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MEASURING GLOBAL ECONOMIC ACTIVITY

James D. Hamilton

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ABSTRACT

A number of economic studies have used a proxy for world real economic activity derived from shipping costs. This measure turns out to depend on a normalization that has substantive consequences of which users of the index had been unaware prior to this paper. This paper further evaluates this and alternative measures in terms of treatment of trends, coherence with world output, and ability to predict commodity prices. I conclude that measures derived from world industrial production offer a better indicator of global real economic activity.

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A data appendix is available at http://www.nber.org/data-appendix/w25778

Applied economists often want a monthly measure of the level of global economic activity in empirical models of variables like commodity prices, exchange rates, and interest rates. One popular measure that has been used in dozens of studies[1] was developed by Kilian (2009) based on the cost of shipping.

In this paper I review the mechanical details behind Kilian's index and evaluate its appropriateness as a measure of global real economic activity.

1 Details behind Kilian's index.

The market for shipping services is governed by supply and demand, just like any other market. In a typical year, increasing global economic activity increases the demand for shipping, which by itself would lead to an increase in the cost of shipping. On the other hand, increases in shipping capacity and improvements in shipping productivity also shift the supply curve out, leading to lower prices. The trend in real shipping costs has been downward over time, meaning that in most years the second effect is bigger than the first. If the growth in shipping capacity, improvements in shipping productivity, and growth of potential real GDP could be characterized by deterministic time trends, then we might interpret the residuals from a regression of the real cost of shipping on a time trend as the cyclical component of global real economic activity.

As a first step in constructing his index of real economic activity, Kilian (2009) developed a monthly measure x_t of the nominal cost of shipping. This was calculated by initializing $x_{1968:1} = 1$ and for each subsequent month through 2007:12 adding an average of the change in the natural logarithm across a set of different freight rates to the previous month's value x_{t-1},

$$x_t = x_{t-1} + \frac{\sum_{i=1}^{I} \delta_{it} \Delta \log p_{it}}{\sum_{i=1}^{I} \delta_{it}} \qquad \text{for } t = 1968{:}2,\ 1968{:}3,\ \ldots{,}2007{:}12 \tag{1}$$

where p_{it} is the cost of shipping a particular bulk dry cargo i from monthly issues of Drewry's *Shipping Insight* and $\delta_{it} = 1$ if that cost is known for t and $t-1$. For data since 2008, Kilian and Murphy (2014) updated x_t using the Baltic Dry Index (BDI) of shipping costs:

$$x_t = x_{t-1} + \Delta \log(BDI_t) \qquad \text{for } t \geq 2008{:}1. \tag{2}$$

Kilian continued through 2018 to update x_t using equation (2) and reported on his website a measure of real economic activity described in equation (3) below.

[1] See McPhail (2011), Baumeister and Peersman (2013), Charnavoki and Dolado (2014), Degiannakis, Filis and Kizys (2014), Gargano and Timmermann (2014), Juvenal and Petrella (2014), Kilian and Murphy (2014), Lütkepohl and Netšunajev (2014), Anzuini, Pagano and Pisani (2015), Herwartz and Plödt (2016), Kang, Perez de Gracia and Ratti (2017), Antolín-Díaz and Rubio-Ramírez (2018), ElFayoumi (2018), Kilian and Zhou (2018), and Wieland (forthcoming), among many others.

Kilian converted his nominal index x_t into a real index by dividing x_t by the U.S. consumer price index (CPI_t). He then took the log of this ratio,

$$\log(x_t/CPI_t) = \log(x_t) - \log(CPI_t),$$

and regressed the result on a linear time trend:

$$\log(x_t) - \log(CPI_t) = \alpha + \beta t + \varepsilon_t. \tag{3}$$

The residuals ε_t from this regression are the Kilian index of real economic activity that has been used by the studies cited in footnote 1 and many others. This index is plotted in the top panel of Figure 1.

One feature of this construction that appears not to have been understood by the many users of this index is the following. Equation (2) implies that for $t \geq$ 2008:1,

$$\begin{aligned} x_t &= x_{2008:1} + \log(BDI_t) - \log(BDI_{2008:1}) \\ &= \log(BDI_t) + c_0 \end{aligned} \tag{4}$$

for $c_0 = x_{2008:1} - \log(BDI_{2008:1})$. No one before me had noticed the simple identity in (4), and Kilian has never made public his data for the underlying index x_t. However, it turns out to be possible to uncover the underlying series for x_t from publicly available data. For $t \geq$ 2008:1, the unknown value for x_t is related to the observed value of BDI_t according to equation (4) which involves a single unknown constant c_0. We further know that $z_t = \log(\log(BDI_t) + c_0) - \log(CPI_t) - \alpha - \beta t$ should be exactly equal to the value for ε_t reported by Kilian for $t \geq$ 2008:1 for some values of c_0, α, and β. The values of c_0, α, and β can be estimated by a nonlinear least squares regression[2] of the reported ε_t on the value of z_t using data after 2008 and CPI of the appropriate vintages.[3] The resulting estimated values for c_0, α, and β give the fitted regression an R^2 of unity in explaining ε_t, confirming that we have exactly replicated Kilian's procedure. With α and β thus known, the pre-2008 values of x_t are then obtained by adding back in the time trend to ε_t.[4]

The uncovered series for x_t is plotted in the bottom panel of Figure 1. The value for c_0 turns out to be -5.236 when $x_{1968:1}$ is normalized to be unity. However, if the sequence x_t had been generated with some initial value for $x_{1968:1}$ other than unity (corresponding to choosing

[2] One could also find essentially the same answer using any arbitrary 3 data points. However, because of rounding errors in the reported data, a more accurate reconstruction of the original series is obtained by pooling all the observations in a nonlinear regression.

[3] When matching Kilian and Murphy (2014), the CPI as reported in October 2009 was used (in order to match their data exactly), and when matching the data as downloaded from Kilian's website in July 2018, the CPI as reported in April 2018 was used.

[4] Data and code for all calculations and series produced in this paper are available at http://econweb.ucsd.edu/~jhamilto/REA.zip.

some month other than 1968:1 to be normalized to unity), the value of c_0 would be a different number. For example, if we started the recursion from a value of $x_{1968:1}$ that results in a value for $x_{1973:1}$ of 1, the value of c_0 would be -5.694.

The implications of this can be seen when we substitute (4) into (3):

$$\log[\log(BDI_t) + c_0] - \log(CPI_t) = \alpha + \beta t + \varepsilon_t. \quad (5)$$

Taking logs twice is an uncommon procedure for economic data, but no one noticed prior to my paper that this is what the Kilian index used in the papers referenced in footnote 1 was in fact doing. One consequence of taking double logs in this context is that the resulting series for real economic activity ε_t would be different depending on the value of c_0, that is, different depending on whether we normalize $x_{1968:1}$ to be 1, $x_{1973:1}$ to be 1, or choose some other month to normalize to be 1. Figure 2 shows how different normalizations affect the resulting measure of real economic activity.

After seeing an initial draft of this paper, Kilian (forthcoming) revised his index, and bases it now on the residuals of the regression

$$x_t - \log(CPI_t) = \alpha + \beta t + \varepsilon_t. \quad (6)$$

The original index based on (3) and the revised index based on (6) are compared in Figure 3. Kilian (forthcoming) wrote that the revised index "differs only slightly from the original index." However, statistical tests in the following section find significant differences.

2 Evaluating alternative measures of real economic activity.

A primary motivation given by Kilian (2009, p. 1057) for the validity of his index as a measure of global real economic activity came from an anecdotal review of global developments over 1970-2007. He concluded, "Figure 1 is fully consistent with the anecdotal evidence on the relative importance and timing of these fluctuations in global real economic activity." Applying that same standard to the more recent values of either of the indexes in Figure 3 raises substantial doubts about the measures' continuing reliability. The series would lead us to conclude that the cyclical component of world economic activity reached a far lower level in 2016 than was seen in either the financial crisis of 2008-2009 or the 1974-75 global recession. That conclusion seems hard to justify on the basis of GDP data for any major country, and certainly does not square with the assertion in Kilian (2009, p. 1056) that "the level of global real economic activity as it relates to industrial commodity markets is proportionate to this index." In later work, Kilian and Zhou (2018) stressed the index's potential usefulness as a leading indicator of global real economic activity. But we now have several years of data from which we know that no great global collapse followed the indexes' extreme bearish signal in 2016.

In this section I follow up with formal statistical tests, looking at evidence on stationarity, coherence with known data on global real GDP, usefulness for modeling real commodity prices, and other issues.

2.1 Deterministic time trends.

The implicit, but never tested, assumption behind the use of residuals from these time-trend regressions is that either $\log(x_t) - \log(CPI_t)$ for Kilian's original index or $x_t - \log(CPI_t)$ for the revised index can be characterized as a stationary process around a deterministic linear time trend. Letting $s_t = x_t - \log(CPI_t)$ and using the sample of observations for $t =$ 1968:1 through 2018:6, an augmented Dickey-Fuller test (with 3 lags of Δs_t) of the null hypothesis that s_t can be characterized as a unit-root process fails to reject the null at the 10% significance level.[5] Alternatively, the test of Kwiatkowski et al. (1992) takes the null hypothesis to be that s_t is stationary around a linear time trend. This test leads to rejection of the null at the 1% significance level.[6] Thus the assumption behind Kilian's index is not supported by the data.

If real shipping costs in reality contain a unit root, fitting a linear time trend causes the residuals for date t to incorporate information about values observed through the end of the sample. This could cause the residuals to perform spuriously well at in-sample forecasting evaluations. In practice, we observe that the coefficients characterizing the time trend continue to change as more data are added. For example, Figure 4 compares the time trend when estimated through 2009:8 (the sample period used by Kilian and Murphy (2014)) with the trend estimated through 2018:6.

2.2 Coherence with world economic activity.

The results in Section 2.1 suggest that a better way to obtain a stationary series is by differencing rather than regressing on a time trend. If we want the cyclical component, Hamilton (2018) proposed that the two-year difference

$$c_t = s_t - s_{t-24} \tag{7}$$

[5]The t-statistic is -2.46 with $T = 603$, which falls short of the 10% critical value of -2.57 from Hamilton (1994, Table B.6, Case 2).

[6]Here I used 4 lags to obtain a test statistic of 0.321 which exceeds the 1% critical value of 0.216.

is often a robust way to isolate the cyclical component of most economic time series.[7] Kilian's revised index is compared with (7) in the top two panels of Figure 5. The reason that Kilian's measure regards 2016 as the worst downturn in record is in part because a linear trend was used to construct it. The measure in the second panel, which does not assume a linear time trend, would still describe 2016 as a severe contraction, but not worse than the global financial crisis. Notwithstanding, a big factor in the record low shipping prices in 2016 was overbuilt shipping capacity, not a severe global economic contraction.

OECD Main Economic Indicators published an estimate of monthly industrial production for the OECD plus 6 other major countries (Brazil, China, India, Indonesia, the Russian Federation and South Africa). The OECD series begins in 1958:1 and ends in 2011:10.[8] Baumeister and Hamilton (2019) reproduced the methodology by which the original index was constructed to extend the series through 2018:7.[9] The bottom panel of Figure 5 plots the cyclical component of the log of this series again using the two-year difference (7). Unlike the Kilian index, the industrial production data imply that the 1974-75 and 2008-2009 recessions were clearly the most significant downturns in global real activity during this period. The series also suggests that there was a period of strong growth following the recovery from the 2008-2009 downturn, and characterizes 2015-2016 as sluggish global growth rather than a separate severe global contraction. All of this accords well with what is commonly understood about global economic activity.

Kilian and Zhou (2018) argued that one drawback to using world real GDP is that researchers often want to estimate higher frequency models, and they state that quarterly real GDP is only available since 1990. However, the World Bank has published estimates of annual world real GDP going back to 1960. One obvious check is to look at the correlation between these annual figures and alternative proposed monthly measures of the cyclical component of real economic activity. Consider an OLS estimation of

$$g_t = \alpha + \beta c_t + v_t \tag{8}$$

where g_t is the growth rate of world real GDP in year t, c_t is a proposed cyclical measure as of the last month of year t, and t runs from 1971 to 2017. Row 1 of Table 1 shows that the cyclical component of industrial production is very strongly correlated with observed annual GDP growth. By contrast, the correlation between GDP growth and either of Kilian's measures is not statistically significant at conventional levels (rows 2 and 3). The cyclical

[7] Hamilton (2018) proposed that we could isolate the cyclical component more generally using an OLS regression. Given the evidence of a unit root noted above, here we use the simple and more robust alternative in equation (7). This also simplifies interpretation of forecasting regressions below as it is a true real-time measure.

[8] Kilian and Zhou (2018, Table A1a) mistakenly assert that the series is only available since 1973:1. Kilian and Zhou (2018, p. 66) also give the mistaken impression that this series only included China beginning in 2006. In fact, China has been included in the world industrial production index at least since 1999.

[9] This series is regularly updated at https://sites.google.com/site/cjsbaumeister/research.

component of real shipping costs (row 4) does somewhat better than Kilian's measures but is not nearly as strongly related to GDP as is world industrial production.

Kilian and Zhou (2018) also noted that delays in obtaining the GDP or industrial production numbers undermines their usefulness for real-time assessment. For example, as of January of year $t+1$ we would know the value of the BDI and CPI for December of year t (and thus could construct any of the measures in rows 2-4 of Table 1 as of January) but would typically only know the value for industrial production through June of year t at that time.[10] Kilian and Zhou (2018, p. 58) asserted that another advantage of their approach is that "the Kilian index [is] a leading indicator with respect to global real output, unlike global industrial production, which is a coincident indicator," though they provided no statistical evidence in support of this claim.

One obvious way to evaluate both concerns is to base the industrial-production measure c_t for year t on the June value of industrial production rather than December, evaluating equation (8) as a possible tool for purposes of nowcasting. Row 5 of Table 1 shows that the June value is still quite useful. Indeed, one gets a far better picture of world GDP growth for year t by looking at industrial production through June of that year rather than shipping costs through December. Interestingly, either of Kilian's measures based on shipping costs through June actually have a slight negative correlation with what world GDP growth for that year turned out to be.

2.3 Forecasting commodity prices.

Another argument given by Kilian and Zhou (2018) in favor of their measure is based on its purported usefulness for modeling commodity prices. Here I investigate this claim using a number of different commodity prices. Let p_t be the change in the logarithm of the real price of a particular commodity or index of commodities between month $t-1$ and t and z_t either the growth rate of industrial production or one of the two Kilian measures. Consider forecasting regressions of the form

$$p_t = \alpha + \sum_{j=1}^{3} \phi_j p_{t-j} + \sum_{j=1}^{3} \beta_j z_{t-j} + v_t. \tag{9}$$

Table 2 reports p-values for the F-test of the null hypothesis $H_0 : \beta_1 = \beta_2 = \beta_3 = 0$ that the measure of real economic activity is of no use for forecasting the commodity price p_t. The commodity prices considered are the World Bank's two broad commodity price indexes (energy and non-energy), two more specialized indexes (agriculture and base metals), and prices of four important individual commodities (crude oil, soybeans, aluminum and copper). The

[10] An alternative option is to use the production-weighted index of world industrial production that is included in the World Trade Monitor Database reported by CPB Netherlands Bureau for Economic Policy Analysis. This series begins in January 2000 and is reported with only a two-month delay. Its growth rate is similar to the OECD+6 index and appears to be a good way to update the OECD+6 index.

regression (9) was estimated for $t = 1968{:}4$ to 2018:2. Industrial production has statistically significant coefficients for purposes of forecasting every commodity except aluminum. The Kilian-Zhou index does not give statistically significant predictions of any of these prices. The Kilian (forthcoming) index gives better forecasts than Kilian-Zhou, and is statistically significant for purposes of predicting the agricultural price index, the base-metals price index, and copper prices. But it is never as good as industrial production.

2.4 Additional considerations.

Finally I offer some observations on the nominal shipping index x_t itself. One notices in the bottom panel of Figure 1 that this series seems to behave differently before and after 2008. This was the date at which Kilian switched from updating the index using equation (1) to updating it based purely on the BDI as in equation (2). Odom (2010) noted that changes in the methodology behind BDI may have contributed to its volatility. Figure 6 compares Kilian's nominal index x_t with the path it would have taken since 2008 if he had continued to update it using equation (1). The series would exhibit less of a downward trend, less of a drop in 2016, and less volatility.

If in spite of the many issues raised above one still wanted to use the BDI as a measure of global real economic activity, it has the appealing feature that it is actually available daily.[11] To use the daily BDI as a cyclical indicator, the evidence in Sections 2.1 and 2.2 argues strongly for using a two-year difference rather than residuals from a linear time trend.[12] A daily indicator could thus be obtained from

$$c_t = \log(BDI_t/CPI_t) - \log(BDI_{t-(2\times 247)}/CPI_{t-(2\times 247)})$$

where t now denotes daily data with 247 the number of business days in a year and CPI_t is a value for the consumer price index associated with day t. Constructing the latter raises two modest technical challenges. First, the CPI is only available with a lag, and second, the CPI only changes at monthly intervals. To solve these issues, I associated the value of the BDI for the first business day in March with the CPI for January,[13] and linearly interpolated between the January and February CPI to fill in each subsequent day in March.[14] The resulting

[11] Daily values for the BDI were obtained from TradingEconomics.com.

[12] Bruno, Büyükşahin, and Robe (2016) used residuals from a regression of the BDI on a linear time trend to construct a weekly indicator of economic activity. They did not propose solutions to how to develop this into a practical real-time estimator.

[13] Alternatively, if the goal is to develop a daily index for use in historical academic research rather than for real-time nowcasting, one could logically associate the value of the BDI for the 11th business day in March with the CPI for March and linearly interpolate using the CPI for April to fill in subsequent days in March and the first 10 business days in April.

[14] An alternative would be to use daily nowcasts of the CPI developed by Knotek and Zaman (2017) and updated by the Federal Reserve Bank of Cleveland. A drawback of this is that the series would exhibit discrete jumps at release dates, unlike the procedure developed here.

series, plotted in Figure 7, might in the spirit of Kilian (2009) be viewed as a daily indicator of the cyclical component of global real economic activity.

3 Conclusions.

This paper made publicly available for the first time details that allow researchers to investigate the properties of popular measures of global real economic activity based on shipping costs. Doing so uncovered significant problems in a widely-used index and established that alternative approaches to handling the trend in shipping costs offer both a better description of the shipping data and better coherence with world GDP. Notwithstanding, monthly estimates of world industrial production are far better than measures based on shipping costs at describing world GDP or predicting commodity prices.

References

Antolín-Díaz, Juan, and Juan F. Rubio-Ramírez (2018). "Narrative Sign Restrictions for SVARs," *American Economic Review* 108(10): 2802-2829.

Anzuini, Alessio, Patrizio Pagano, and Massimiliano Pisani (2015). "Macroeconomic Effects of Precautionary Demand for Oil," *Journal of Applied Econometrics* 30: 968-986.

Baumeister, Christiane, and James D. Hamilton (2019). "Structural Interpretation of Vector Autoregressions with Incomplete Identification: Revisiting the Role of Oil Supply and Demand Shocks," *American Economic Review* 109(5).

Baumeister, Christiane, and Gert Peersman (2013). "The Role of Time-Varying Price Elasticities in Accounting for Volatility Changes in the Crude Oil Market," *Journal of Applied Econometrics* 28: 1087-1109.

Bruno, Valentina G., Bahattin Büyükşahin, and Michel A. Robe (2016). "The Financialization of Food?," *American Journal of Agricultural Economics* 99: 243-264.

Charnavoki, Valery, and Juan J. Dolado (2014). "The Effects of Global Shocks on Small Commodity-Exporting Economies: Lessons from Canada," *American Economic Journal: Macroeconomics* 6: 2017-2037.

Degiannakis, Stavros, George Filis and Renatas Kizys (2014). "The Effects of Oil Price Shocks on Stock Market Volatility: Evidence from European Data," *Energy Journal,* 35: 35-56.

ElFayoumi, Khalid (2018). "The Balance Sheet Effects of Oil Market Shocks: An Industry Level Analysis," *Journal of Banking and Finance* 95: 112-127.

Gargano, Antonio, and Allan Timmermann (2014). "Forecasting Commodity Price Indexes Using Macroeconomic and Financial Predictors," *International Journal of Forecasting* 30: 825-884.

Hamilton, James D. (1994). *Time Series Analysis.* Princeton University Press.

Hamilton, James D. (2018). "Why You Should Never Use the Hodrick-Prescott Filter," *Review of Economics and Statistics* 100: 831-843.

Herwartz, Helmut, and Martin Plödt (2016). "The Macroeconomic Effects of Oil Price Shocks: Evidence from a Statistical Identification Approach," *Journal of International Money and Finance* 61: 30-44.

Juvenal, Luciana, and Ivan Petrella (2014). "Speculation in the Oil Market," *Journal of Applied Econometrics* 30: 621-649.

Kang, Wensheng, Fernando Perez de Gracia, and Ronald A.Ratti (2017). "Oil Price Shocks, Policy Uncertainty, and Stock Returns of Oil and Gas Corporations," *Journal of International Money and Finance,* 70: Pages 344-359.

Kilian, Lutz (2009). "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market," *American Economic Review* 99: 1053-1069.

Kilian, Lutz (forthcoming). "Measuring Global Real Economic Activity: Do Recent Critiques Hold Up to Scrutiny?," *Economic Letters.*

Kilian, Lutz, and Daniel P. Murphy (2014). "The Role of Inventories and Speculative Trading in the Global Market for Crude Oil," *Journal of Applied Econometrics* 29: 454-478.

Kilian, Lutz, and Xiaoqing Zhou (2018). "Modeling Fluctuations in the Global Demand for Commodities," *Journal of International Money and Finance* 88: 54-78.

Knotek, Edward S., and Saeed Zaman (2017). "Nowcasting US Headline and Core Inflation," *Journal of Money, Credit and Banking* 49: 931-968.

Kwiatkowski, Denis, Peter C.B. Phillips, Peter Schmidt, and Yongcheol Shin (1992). "Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root: How Sure Are We That Economic Time Series Have a Unit Root?," *Journal of Econometrics* 54(1-3): 159-178.

Lütkepohl, Helmut, and Aleksei Netšunajev (2014). "Disentangling Demand and Supply Shocks in the Crude Oil Market: How to Check Sign Restrictions in Structural VARs," *Journal of Applied Econometrics* 29: 479-496.

McPhail, Lihong Lu (2011). "Assessing the Impact of US Ethanol on Fossil Fuel Markets: A Structural VAR Approach," *Energy Economics* 33: 1177-1185.

Odom, Payton (2010). "Shipping Indexes Signal Global Economic Trends," in *Annual Report, Globalization and Monetary Policy Institute* (2010): 28-35.

Wieland, Johannes (forthcoming). "Are Negative Supply Shocks Expansionary at the Zero Lower Bound?" *Journal of Political Economy.*

Table 1. Results from regressions of year *t* world real GDP growth on alternative measures of global economic activity as of December or June of year *t*.

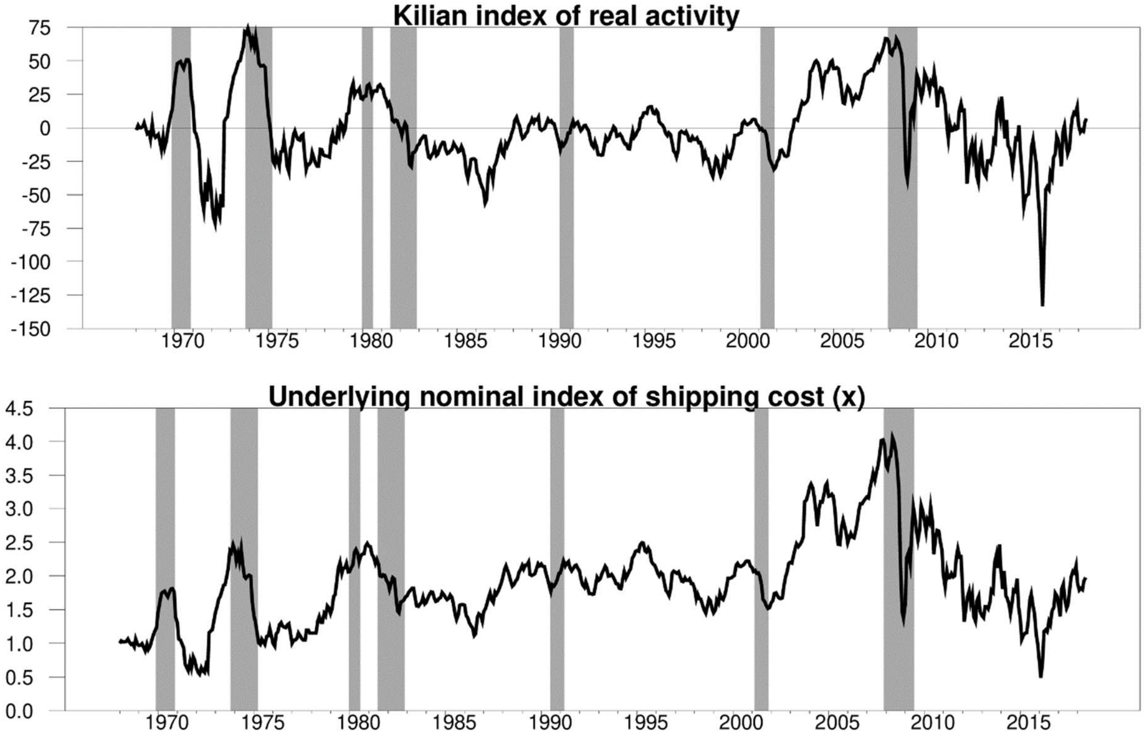
Measure of real economic activity	*t*-statistic	R^2
December		
(1) Industrial production	12.21	0.77
(2) Kilian-Zhou (2018)	1.45	0.04
(3) Kilian (forthcoming)	1.27	0.03
(4) Real shipping cost	3.68	0.23
June		
(5) Industrial production	5.23	0.38
(6) Kilian-Zhou (2018)	-0.52	0.01
(7) Kilian (forthcoming)	-0.53	0.01
(8) Real shipping cost	0.77	0.02

Notes to Table 1. The table reports the *t*-statistic on β and the R^2 from OLS estimation of equation (8) for c_t the cyclical component of the log of world industrial production in December (row 1) or June (row 5) of year *t*; the index used by Kilian and Zhou (2018) (as obtained by downloading from Kilian's webpage July 2018) for December (row 2) or June (row 6) of year *t*; the index proposed by Kilian (forthcoming) (as obtained by downloading from Kilian's webpage April 2019) for December (row 3) or June (row 7) of year *t*; and the cyclical component of real shipping costs (from equation (7)) for December or June.

Table 2. *P*-values for tests of null hypothesis that alternative measures of real economic activity are no help in forecasting real commodity prices.

Commodity price	Industrial production	Kilian-Zhou (2018)	Kilian (forthcoming)
Energy	**0.02**	0.33	0.16
Non-energy	**< 0.01**	0.15	0.06
Agriculture	**< 0.01**	0.10	**0.05**
Base metals	**0.01**	0.12	**0.02**
Crude oil	**0.05**	0.52	0.27
Soybeans	**0.05**	0.14	0.08
Aluminum	0.06	0.38	0.08
Copper	**0.01**	0.06	**0.02**

Figure 1. Kilian's original monthly index of real economic activity and underlying nominal index, 1968:1 to 2018:6.



Notes to Figure 1. Top panel: calculated by the author as 100 times the residuals from regression (3) when $x_{1968:1}$ is normalized at 1. Bottom panel: constructed by the author as described in the text. Shaded regions denote NBER U.S. recession dates.

Figure 2. Residuals from regression (3) for two different normalizations for the level of x_t.

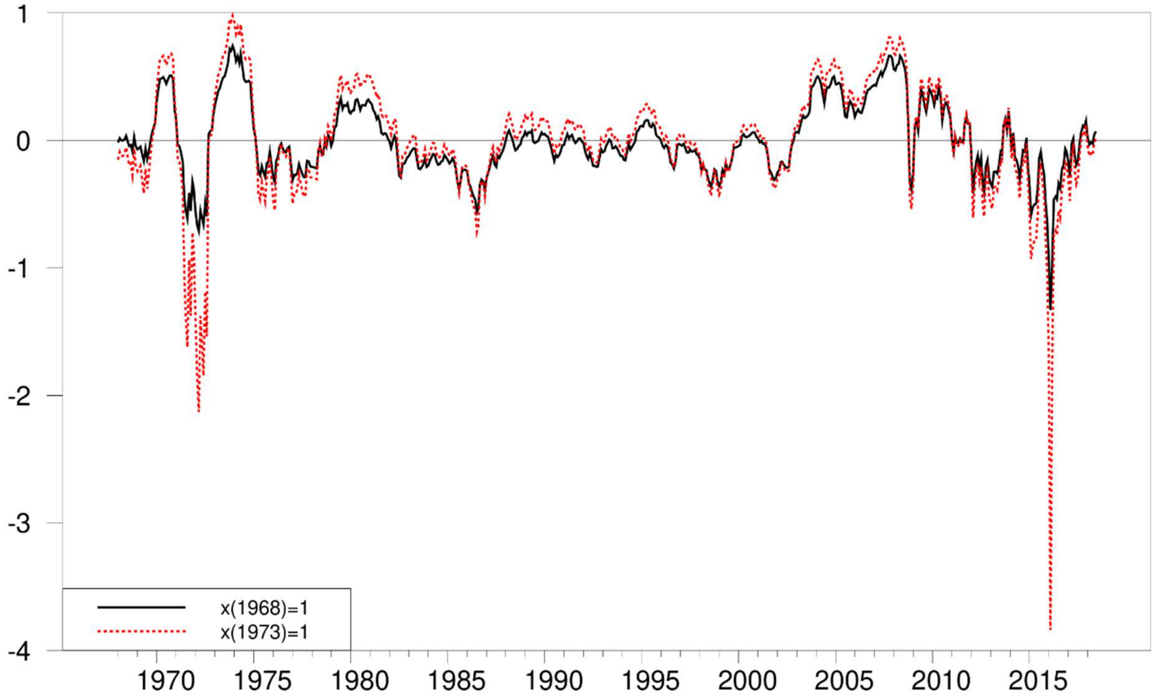
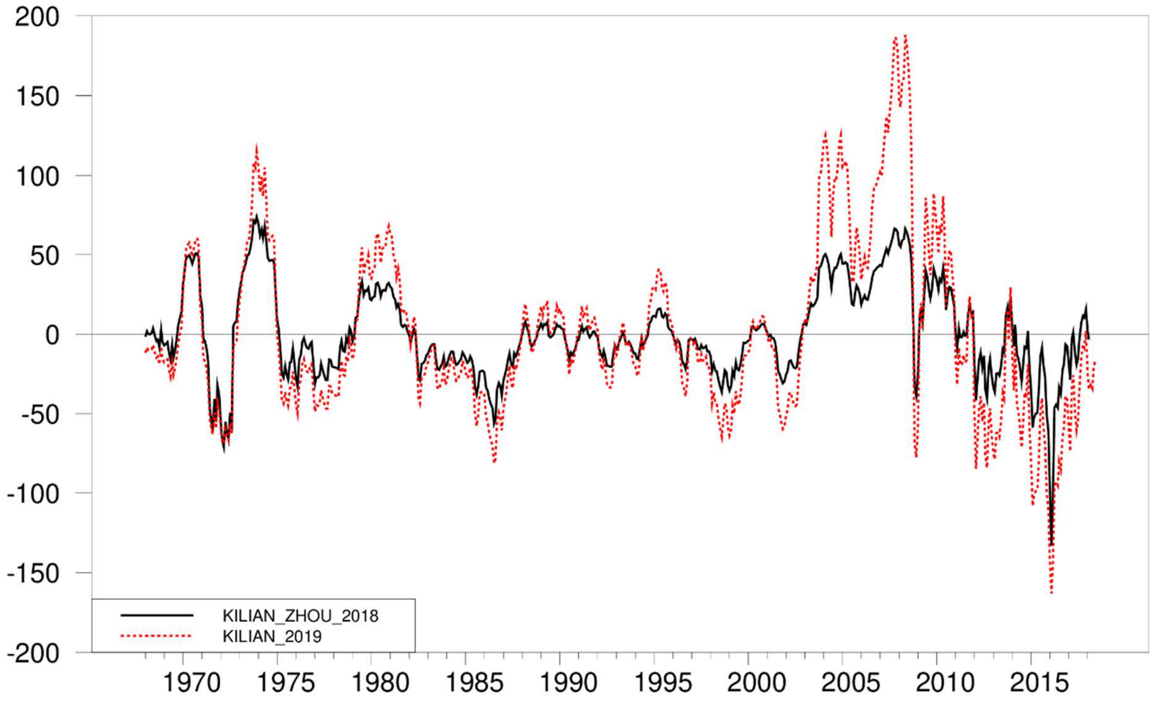


Figure 3. Comparison of the measures used by Kilian and Zhou (2018) and Kilian (forthcoming).

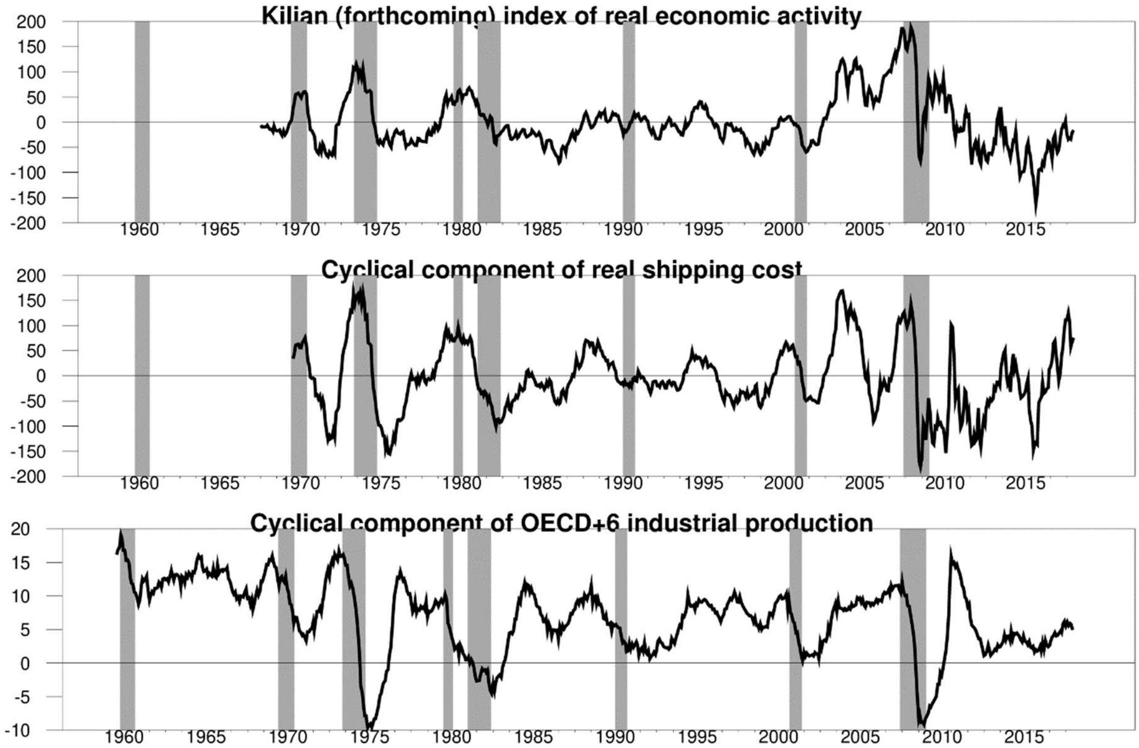


Notes to Figure 3. Black: series downloaded from Kilian's webpage July 2018. This is the measure used by Kilian and Zhou (2018), and corresponds to 100 times the residuals from regression (3). Dotted red: series downloaded from Kilian's webpage April 2019. This is the measure used by Kilian (forthcoming) and corresponds to 100 times the residuals from regression (6).

Figure 4. Real cost of shipping and time trends estimated over two different samples.

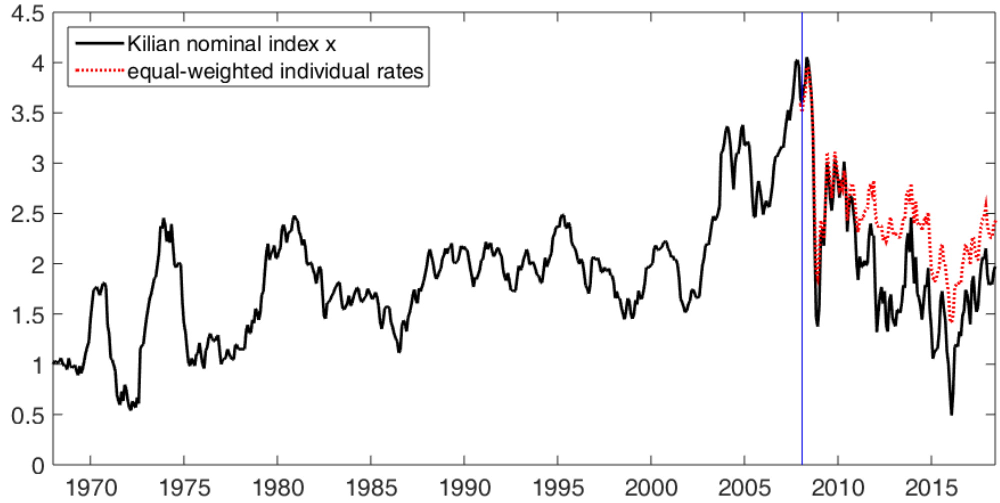
Notes to Figure 4. Black: natural log of real cost of shipping, calculated as $100[x_t - \log(CPI_t)]$. Solid blue: time trend estimated 1968:1-2009:8. Dashed red: time trend estimated 1968:1-2018:6.

Figure 5. Alternative measures of global real economic activity.



Notes to Figure 5. Top panel: measure used by Kilian (forthcoming), 1968:1-2018:6, obtained by downloading the real activity measure from Kilian's webpage in April 2019. Middle panel: cyclical component of real shipping costs, as calculated by equation (7) with $s_t = 100[x_t - \log(CPI_t)]$. Result is plotted for 1970:1-2018:6. Bottom panel: cyclical component of world industrial production, as calculated by equation (7) with s_t 100 times the log of the industrial production index for OECD plus 6 major countries. Result is plotted for 1960:1-2018:6. Shaded regions denote NBER U.S. recession dates.

Figure 6. Alternative measures of nominal shipping costs.



Notes to Figure 6. Solid black: nominal index x_t underlying Kilian's real activity index; constructed by the author as described in the text. Beginning 2008:1 the change in x_t is simply the change in the log of the *BDI*. Dotted red: results of extending x_t after 2008:1 using equation (1).

Figure 7. Daily cyclical component of real shipping cost, March 16, 2011 to July 16, 2018.