

## DISCUSSION PAPER SERIES

No. 7265

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*INTERNATIONAL MACROECONOMICS*



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April 2009

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April 2009

## ABSTRACT

### Did Unexpectedly Strong Economic Growth Cause the Oil Price Shock of 2003-2008?

Recently developed structural models of the global crude oil market imply that the surge in the real price of oil between mid-2003 and mid-2008 was driven by repeated positive shocks to the demand for all industrial commodities, reflecting unexpectedly high growth mainly in emerging Asia. This note evaluates this proposition using an alternative data source and a different econometric methodology. Rather than inferring demand shocks from an econometric model, we utilize a direct measure of global demand shocks based on revisions of professional real GDP growth forecasts. We show that recent forecast surprises were associated primarily with unexpected growth in emerging economies (and to a lesser extent in Japan), that markets were repeatedly surprised by the strength of this growth, that these surprises were associated with a hump-shaped response of the real price of oil that reaches its peak after 12 to 16 months, and that news about global growth predict much of the surge in the real price of oil from mid-2003 until mid-2008 and much of its subsequent decline.

JEL Classification: C42, C53 and Q43

Keywords: demand, eiu, forecast revisions, global real activity, news, oil price and shocks

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Submitted 06 April 2009

## 1. Introduction

A central question for macroeconomists and financial analysts alike is what caused the dramatic surge in the real price of oil between 2003 and mid-2008. The structural VAR model of Kilian (2009a) implies that this surge was driven by repeated positive shocks to the demand for industrial commodities including crude oil.<sup>1</sup> This model relies on the use of a proxy for fluctuations in global real economic activity based on dry cargo ocean shipping freight rates. Further analysis in Kilian (2009a) based on a linearly detrended index of OECD industrial production as an alternative proxy for global real economic activity suggests that the unexpected increase in the demand for oil after 2002 was not driven primarily by unexpectedly high growth in the OECD, but by unexpected growth from countries outside of the OECD. This finding is consistent with the widespread perception that much of the recent boom in industrial commodity markets was driven by the economic transformation of countries in emerging Asia such as China and India.

At first sight it may strain credulity that markets would have been repeatedly surprised by high growth in emerging Asia, as suggested by the econometric model, rather than adjusting their expectations early on when it became apparent that the emerging Asian economies were booming. In this paper, we show that this central implication of the model is consistent with independent evidence based on professional forecasts for real economic growth in China and other countries.

Based on the data provided by the Economist Intelligence Unit we first document that, starting in mid-2003, forecasters were repeatedly surprised by high economic growth in emerging economies. In contrast, forecast errors for OECD real economic growth were much

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<sup>1</sup> This type of a model has been employed in a variety of contexts to study the effect of oil demand and oil supply shocks on macroeconomic aggregates and financial markets (see, e.g., Alquist and Kilian 2008; Kilian 2008; Kilian 2009b; Kilian and Park 2008; Kilian, Rebucci and Spatafora 2009).

less biased. Second, we construct estimates of the response of the real price of crude oil to weighted errors in professional real GDP forecasts. We exploit the fact that suitably weighted real GDP forecast errors can be treated as exogenous demand shocks for the global crude oil market.<sup>2</sup> We show that the response of the real price of oil to such news shocks is similar to the response estimates generated by the structural VAR model of Kilian (2009a). Unexpected growth in China, for example, is associated with a large hump shaped response that builds slowly and peaks after about one year. The same regressions for an aggregate of the United States, Germany and Japan yield an increase in the real price of oil that peaks after 16 months. Third, a historical decomposition shows that unexpected growth in emerging economies as well as advanced economies jointly explains much of the rise and decline of the real price of oil between 2000.12 and 2008.12, underscoring the importance of fluctuations in global real economic activity for the real price of oil.

We conclude that unexpected growth in emerging economies played a central role in driving up the real price of oil until mid-2008, but that it was aided by unexpectedly high growth in some OECD economies, most notably Japan. Likewise, much of the decline in the real price of oil is explained by large negative growth shocks since mid-2008 both in emerging and in advanced economies. The remainder of the paper is organized as follows. Section 2 discusses the data on real GDP forecast surprises and the evolution of the real GDP weights. Section 3 presents the econometric methodology and impulse response estimates. Section 4 contains the concluding remarks.

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<sup>2</sup> The link between innovations to global real GDP and the real price of oil is discussed, for example, in Barsky and Kilian (2002). Our econometric methodology is based on the work of Andersen, Bollerslev, Diebold, and Vega (2007) and Faust, Rogers, Wang, and Wright (2007), for example. Kilian and Vega (2008) conduct a similar analysis using high frequency U.S. macroeconomic news measures. For a related analysis of oil inventory surprises see Arsenau, Beechey, and Vigfusson (2008).

## 2. Forecast Surprises

### 2.1. Data Construction

We construct measures of exogenous shocks to real activity based on forecasts of real activity provided by the Economist Intelligence Unit (EIU).<sup>3</sup> The EIU is one of the leading providers of such forecasts. Country-specific forecasts of annual real GDP growth for the current and future years are available every month. The sample period is 2000.11-2008.12.<sup>4</sup> We define revisions of forecasts of real GDP growth as a forecast surprise or news shock.<sup>5</sup> Let  $F_{i,t}$  denote the EIU forecast of annual real GDP growth for the current year or the next year. We focus on the one-year forecast horizon because one-year forecasts are more reliable and watched more closely by market participants and because there is much less variability in forecast revisions at longer horizons. We follow the EIU in treating current annual growth as unknown for January through September of that calendar year. Starting in October of every year, we follow the EIU in focusing on forecasts for the following calendar year. A news shock then can be defined as the forecast revision:

$$N_{i,t} = F_{i,t} - F_{i,t-1},$$

where  $i$  denotes the country and  $t$  denotes the current month. Since the news shocks already are expressed in annualized percent growth rates we do not standardize them. However, a given country's news shock is weighted by the time-varying share  $\omega_{i,t}$  of the country's purchasing-power adjusted real GDP in purchasing power adjusted world real GDP:

$$S_{i,t} = N_{i,t}\omega_{i,t}$$

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<sup>3</sup> The data are proprietary and available from the EIU at [www.eiu.com](http://www.eiu.com)

<sup>4</sup> No monthly data are available prior to this date.

<sup>5</sup> An alternative approach would be to compare forecast to ex post realizations of ex post revised data. Since the lags with which such data are available are long and variable, since the quality of the final data for China and India is questionable, and since we are interested in measuring the news component of forecast announcements in real time, defining news in terms of forecast revisions is more natural.

This approach helps us capture the growing importance of economies such as China in the world economy over our sample period. The share data are constructed from purchasing power adjusted real GDP data in the Penn World Table 6.2.<sup>6</sup> Since the table ends in 2003, we extrapolate the shares for 2004 through 2009 from the average growth rate of each country's share over 1996-2003.<sup>7</sup> Given the approximate linearity of the time path of the shares, this approach should provide a good approximation. Since the Penn World Table is annual, we linearly interpolate the shares to obtain the monthly weights used in constructing  $S_{i,t}$ . Similarly, in constructing aggregates of news shocks across countries we use country weights reflecting purchasing-power adjusted real GDP estimates:

$$S_{i \in I, t} = \sum_{i \in I} N_{i,t} \omega_{i,t},$$

where  $I$  denotes a set of countries.

## 2.2. Data Analysis

A testable implication of the Kilian (2009) analysis is that real GDP forecast surprises in emerging Asia should be positive on average and should be much higher than in OECD economies starting in 2003. Table 1 supports that view. We focus on the four largest emerging economies (Brazil, Russia, India and China), often collectively referred to as the BRIC countries, and the three largest OECD economies (the United States, Germany and Japan). Table 1 shows that of these economies only Russia exhibited strong unexpected growth in 2000.12-2003.5. All other economies experienced (often large) negative growth shocks. In contrast, between 2003.6 and 2008.6, the world economy accelerated unexpectedly and – with the exception of Germany –

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<sup>6</sup> These data are available from the Center for International Comparisons at the University of Pennsylvania at [pwt.econ.upenn.edu](http://pwt.econ.upenn.edu).

<sup>7</sup> Although the Penn World Table 6.2 includes some data for 2004, there are no real GDP data for the world as a whole.

across the board. The largest growth shocks were recorded in China, Russia, and Japan. In addition, India, Brazil, and the United States experienced smaller positive growth shocks. After 2008.6, growth collapsed unexpectedly in all countries with the exception of Brazil, as did the real price of oil. The largest forecast revisions occurred in Germany, Japan and Russia (in that order), but even China, and India experienced large negative forecast surprises. This evidence is consistent with the view that the oil price shock of 2003-2008 was driven at least in part by an unexpected acceleration and deceleration of world economic activity.

Table 1 shows that unexpected growth in emerging economies played an important role in this event, but not at the complete exclusion of growth shocks in advanced economies. Japan's unexpected recovery starting in mid-2003 certainly was a factor. More generally, the relative importance of different countries evolved over time. For example, growth shocks in emerging economies such as China were dominant between mid-2003 and mid-2008, whereas the decline in the real price of oil since mid-2008 was associated as much with negative growth shocks in OECD economies as in emerging Asia.

Many of the forecast surprises during 2003.6-2008.5 were quite sizable. For example, the average monthly forecast surprise about Chinese GDP growth was +0.12 percentage points of annual growth. While a shock of this magnitude may seem modest by itself, successive shocks of this magnitude over several years have the potential to trigger large adjustments in the demand for industrial commodities in general and crude oil in particular. Economic theory suggests that unexpectedly high economic growth without a commensurate increase in global oil supplies should be associated with increases in the real price of oil, as global demand for crude oil grows (see, e.g., Barsky and Kilian 2002).

### **3. Estimating the Effect of Forecast Surprises on the Real Price of Crude Oil**

A natural question is how much of the observed movements in the real price of oil are explained by the forecast surprises documented in section 2. Since response estimates for individual countries can be erratic and since there is reason to believe that emerging economies have a larger industrial sector than advanced economies, we focus on two broad aggregates of countries. The emerging economy aggregate includes China and India, which jointly account for 23.1% of world GDP in 2008 (see Table 2). It may have seemed natural to include the remaining BRIC countries as well. We exclude Russia from the set of emerging economies because it is unclear whether Russian growth shocks are exogenous with respect to the real price of oil, given the dependence of the Russian economy on foreign exchange earnings from oil and gas exports. We exclude Brazil because that economy is effectively decoupled from global crude oil markets to the extent that much of its energy needs are satisfied by domestic ethanol production. We note, however, that the estimated responses for the aggregate for China and India shown below would be very similar, if we included Brazil and Russia among the emerging economies. The aggregate of the advanced economies consists of the United States, Germany and Japan and accounts for 28.3% of world GDP in 2008.

While instructive, the forecast surprises shown in section 2 do not account for the increasing weight of China and India in the world economy in recent years, and the declining weight of OECD economies. Table 2 shows that the combined weight of the United States, Germany and Japan has declined from 33.6% in 1996 to 28.3% in 2009. The weight of all OECD economies has fallen from 58.4% to 51.0%. At the same time, the combined weight of China and India has risen from 14.4% to 23.1%, with China alone accounting for almost 16% of the world economy in 2009. In assessing the impact the forecast errors had on the crude oil market, it is

important that we control for the increasing weight of China and India in the world economy in recent years. Figure 1 plots the weighted forecast errors,  $S_{i \in I, t}$ , since 2001 for China and India combined and for the aggregate of the United States, Germany and Japan. The correlation of  $S_{China+India, t}$  with  $S_{US+Germany+Japan, t}$  is 0.29. We treat these series as measures of exogenous shocks to global real economic activity.

Data for the real price of oil are obtained by deflating the U.S. refiners' acquisition cost of imported crude oil by the U.S. consumer price index for all urban consumers.<sup>8</sup> We relate the percent change in the real price of oil to current and lagged news shocks:

$$\Delta rpoil_t = \alpha_{i \in I} + \sum_{j=0}^{18} \beta_{j, i \in I} S_{i \in I, t-j} + \varepsilon_{i \in I, t}, \quad (1)$$

where  $\varepsilon_{i \in I, t}$  is possibly serially correlated. Following the literature on news regressions, the baseline regression estimates are based only on dates  $t$  on which a nonzero forecast surprise occurred. The parameter  $\beta_{j, i \in I}$  measures the response of  $\Delta rpoil_{t+h}$ ,  $h = 0, 1, 2, \dots$ , to a unit news shock at date  $t$  in the set of countries  $I$ . An estimate of  $\beta_{j, i \in I} = 0.1$ , for example, would imply that a forecast revision of one percentage point would cause an increase in the real price of oil by 0.1%. Since actual forecast surprises are much smaller, we scale all responses to represent the effects of a +0.1 percentage point shock in  $N_{it}$ . In practice, we report the cumulative responses with one standard error bands obtained by the block bootstrap method (see, e.g., Berkowitz, Birgean, and Kilian 1999).<sup>9</sup>

The two panels of Figure 2a show the dynamic response of the price of oil to the news shocks  $S_{China+India, t}$  and  $S_{US+Germany+Japan, t}$ . In the first panel, a revision of annual real GDP growth

<sup>8</sup> The oil price data were obtained from the *Monthly Energy Review* of the Energy Information Administration at <http://www.eia.doe.gov>. The CPI data are from the FRED database.

<sup>9</sup> Results shown are for a block size of 8. Almost identical results are obtained with block sizes of 4 and 12.

forecasts for China and India by 0.1 percentage points raises the real price of oil by about five percent. The response is hump shaped with a peak after 10 months. The price response is quite persistent and most statistically significant in months 9 through 15.<sup>10</sup> The same type of shock in the second panel induces a price increase of almost the same magnitude, with a peak after 16 months, but the hump shape is less pronounced and the response is barely statistically significant in months 8 through 13. The qualitative features of both responses in Figure 2a are consistent with economic theory.<sup>11</sup> Figure 2b shows that similar results are obtained even if we include periods of zero forecast surprises in the regressions. The main difference is that the peak response to  $S_{China+India,t}$  occurs after 14 rather than 10 months.

The upper panel of Figure 2c shows for comparison the response to a positive shock to global demand for all industrial commodities estimated from the Kilian (2009a) structural VAR model. This VAR response is the direct analogue of the response shown in the lower panel of Figure 2c, which is based on regression model (1) applied to a suitably weighted aggregate of the three OECD economies, China and India. Although by construction the magnitude of the shock is not the same, the overall pattern of the impulse response is quite similar. The responses are weakly hump shaped and persistent. They build slowly with a peak after 12 or 13 months for the VAR estimate and somewhere between 10 and 16 months for the news regression estimate. These aggregate results, of course, ignore inherent differences between shocks originating in emerging economies and in OECD economies.

One immediate implication of our analysis is that for the same shock  $S_{i \in I,t}$  the response

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<sup>10</sup> Similar results hold for regressions on China shocks alone. The response to  $S_{China,t}$  is slightly larger than the response to  $S_{China+India,t}$ , but otherwise similar.

<sup>11</sup> Regressions for broader forecast aggregates including all OECD economies yield a similar hump shaped response with a peak after 11 months, but the response is very imprecisely estimated. This result may reflect the lower quality of forecasts (and real GDP weights) for many smaller OECD economies as well as a preoccupation of markets with the real GDP forecasts for the major economies. We therefore concentrate on the three largest OECD economies.

to  $S_{US+Germany+Japan,t}$  would be somewhat smaller in magnitude than the response to  $S_{China+India,t}$ .

This result is expected. Since much of the world's industrial production has moved to emerging Asia, a given surprise about real GDP growth all else equal is associated with a larger increase in the demand for industrial commodities, if the shock emanates from that region. This difference is compensated for in Figures 2a and 2b by the smaller weight in world GDP associated with China and India.

Finally, we assess the overall importance of news about real economic activity for the real price of oil based on the fitted value of the regression (1). We construct a historical decomposition by extrapolating the real price of oil from 2001.5 on the basis of the observed forecast surprises. All regressions are based on the full sample. The first panel of Figure 3 shows that  $S_{China+India,t}$  cumulatively explains a substantial part of the increase in the real price of oil starting in mid-2004. It is not the only explanation, however. The upward pressure on the price is reinforced by the cumulative effect of  $S_{US+Germany+Japan,t}$  starting in early 2004. Although these two news shocks are not uncorrelated, their correlation is fairly low. Thus, to a first approximation, we can add the two fitted values to obtain a crude estimate of the combined effect of global demand pressures on the real price of oil. The third panel shows that  $S_{China+India,t}$  and  $S_{US+Germany+Japan,t}$  jointly explain the bulk of the increase and decline of the real price of oil between 2002.1 and 2008.12, underscoring the explanatory power of demand shifts for the real price of oil.

#### **4. Conclusion**

Many explanations have been proposed for the surge in the real price of crude oil after 2003 including speculation in oil futures and spot markets, adverse oil supply shocks, deliberate

restrictions on OPEC crude oil production, and shifts in global real economic activity.

Understanding the causes of that increase is important for understanding the macroeconomic effects of oil price shocks and for the design of policy responses (see, e.g., Kilian 2008). This paper added to a growing body of evidence that the latest surge in the real price of oil is explained primarily by rising global demand for industrial commodities driven by unexpected economic growth. Our analysis differed from earlier work in that we utilized a direct measure of demand shocks (based on revisions of professional real GDP growth forecasts) rather than inferring demand shocks from an econometric model. We showed (1) that recent forecast surprises were associated primarily with unexpected growth in emerging economies (and to a lesser extent in Japan), (2) that markets were repeatedly surprised by the strength of this growth, (3) that these surprises were associated with a hump-shaped response of the real price of oil which reaches its peak after 12-16 months, and (4) that news about global growth predict much of the surge in the real price of oil from mid-2003 until mid-2008 and much of its subsequent decline.

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**Table 1: Average Forecast Surprises (Percentage Points)**

	2000.12-2003.5	2003.6-2008.6	2008.7-2008.12
USA	-0.05	0.02	-0.08
Germany	-0.12	0.00	-0.33
Japan	-0.10	0.08	-0.27
Brazil	-0.10	0.03	0.07
Russia	0.06	0.12	-0.42
India	-0.06	0.03	-0.17
China	-0.04	0.12	-0.17

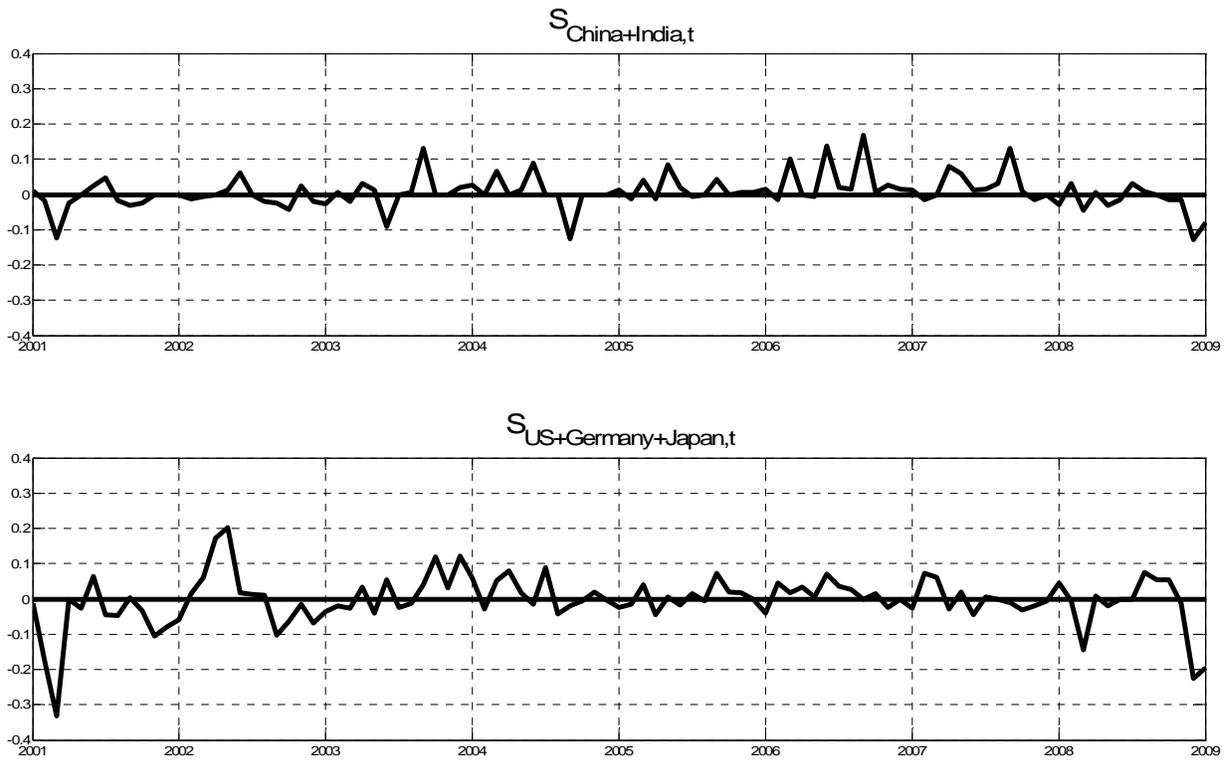
SOURCE: Computations of the authors based on successive annual forecasts of real GDP growth reported by the *Economist Intelligence Unit*.

**Table 2: Shares in World Real GDP (Percent)**

	1996	2002	2009
USA	21.1	20.7	19.9
Germany	4.9	4.3	3.6
Japan	7.6	6.4	4.9
USA+Germany+Japan	33.6	32.2	28.3
OECD	58.4	55.4	51.0
Brazil	3.0	2.6	2.3
Russia	3.0	3.3	3.8
India	5.3	6.1	7.2
China	9.2	12.3	15.9
China+India	14.4	18.4	23.1

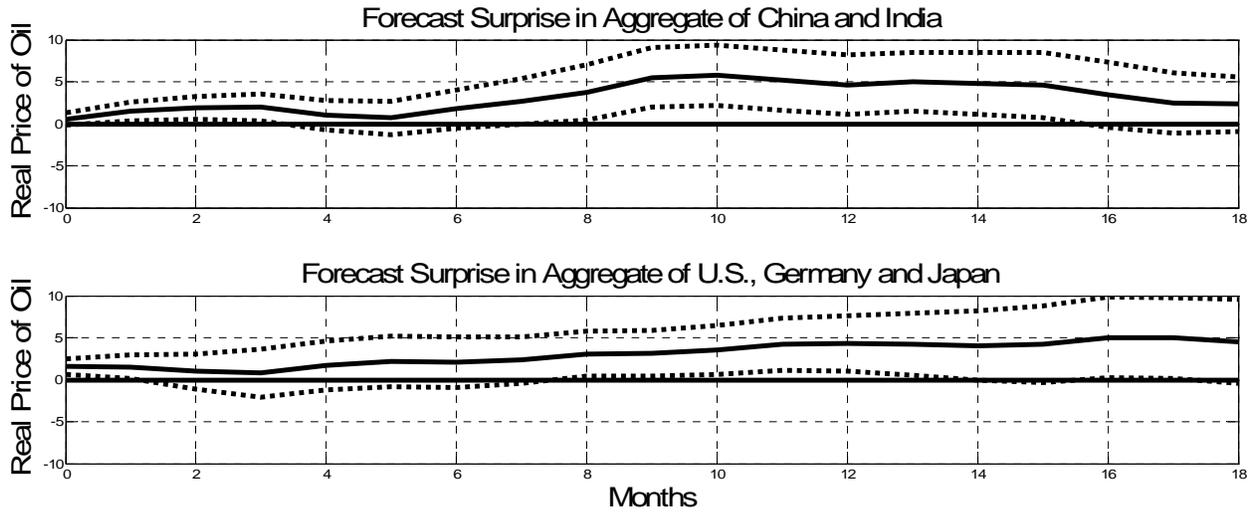
SOURCE: Computations of the authors based on the purchasing power adjusted real GDP data in the Penn World Table 6.2. The shares for 2009 have been obtained by linear extrapolation.

**Figure 1: Weighted Real GDP Growth Forecast Surprises: 2000.12-2008.12**



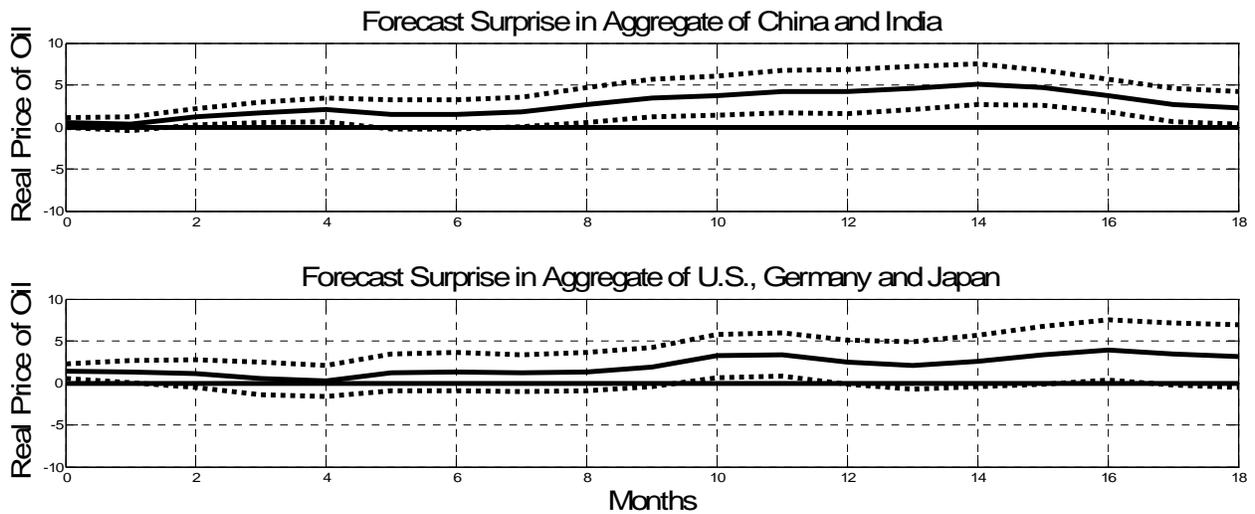
SOURCE: EIU revisions of annual real GDP growth forecasts for each country, constructed by the authors as described in the text and weighted by each country's share in purchasing power adjusted world real GDP, computed from data in the Penn World Table.

**Figure 2a: Responses of the Real Price of Oil to Real GDP Forecast Surprises**  
**Sample Restricted to Months with Nonzero Forecast Surprises**



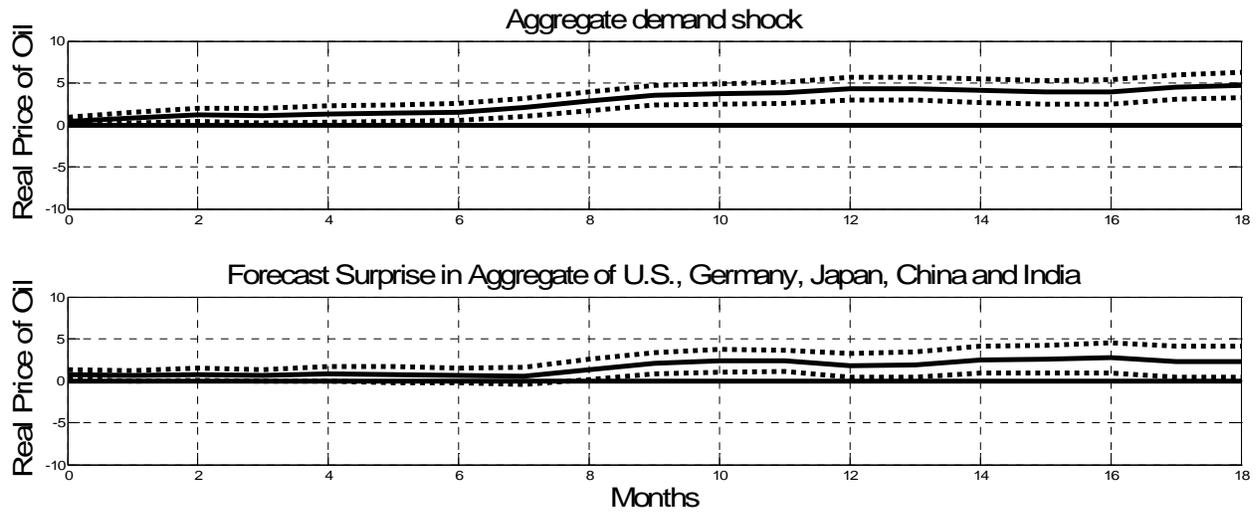
Source: Estimates based on regression model (1).

**Figure 2b: Responses of the Real Price of Oil to Real GDP Forecast Surprises: Full Sample**



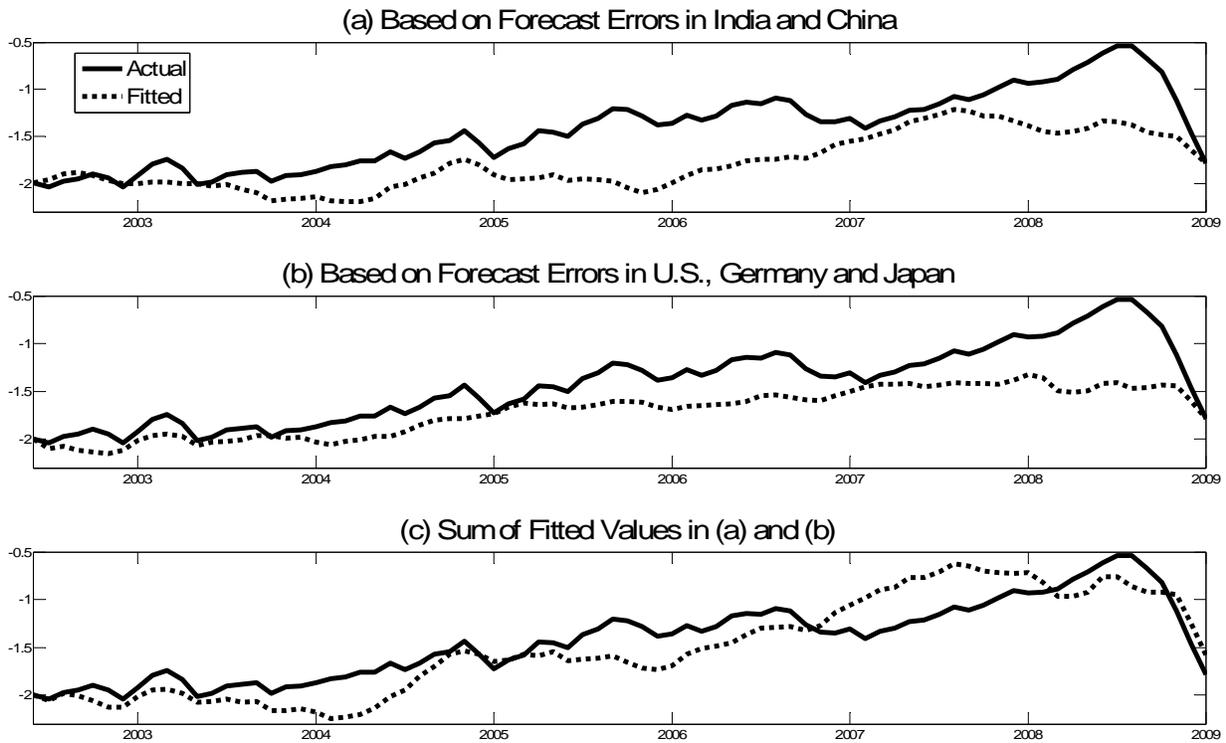
Source: Estimates based on regression model (1).

**Figure 2c: VAR Response to Global Aggregate Demand Shock**



Source: Estimates based on regression model (1) and the VAR model in Kilian (2008, 2009).

**Figure 3: Fitted Value of the Real Price of Oil**



NOTES: Fitted values based on regression model (1) including periods in which forecast errors are zero. Projection of the real price of oil conditional on its value in 2001.5.