

# Measuring Global Economic Activity\*

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## Abstract

A number of economic studies have used a proxy for world real economic activity derived from shipping costs. The measure turns out to depend on a normalization that has substantive consequences of which users of the index have been unaware. This note describes alternative measures that avoid this and other problems with the commonly used proxy.

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Obtaining a monthly measure of the level of global economic activity faces a number of challenges; see Kilian (2009) and Kilian and Zhou (2018) for a catalog of some of the concerns. For this reason, Kilian (2009) proposed using the cost of shipping to construct an alternative proxy for global economic activity. His measure has since been used in dozens of studies.<sup>1</sup>

Figure 1 illustrates the basic motivation for how we might use the cost of shipping to infer something about economic activity. In a typical year, increasing global real economic activity shifts the demand for shipping to the right, which by itself would lead to an increase in the price. Increases in shipping capacity and improvements in shipping productivity also shift the supply curve to the right, 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. Kilian (2009) suggested that growth in shipping capacity, improvements in shipping productivity, and growth of potential real GDP could be characterized by deterministic time trends, and proposed interpreting 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 shipping costs to the previous month's value  $x_{t-1}$ ,

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

where  $p_{it}$  is the cost of shipping a particular bulk dry cargo  $i$  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:

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

Kilian has subsequently continued to update  $x_t$  using equation (1) and report on his website a measure of real economic activity described below.

Kilian thought the appropriate way to convert his nominal index  $x_t$  into a real index would be to divide  $x_t$  by the consumer price index ( $CPI_t$ ). He took the log of this ratio, thinking it was like the log of a relative price:

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

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<sup>1</sup>See Baumeister and Peersman (2013), Charnavoki and Dolado (2014), Gargano and Timmermann (2014), Juvenal and Petrella (2014), Kilian and Murphy (2014), Lütkepohl and Netšunajev (2014), Anzuini, Pagano and Pisani (2015), Antolín-Díaz and Rubio-Ramírez (forthcoming), and Wieland (forthcoming), among many others.

He then regressed this difference on a linear time trend:

$$\log(x_t) - \log(CPI_t) = \alpha + \beta t + \varepsilon_t. \quad (2)$$

The residuals  $\varepsilon_t$  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 2.

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

$$\begin{aligned} x_t &= x_{2008:1} + \log(BDI_t) - \log(BDI_{2008:1}) \\ &= \log(BDI_t) + c_0 \end{aligned} \quad (3)$$

for  $c_0 = x_{2008:1} - \log(BDI_{2008:1})$ . No one seems to have noticed the simple identity in (3), and Kilian has never made public his data for the underlying index  $x_t$ .<sup>2</sup> 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 (3) 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  $\varepsilon_t$  reported by Kilian for  $t \geq 2008:1$  for some values of  $c_0$ ,  $\alpha$ , and  $\beta$ . The values of  $c_0$ ,  $\alpha$ , and  $\beta$  can be estimated by a nonlinear least squares regression of the reported  $\varepsilon_t$  on the value of  $z_t$  using data after 2008 and  $CPI$  for the vintages used in Kilian and Murphy (2014) or Kilian's web page. The resulting estimated values for  $c_0$ ,  $\alpha$ , and  $\beta$  give the fitted regression an  $R^2$  of unity in explaining  $\varepsilon_t$ , confirming that we have exactly replicated Kilian's procedure. With  $\alpha$  and  $\beta$  thus known, the pre-2008 values of  $x_t$  are then obtained by adding back in the time trend to  $\varepsilon_t$ .<sup>3</sup>

The uncovered series for  $x_t$  is plotted in the bottom panel of Figure 2. 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 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 (3) into (2):

$$\log[\log(BDI_t) + c_0] - \log(CPI_t) = \alpha + \beta t + \varepsilon_t. \quad (4)$$

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<sup>2</sup>If Kilian had made his nominal index  $x_t$  public, someone would have noticed the error to which I call attention below years ago.

<sup>3</sup>Data and code for all calculations and series produced in this paper are available at <http://econweb.ucsd.edu/~jhamilto/REA.zip>.

Taking logs twice is an uncommon procedure for economic data. One consequence of its application in this context is that the resulting series for real economic activity  $\varepsilon_t$  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 3 shows how different normalizations affect the resulting measure of real economic activity.

After seeing an initial version of this paper, Kilian (2018) acknowledged the problems with constructing an index based on (2), and now proposes a new measure of real economic activity based on the residuals of the regression

$$x_t - \log(CPI_t) = \alpha + \beta t + \varepsilon_t. \quad (5)$$

But either equation (4) or equation (5) relies on the strong assumption that there exist values for  $\alpha$  and  $\beta$  that completely capture changes over time in shipping capacity, productivity, and potential real GDP, so that the resulting series for  $\varepsilon_t$  isolates the effects of cyclical movements in real economic activity. This is a rather strong claim. In practice, the trend is constantly re-estimated with changing coefficients. When estimated using data through 2009:8 (the sample period used by Kilian and Murphy, 2014), the intercept of (2) is  $\hat{\alpha} = -0.05$  and the slope coefficient  $\hat{\beta}$  implies an annual decline rate of 2.3%. When estimated using data through 2018:6, the intercept is  $\hat{\alpha} = +0.02$  and the annual decline rate is 2.8%.

Does the Kilian index correspond to other things we know about global business conditions? The original Kilian real activity index (obtained from the residuals of (2) with  $x_{1968:1} = 1$ ) is reproduced in the top panel of Figure 4. This series invites us to conclude that there was a drop in world economic activity in 2016 that was far more severe than that in either the financial crisis of 2008-2009 or the 1974-75 global recession. The same is also true of the residuals from (5). That conclusion seems hard to justify on the basis of output data we have for any major country.

There are some appealing alternatives. 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 ends in 2011:10, but Baumeister and Hamilton (2018) reproduced the methodology by which the original index was constructed to extend the series through 2017:12. If we want to isolate a cyclical component of the series, Hamilton (forthcoming) suggested that the two-year change in the log offers a simple and robust way to remove the trend in series like this. The resulting estimate of the cyclical component of industrial production in the OECD plus 6 is plotted in the second panel of Figure 4. Unlike the Kilian measure, this series implies 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 growth

rather than a separate severe global contraction.

If one were committed to constructing a proxy for global economic activity from the cost of shipping, a more natural measure would use the log of the relative price rather than the double-log transformation. Since  $x_t$  is already in units of a constant plus the log of shipping costs, the log of the relative price is given simply by  $\pi_t = x_t - \log(CPI_t)$ . Again the preferred way to isolate the cyclical component is to take the 2-year difference  $\pi_t - \pi_{t-24}$  rather than deviations from a constantly re-estimated time trend. The values of  $\pi_t - \pi_{t-24}$  are plotted in the last panel of Figure 4. Like the middle panel, this would again lead us to conclude that 1974-75 and 2008-2009 were the two most significant downturns.

One important benefit of using a price series like the *BDI* is that it is available at the daily level,<sup>4</sup> allowing us to calculate a version of  $\pi_t$  at the daily level. Doing so 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, and interpolated between the January and February *CPI* to fill in each subsequent day in March. The two-year difference of  $\pi_\tau = x_\tau - \log(CPI_\tau)$  for  $\tau$  a daily index is plotted in Figure 5, and could in the spirit of Kilian (2009) be viewed as a daily measure of the cyclical component of global real economic activity.

I conclude that either the second or third panels of Figure 4 are better measures of the cyclical component of world economic activity than the index proposed by Kilian. Moreover, the method used in the third panel can easily be used to construct a daily measure that can be continuously updated.

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<sup>4</sup>Daily values for the BDI were obtained from TradingEconomics.com.

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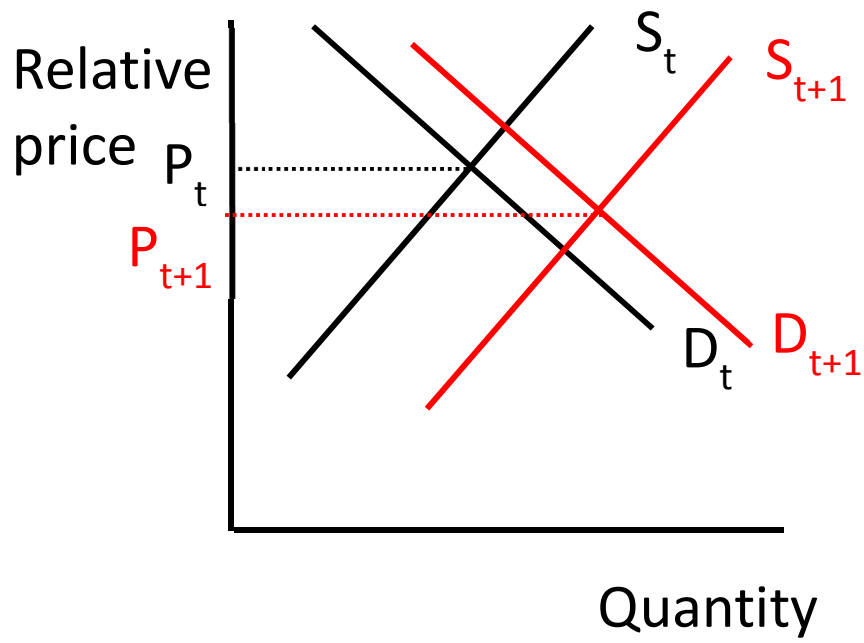


Figure 1. World market for shipping services.

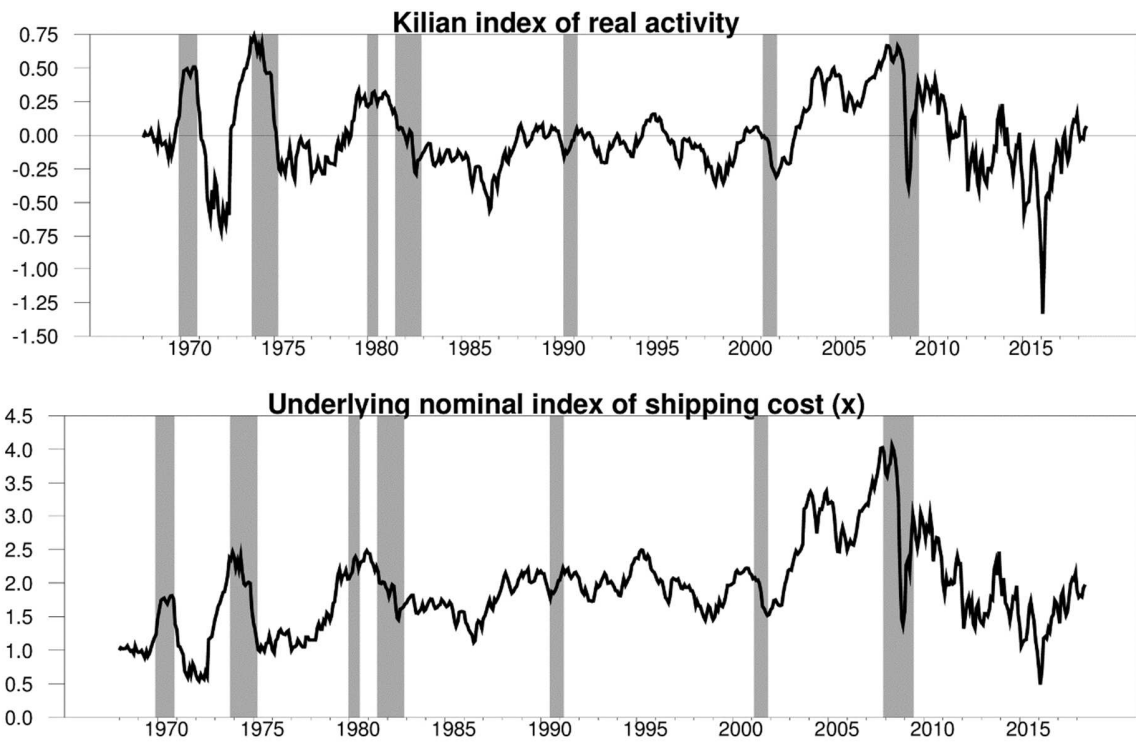


Figure 2. Kilian's monthly index of real economic activity and underlying nominal index, 1968:1 to 2018:6.

Notes to Figure 2. Top panel: calculated by the author from the residuals from regression (2) when  $x_{1968:1}$  is normalized at 1. Bottom panel: constructed by the author as described in the text. Shaded regions denote NBER recession dates.



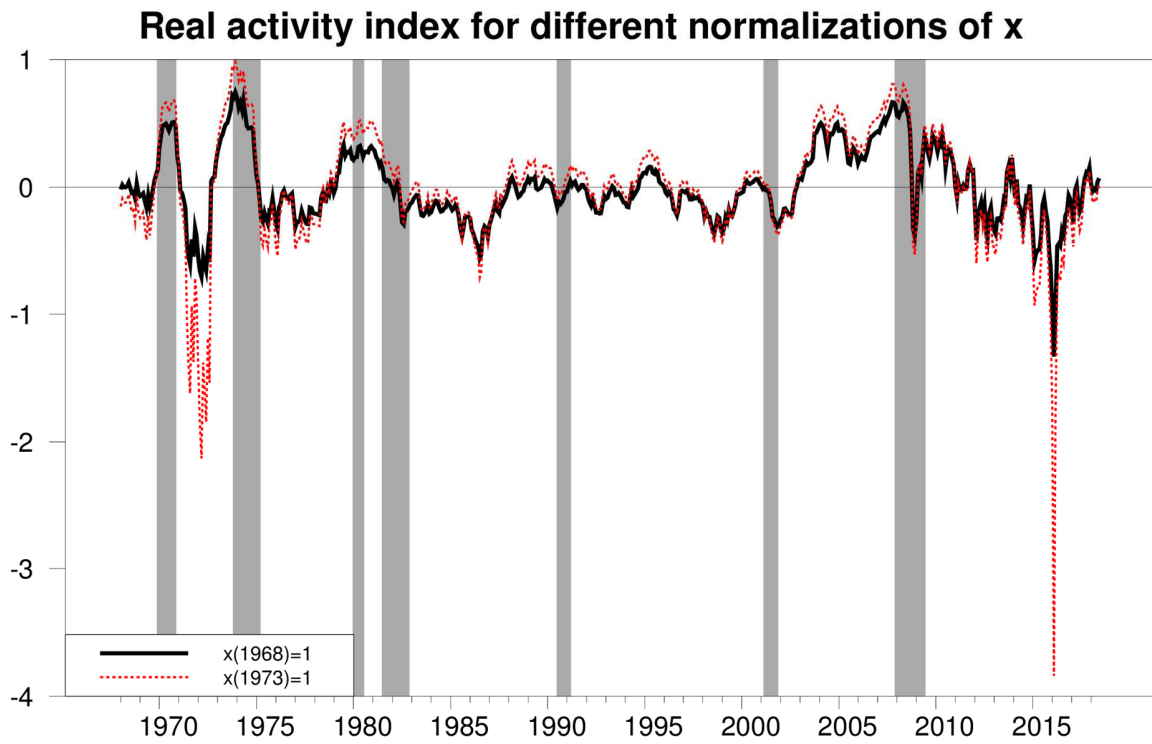


Figure 3. Residuals from regression (2) for two different normalizations for the level of  $x_t$ .

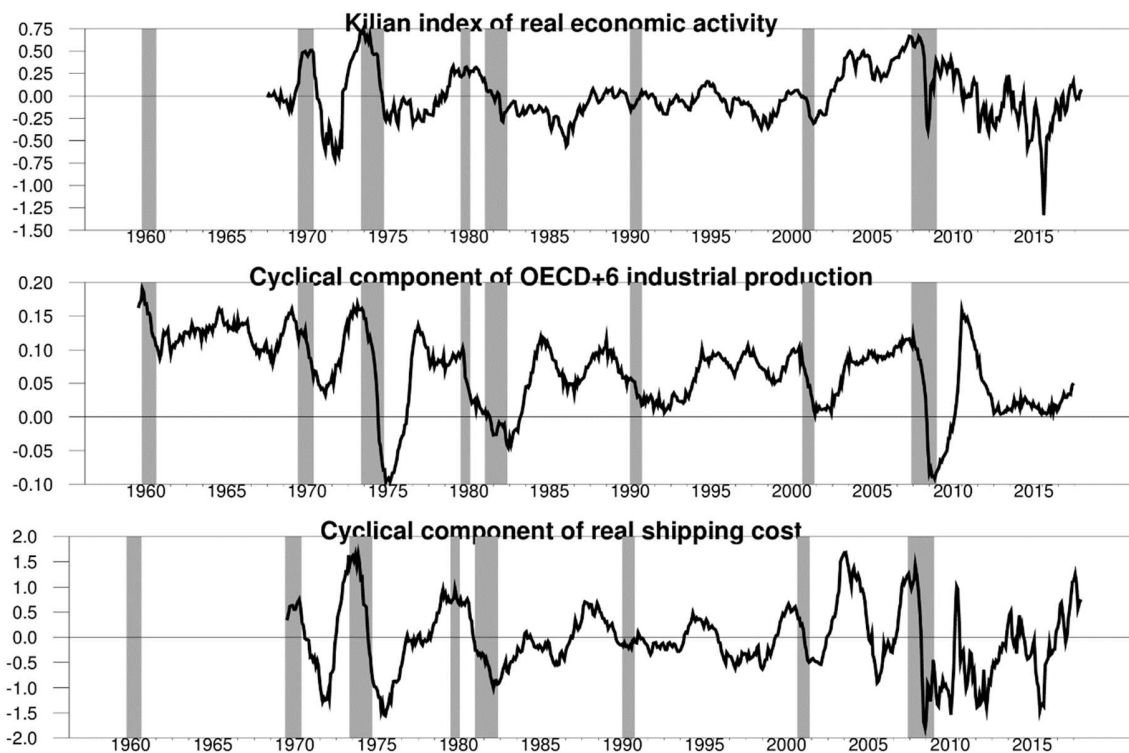


Figure 4. Three different monthly measures of global real economic activity, 1960:1 to 2018:6.

Notes to Figure 4. Top panel: Kilian measure. Middle panel: 2-year change in log of industrial production for OECD countries plus 6 others. Third panel: 2-year change in difference between  $x_t$  and the log of the *CPI*.

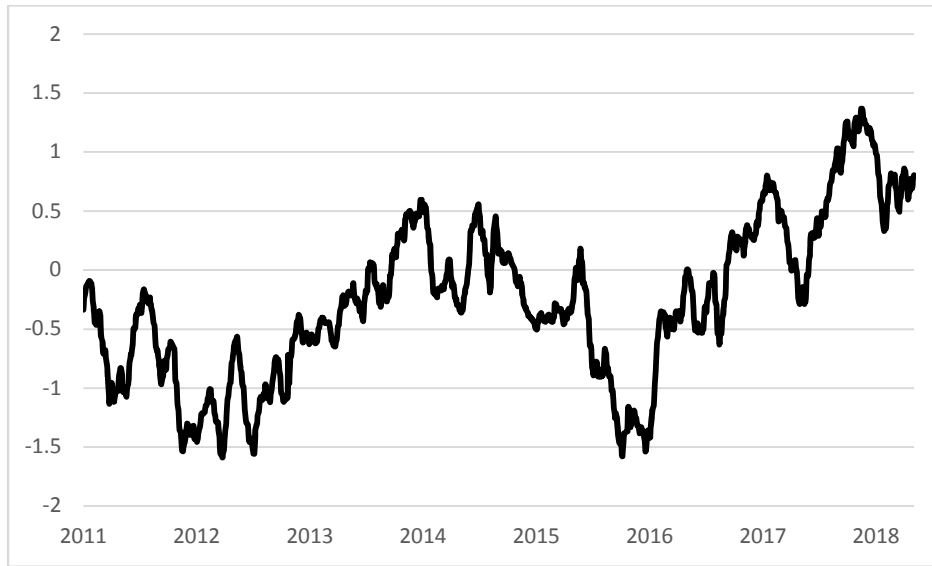


Figure 5. Daily cyclical component of real shipping cost, March 16, 2011 to July 16, 2018.