since 2011, with some observers claiming that the BDI no longer provides a useful indicator of the state of the global economy. The central question raised in this debate has been whether the decline in the BDI and in the Kilian index after 2010 reflects a genuine economic slowdown in global commodity markets or is an artifact of excess capacity in global bulk dry cargo shipping markets. Much of the discussion of this evidence has been informal, with little distinction being made between ocean carriers of different types such as container vessels, oil and LNG tankers, bulk carriers, reefers, and more specialized carriers of chemicals (see, e.g., Ready, Roussanov, and Ward 2017). Often press articles make vague references to a shipbuilding spree in some country, to changes in the capacity of a country's shipyards, or to the number of vessels ordered by a given country in recent months. It is therefore useful to examine the relevant data in more detail.

The upper panel of Figure 4 shows the evolution of the global fleet size of bulk dry cargo carriers since 1973, measured in deadweight tons (dwt).[10] The data source is Clarkson Research. The plot shows that the bulk dry cargo fleet size has steadily increased over time, especially since 2005. Between early 2005 and the end of 2016, the bulk dry cargo fleet increased in size by 86% cumulatively, which translates to an average annual rate of growth of 5%. This growth, of course, must be viewed relative to the overall growth of the global bulk dry cargo market over the same period. One way of controlling for this trend is to normalize the change in the fleet size relative to its long-run average growth rate. The middle panel of Figure 4 shows that the global bulk dry cargo fleet size has evolved quite smoothly over time and has been remarkably stable relative to trend, generally remaining between +/–20% of the trend line. During 1975–91 and during 2010–16, the size of the bulk dry cargo fleet grew faster than on average. During the early 1970s and between 1990 and 2010, it grew more slowly.

The lower panel of Figure 4 displays the evolution of the Kilian index of global real economic activity over the same period. It is immediately apparent that the fluctuations in this

[10] The definition of bulk (dry cargo) carriers includes ocean-going as well as Great Lakes vessels that are larger than 10,000 deadweight tons (dwt). Tankers, container ships, liquefied gas or petroleum carriers, chemical carriers, and reefers (refrigerated carriers) are excluded. The bulk carrier fleet size declines to the extent that bulk carriers are scrapped. Inactive and laid-up vessels, however, are included in the stock, which therefore overstates the effective fleet size.

index must be driven mainly by the demand side of the shipping market, because the supply of bulk dry carriers is quite smooth over time, whereas the index of global real economic activity is not. This does not mean that changes in shipping capacity did not contribute to the lower-frequency movements of the index, but that this effect is likely to be of secondary importance. In related work, Odom (2010) attributes the fall in the BDI (and thus in the Kilian index) after mid-2008 to a combination of lower demand for bulk dry cargo shipping and higher supply of bulk dry cargo carriers. This conjecture is implausible, however, because the fleet size increased smoothly in 2007–08, whereas the index fell sharply in the second half of 2008, consistent with a sharp fall in global demand caused by the financial crisis. Nor can the continued increase in the fleet size of bulk dry cargo carriers after the crisis explain the equally rapid recovery in the index of global real economic activity in 2009.

3.2.3. Why Is There a Negative Spike in the Index in Early 2016?

A striking feature of the Kilian index of real economic activity is the large and unprecedented negative spike in the index in February and March 2016 (see Figure 1). Since there is no evidence of a similar negative spike in other indicators of the global business cycle, an obvious concern is whether this spike is perhaps spurious. It can be shown that this drop in the Kilian index is associated with a sharp decline in the BDI, which dropped by 41% in only two months. A very similar cumulative decline would have been obtained based on the average change in single-voyage dry bulk cargo freight rates, as reported in Drewry's *Shipping Insight*. It is immediately clear that this negative spike is not an artifact of the increase in the fleet size of bulk dry cargo vessels. Not only did the supply of vessels not suddenly increase in early 2016, as shown in Figure 4, but the decline in the BDI in February 2016 was quickly reversed, which rules out this explanation.

Closer inspection of the ocean freight rate data provided by Drewry's *Shipping Insight* shows that this drop in the BDI was mainly driven by a decline in iron ore freight rates and, to a lesser extent, in coal freight rates, in particular for the largest vessels used for intercontinental trade. Iron ore in 2015 accounted for 79% of bulk dry cargo trade, with coal coming in a distant second at 19%. Much of the world's iron ore is transported to China, which accounts for half of the world's steel production. Coal is an additional input in producing steel.

One telltale sign that the sharp drop in the BDI may indeed be an indication of a sharp reduction in the volume of dry bulk cargo trade is that, between December 2015 and February 2016, the dollar value of Chinese imports of iron ores and concentrate dropped by 37%. Given a simultaneous increase in the IMF price of iron ore by 14%, this implies a 45% drop in the volume of Chinese iron ore imports in just two months. This sharp drop was followed by a sustained increase in the volume of iron imports between February 2016 and December 2016. The 45% drop in the volume of Chinese iron ore imports between December 2015 and February 2016 is in the same ballpark as the 41% drop in the BDI over the same period, lending some credence to the BDI data and hence to the Kilian index of global real economic activity.[11]

This is not to say that traditional measures of global real output such as world industrial production and world real GDP would be expected to show a similar negative spike. As emphasized earlier, the latter indicators are not designed to capture changes in the volume of commodities traded, but changes in overall real output. Thus, this example underscores the point that the choice of the indicator of global real activity matters in modeling global commodity

[11] In light of this new evidence, one may be concerned that the BDI in recent years has become overly exposed to idiosyncratic shocks in the market for iron ore, as alternative bulk dry cargoes such as scrap metal, phosphate, fertilizer, and oil seeds have diminished in importance in the construction of the BDI. Given that the shipping rates considered in the BDI are representative for world trade of bulk dry cargo, however, there is no a priori presumption that the drop in the BDI in early 2016 is not representative of a temporary decline in the volume of trading in global industrial commodity markets.

markets. To the extent that observers recently have questioned the use of freight rates data for predicting real output and stock markets, our analysis explains why these observers should not necessarily have expected a tight relationship between the BDI and these macroeconomic variables in the first place.

An interesting question is why Chinese iron ore import volumes fell so dramatically in early 2016. A partial explanation is a major industrial accident in the Samarco iron ore mine in Brazil in November 2015. Brazil is a major supplier of iron ore to China. Because of this accident, Chinese steel producers did not have to honor their long-term contracts for the purchase of Brazilian iron ore and the volume of shipping dropped. The accident suddenly and permanently reduced world trade in iron ore by about 4%.[12] Thus, part of the 41% decline in the BDI can be explained by an exogenous shift in iron ore supply. The remaining drop in the BDI, however, in the absence of other iron ore supply shocks must be driven by a reduction in global demand.

The fact that iron ore prices rose in the months after the Samarco mine accident at first may seem inconsistent with a reduction in the demand for iron ore. This is not the case, since the reduction in demand for iron ore coincided with a reduction in the supply of iron ore. It can be shown that, as long as the demand for iron ore is less price elastic than the supply of iron ore, a simultaneous reduction in both demand and supply on balance may result in higher iron ore prices, as observed in the data. Since there is general agreement that the supply of iron ore is fairly price inelastic, this explanation requires the demand for iron ore to be even more inelastic.

[12] This fraction is computed as follows. We add the total production of iron ore and pellets in 2015Q3 from the Samarco mine in millions of metric tons, as reported in *Vale's Quarterly Production Report*. We then scale this number by four to annualize production. We further multiply the result by two to account for the fact that Vale only owns half of this mine. The resulting loss in total production of 59.7 million metric tons accounts for 16.3% of Brazil's iron ore exports, as reported by www.statistica.com. We weight this number by Brazil's share in global iron ore exports of 24.2%, as reported by www.statistica.com, and round the result to 4%.

Recent studies of the global crude oil market show that the price elasticity of oil demand is distinctly higher than the price elasticity of oil supply (see, e.g., Kilian and Murphy 2014). The reason why the iron ore market is likely to be different is the tendency of Chinese steel producers to rely on long-term contracts that create secure supply chains, which makes demand very inelastic in the short run. Thus, much of the negative spike in the BDI and hence in the global real economic activity index in early 2016 appears to reflect a temporary reduction in demand. Although the indirect evidence for a temporary decline in the demand from China is strong, the precise causes of this reduction are not known. Indeed, the causes are likely to be manifold, including changes in regulations in China and skepticism about the level of future demand for steel.

Even granting that the Kilian index has become more sensitive to major iron ore supply disruptions than when it was proposed, reflecting the increasing weight on iron ore and coal freight rates in the index, we conclude that there is no compelling evidence that the relationship between this index and the volume of commodity shipping has broken down. It may seem that the negative spike in early 2016 would necessarily imply a decline in real commodity prices as steep as that during the financial crisis of 2008. This is not the case, however. For example, when re-estimating the global oil market model of Kilian (2017) on data extending to 2017.8, the negative spike in the Kilian index in 2016 has little effect on the evolution of the real price of oil, in sharp contrast to the large decline in the real price of oil associated with the drop in the Kilian index in late 2008.

4. Alternative Measures of Global Real Economic Activity

The Kilian index was explicitly proposed as an alternative to the use of more traditional indices of global real economic activity such as proxies for global real GDP or for global industrial production. In this section we assess the merits of using these measures of global real output as proxies for global real economic activity in models of commodity markets. We also discuss an alternative proxy based on global steel production.

4.1. Quarterly World Real GDP

In the 1960s, 1970s, and 1980s, a common perception was that U.S. economic growth effectively determined global economic growth, allowing us to use the former as a proxy for the latter (see, e.g., Gerlach 1988). If this perception was ever valid, it certainly has not been valid for a long time. As shown in Kilian and Hicks (2013), no country in the world accounts for more than 20% of global real output. For example, the U.S. economy alone by 2009 represented less than 20% of global real GDP. The member countries of the Organization for Economic Co-operation and Development (OECD) accounted for 51% of global real GDP and the BRIC countries (Brazil, Russia, India, China) jointly accounted for 29% (with China alone contributing 16 percentage points). In short, there is no substitute for using truly global measures of real economic activity. We cannot use real output in any single country (or a single bloc of countries) as a proxy for global real output. Indices of global real GDP are therefore constructed from PPP-weighted average of individual countries' real GDP growth rates, typically measured at quarterly frequency, although the OECD recently has developed a monthly measure as well (see section 4.3). One common proxy for quarterly global real GDP is reported by the World Bank. The construction of the World Bank series is not clear, but visual inspection of this series suggests that it closely tracks the PPP-weighted measure for 144 countries constructed by Stratford (2013). The World Bank global real GDP data cover all World Bank member countries, including China since 1992.[13]

There are several obvious drawbacks of quarterly real GDP measures. First, structural models of commodity markets tend to rely on monthly data, because it is easier to come up with credible identifying restrictions at the monthly frequency than at the quarterly frequency (see, e.g., Kilian 2009a, Kilian and Murphy 2014). Hence, measures of quarterly real GDP are of limited use in modeling global commodity markets. Second, commonly used quarterly global real GDP data are only available starting in 1990Q1 or 1991.Q1, depending on the source. These time series are too short to estimate typical structural models of commodity markets.

Third, even in a world in which the real price of commodities is entirely determined by global aggregate demand, there is no reason to expect correlations between changes in global real GDP and changes in real commodity prices to be stable. The reason is that countries' propensity to import commodities differs depending on whether real GDP growth is driven by growth in the service sector or growth in the industrial sector. As is well known, the percent contribution of the service sector to global real GDP has steadily risen since the 1970s, as the share of the goods-producing sector has declined. Between 1970 and 2015, the share of private services in U.S. value added increased from 51.8% to 74.1%. At the same time, the share of private-goods producers declined from 31.4% to 18.9%. Since the service sector is less dependent on imports of industrial commodities than the industrial sector, one would not expect a stable statistical relationship between changes in real GDP and changes in real commodity prices even under idealized conditions, making measures of the cyclical variation in global real

[13] Until recently, the IMF provided an alternative measure of quarterly global real GDP in its IFS database. That series was discontinued in 2013. Because the IMF series differs substantially from alternative PPP-weighted global real GDP indices in the literature and because it is no longer available, it is not considered in this paper.
A related measure is the quarterly PPP-weighted index of real GDP in the OECD economies reported in the *OECD Main Economic Indicators*, but that measure excludes most emerging economies and hence is not suitable for the analysis of global commodity markets. For example, Kilian and Hicks (2013) document that by 2009 the OECD share in global value added had fallen to about one half.

GDP a poor proxy for global real economic activity in modeling commodity markets. A better proxy would be industrial production, as discussed in section 4.2. Although this evidence is for the United States only, there is every reason to believe that the same problem arises more generally in other countries.

Fourth, global real GDP is a coincident indicator for fluctuations in global real economic activity. In contrast, measures of global real economic activity designed to capture shifts in the demand for industrial commodities by construction must be leading indicators for latent fluctuations in global real output. The reason is that fluctuations in global real economic activity require industrial raw materials as inputs. If inventories of these commodities primarily serve as insurance against supply disruptions, the industrial commodities to be used in production must be shipped before production can increase. Hence, real activity in global commodity markets peaks before global real GDP peaks (see, e.g., Tapia 2016). As a result, changes in coincident indicators such as global real GDP (or for that matter global industrial output) are not capturing the timing of shifts in the demand for industrial commodities correctly.

Fifth, the construction of global real GDP measures is complicated by the fact that for many economies quarterly real GDP data are not available for the entire sample period. For example, we know that, starting in the early 2000s, economies in emerging Asia played an important role in driving the demand for global commodities (see Kilian and Hicks 2013). Yet there are no accurate data for Chinese real GDP, for example. There is also the concern that suspiciously smooth and high Chinese real GDP growth rates, especially after the end of the Chinese growth boom, may reflect political mandates more than economic realities (see, e.g., Holz 2014; Wallace 2015). Even for countries with readily available real GDP growth rates, moreover, it is often difficult to construct accurate PPP weights. Thus, commonly used indicators of global real GDP are only crude measures of global real value added.

Sixth, in measuring cyclical variation in global real GDP, the user must decide how to model the trend in the data. Whereas there is no ambiguity about how the trend is removed in constructing the Kilian index, different users have made different choices when it comes to the detrending of global real GDP measures.[14] Common approaches include expressing global real GDP as deviations from a log-linear trend, as log deviations from the smooth trend line implied by the Hodrick-Prescott (HP) filter, as quarter-by-quarter growth rates or as year-by-year growth rates (see Figure 5). The latter approach tends to be incompatible with the measurement of other variables in structural models of commodity markets. Which specification one uses affects how much of the variation in the data is considered cyclical and how much is considered the trend. For example, the upper panel of Figure 5 suggests that, by the end of 2016, global real GDP relative to trend declined to levels last seen during the Great Recession, whereas the lower panel of Figure 5 suggests that year-on-year real GDP growth was near average by the end of 2016.

Finally, it should be noted that it is not possible to construct real-time measures of global real GDP measures, which calls into question their use in simulated out-of-sample forecasting exercises, but does not affect their usefulness in structural modeling.

4.2. Monthly Global Industrial Production

There are two immediate advantages of focusing on PPP-weighted measures of global industrial production. First, industrial production data are available at monthly frequency and, second, they focus on variation in industrial production, which is more closely linked to fluctuations in the global demand for industrial commodities. As in the case of measuring global real GDP, it is

[14] It should be noted that the downward trend in real shipping rates, which reflects increasing returns to scale in shipping, is inherently different from the upward trend in real output, which reflects a wide range of determinants. There is no reason for the trends or the appropriate trend models to be the same in both cases.

important not to use the OECD measure of OECD industrial production. Instead, we focus on the PPP-weighted measure of OECD+6 industrial production reported by the OECD in its *Main Economic Indicators*, which includes data for six non-OECD emerging economies (China, India, Brazil, Russia, South Africa and Indonesia) starting in 2006.[15]

Although superior to measures of OECD industrial production, the OECD+6 industrial production indicator is not without its own limitations. First, it is a coincident indicator rather than a leading indicator, which undermines our ability to identify shifts in the aggregate demand for industrial commodities. Second, we know that starting in the early 2000s economies in emerging Asia played an important role in driving the demand for global commodities, yet there are no data for Chinese industrial output or for that matter for most other emerging economies included in the OECD+6 measure prior to 2006. Likewise, there are no industrial production data even for many advanced countries in the early part of the sample period covered by the index.

Third, there are some inconsistencies in the construction of the OECD+6 measure of industrial production. Industrial production is a measure of gross output rather than value added. Some countries (such as China) do not have official industrial production statistics. China, for example, only reports value added in industry (defined as gross output in industry minus the cost of factor inputs), which is incompatible with gross output measures for other countries. Clearly, the growth rate of value added in industry is not the same as the growth rate of gross output in industry. Hence, any PPP-weighted index based on such data is an imprecise measure of global industrial production. Finally, like its real GDP counterpart, the OECD+6 industrial production index is not suitable for real-time forecasting.

In addition, as in the case of global real GDP, much depends on how the trend is

[15] The construction of this indicator was discontinued by the OECD in 2012, but the time series has been updated by Baumeister and Hamilton (2015) based on the PPP weights reported in the IMF's World Economic Outlook database.

extracted from the OECD+6 industrial production index. One common approach is to express OECD+6 industrial production in log-deviations from a linear deterministic time trend. Alternatively, we can express this index in month-by-month growth rates or year-on-year growth rates. The former representation is more conducive to econometric modeling, whereas the latter highlights persistent changes in the index. A priori it is not clear whether growth rates or log-linear trend deviations are the more appropriate econometric representation of this index. Yet another approach is to focus on log-deviations from a smooth trend in OECD+6 industrial production, as measured by the HP filter. This is the approach used in constructing the OECD leading economic indicator, as reported in the *Main Economic Indicators*. The underlying reference series traditionally has been OECD+6 industrial production (see Gyomai and Guidetti 2012). The HP-filter approach is considered problematic by econometricians because it may create spurious cycles and hence undermine the identification of aggregate demand shocks (see, e.g., Diebold and Kilian 2001, Canova 2014; Hamilton 2017).

As Figure 6 shows, the choice of detrending method can have substantial effects on the estimated degree of cyclical variation. For example, in the middle panel of Figure 6, the global economy appears stronger after the financial crisis than it was before the crisis, whereas in the upper panel the recovery is much weaker. The HP-filtered data in the bottom panel of Figure 6, in contrast, tends to over-smooth during major economic expansions or contractions. It often understates the amplitude of the business cycle relative to alternative measures and paints a different picture of the relative magnitudes of peaks and troughs.[16]

4.3. Monthly World Real GDP

[16] The OECD somewhat misleadingly refers to this index as the "OECD leading economic indicator" for world real GDP, but from our point of view this industrial output gap series is better viewed as a coincident indicator of the business cycle in OECD+6 industrial production.

As mentioned earlier, one of the drawbacks of global real GDP measures in the literature is that they are only available at quarterly or annual frequency. Recently, the OECD published a monthly proxy for global real GDP constructed from PPP-weighted real GDP growth rates.[17] This time series has been used, for example, by Manescu and van Robays (2014). Its coverage is not truly global, but includes all OECD member countries. After 2006 it also includes six non-OECD emerging economies (China, India, Russia, Brazil, South Africa and Indonesia).

Note that the Bureau of Economic Analysis does not release monthly U.S. real GDP data. Nor are there such data for China and other important economies, even in recent years.[18] It is clear therefore that the OECD must have constructed this index by some form of interpolation, so the index must be viewed with caution.[19] Leaving aside these concerns, Figure 7 illustrates why this monthly real GDP measure should not be used for modeling commodity markets. Compared with the corresponding OECD+6 industrial production index, it not only greatly underestimates the amplitude of the business cycle, but it may also indicate an expansion, when the corresponding industrial production measure is below the trend, or indicate below-trend output, when the industrial production measure is above trend.

4.4. Global Steel Production as a Proxy for Global Real Economic Activity

Since the publication of Kilian (2009a), a number of alternative proxies for global real economic activity has been proposed. One example is the measure of global crude steel production

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[17] This series recently has also been used as the reference series in constructing the OECD Leading Economic Indicator, reported in the *OECD Main Economic Indicators*.

[18] Unofficial measures of monthly U.S. real GDP constructed similarly to the official quarterly data have recently been provided by Macroeconomic Advisers, LLC. These time series are currently only available for a small subset of our sample, however.

[19] As noted by Gyomai and Guidetti (2012), until March 2012, the OECD composite leading indicator relied on a monthly index of industrial production as the reference series rather than on quarterly real GDP. In March 2012, the OECD investigated the feasibility of generating its own monthly estimates of real GDP based on the official quarterly estimates. Based on this investigation, from April 2012 therefore the OECD has switched to using real GDP as the reference, ceasing to rely on the industrial production.

proposed by Ravazzolo and Vespignani (2015). The data are readily available from the World Steel Association. The aggregation of crude steel production by country is facilitated by the fact that crude steel is comparatively homogeneous. Thus, no PPP weighting is required. Nor do these data have to be deflated. Total global production of crude steel is measured in thousands of tons (see upper panel of Figure 8). The major steel producer in the world by far in recent years has been China. Chinese steel production is included in total production starting in 1990.[20]

The rationale for this proposal is simple. Steel is an important input for many industries including construction, transportation, and manufacturing. Because crude steel is produced from iron ore, the production of crude steel is a key determinant of the demand for iron ore, which is one of the key industrial commodities in the world. For example, iron ore is one of the commodities included in the metals price indices discussed in section 5. Likewise, the Kilian index of real economic activity covers iron ore carriers as one of several types of bulk dry cargo carriers. The lower panel of Figure 8 shows the evolution of log-linearly detrended and deseasonalized global steel production since January 1990. Unlike the original index developed by Ravazzolo and Vespignani (2015), our data are not measured in real time because our focus is not on out-of-sample forecasting. Ravazzolo and Vespignani's proposal is to treat this time series as a proxy for fluctuations in global real economic activity more broadly. Effectively, we are treating one component of the global industrial production index as a proxy for the entire index.[21]

One obvious advantage of this proxy is that the data are available monthly and are easily measured. There are also several drawbacks, however. For example, total global steel production is more susceptible to supply shocks than a broad-based index would be, it ignores changes in

[20] It can be shown that the global steel production data in the *World Steel Association Yearbook* for 1993 and 2002 are incorrect in the original source due to transcription errors. We were informed by the World Steel Association that the original data are no longer available. These data were replaced by monthly data collected from earlier monthly publications of the World Steel Association by Francesco Ravazzolo and Joacquin Vespignani.
[21] This approach can be traced back to the early literature on measuring business cycles (see, e.g., Macaulay (1938)).

iron ore inventories, the data must be deseasonalized, and no data are available prior to 1979. In fact, only the data since 1994 appear usable in practice, for reasons explained below. Thus, this measure of global real economic activity is of limited use in modeling commodity markets.

By far the biggest concern with this measure is that the number of steel-producing countries included in the crude steel production statistics has varied over time. For example, in 1990 fourteen additional countries were added, in 1991, thirteen more countries, and in 1992 another eleven countries. Since 1992 the number of countries has been fluctuating between 61 and 67. This fact matters because crude steel production is not an index, but a measure of the physical production of crude steel in thousands of tons. When the number of countries included in this count changes, the level of production changes discontinuously by construction, distorting the measure of global crude steel output. For example, the increase from 29 to 43 countries in 1990 is reflected in a readily apparent structural break in the upper panel of Figure 8. Even after restricting attention to data since 1990, as in Ravazzolo and Vespignani (2015), the number of countries covered by the World Steel Association statistics ranges from 43 in 1990 to 67 in 2016. Although one could address the problem of structural breaks by restricting the sample to the initial set of countries, this would defeat the purpose of constructing a global measure of steel production.

These concerns may be mitigated to some extent by restricting attention to the period since January 1994. During this period, the number of steel-producing countries fluctuated between 61 and 67, reducing the distortions in the World Steel Association measure of the evolution of the global production of crude steel. Figure 9 shows that the resulting proxy for global economic activity shares many of the characteristics of the global real economic activity index of Kilian (2009a). In fact, the contraction in global crude steel production in late 2008 was even more pronounced than in the global real economic activity index. The main difference is that global steel production suggests a stronger global economy between 2011 and 2013 than the global real economic activity index and that it does not mirror the sharp drop in early 2016.

5. Common Factors in Industrial Commodity Prices

Another alternative to the Kilian index is the use of changes in real industrial commodity prices. In some cases, this involves the use of cumulative changes in selected commodity prices such as monthly real iron ore or real copper prices (see, e.g., Baumeister and Kilian 2016b, Newell et al. 2016), but more commonly one uses broad monthly indices of real industrial commodity prices or common factors extracted from a wide range of monthly real commodity prices (see, e.g., Barsky and Kilian 2002, Kilian 2009b, Baumeister and Kilian 2012, Alquist and Coibion 2014, Delle Chiaie et al. 2016). The latter approach has the advantage that supply shocks in individual commodity markets tend to be idiosyncratic and hence average out, when considering a large cross-section of changes in real commodity prices. Thus, sustained changes in broad-based indices of real commodity prices tend to be indicative of aggregate demand pressures.

For example, Barsky and Kilian (2002) interpreted the strong comovement of the real price of oil and a real price index of industrial raw materials and metals as evidence of a common demand component in both prices. Baumeister and Kilian (2012) and Alquist, Kilian and Vigfusson (2013), among others, documented that cumulative changes in equal-weighted indices of industrial raw materials prices have predictive power for the price of crude oil. In fact, these predictors largely capture the same predictive information as the Kilian index of real economic activity (see Baumeister, Kilian and Lee 2014). Alquist and Coibion (2014) proposed a factor model of level of selected real industrial commodity prices rather than relying on simple averages. In closely related work, Delle Chiaie et al. (2016) estimate the common factor in percent changes in real industrial commodity prices including the real price of crude oil.

Like the Kilian index of real economic activity, the use of broad-based indices of or common factors in real commodity prices has the advantage that the data are available in real time at monthly frequency and that these price fluctuations are instantaneous indicators of aggregate demand pressures. Also like the Kilian index, the resulting indices have no intrinsic quantitative meaning, but can only be interpreted as being proportionate to the underlying business cycle fluctuations. A potential drawback of commodity price indices is that they may be sensitive to how the commodity price trend is modelled and may require additional smoothing. For example, Alquist and Coibion (2014) apply an HP-filter to their monthly common factor to reduce the noise in the estimate. Delle Chiaie et al. (2016) report cumulative changes in their common factor estimate, which facilitates the interpretation, but is at odds with the construction of standard structural models of commodity markets.

In measuring global real activity based on common factors in commodity prices it is important to extract the common factor from the real prices of these commodities. This approach not only avoids capturing the common inflation component in dollar-denominated commodity prices, but is in line with standard microeconomic models of demand and supply. Whereas the question of whether to construct common factors from the log-detrended or log-differenced data is likely to be of lesser practical importance, the choice of the commodity prices to be included in the model is central. As discussed on Alquist and Coibion (2014), there are four criteria for including a commodity price series in the construction of the common factor. First, the commodities to be evaluated must not be vertically integrated to minimize the danger of an idiosyncratic shock in one commodity market being passed on to another market. This fact suggests excluding food commodities, fertilizer and energy commodities from the construction of the common factor. It also suggests excluding commodities that are closely related such as soybean meal and soybean oil. Second, one should exclude commodities such as gold and other precious metals that behave more like financial assets than industrial commodities. Third, one should exclude derivative products that are recovered in the process of mining or producing another commodity. Finally, one has to exclude commodities that are not freely traded in spot markets, but whose price is determined by long-term agreements and remains fixed for extended periods (such as the price of iron ore until 2009 or the price of oil prior to 1973).

How important imposing each of these constraints is in practice, remains an open question at this point. For example, Baumeister and Kilian (2014b) present evidence that the pass-through from shocks to the price of crude oil to many other commodity prices may be safely ignored, suggesting that there may be efficiency gains in estimating the global factor by including the real price of crude oil as in Delle Chiaie et al. (2016). Moreover, the use of block factors in specifying the factor model, as practiced by Delle Chiaie et al. (2016), may alleviate some of the concerns raised by Alquist and Coibion (2014). Here we focus on the common factor estimate of Delle Chiaie et al. (2016) and the deflated IMF index of metals prices.[22]

Figure 10 plots the real IMF index of metals prices in deviations from trend and cumulative growth rates against the Kilian index of global real economic activity. Very similar results hold for the IMF global price index of industrial inputs (which includes agricultural raw materials but excludes crude oil) and for the IMF global price of copper.[23] As Figure 10 illustrates, there are many similarities between these series, but also some differences. The same

[22] The IMF commodity price data are similar, but not identical to the monthly commodity price data reported by the World Bank starting in 1960, facilitating the construction of commodity price indices back to the early 1970s. We do not report results for the alternative commodity price indices provided by the Commodity Research Bureau (CRB) because the latter assign increasing weight to the price of crude oil in recent years, making it difficult to interpret the time series.
[23] In constructing the global price index, the individual prices are weighted based on export earnings.

conclusion holds for the year-on-year growth rates in the global commodity price factor constructed by Delle Chiaie et al. (2016), shown in Figure 11, but the latter specification appears to track the Kilian index of global real economic activity more closely overall than the real IMF commodity price index in Figure 10.

In related work, Hamilton (2014) and Bernanke (2016) recently postulated that copper prices, interest rates and the value of the dollar are good proxies for “global demand,” allowing them to estimate the global demand component of the change in oil prices or the prices of other commodities. It is important to reiterate in this context that global demand is unobservable. Indeed, their approach is not designed either to measure global demand or, for that matter, to quantify fluctuations in global real economic activity. It is nevertheless useful to relate their approach to the use of real commodity price indicators of the type considered in this section.

Hamilton’s and Bernanke’s proposal is that we regress the percent change in the nominal price of oil on the contemporaneous percent change in selected nominal variables including copper prices, the value of the dollar, long-term interest rates, and possibly other variables. The fitted value from this static regression is interpreted as the change in the price of oil that reflects changes in global economic conditions. The strength of “global demand pressures” on the percent change in the price of oil is measured by the pairwise correlations with the regressors. The intuition underlying this approach is that when a change in the price of oil coincides with a similar change in the price of copper, for example, these changes must reflect a common global demand factor. This is indeed the same intuition that also motivates the use of indices of real commodity prices, and builds on the insights in Barsky and Kilian (2002). Of course, using a single commodity such as copper as a proxy for an index of all non-oil industrial commodities may not be a good idea, as discussed in section 5.

Another caveat regarding Hamilton's and Bernanke's approach is that positive correlations between nominal variables may arise simply from a common inflationary component. Thus, it would have been more appropriate to focus on correlations between changes in the real prices of crude oil and copper. Whether any correlation with changes in interest rates and the dollar exchange rate reflects global demand pressures is less clear. For example, changes in interest rates may also affect the supply side of commodity markets. Given that the fitted value from these regressions or, for that matter, the correlations implied by this regression are not a measure of global real economic activity, we do not consider this approach any further.

6. Has Global Real Economic Activity Slowed Down Since 2010 and by How Much?

The Kilian index declined from +40% relative to trend in 2010 to –60% in early 2015 and, ultimately, to –8% relative to trend by the end of 2016 (see Figure 1). Although these index numbers have no intrinsic meaning, as discussed earlier, they are indicative of a substantial deterioration in global real economic activity with far-reaching economic implications. How plausible is it that the cumulative decline in this index in recent years was driven by lower aggregate demand as opposed to overcapacity in the bulk dry carrier market, as some critics have suggested? That question may be answered to some extent by comparing the evolution of this index to that of other indicators.

6.1. Macroeconomic Indicators for China

It is widely recognized that the demand for industrial commodities in recent years has been heavily influenced by the growth of the Chinese economy. One piece of evidence consistent with a global economic slowdown since 2011 is the decline in the year-on-year growth in China's real GDP reported by the National Bureau of Statistics. Figure 12 shows that China's real GDP growth recovered to about two-thirds of its level prior to the global financial crisis by early 2010, followed by a large and sustained decline. By mid-2016, year-on-year growth in China‘s real GDP had reached rates only slightly higher than in late 2008. In fact, several third-party estimates of China's year-on-year growth suggest that official growth estimates for China after 2012, in particular, are systematically inflated. For example, the data provider Capital Economics, based on data such as cargo freight volumes, estimates that the actual year-on-year Chinese real GDP growth in recent years has been closer to 5% than to 7%, implying a decline well below the trough of late 2008. Likewise, The Conference Board's alternative estimates of Chinese real GDP growth are on average 2% lower during 2011–16 than the official growth rates. In fact, during the trough of 2015, Chinese GDP growth averaged only 3.5%, according to The Conference Board, well below the 6% estimate during the Great Recession of 2008. These estimates are supportive of a global economic slowdown in industrial commodity markets since 2011.

Figure 13 shows complementary evidence based on one component of China's real GDP. It shows the year-on-year growth in the real value added by China's industrial sector. For comparison, the figure also plots the Kilian index of global real economic activity, whose amplitude has been adjusted to match that of the Chinese data. Figure 13 shows that there is a fair degree of comovement between these two series. One key difference is that both the decline in Chinese industrial growth in 2008 and its recovery in 2009 were more pronounced than the corresponding movements in the global index of real economic activity. This is not surprising, because the global index reflects the state of the global economy rather than merely that of China's economy. Even more importantly, Figure 13 highlights that China's industrial growth, after fully recovering in 2009, declined sharply starting in late 2010. That decline continued for five years. By late 2015 the year-on-year growth had fallen about as low as during the height of the global financial crisis. Thus, Figure 13 again provides strong evidence in support of the sustained decline in the Kilian index since 2011.

An alternative metric of the state of China's economy in recent years is provided by data on electricity consumption. Because electricity cannot be stored easily, Chinese electricity consumption may be approximated by official data on electricity production. Figure 14 highlights a close statistical association between detrended electricity production in China and the suitably scaled index of global real economic activity. The cumulative decline in China's electricity production between 2010 and 2016 actually exceeds that in the index of global real economic activity. A plausible conjecture is that China's electricity production staying below the Kilian index during 2003–05 and staying above that index between 2011 and 2013 may reflect excess capacity in bulk dry cargo shipping and a shortage of vessels, respectively. This does not affect the overall result of a persistent global economic slowdown after 2011, however.

6.2. Survey-Based Qualitative Global Indicators

An alternative set of indicators of the state of the global economy in recent years is monthly survey data such as J.P. Morgan's global Purchasing Managers' Index (PMI) or the CESifo index of the current world economic climate (see, e.g., Stratford 2013). Survey indices simply indicate the percentage of positive responses among the private sector manufacturing firms responding to the survey. Unlike the quantitative measures of the global business cycle discussed earlier, these survey data are qualitative nor are they available for extended time periods, which is why we have abstracted from these data so far. Nevertheless, these data may be used to corroborate evidence from quantitative indicators.

Figure 15 shows the demeaned ISM U.S. Manufacturing Index of Export Orders. Although this index does not account for additional demand for industrial commodities arising from construction (such as iron ore and copper), one would expect export orders to be correlated with real economic activity in global industrial commodity markets (see Khalil 2017). Of course, the amplitude of fluctuations in this index cannot be compared with that of the Kilian index of global real economic activity. We can, however, compare the sign of these two indices, with positive values indicating a global economic expansion and negative values indicating a contraction. Figure 15 provides additional support for a global economic slowdown after 2010, consistent with the implications of the Kilian index. It shows a high degree of comovement in the sign of the two indices since the 2000s. In fact, the probability of the sign of the ISM index matching the sign of the Kilian index of global real economic activity is 78%.

Table 2 documents that related survey-based indices such as the CESifo Index of the Current World Economic Climate and the output and export order components of the J.P. Morgan Global Manufacturing PMI are also positively correlated with the Kilian index to varying degrees. The probability of a matching sign ranges from 64% to 67% for measures of real output and from 71% to 78% for measures of export orders, which are likely to be better proxies for conditions in global industrial commodity markets (see Khalil 2017).

6.3. Commodity Price Indicators

An alternative indicator of changes in real economic activity in commodity markets is the cumulative change in real commodity prices. Table 3 documents sustained real declines between mid-2010 and the end of 2015 not only in an index of industrial raw materials prices (excluding crude oil) maintained by the IMF (–40.9%), but in particular in an index of industrial metals prices (--51%). For example, the real price of copper, which Newell, Prest and Vissing (2016) consider a proxy for global real economic activity, declined by 38%, while the real price of iron ore, which was used as an indicator of global real economic activity in Baumeister and Kilian

(2016b), declined by 77%, mirroring a 54% decline in the real price of Brent crude oil, consistent with a broad-based decline in the demand for industrial commodities.[24] This conclusion is reinforced by the cumulative index of the monthly global real commodity price factor estimated by Delle Chiaie et al. (2016), which between February 2011 and January 2016 declined to levels only slightly higher than in late 2008 during the height of the global financial crisis.

6.4. Traditional Proxies for Global Real Economic Activity

An interesting question is what the evidence for a sustained decline in global real economic activity is based on traditional proxies for global real output such as world real GDP or OECD+6 industrial production. Notwithstanding the many drawbacks of these traditional proxies in modeling commodity prices, one would expect a major economic slowdown in commodity markets over a five-year period to be reflected in a sustained decline in global industrial production and real GDP.

This is indeed what the data show, but the interpretation of the data depends to some extent on how the data are transformed. For example, log-linearly detrended world real GDP by late 2016 had declined to a level last seen in 2008 during the global financial crisis or equivalently in the early 1990s (see Figure 5). A similar sustained global economic slowdown may be seen even in log-linearly detrended OECD+6 industrial production data. Figure 6 shows that the industrial production index has steadily declined relative to trend from 2012 to the end of 2016, reaching levels last seen in the early 1980s. The main difference compared with the Kilian index of global real economic activity is that there is much less evidence of a recovery in world real GDP in 2009. This difference is likely to reflect the fact that the overall economy responds

[24] Given the cost share of crude oil in producing diesel fuel, given the cost share of diesel fuel in mining, and given our earlier evidence on the effect of lower oil prices on bulk dry cargo ocean freight rates, it seems implausible that these commodity price declines were caused by lower costs for diesel fuel (for related analysis, see, e.g., Baumeister and Kilian 2014b, 2017).

to demand shocks more sluggishly than commodity markets. Likewise, Figure 5 shows that the year-on-year growth in world real GDP by 2016 had slowed to rates as low as in 2003, before the start of the global commodity price boom, consistent with a major economic slowdown. A very similar conclusion is supported by the OECD+6 year-on-year growth in industrial production in Figure 6. Thus, our findings of a sustained decline appear quite robust to the use of alternative measures of global real economic activity.

6.5. Summary

The question of whether real economic activity in global commodity markets has declined substantially since about 2010 is of obvious importance for the construction of models of commodity prices and for understanding and forecasting the evolution of commodity prices. We provided broad-based evidence that suggests that this decline is not an artifact of the construction of the Kilian index of global real economic activity. It cannot be explained simply based on excess capacity in the market for bulk dry cargo vessels. Rather it is supported by a range of other data including Chinese macroeconomic indicators, survey responses, and broad-based changes in real global industrial commodity prices, which cannot be explained based on changes in the supply of bulk dry cargo vessels. This decline is also consistent with the evolution of more conventional proxies for global real output.[25]

7. Concluding Remarks

The question of how changes in global real activity are related to fluctuations in real commodity prices is central for understanding commodity price fluctuations (see Barsky and Kilian 2002; Kilian 2009a; Kilian and Murphy 2014). The answer to this question is also crucial for assessing

[25] In addition, the sustained decline in the Kilian index after 2010 is consistent with evidence that overall trade growth declined from 7.4% at annual rates during 1995–2007 to 3.1% during 2012–15. At the same time, the income elasticity of trade for emerging economies fell by half from 1.5 to 0.8, signaling the end of a period of disproportionate growth in trade relative to real GDP (see Francis and Morel 2015; IRC Trade Task Force 2016).

the impact of commodity price shocks on commodity exporters and importers (see, e.g., Baumeister and Kilian 2017; Kilian 2017). Answering this question requires the construction of indicators of cyclical variation in global real economic activity. The purpose of this paper was to review the pros and cons of a number of alternative indicators of global real economic activity that have been used in modeling global commodity markets.

In modeling commodity markets, we usually require a monthly quantitative indicator of global real economic activity available as far back as the early 1970s. This requirement alone rules out measures of quarterly world real GDP as well as all qualitative indices in the literature. Related real output proxies for global industrial production such as global steel production are only available for a much shorter time span, and hence are not a practical alternative for our purposes. The same is true for alternative indicators of global real economic activity based on satellite imagery that have not been reviewed in this paper. Finally, we noted that the proxy for monthly world real GDP recently, which was recently developed by the OECD, is not well-suited for modeling global commodity markets.

This leaves three potential choices: (a) the Kilian (2009a) index of global real economic activity derived from bulk dry cargo shipping rates, (b) the PPP-weighted index of OECD+6 industrial production, and (c) various indices of global real commodity prices. Estimates of common factors in commodity prices are not always available back to the 1970s, but the equal-weighted index of real metals prices is, as is the index of the real price of copper.

Among these three choices, the Kilian index and indices of real commodity prices have the advantage of being leading indicators with respect to changes in latent global real output and of accounting for the role of expectations about the business cycle. Thus, they are better suited than other measures for capturing the timing and amplitude of fluctuations in the global business cycle, as they relate to global commodity markets. They are also designed to have broader coverage and to adapt automatically to various forms of structural change in the global economy that are not accounted for by OECD+6 industrial production. These advantages must be weighed against the fact that both real commodity price indices and the Kilian index may potentially be susceptible to commodity supply shocks. The Kilian index of global real economic activity and the bulk dry cargo shipping rate data underlying the construction of that index, as represented by the BDI, have also been criticized by some observers for being distorted by fluctuations in the real price of oil and by the ship-building cycle, especially after 2010. We demonstrated that the first argument is without merit, while the second argument does not appear quantitatively important.

Differences in how one measures the global business cycle can easily affect conclusions about the timing and magnitude of an economic slowdown or expansion, and using inappropriate proxies is likely to distort estimates of commodity market models and of price elasticities of supply. Our analysis supports the use of indices of real activity derived from dry bulk cargo freight rates such as the BDI as well as the use of indices based on real commodity prices, for example, but raises concerns about the use of measures of world real GDP and, to a lesser extent, of OECD+6 industrial production. This does not mean that traditional measures of word real GDP or world industrial production should never be used in empirical work, but rather that the intended use of these time series matters. Data that are appropriate for modeling cyclical fluctuations in global real output in macroeconomic models, for example, may not be appropriate for identifying shifts in the demand for global commodities, and conversely many indicators of global real economic activity in the literature are poor measures of fluctuations in global income. In modeling industrial commodity markets, for example, changes in the volume of shipping of industrial raw materials are a better proxy for global real activity than changes in the overall real output of the global economy because they more accurately capture the timing and magnitude of shifts in demand.[26] In contrast, in modeling food commodities such as wheat, corn, or rice, the case can be made that demand depends on global real income, making world real GDP a potentially more suitable measure of global real economic activity (see Jacks and Stürmer 2016).

This analysis is not merely academic; it sheds new light on an ongoing debate about the volatility of commodity prices and about how best to respond to commodity price fluctuations. When global commodity prices surged across the board after 2003, this increase was correctly attributed to an unexpected economic boom in emerging Asia, led by China (see, e.g., Kilian 2009a; Kilian and Hicks 2013). One of the questions raised at the time was whether this demand boom was driven by a permanent structural transformation of the Chinese economy, or whether it reflected a confluence of various transitory phenomena. Many observers at the time favored the view that real economic activity had increased permanently. Indeed, in 2009, global real commodity prices quickly recovered from the financial crisis. As we showed, however, starting in 2011, there was mounting evidence of a global economic slowdown. The precise timing and extent of this slowdown differs, depending on which indicator of global real economic activity one focuses on, but, by most accounts, the slowdown continued until early 2016, suggesting that the boom in real economic activity between 2003 to mid-2008 was indeed largely transitory rather than permanent.

One of the early warning signs of this global economic slowdown was a sustained decline in indicators of real economic activity based on bulk dry cargo shipping rates. Some observers

[26] Of course, such data are only available since the early 1970s. When working with long-run annual data as in Jacks and Stürmer (2016) and Stürmer (2018), for example, there is no alternative to the use of annual world real GDP data. At such low frequency, the identification of structural shocks in commodity market models tends to rely on long-run rather than short-run identifying restrictions, thus mitigating concerns about the timing of fluctuations in global real economic activity.

have attributed this decline to an increase in the supply of bulk dry cargo vessels and/or declines in bunker fuel rates as well as positive commodity supply shocks. They have questioned the continued use of shipping rate data for business cycle analysis and denied the existence of a global economic slowdown. The analysis in our paper suggests that these alternative explanations are either flawed or unable to explain the extent of the decline in bulk dry cargo shipping rates. We also provided complementary evidence based on alternative indicators of global real economic activity that supports the existence of a persistent global economic slowdown between 2010 and 2016.

This finding has important implications for the modeling of global commodity markets in general. First, our analysis suggests that, judging by the data available at the end of 2016, the demand boom in emerging Asia is likely to have been a persistent, but ultimately transitory phenomenon, much like the persistent demand booms in the early 1970s and in the late 1970s and early 1980s (see, e.g., Barsky and Kilian 2002; Jacks and Stürmer 2016; Stürmer 2018). An interesting question for future research will be to identify in more detail the determinants of the boom in global real activity in the 2000s. Second, our analysis implies that, all else equal, low real commodity prices are likely to persist, which constrains the policy options available to commodity producers and exporters (see, e.g., Kilian 2017).

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Table 1a: Overview of Alternative Indicators of Global Real Economic Activity: Measures of Real Output

		Real GDP	Real GDP	Industrial Production	Leading Economic Indicators	Crude Steel Production	Index of Global Real Economic Activity
Measurement:	Qualitative						
	Quantitative	**X**	**X**	**X**	**X**	**X**	**X**
Frequency:	Monthly		**X**	**X**	**X**	**X**	**X**
	Quarterly	**X**		**X**	**X**	**X**	**X**
Coverage:	Global	**X**				**X**	**X**
	OECD+6[2]		**X**	**X**	**X**		
Available Since:		1990.I	1970.I	1973.1	1973.11	1994.1[1]	1968.1
Concept:	Gross Output					**X**	**X**
	Value Added	**X**	**X**				
	Mixture of Both			**X**	**X**		
Indicator:	Coincident	**X**	**X**	**X**		**X**	
	Leading				**X**		**X**
Real-time Version of Index Feasible:						**X**	**X**
Source:		World Bank	OECD, as reported in Manescu & van Robays (2014)	OECD, extended by Baumeister & Hamilton (2015)	OECD	World Steel Association	Kilian (2009a), updated by the author

NOTES: A more detailed description of each indicator can be found in the text.

[1] After discarding unreliable data.

[2] Coverage includes all OECD member countries. Since 2006, additional data for the non-OECD countries China, India, Brazil, Russia, South Africa and Indonesia have been incorporated.

Table 1b: Overview of Alternative Indicators of Global Real Economic Activity: Real Commodity Price Indices

		Index of Real Metals Prices	Global Real Commodity Price Factor	Global Real Commodity Price Factor	Index of Real Copper Price	Index of Real Iron Ore Price
Measurement:	Qualitative					
	Quantitative	**X**	**X**	**X**	**X**	**X**
Frequency:	Monthly	**X**	**X**	**X**	**X**	**X**
	Quarterly	**X**	**X**	**X**	**X**	**X**
Coverage:	Global	**X**	**X**	**X**	**X**	**X**
	OECD+6					
Available Since:		1980.1	1981.12	1968.1	1980.1	2009.1[1]
Concept:	Gross Output	**X**	**X**	**X**	**X**	**X**
	Value Added					
	Mixture of Both					
Indicator:	Coincident					
	Leading	**X**	**X**	**X**	**X**	**X**
Real-time Version of Index Feasible:		**X**	**X**	**X**	**X**	**X**
Source:		IMF, World Bank since 1960.1	Delle Chiaie et al. (2016) based on IMF data	Alquist & Coibion (2014) based on IMF, CRB, etc., data	IMF, World Bank since 1960.1	IMF

NOTES: See Table 1a.

Table 1c: Overview of Alternative Indicators of Global Real Economic Activity: Qualitative Indicators

		CESifo Current World Economic Climate	J.P. Morgan Global Manufacturing PMI: Output	J.P. Morgan Global Manufacturing PMI: Export Orders	ISM U.S. Manufacturing Export Orders
Measurement:	Qualitative	**X**	**X**	**X**	**X**
	Quantitative				
Frequency:	Monthly		**X**	**X**	**X**
	Quarterly	**X**	**X**	**X**	**X**
Coverage:	Global	**X**	**X**	**X**	**X**
	OECD+6				
Available Since:		1990.I	1998.1	1998.1	1988.1
Concept:	Gross Output	**X**	**X**	**X**	**X**
	Value Added				
	Mixture of Both				
Indicator:	Coincident	**X**	**X**		
	Leading			**X**	**X**
Real-time Version of Index Feasible:					
Source:		CESifo	J.P. Morgan/ HIS Markit	J.P. Morgan/ HIS Markit	ISM

NOTES: See Table 1a.

Table 2: Consistency of the Sign of the Global Real Economic Activity Index with Qualitative Survey-Based Indicators of the Global Business Cycle

Qualitative Indicators	Probability of Matching Sign (%) 1998.I–2016.IV
CESifo Current World Economic Climate	64
J.P. Morgan Global Manufacturing PMI: Output	67
J.P. Morgan Global Manufacturing PMI: Export Orders	71
ISM U.S. Manufacturing Export Orders	78

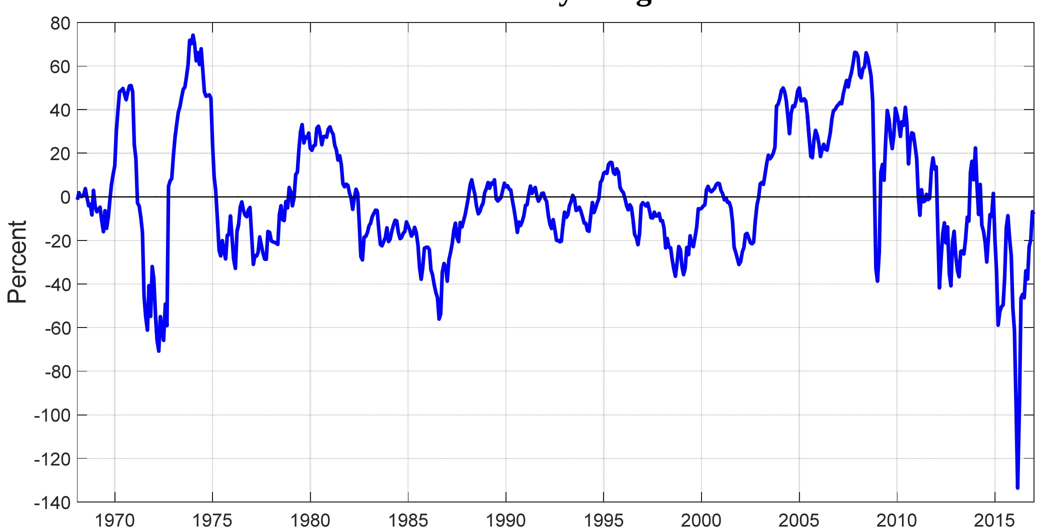
NOTES: The table reports the fraction of quarters, during which both the quarterly average of the global real economic activity index of Kilian (2009a) and the qualitative index in question are in agreement that the global economy is expanding or are in agreement that it is contracting.

Table 3: Cumulative Percent Change in Real Global Commodity Prices, 2010.5–2015.12

Global Commodity Price Index	Cumulative Change in Real Price (%)
Industrial Raw Materials Price Index	-40.93
Metals Price Index	-51.46
Copper Price	-38.12
Iron Ore Price	-76.87
Brent Price of Crude Oil	-54.32

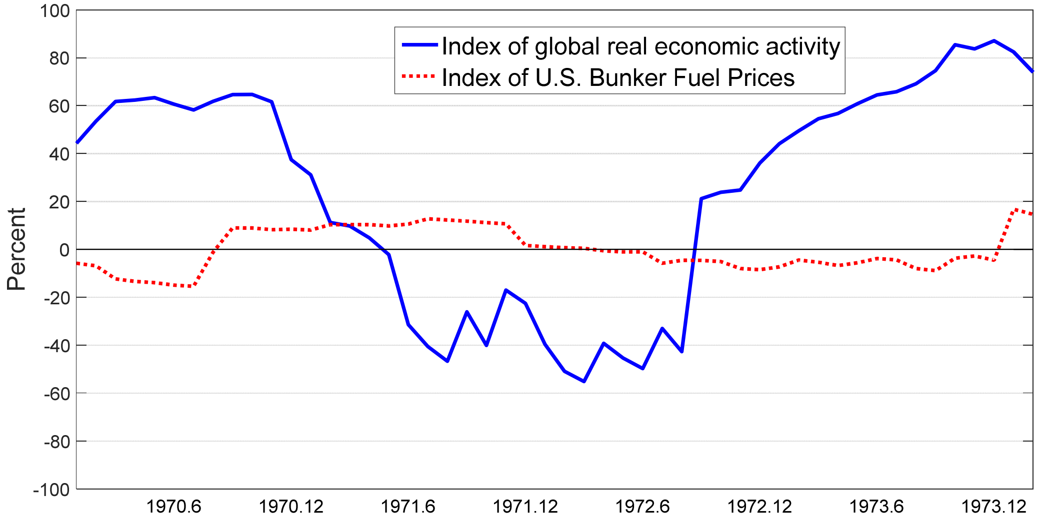
NOTES: All commodity price data but the Brent price of oil are from the IMF, and the Brent price is from the U.S. EIA. All prices have been deflated by the U.S. CPI.

Figure 1: Index of Global Real Economic Activity Derived from Ocean Shipping Rates for Bulk Dry Cargo



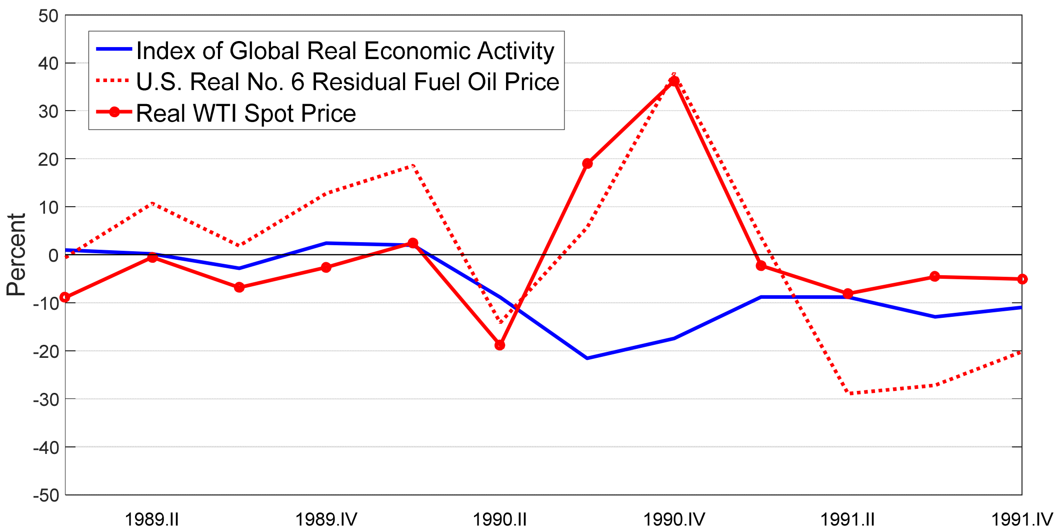
NOTES: Based on Kilian (2009a), as updated on http://www-personal.umich.edu/~lkilian/paperlinks.html.

Figure 2: Index of Global Real Economic Activity and Index of U.S. Bunker Fuel Prices, 1970.1–1974.2



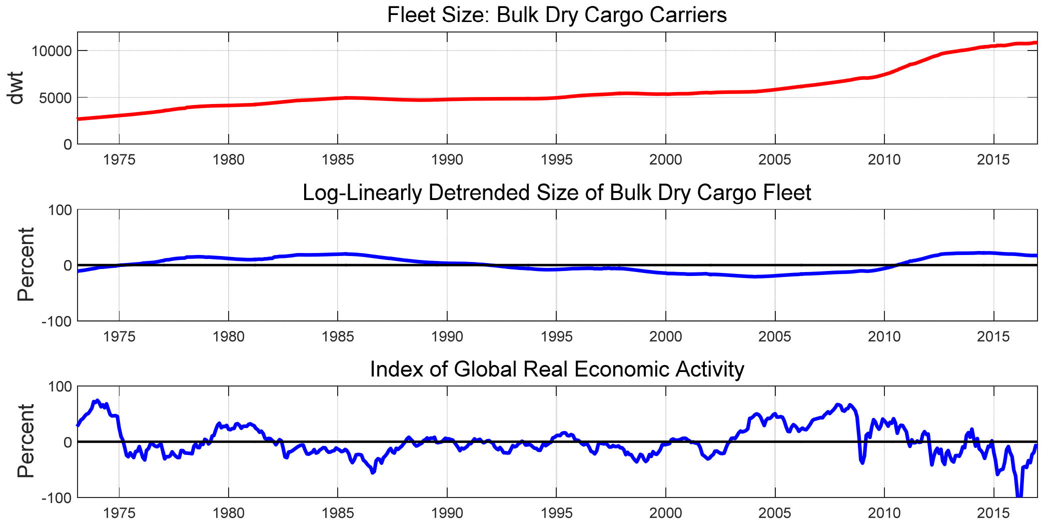
NOTES: The index of bunker fuel prices was constructed based on the average of the U.S. bunker fuel rates in four major U.S. ports, as reported in the *Oil and Gas Journal*. The index of global real economic activity is from Kilian (2009a).

Figure 3: Index of Global Real Economic Activity, Real WTI Price and Real Bunker Fuel Prices, 1989.I–1991.IV



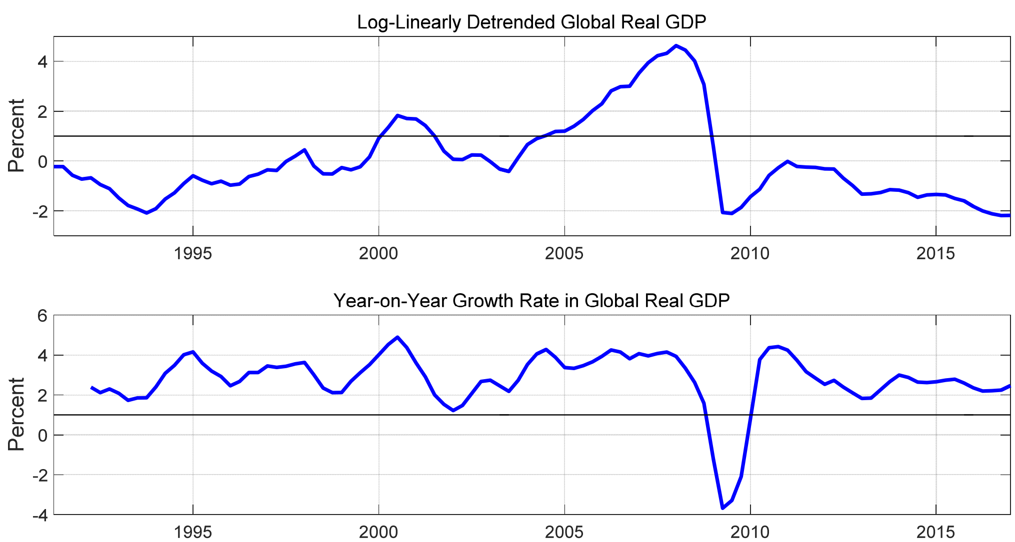
NOTES: No. 6 Residual Fuel Oil is the most common form of bunker fuel. Its quarterly price was obtained from the historical data section of selected issues of the U.S. Energy Information's (EIA) Short-Term Energy Outlook. WTI refers to West Texas Intermediate crude oil. The monthly WTI spot price was obtained from the U.S. EIA website and averaged by quarter. All prices have been deflated by the U.S. CPI and expressed as percent deviations from their sample average. The index of global real economic activity is from Kilian (2009a).

Figure 4: Fleet Size for Bulk Dry Cargo Carriers and Global Real Economic Activity, 1973.1–2016.12



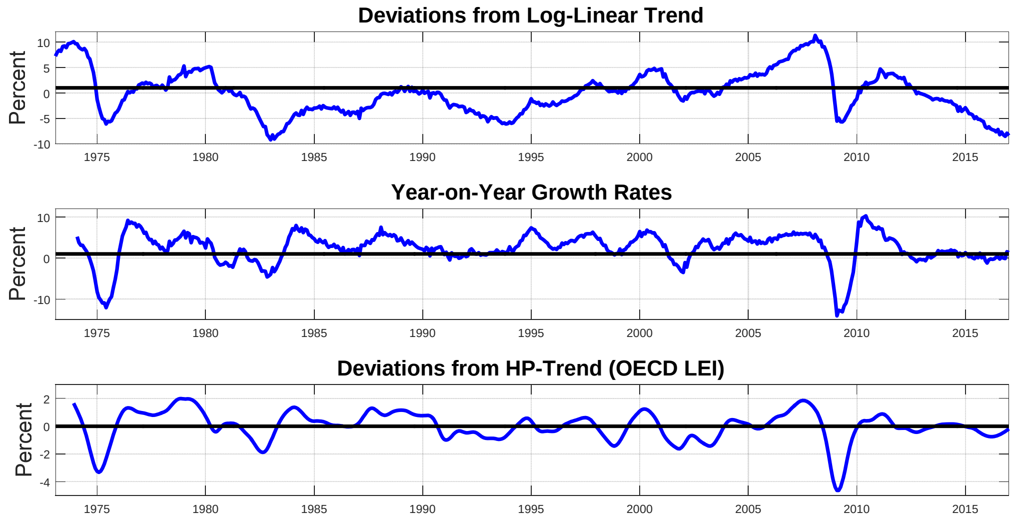
NOTES: The size of the global fleet of bulk dry cargo carriers is measured in dwt, as reported by Clarkson Research. These data are only approximate in that inactive or laid-up bulk carriers are included. The index of global real economic activity is based on Kilian (2009a), as updated on http://www-personal.umich.edu/~lkilian.

Figure 5: World Bank Estimate of Quarterly Global Real GDP, 1991.I–2016.IV



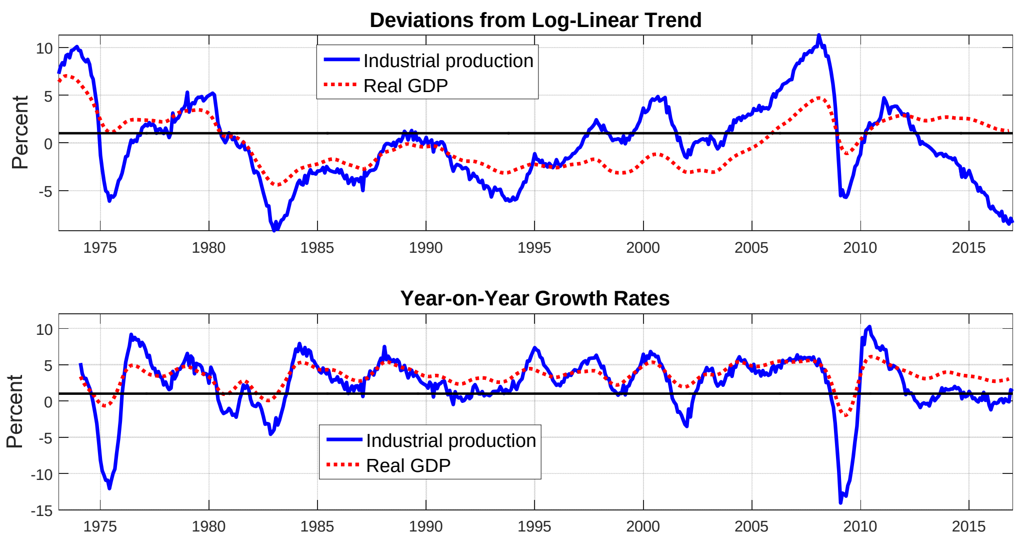
NOTES: The raw data are expressed in constant 2010 dollars and seasonally adjusted, as reported by the World Bank. The estimate covers all World Bank member countries. China is included after 1992.

Figure 6: OECD+6 Industrial Production, 1973.1–2016.12



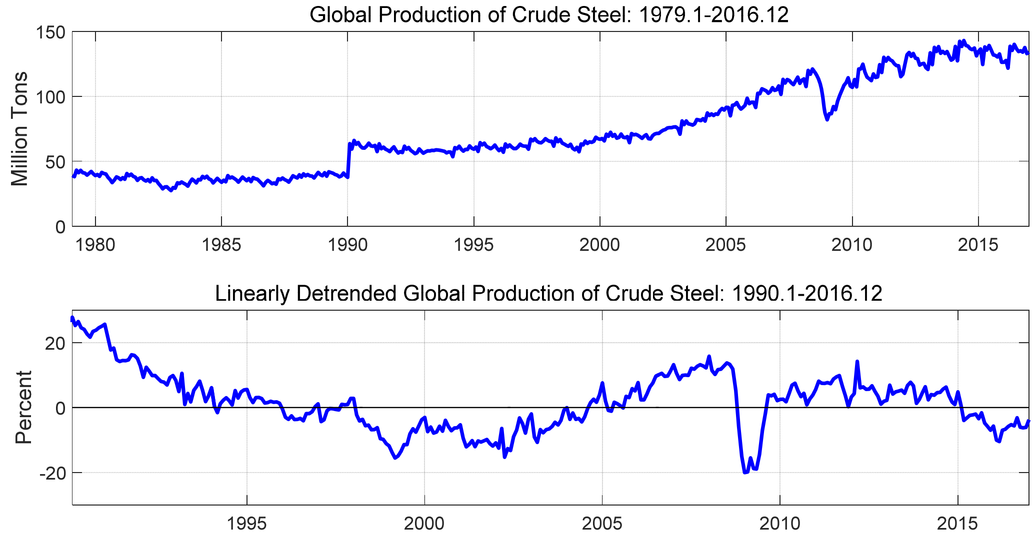
NOTES: The data are constructed as a PPP-weighted average of industrial production in the OECD member countries. Since 2006, additional data for the non-OECD countries China, India, Brazil, Russia, South Africa and Indonesia have been incorporated. This time series was discontinued by the OECD in 2012, but has been updated by Baumeister and Hamilton (2015). The OECD+6 leading indicator is obtained by HP-filtering the reference series for aggregate industrial activity.

Figure 7: Monthly Industrial Production and Real GDP for OECD+6, 1973.1–2016.12



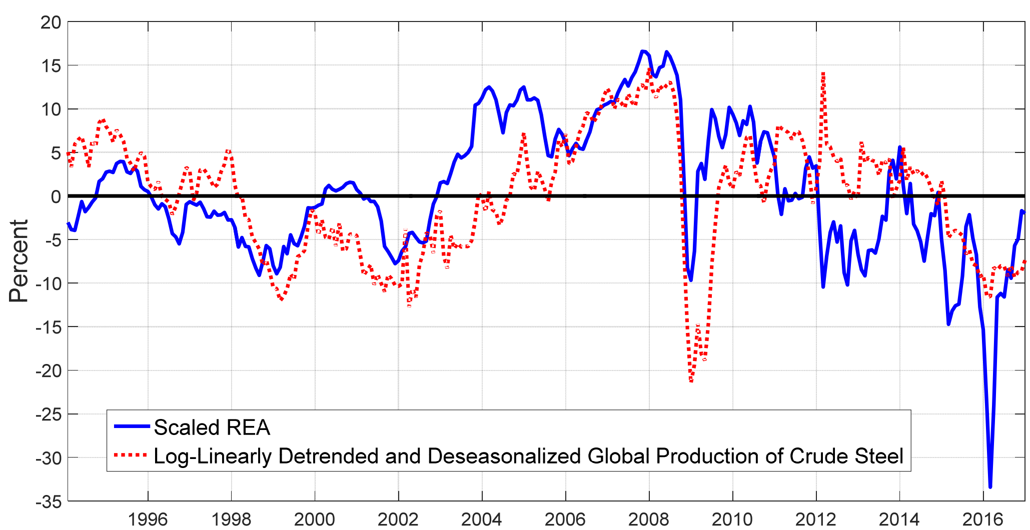
NOTES: The data are constructed as a PPP-weighted average of industrial production in the OECD member countries. Since 2006, additional data for the non-OECD countries China, India, Brazil, Russia, South Africa and Indonesia have been incorporated. The industrial production index was discontinued by the OECD in 2012, but has been updated by Baumeister and Hamilton (2015). The monthly OECD+6 real GDP index is from the OECD, as reported in Manescu and van Robays (2014).

Figure 8: Global Production of Crude Steel as a Measure of Global Real Economic Activity



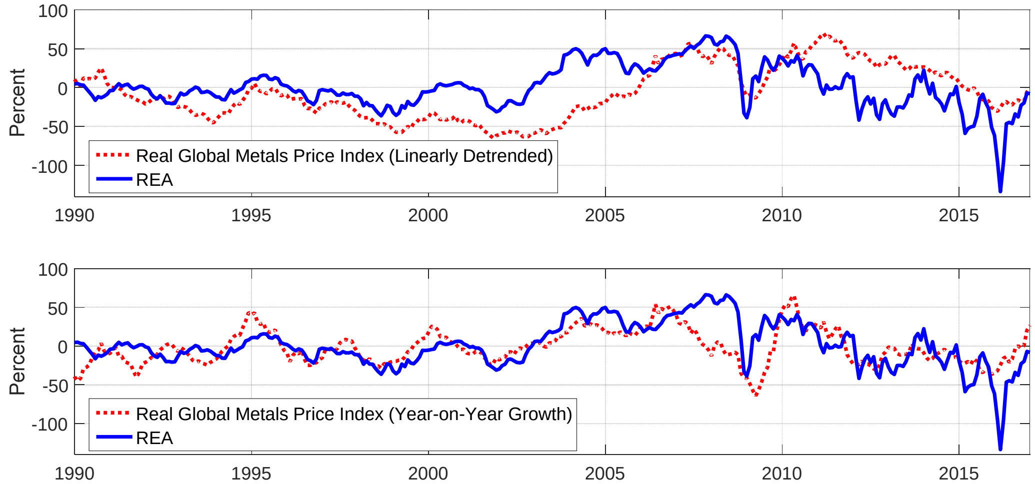
NOTES: The data source is the yearbook of the World Steel Association. The lower panel focuses on the period since January 1990, in recognition of the major structural break in 1990 that is visible in the upper panel. The data transcription errors in the original data source for the years 1993 and 2002 have been corrected based on the alternative data set used in Ravazzolo and Vespignani (2015). The series in the lower panel is obtained by removing a log-linear deterministic time trend and seasonal variation from the data since January 1990, as proposed in Ravazzolo and Vespignani (2015).

Figure 9: Index of Global Real Economic Activity and Global Crude Steel Production, 1994.1–2016.12



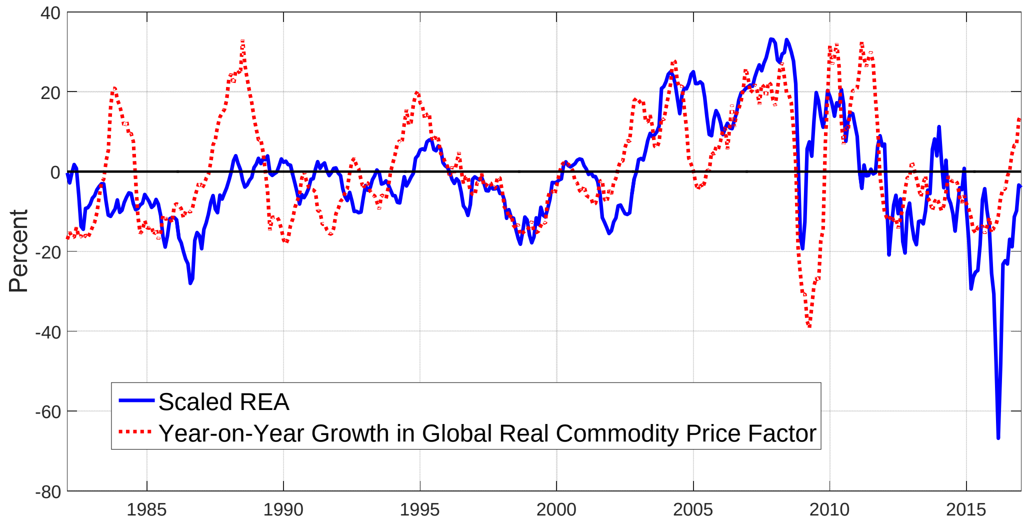
NOTES: The data source is the World Steel Association. The sample has been restricted to reduce distortions from the addition or deletion of steel-producing countries in the statistics of the *World Steel Association*. The index of global real economic activity (REA) is based on Kilian (2009a), as updated on http://www-personal.umich.edu/~lkilian.

Figure 10: Index of Global Real Economic Activity and Detrended Global Index of Real Metals Prices, 1990.1–2016.12



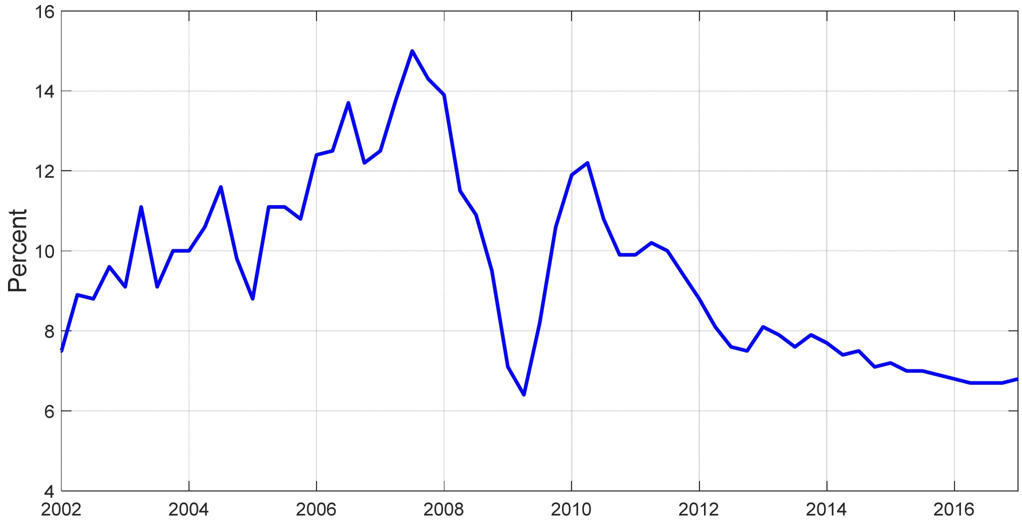
NOTES: The monthly global index of metals prices is from the International Monetary Fund (IMF) and has been deflated by the U.S. CPI. The index of global real economic activity (REA) is based on Kilian (2009a), as updated on http://www-personal.umich.edu/~lkilian.

Figure 11: Index of Global Real Economic Activity and Year-on-Year Growth Rate in Global Real Commodity Price Factor, 1981.12–2016.12



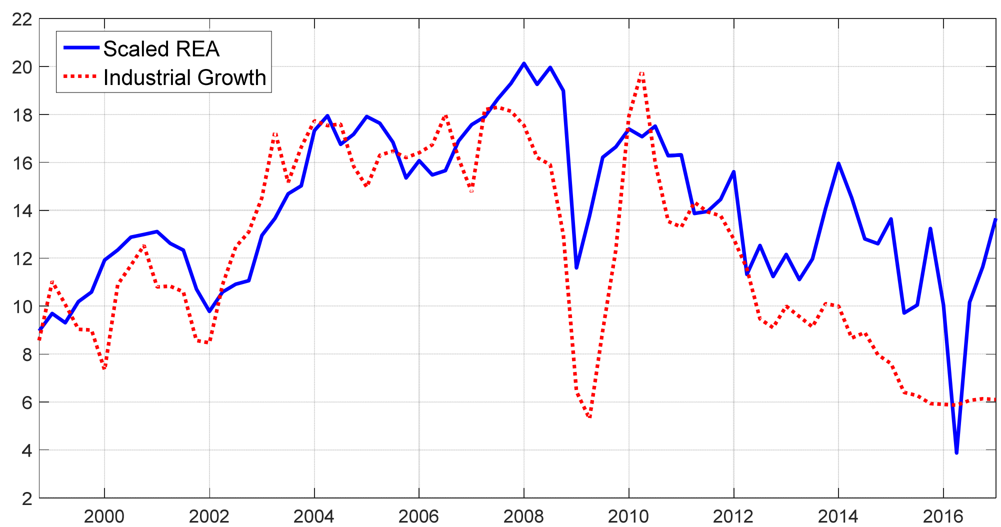
NOTES: The global factor index was proposed by Delle Chiaie et al. (2016) as a proxy for global real economic activity. It is obtained by fitting a dynamic factor model to the real growth rates of global commodity prices. The factor is expressed in year-on-year growth rates. The index of global real economic activity (REA) is based on Kilian (2009a), as updated on http://www-personal.umich.edu/~lkilian.

Figure 12: Year-on-Year Growth in China's Real GDP



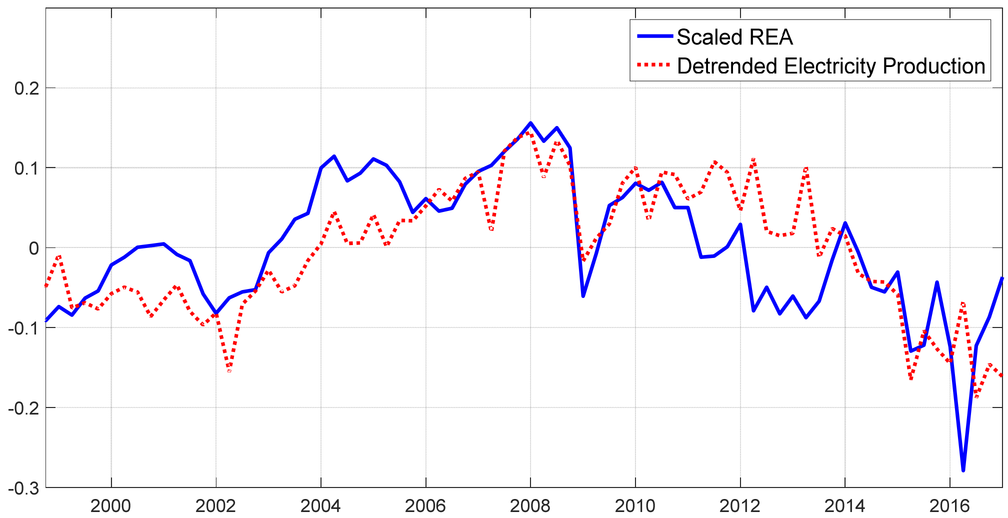
NOTES: Year-on-year growth reported by China's National Bureau of Statistics.

Figure 13: Quarterly Average of Index of Global Real Economic Activity and Growth Rate of Real Value Added in China's Industrial Sector, 1998.III–2016.IV



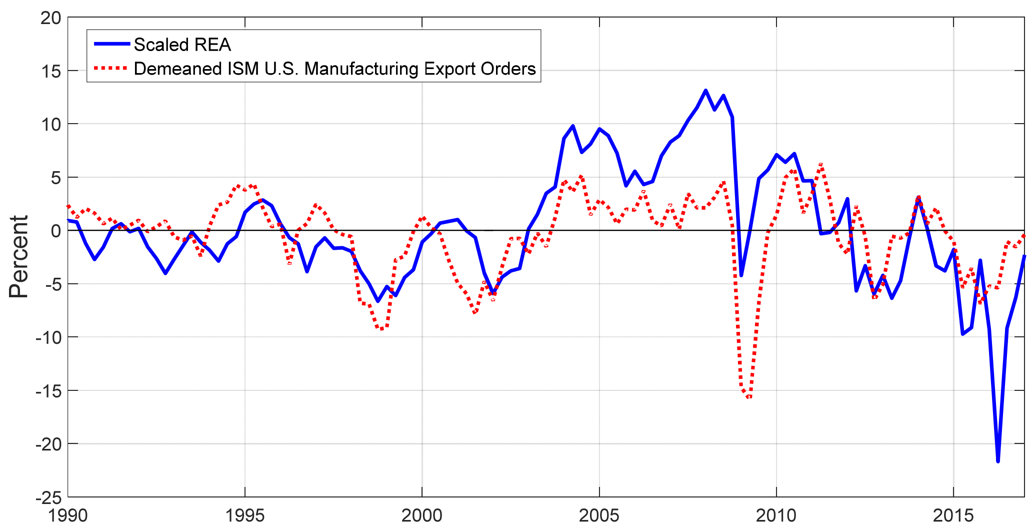
NOTES: The Chinese data are from the National Bureau of Statistics. The index of global real economic activity (REA) is based on Kilian (2009a), as updated on http://www-personal.umich.edu/~lkilian.

Figure 14: Quarterly Average of Index of Global Real Economic Activity and Chinese Quarterly Electricity Consumption, 1997.I–2016.IV



Notes: The Chinese electricity production data are from the National Bureau of Statistics and have been log-linearly detrended and deseasonalized. Given the lack of storage, the production data may be viewed as a measure of consumption. The index of global real economic activity (REA) is based on Kilian (2009a), as updated on http://www-personal.umich.edu/~lkilian.

Figure 15: The Global Real Economic Activity Index and U.S. Manufacturing Export Orders, 1990.1–2016.12



NOTES: The ISM Manufacturing Index of Export Orders is a component of the Purchasing Managers Index produced by the Institute of Supply Management (ISM) based on a monthly survey of U.S. private sector manufacturing companies. The raw index refers to the percentage of positive survey responses. The index of global real economic activity (REA) is based on Kilian (2009a), as updated on http://www-personal.umich.edu/~lkilian.