The 2008 Boom/Bust in Oil Prices

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May 17, 2010

1 Introduction

The dramatic rise and subsequent sharp decline in crude oil prices during 2008 has been a catalyst for consideration of major regulatory reforms in the markets for commodities. Surely major motivations for this discussion are the substantial costs that oil price rises, subsequent collapses, and the associated increased volatility impose on the real economy.[1] These include large changes in the cost of a key input into production for firms facing inflexible contracts on other inputs or their final products, large losses in output as those firms curtail production to mitigate risk, large transactions costs, burdensome losses associated with imperfect hedges, and higher costs of capital owing to the greater uncertainty faced by potential lenders.

Many attribute these swings to changes in fundamentals of supply and demand with the price effects and volatility actually moderated by the participation of non-user speculators and passive investors in oil futures markets and in energy-related derivatives. My analysis of these arguments and the evidence purporting to support it leads me to a different conclusion. In my view, while spot-market supply and demand pressures were influential factors in the behavior of oil prices, so were participation in oil futures markets by hedge funds, long-term passive investors, and other traders in energy derivatives. The presence of these non-user participants significantly increased both the level and volatility of oil prices leading up to the sharp price decline in late 2008.

This assessment is based on the following observations:

- Economic theory shows that rational management of crude oil inventories can enhance volatility in oil prices when aggregate demand has a persistent growth component. A

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[1]See, for example, Hooker (1996), Rotemberg and Woodford (1996), Hamilton (2003), and the survey by Sauter and Awerbuch (2003).

widely perceived feature of the recent commodity boom is that demand from emerging economies has been a central driving factor, and the stochastic growth component of demands in emerging countries is quantitatively important.

- There are major identification issues with the empirical work purporting to document that most of the run up in oil prices into 2008 is explained by increased aggregate demand in the presence of stagnant supply. Furthermore, even when this evidence is taken as is, it suggests that 2008 was an anomalous period during which economic forces beyond basic supply/demand shocks were important.

- There is considerable empirical evidence suggesting that the investment flows from non-user participants had significant impacts on commodity price changes during the 2006-2009 period, even after controlling for inventory adjustments and past changes in prices. The presence of these effects is consistent with recent economic theories on rational investor behavior in the presence of imperfect information.

2 Models of Supply/Demand and Price Setting in Energy Markets Typically Omit Essential Ingredients for Reliable Policy Analysis

The current generation of models use to examine supply/demand forces in commodity markets are typically illustrative in form and, in particular, are not designed to test whether, say during 2008, non-user participants had a significant effect on the distribution of oil prices.

2.1 Stylized Models of Supply/Demand and Oil Price Volatility

The same economic fundamentals at the core of supply/demand explanations for oil price behavior are key ingredients in models where speculation plays a central role. Dynamic supply/demand models typically abstract entirely from many of the incentives for speculative trading that have been extensively documented in other markets as having large effects on prices. Therefore, these models cannot provide constructive insights into the channels through which the portfolio allocations of traders and the quantity decisions by producers/consumers/refiners interact to determine prices in commodity markets.

Hamilton (2009a) presents a protypical "supply/demand" model that highlights the multi-period aspects of price setting in commodity markets. His model is developed in a

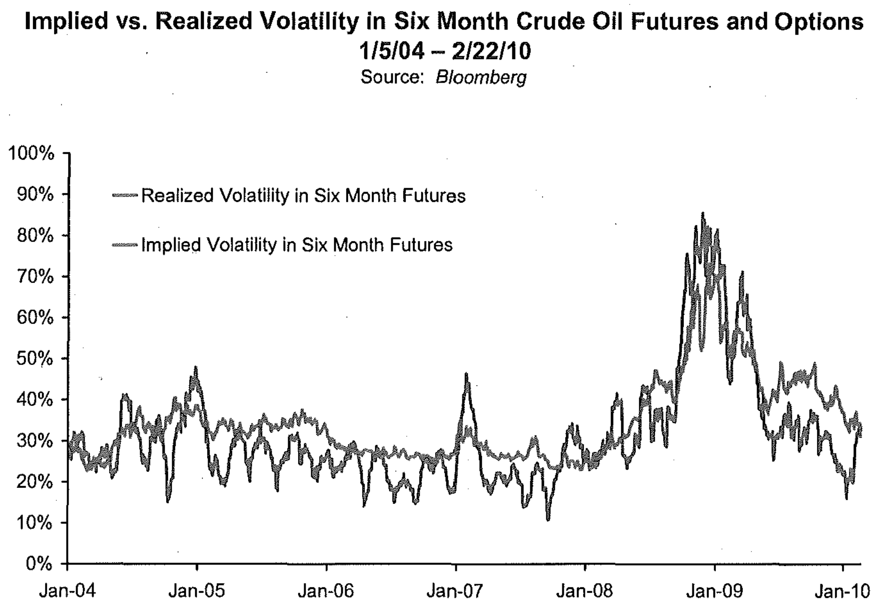


Figure 1: Implied and Realized Volatilities for Six-Month Futures Options and Prices

perfect-foresight setting: all economic agents are fully omniscient about the future, so there is no role for disagreement (different expectations), learning, or risk. A reliable assessment of the proportions of oil price increases during say 2008 that arose as consequences of activities of the various market participants is not attainable under these simplifying assumptions.

Moreover, much of the literature on supply/demand shocks has focused on conditional means (levels) of commodity prices and not their volatilities. Figure 1 displays the implied volatilities on options on six-month futures and the associated realized volatilities computed from futures prices.[2] For the period from January, 2004 through the summer of 2008, implied volatilities reach their local peak around the time of the peak in oil prices. The studies by Hamilton (2009a,2009b), and Kilian and Hicks (2009), among others, do not address the reasons for the enormous increase in price volatility during 2008.

To address volatility in oil markets, standard supply/demand models must be augmented by sources of time varying risks, or they must be extended to accommodate sufficient nonlinearity to generate time-varying volatility in equilibrium prices. Pirrong (2009) explores the former route by introducing a stochastic variance (time-varying volatility) for surprise

[2] Realized volatilities are computed as rolling twenty-one day sample standard deviations, representing approximately monthly volatilities computed from daily data.

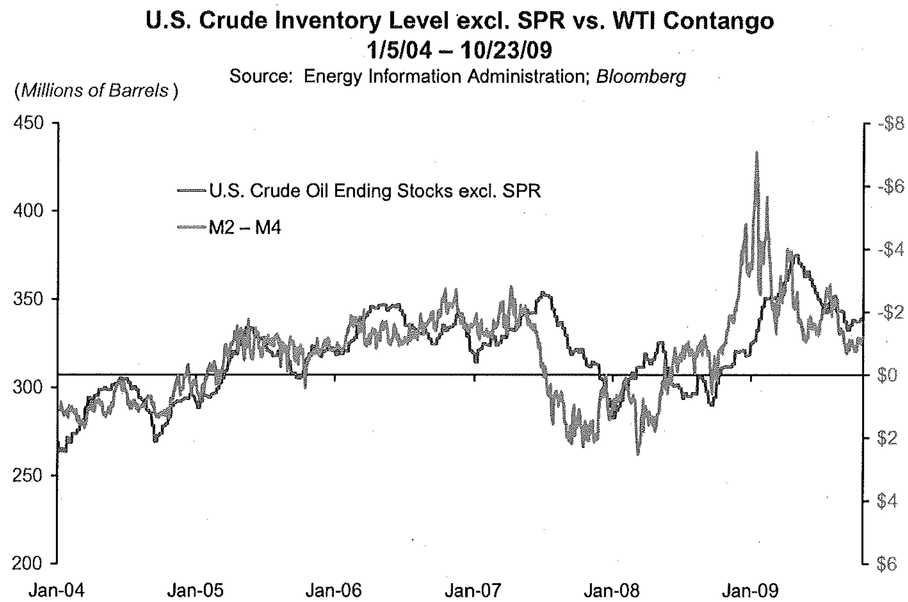


Figure 2: U.S. Commercial Inventories of Crude Oil Plotted Against the Spread Between Two-Month and Four-Month Futures Prices

movements in the demand for oil. But the market participants who are engaging in speculative storage in his model have risk-neutral preferences and, therefore, there are no risk premiums associated with either demand shocks or surprise changes in market volatility.

Pirrong's model also implies that price volatilities tend to peak when the market is in severe backwardation. A comparison of Figure 2 and Figure 1 suggest that, at least for this boom period, the reverse was true for oil markets: implied volatilities in futures and options markets reached their all-time high when the market was in severe contango. Additionally, as he notes, inventory behavior in his model is not realistic.

More generally, as typically specified, supply/demand models abstract from the key frictions that make high volatility in oil prices costly for commercial users of oil. Such users often face long-dated contracted, both for costs (e.g., labor or leases of capital) and for revenues. These contracts, as well as other operational frictions, are likely to amplify the costs to users of excessive volatility in commodity markets. Absent richer models that recognize these frictions, it seems impossible to reliably quantify the welfare losses and sectoral dislocations associated with high levels of or variability in oil prices.

2.2 Inventories, Prices, and Speculative Activity

Inventory adjustment may stabilize prices when uncertainty is modeled as a trend-free process.[3] *Yet there is little doubt that, during 2000 - 2009, market participants were frequently surprised by the* growth rates *of demands for commodities, particularly from emerging economies. When standard models of inventory adjustment are extended to accommodate uncertain growth rates in demand (or supply), then rational inventory adjustment enhances market volatility.*

A widely held view is that, if trading by speculators led to price increases above their *fundamental* values, then we should have seen sizable increases in inventories. This argument has appeared in many forms and venues, with a representative industry perspective being that of the International Energy Agency (IEA): "if speculators are driving spot oil prices, an imbalance in the form of higher stocks should be apparent (IEA (2008a))." This supposed inventory-price relationship has been used by both sides of the speculation/fundamentals debate. Some arguing for fundamentals have noted that we did not see large accumulations in inventories on the parts of refiners (e.g, Hamilton (2009a)), while others (e.g., U.S. Senate Permanent Subcommittee on Investigations (2006)) argued that the coincident increases in U.S. inventories, net of strategic petroleum reserves, and oil prices from 2004 to 2006 was evidence of speculative activity inducing higher spot prices.

The patterns underlying these debates are displayed in Figure 3. Prior to 2003 there was a strong negative relationship between the price of oil and the amount of oil stored for commercial use. These are U.S. numbers and the price of oil is set in global markets, so it is potentially misleading to carry out a debate about inventory/price relationships by focusing on U.S. numbers alone. With this caveat in mind, the U.S. Senate report highlighted the shift to a positive price/inventory relationship between 2004 and 2006 as being suggestive that speculative forces were a factor. Updating their analysis, Figure 3 shows that the price/inventory relationship weakened in 2007 and turned negative, and then was weakly positive again during the first half of 2008. The speculative motives for holding inventories that underlie these price/inventory patterns are well understood.

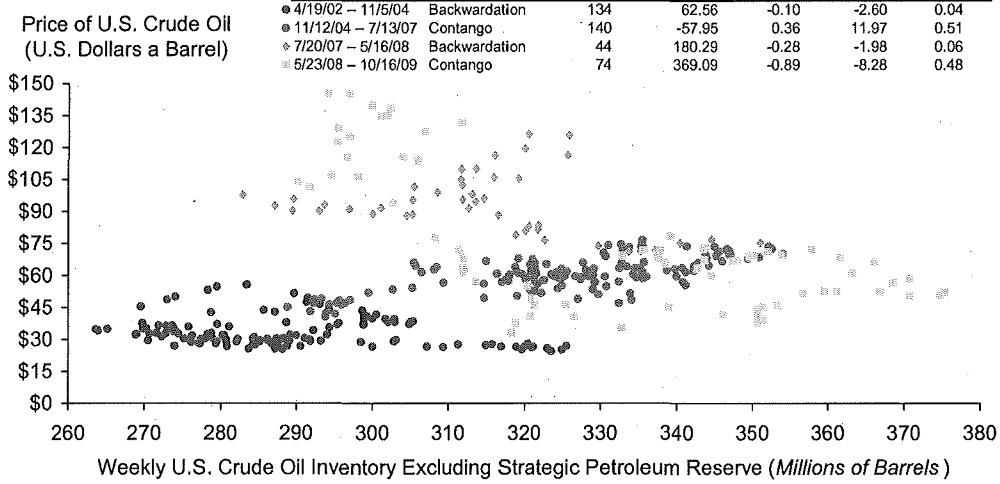
Pirrong (2009) shows that, under the assumption that there is time-varying volatility (risk) related to either the demand and supply of oil, those with storage capacity may also have a precautionary demand for oil. An inherent feature of precautionary demand is that it increases with the degree of uncertainty. In a model of rational market participants in which there is time-varying economic uncertainty about the future, but otherwise similar

[3]See, for example, the classic studies by Working (1962), Brennan (1958), Williams (1986), and Deaton and Laroque (1996).

Crude Oil Spot Price vs. U.S. Stocks
4/19/02 – 10/16/09
Source: Energy Information Administration; *Bloomberg*

Regression Results of Spot Prices on Inventories

Time Period	Term Structure[1]	Number of Observations	Intercept	Coefficient	T Stat for Coefficient	Adjusted R Squared
4/19/02 – 11/5/04	Backwardation	134	62.56	-0.10	-2.60	0.04
11/12/04 – 7/13/07	Contango	140	-57.95	0.36	11.97	0.51
7/20/07 – 5/16/08	Backwardation	44	180.29	-0.28	-1.98	0.06
5/23/08 – 10/16/09	Contango	74	369.09	-0.89	-8.28	0.48



Note 1: Contango and Backwardation are defined using the spot price and the three-month futures price.

Figure 3: U.S. commercial inventories of crude oil plotted against the spot price of oil, for various recent subperiods.

features to Hamilton's framework, Pirrong shows that "...there is no stable relation between inventories and prices. There are periods of time during which there is a negative relation between these variables... Moreover, there are extended periods during which inventories and prices increase together." In particular, a positive inventory-price relationship occurs in his model when there is more demand- or supply-side uncertainty. His analysis suggests that *the sign of the correlation between inventories and price moves is an imperfect indicator of whether traditional speculators were influencing prices.*

Equally importantly, recent developments in economic theory show that the impact of inventory adjustments on the volatility of prices depends critically on what one assumes about the nature of uncertainty about supply and demand. Many storage models (e.g., Deaton and Laroque (1996)) assume that, subsequent to a surprise change in inventories induced by a shock to demand, inventories revert to a long-run mean. It is this response pattern that led Verleger (2010), among others, to expect inventory adjustments to have a stabilizing effect on oil prices.

However, these models of storage cannot simultaneously explain the high degree of persistence in oil prices and the high level of oil price volatility over the past 30 years. Dvir and Rogoff (2009) document significantly different epochs of oil price behavior related to major technological advances or regional growth spurts over the last two centuries. The period since the 1970's, like portions of the 1800's, is characterized by rapid economic growth in emerging economies (Asia in particular), relatively restrictive supplies of oil, and relatively high volatility in oil prices.

Arbitrageurs (those who store to make a profit from price changes) are confronted with two opposing implications of a positive income or demand shock. The price of oil increases and there is a drop in effective availability, both of which encourage a reduction in optimal storage. On the other hand, the persistent nature of aggregate demand means that both income and prices are expected to be higher in the future. Under the classic "leaning against the wind" view of storage, aggregate demands are presumed to revert to their long-run means. Therefore, the former dominates the latter effect and, in response to a positive income shock, storage will be reduced until the price falls back to its steady state value.

A very different pattern emerges from the empirically more realistic case of a stochastic trend in economic growth as in the model of Dvir and Rogoff (2009). Again arbitrageurs face two opposing forces when confronted by a shock to economic growth. However, when growth has an important trend component, the expectation that prices will be higher in the future encourages an *increase* in inventories and this effect dominates the reduction in storage induced by the immediate post-shock increase in prices. On balance, then, storage (by arbitrageurs, refiners or consumers) amplifies the effects of demand shocks on prices.[4]

A notable feature of economic growth growth in emerging economies is that the shocks to growth tend to be more important for understanding consumption patterns (Aguiar and Gopinath (2007)). That is, shocks to growth contribute more to variability in output in emerging than in developed economies. It seems indisputable that the strong patterns of growth in emerging economies contributed significantly to the demand pressures in commodity markets during the recent boom. This empirical regularity together with the preceding theoretical reasoning suggest that speculation about future growth may have had destabilizing effects on prices as a consequence of participants following rational storage policies.

Consistent with these observations, Figure 2 plots the level of U.S. crude oil inventories (excluding the strategic petroleum reserve) against the spread between the futures prices for two- and four-month contracts (inverted scale). Spreads that are above the zero line occur

[4]While this amplification mechanism has some characteristics of the *precautionary* demand studied by Pirrong, the economic mechanism underlying it is not driven by uncertainty about demand, but rather by expectations of rising prices.

with the futures market is in contango, and spreads below this line indicate backwardation. There is a clear tendency throughout the period of 2004 through 2009 for inventories to increase when the futures market is in contango.[5]

3 Global Demand/Supply Imbalances Do Not Account for the Behavior of Oil Prices During 2004- 2008

The supply/demand model attributes nearly all of the run up and subsequent rapid decline in prices from 2003 - 2009 to expectations of expanding and contracting world demand for oil against a largely stagnant supply. There are many nontrivial identification issues that compromise efforts to empirically document this attribution. While the direction of these economic forces is consistent with the recent behavior of oil prices, it seems unlikely that they fully explain the magnitudes of either the levels or volatilities of prices.

Until mid-2008, demand for oil was growing, particularly in Asia, and supply was roughly flat or slightly falling. These patterns, combined with a presumed low price elasticity of demand for oil based products (see, e.g., Hamilton (2009b)), underlie the conclusions of Hamilton (2009a), Helbling, Mercer-Blackman, and Cheng (2008), and International Monetary Fund (2008), among many others, that the boom in oil prices during 2008 was largely a consequence of increasing demand inducing upward pressure on prices. Evidence that demand was growing along with prices does not by itself *explain* the sharp run up in oil prices. Demand elasticities are difficult to measure accurately (Hamilton (2009b)), and a small change in an estimate may lead to a very different conclusion regarding the proportion of high oil prices that resulted from demand pressure versus other economic factors.

The literature has explored the links between economic growth and commodity prices by examining the correlations between surprise changes in the supply and demand for commodities and current and future changes in oil prices. This research is statistical in nature in the sense that the assumptions made to distinguish between demand and supply shocks are that certain correlations are zero, not that demand and supply functions for commodities take a specific structural form. For the period of interest, particular attention has been given to growth in emerging economies.

Kilian (2009) and Kilian and Hicks (2009) present some of the most comprehensive empirical evidence on the effects of supply and demand shocks on oil prices during the price

[5]These patterns are even stronger when inventory levels from Cushing or Padd2 are used.

boom from 2003 through the middle of 2008. As background to these studies Kilian (2008) argues that oil supply shocks explain only a small percentage of oil price fluctuation, and so a primary goal of this more recent research is to identify and measure the effects of demand shocks on prices. Distinguishing between the effects of surprise changes in supply and demand on prices is an inherently challenging problem owing to the simultaneous determination of prices by supply and demand in an uncertain, dynamic environment. Moreover, it is not just current demand and supply that determines current prices, but also the expectations (forecasts) of market participants about future supply and demand patterns. For a storable commodity like oil, we should also bear in mind that a portion of measured oil purchases is for storage for future consumption.

To circumvent some of the measurement issues with demand data in particular, economists have turned to indirect measures based on transport costs for dry bulk goods. Using transport costs is not without potential problems, both because of challenges in separating the effects of demand versus supply and the fact that transport costs will increase precisely when the price of oil increases.

Kilian (2009) finds that a large proportion of the variation in oil prices over the past thirty years was explained by his oil-market specific shock, what he calls a precautionary demand shock. The literal interpretation of this shock is that it is the component of surprise movements in oil prices that are not explained by either supply shocks or surprise changes in bulk transportation costs (his measure of demand). There is no formal link between the oil-specific shock to the demand for oil, nor to precautionary demand. If it does represent a precautionary demand, then changes in this oil-market specific variable should be correlated with volatility in oil prices. However, Pirrong (2009) found that there is essentially no correlation between his estimate of Kilian's precautionary demand shock and oil price risk. Therefore, we are left with the possibility that Kilian's oil-specific shock is capturing a very different economic phenomenon than precautionary demand.

Kilian and Hicks (2009) go further and attempt to answer the question of whether surprise increases in the global demand for oil explain the price run-up and subsequent decline in oil prices during 2008. Using forecasts of GDP growth for emerging and developed economies provided by the Economist's Economic Intelligence Unit, these authors attempt to quantify the proportion of oil price increases induced by positive surprises in output growth. Specifically, they compare the predicted values of the real price of oil from past errors in forecasting growth in India and China on the one hand, and from past errors in forecasting growth in the U.S., Germany, and Japan. Using either set of countries, they find that their model's growth-based predicted prices of oil are well below the actual prices, and these gaps are particularly large during 2008 when oil prices reached their peak.

Kilian and Hicks proceed to add together the fitted oil prices for their two sets of countries and this sum gives fitted values that are much closer to the actual oil prices. But within the framework of their analysis, their fitted prices are not additive. Indeed, in their own words "these results have to be taken with a grain of salt because the two shock series are weakly correlated.. (Kilian and Hicks (2009), pg. 11)." Contrary to the authors' conclusions that news surprises about output growth explain the high real prices of oil during 2008, their graphs suggest that some other economic factor, over and above global growth in demand, was a central determinant of oil prices, particularly during 2008.

There is another, more fundamental, problem with their analysis. Kilian and Hicks construct their GDP news series from GDP forecasts that, presumably, take account of all relevant past information for forecasting future output. One such piece of information is the past price of oil. Therefore, the predictor variables in their regressions– their GDP news series– embodies news that is specific to the price of oil. As such, they are effectively regressing the price of oil on past news surprises about the price of oil. It seems plausible that one consequence of their mismeasurement of surprises in world output growth is an overstatement of the importance of such surprises for the run up in the price of oil.

Using a very different approach, Saporta, Trott, and Tudela (2009) also explore the links between oil supply/demand and prices during 2008. Positive surprises in global aggregate demand were directionally consistent with the run-up in oil prices starting in 2003, and developments on the supply side reinforced market tightness. Moreover, they document substantial revisions to forecasts of market tightness,[6] based on data reported by the EIA, especially during 2007. After comparing news about, and revisions in forecasts of, supply and demand for oil during 2008, these authors conclude that "Based on the news about the balance of demand and supply in 2008 ... it seems that one can justify neither the rise in prices in the first half of 2008, nor the fall in prices in the second half (Saporta, Trott, and Tudela (2009), pg. 222)."

4 Economic Theory Shows that Investor Flows, Even from "Passive" Investors, Can Have Major Effects on Commodity Prices

Economic theory suggests that important missing ingredients from supply/demand models of oil price determination are the economic forces underlying the extensive

[6]Market tightness is defined as total consumption (excluding stocks) minus the sum of non-OPEC and OPEC production.

trading we see in the energy-related securities markets. The models we have discussed so far accommodate only a limited set of representative *participants and, thereby, they abstract from the complex interactions among commercial and non-commercial investors in commodity derivatives and from the extensive heterogeneity among investors both across and within categories of traders.*

4.1 Investor Heterogeneity, Imperfect Information, and Volatility

Central to the ongoing debate about regulation of commodity markets are the roles of different categories of market participants in generating excess volatility in prices, and the cost to society of any "excessive" speculation. The conceptual frameworks underlying most demand/supply-based explanations for recent price behavior cannot, by construction, address either of these issues. Most models of commodity prices ignore the heterogeneity of beliefs or expectations held not only across different groups of investors, but also within each of these groups. That it is plausible that investors hold different beliefs about the future course of economic events that impinge on commodity prices hardly seems controversial. There is likely to be some disagreement among market participants about virtually every source of fundamental risk, including the future of global demands, the prospects for supply, future financing costs, etc.

Saporta, Trott, and Tudela (2009) summarize the large errors in forecasting demand for oil. Errors were typically on the side of under estimation of demand, with most of the error arising because of under estimation of demand from non-OECD Asia and the Middle East. Additionally, the IEA (2009) observed that there were substantial revisions to their monthly estimates of demands for the U.S. Similarly, regarding non-OECD inventories, IEA (2008b) observes that "detailed inventory data [for China] continues to test observers' powers of deduction. As we have repeatedly stressed in this report, these data are key to any assessment of underlying demand trends... (p. 15)"

Turning to supply, Sornette, Woodard, and Zhou (2008) document significant differences in the total world supplies for liquid fuels published by the IEA and the U.S. Energy Information Administration (EIA), particularly from 2006 until 2008. As the IEA also notes, the timeliness of non-OECD data is highly variable. Regarding OPEC supply, as Hamilton (2009b) notes, their quotas and measured production levels are quite vague.

When market participants hold different views about the future, it is optimal for each participant to forecast the forecasts of others (Townsend (1983), Singleton (1987)). That is, it is optimal for each participant to try to guess what other participants are thinking and to adjust their investment strategies accordingly. Within present value models that share many of the same intertemporal considerations involved in pricing commodities,[7] Xiong and Yan (2009) and Nimark (2009) show that different groups of traders will naturally engage in speculative activity with each other. Intuitively, in economic environments with heterogeneous beliefs, traders will exploit differences between their forecasts and the market consensus by taking speculative positions. Indeed, Allen, Morris, and Shin (2006) show that this heterogeneity allows one to formalize the intuition of Keynes' "beauty contest" in that investors will tend to overweight public opinion and, as a consequence, there will be times when the path of prices will depart from the expected fundamental value of the asset. Moreover, prices will react more sluggishly to changes in fundamentals relevant for the value of a commodity, inducing a form of momentum in prices.

The optimal (rational) behavior of market participants in the presence of disagreement can introduce an important speculative source of price volatility that is entirely absent from the frameworks that focus on representative suppliers, consumers, hedgers, etc. An important and subtle implication of the presence of "forecasting the forecasts" of others is that commodity prices will tend to be more volatile and, from a social welfare perspective, society may be worse off *even though each investor participating in this guesswork is small.* That is, social welfare is reduced even though equilibrium prices do not depend directly on the degree to which any individual investor incorrectly measures values of the fundamental variables.

The welfare costs of excessive speculation are potentially amplified by the fact that the personal costs of near-rational behavior by individual investors– that is, following slightly suboptimal investment or consumption plans– is negligible and yet this behavior might be quite costly for society as a whole (Lucas (1987) and Cochrane (1989)).[8] This point is formally developed in Hassan and Mertens (2010) where it is shown that, when investors make small correlated errors around their optimal investment policies, financial markets amplify these errors and generate excess volatility in securities prices that is unrelated to fundamental supply/demand information.

The particular economic mechanism through which social welfare is reduced in the model of Hassan and Mertens (2010) is that higher volatility in capital markets raises risk premiums and, as a consequence, the cost of capital to firms. This, in turn, affects firms' investment plans and impacts overall output in an economy. The same issues arise, for example, in an economy in which commercial users purchase commodities as intermediate inputs into

[7]These authors study bond marktes. Analogous to the discounting in bond markets, commodity markets involve present values tied to financing cost, convenience yields, and storage costs.

[8]Such suboptimal plans may arise out of misinterpretations of public information say about future economic growth in developing countries, because of small costs to sorting through the complexity of global economic developments and their implications for commodity prices, or because of over-confidence about future economic growth as in Dumas, Kurshev, and Uppal (2006).

production (e.g., airlines, transportation companies, etc.). Furthermore, once more realistic multi-period contracting over labor and physical capital (e.g., airplanes and semi-tractor trailers) is added, one suspects that the social costs of excessive volatility will be higher than what is measured in the extant literature.

Many of these studies abstract from the extensive array of associated derivatives contracts in commodity markets (futures, commodity swaps, etc.). Adding derivatives markets will typically improve price discovery and mitigate some of the informational problems. However enhanced price discovery is only one facet of the complex effects of imperfect information and incomplete financial markets on commodity price setting. In addition to their affects on price discovery, derivatives markets alter participants' access to hedging vehicles and, thereby, affect allocational efficiency as well. These two effects can interact to make society worse off in the presence of certain derivatives when information is asymmetric and participants are not able to hedge against all of their business or income risks (Huang and Wang (1997)).

4.2 How Can Index Investing Affect Commodity Prices?

A contentious issue related to the recent behavior of commodity prices is the degree to which growth in index investing– exposure to commodities through index-linked products– contributed to price volatility. Before taking a closer look at the empirical evidence on whether index flows affected oil prices, it is instructive to address the conceptual question of how index investing might affect commodity prices. Many have characterized index traders as "passive investors." Yet the evidence (see Section 5) from the CFTC's Commodity Index Traders reports shows substantial changes in aggregate positions of index traders over periods as short as a few weeks.

Changes in aggregate positions reflect the inflows of funds from new investors and changes in pre-existing positions of established investors. It seems reasonable to presume that a non-trivial portion of flows into and out of index products reflect investors' expectations about future commodity prices and their assessments of the risks associated with exposure to commodity-linked products. Even if the horizons of a majority of index investors are relatively long (weeks and months, not days), their positions are surely not immune to changes in their assessments of future economic growth, nor of their subjective assessments of the reliability of their forecasts. In this sense (at least), index investing is not entirely passive.

The basic laws of supply and demand in financial markets imply that an increase in long positions in futures markets will tend to put upward pressure on prices as, ceteris paribus, a price increase is needed to induce others to take the opposite side of the long position. Now suppose that a central consideration for a material subset of index investors is the prospective growth in emerging economies. This focus might arise directly, in the sense that index investors are taking long positions in commodity markets based on their views about future growth; or indirectly through portfolio rebalancing by diversified investors, as say rising prices in the stock markets of emerging economies induce increased commitments of funds to commodities. Long-term growth rates are inherently difficult to measure accurately. It is therefore plausible that index investors (among others) are, in part, updating their views about future growth from prices in financial markets, both equities and commodities. Such feedback effects can impact commodity prices through several channels.

First, as formally demonstrated in the model by Hassan and Mertens (2010), small correlated errors related to information relevant for investing in commodities can increase market volatility and reduce social welfare. I stress that there is an amplification process that arises as a consequence of the price discovery role of financial markets. All that is required for there to be significant social costs from index investing is that index investors are just slightly too optimistic (in market rallies) or pessimistic (in market downturns) relative to the true state of the world. These errors are inconsequential for the welfare of the individual index investors, but they are material for society as a whole. When index investors see price increases they do not know (for certain) whether their peers are making errors or (with positive probability) they have actual, more positive information about say future growth in emerging economies. In either case, it will be completely rational for index investors to revise their expectations upwards. This will lead to a further rise in stock prices, which triggers further revisions in expectations, and so on.

The extent of the social costs of this source of excessive volatility depends on the costs to society of the distortions from higher volatility. Hassan and Mertens focus on distortions affecting capital accumulation and output growth. Extending their model to accommodate long-term contracts, regulatory restrictions, etc. would expand the potential economic channels through excessive volatility in commodity markets has real costs to society.

A subtle issue that arrises when considering the implications of small investor errors for economic activity is the effect of these errors on price discovery. The views of individual investors reflect fundamental information. So it might seem that their participation in financial markets improves the information aggregation function of these markets. However, what happens in many models with noisy information is that this noise gets imparted into market clearing prices so that, in the end, markets are less effective at price discovery. The larger the noise in individual investor's views, the more they rely on the market price in constructing their own expectations, which in turn means that there is a larger amount of noise in prices and markets are even less effective at performing their price discovery role.

Currie et al. (2010) advocate one extreme view in arguing that index investors "provide little fundamental information to the market that would impact ... prices." They seem to be saying that if index investors as a whole impact prices, then it is the noise underlying their near-rational investment policies that shows up in prices. This is precisely the type of noise that compromises price discovery and that can have large impacts on operating costs of firms and, ultimately, on society as a whole.

An altogether different economic channel through which index investors might affect price behavior in commodity markets is more indirect and relates to the "natural long" view of index investors. Some argue (e.g. Verleger (2010)) that the large inflows of passive money into commodities facilitated– effectively financed– the accumulation of inventories by arbitrageurs in physical commodities. This is viewed as a positive attribute of index investing because, according to the classical models of inventory adjustment, inventories are buffers that stabilize prices. However we have seen that these models omit critical features of demand growth in emerging economies, most notably that demand embodies a stochastic trend. Once stochastic growth is accommodated, inventory policies may well have destabilizing influences on prices since they reinforce directional moves and increase volatility.

This second illustration raises a broader issue that seems to have received little attention in the academic literature or financial press. Namely, we know very little about the degree to which different groups of commodity investors are effectively trading against each other. To what extent does one group of investors monitor the trading activities of other groups (for instance, as published by the CFTC or mutual funds, or as observed through their own trading operations) and take positions based on this information?[9] Under the plausible assumption that investors, both within and across trading categories, have different views about the future, how does the "forecasting the forecasts of others" problem amplify volatility in commodity markets?[10]

5 Investor Flows Have Significantly Impacted the Levels and Volatilities of Energy Prices

When exploring the impact of speculation on the price of oil, natural focal points are the trading activities of key classes of participants in the commodity markets. The CFTC is now

[9] There is extensive empirical evidence that order flow information in markets is a valuable input into the trading strategies of large financial institutions. See, for example, the evidence on currency markets in Evans and Lyons (2009).

[10] Recent research by Qiu and Wang (2010) shows that when market participants have heterogeneous information, and so asset prices depend on the expectations of the expectations of others, prices tend to be more volatile and the overall welfare of society is lowered.

making available position reports on four categories of traders, back to 2006: traditional commercial (commodity wholesalers, producers, etc.), managed money (hedge funds), commodity swap dealers, and "other."[11] In addition, research staff at the CFTC have undertaken several studies of trader positions using internal proprietary data that has a much finer breakdown of market participants into categories of traders and is available daily.

Overall, most of the evidence from this literature suggests that position changes in futures markets by managed money or commodity swap dealers either have weak or no (statistically significant) impact on prices and there is some evidence that hedging activity tends to stabilize prices (reduce price volatility).[12] For several reasons, however, it seems premature to draw firm conclusions about the role of speculation (broadly construed) in the determination of oil prices from these studies. First, even the more finely defined categories of traders used in the CFTC studies do not home in on the precise groups of traders that allow clear conclusions say about index flows. Part of the trading activities of swap dealers reflect OTC deals with traditional commercial commodity traders. On top of this, positions taken by any category of trader in the futures market typically represent hedging of *net* exposures to oil price risk or a combination of hedging and speculative positions (i.e., exposures different than what a pure hedge would call for). So large inflows of passive index money could be observed concurrently with short futures positions of commodity swap dealers, owing to the risk profiles of their total positions.

Similarly, knowing whether price changes lead or lag position changes over short horizons (a few days) is of limited value for assessing the price pressure effects of flows into commodity derivatives markets. Many factors affect daily price changes. Of more relevance is whether flows affect returns and risk premiums over weeks or months. Also, evidence that any particular group of investors acquires positions after say a price decline is not evidence of lack of intent to corner a market, nor it is evidence against the view that the investment strategy of this group is inducing systematic pressure for prices to move up or down.

More broadly, commodity swap prices balance the trading needs of institutional participants against the balance-sheet risks faced by dealers. The market equilibrating price will be influenced by hedging demands, and passive and active investments. Price pressures in the swap markets will spill over to futures markets, and vice-versa, through the actions of inter-market arbitrageurs. Etula (2010) provides evidence that, over long periods of time, the

[11]Prior to 2009 the Commitment of Traders Report (COT) only reported information for the broad categories of "commercial" and "non-commercial" traders. This information is obviously too coarse to be of value in evaluating whether the trading activities of particular classes of traders contributed to the high oil prices during 2008.

[12]See, for example, Boyd, Buyuksahin, Harris, and Haigh (2009), Buyuksahin and Robe (2009), Buyuksahin and Harris (2009), and Brunetti and Buyuksahin (2009).

risk-bearing capacities of broker-dealers in commodity markets have a significant effect on risk premiums in commodity markets. This evidence corroborates the view that the ebbs and flows of desired long and short positions of investors move futures prices in part through changes in market risk premiums.

Detailed information about the origins of most of the open interest in OTC commodity derivatives is not publicly available. Therefore, one can at best make indirect inferences about flows in these markets and their potential effects on commodity prices. Two such attempts are undertaken by Tang and Xiong (2009) who studies agricultural commodities, and Masters (2009) who uses the information about index flows in agricultural products provided by the CFTC to impute flows into oil index products. Tang and Xiong (2009) focus on what they call the "financialization" of commodities. They show that, after 2004, commodities that are part of the GSCI and DJ-AIG indices became much more responsive to shocks to a world equity index, changes in the U.S. dollar exchange rate, and oil prices. These trends are stronger for those commodities that are part of a major index than for other commodities. Tang and Xiong attribute their findings to "spillover effects brought on by the increasing presence of index investors to individual commodities (page 17)."

They also construct a measure of the investment flow by index traders (IF) into twelve agricultural commodities using the weekly Commodity Index Traders (CIT) report from the CFTC.[13] Within a joint time-series model of agricultural index flows and excess returns on the GSCI Agriculture and Livestock index, the world equity index, the US dollar currency index, and oil, they find that the one-week lagged IF has significant predictive power for all of these returns. They infer from these results that "trading by commodity index investors has closely integrated the commodities markets to the broad financial markets (page 20)." Complementary evidence on the comovement of oil and US equity prices, particularly as it related to trading activity by hedge funds, is presented in Buyuksahin and Robe (2009).

Masters (2009) explores the links between index flows into oil positions and oil price behavior more directly, though less formally. Using the percentage allocation to specific agricultural products in the GSCI and DJ-AIG commodity indices, and the data on flows into these commodities from the CIT reports, Masters computes the implied flows into crude oil positions by index investors. There are limitations to these calculations. The proportion of each index made up of any one agricultural product is small, so any mismeasurement is likely to be amplified through the scaling process. Further, valuation is done at the near-contract futures price (as was the case with Tang and Xiong (2009)), and this might not have been

[13]For this purpose they use the price of the first-month futures contract, and they assume that all position changes occurred during the previous week.

how index traders positioned the actual fund flows in oil markets.[14] Nevertheless, Masters' estimates should be suggestive of the broad patterns in long positions in oil by index funds.

Figure 4 displays the long index positions imputed by Masters against the "swap dealers and managed money" category from the CFTC's Commitment of Traders (COT) report. The latter is the data often used in empirical studies of fund flows into futures markets and their impact on futures prices. It is immediately apparent that these two series are very different, particularly from the fourth quarter of 2007 through the third quarter of 2008, and then again through the second half of 2009. Even with the above caveats regarding measurement in mind, this graph lends support to the view that the CFTC's COT data does not give a reliable picture of the overall demand for and supply of commodity risk exposure.

The imputed index long positions from Masters (2009) are plotted against the spot WTI crude oil price in Figure 5. The comovement is striking and it leads naturally to the question of whether flows as imputed in this manner directly affect *future* changes in oil prices. Although Masters attributes the run-up in oil prices during 2008 to the trading patterns of index investors, it seems premature to reach this conclusion from Figure 5 alone.

Before addressing this issue in more depth, it will be useful to review two related studies. First, Buyuksahin et al. (2008) argue that prior to the early 2000's, the prices of long- and short-dated futures contracts behaved as if these contracts were traded in segmented markets. They find that, since the middle of 2004, the prices of one- and two-year futures have been cointegrated with the nearby contract; that is, that all of these prices trend together. This closer integration of futures along the maturity spectrum was no doubt a consequence of several developments, including the increased trading activities of hedge funds engaged in spread trades (Buyuksahin et al. (2008)) and the incentives for index-fund managers to purchase longer-dated exposures through futures when the market is in contango.

Second, Stoll and Whaley (2009) present one of most comprehensive investigations of the connection between index investing and commodity futures prices for agricultural commodities, using the same CIT data examined by Tang and Xiong (2009) and Masters (2009). One point they emphasize is that patterns similar to Figure 5 (in their case for agricultural commodities) reflect the fact that a portion of the imputed position of index traders in any given commodity is driven by the movement in the underlying commodity price, as opposed to changes in the sizes of the positions of index traders.

Nevertheless, overall position sizes did change. In fact, their evidence contradicts the

[14] The evidence in Buyuksahin et al. (2008), based on proprietary CFTC data, suggests that the net positions of commodity swap dealers were primarily in short-dated futures contracts (three months or under). While this CFTC category is far from a perfect proxy for index positions, it suggests that using the near-term futures for marking imputed index flows is a reasonable starting place.

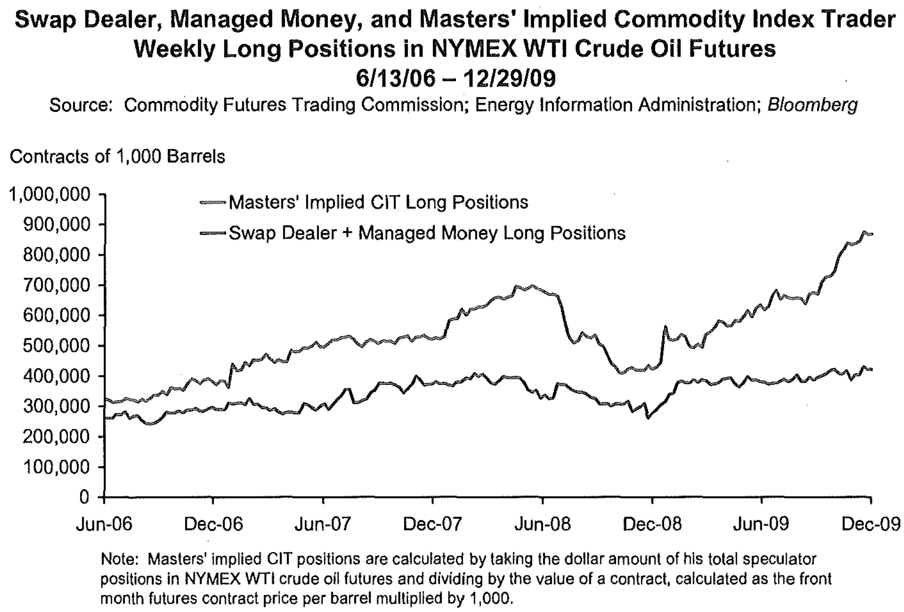


Figure 4: Commodity index long positions (Masters (2009)) plotted against the swap dealer and managed money positions as reported by the CFTC's Commitment of Traders report.

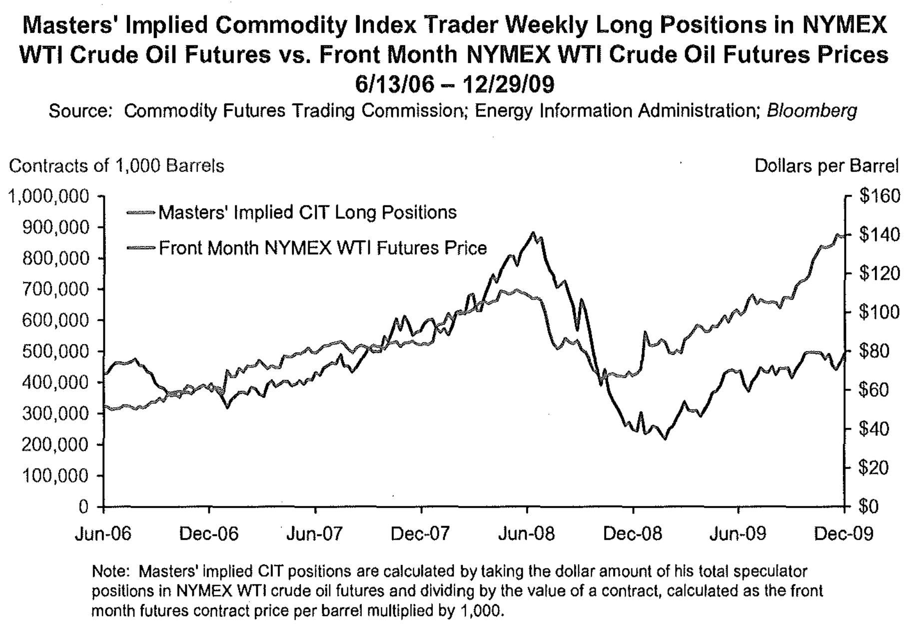


Figure 5: Commodity index long positions (Masters (2009)) plotted against the front-month NYMEX WTI futures price.

view that commodity index investors "do not take a directional view on commodity prices. They simply buy-and-hold futures contracts to take advantage of the risk-reducing properties they provide (Stoll and Whaley (2009), page 17)." Even under the conservative estimates of position sizes by index investors in Stoll and Whaley, they doubled between 2006 and the middle of 2008, and then declined rapidly by nearly one half as of early 2009. Moreover, the evidence in Tang and Xiong (2009) that excess returns in agricultural futures positions were increasingly correlated with global stock price movements during 2004 - 2009 suggests that either index investors were chasing returns in both commodity and emerging equity markets until the global economy weakened, at which point many unwound their long positions in both markets, or that investors in both markets were engaged in correlated trading strategies induced by views about emerging economies.

Another point made by Stoll and Whaley (2009) is that, once lagged returns on futures positions are included in predictive regressions, there is no incremental predictive power for flows into commodity index investment. Similar points related to lagged open interest have been made by others. However, using data over a longer sample period and for a much broader set of commodities, Hong and Yogo (2010) find a very strong predictive relationship between current open interest and subsequent returns on futures positions. Moreover, when both open interest and lagged returns are included in predictive regressions, open interest drives out the forecasting power of returns.

Harrison and Yogo also find that open interest in commodity markets is a useful predictor of future inflation and returns in bond markets. They interpret this finding as evidence that open interest rises in response to macroeconomic news and this news gets impounded into commodity prices with a delay. In the period that we are focusing on they emphasize news about the strong demand for commodities from emerging economies. They conclude that "high commodity market activity appears to predict subsequent appreciation of commodity prices (page 3)."

In the light of this conflicting evidence on the impact of trader positions on futures prices, I explored complementary statistical relationships using the imputed flows into index funds from Masters (2009) as reproduced in Figure 5.[15] Specifically, I computed weekly time-series of excess returns from holding positions in futures at different maturity points along the yield curve. The maturities included were the 1, 3, 6, 9, 12, 15, 18, 21, and 24 month contracts, and the sample period was September 12, 2006 through January 12, 2010. The fitted values

[15]This research is based on ongoing discussions with Stefan Nagel and Kristoffer Laursen. Though the imputed flows into index funds are no doubt measured with some error, this imputed flow is constructed using data that was fully available to the market at the time investors are presumed to make their forecasts. Therefore, it is an admissible predictor that would have been available at the time to market participants.

from these regressions are interpretable as expected excess returns or, equivalently, as risk premiums in futures markets.

Consistent with the findings from other recent studies, returns on US and emerging market stock indices, the growth rate of repurchase positions by US primary dealers in Treasury bonds, the growth in both net and spread positions in futures by managed money (as reported by the CFTC), and the growth rate of imputed flows into commodity index positions entered *jointly* with statistically significant coefficients in predictive regressions for excess returns. Typical adjusted coefficients of determination (R^2's) were 20%, a non-trivial percentage of the variation in realized excess returns. Moreover, including the lagged returns on futures had no affect on the significance of these predictors.

The statistically significant coefficients on the equity indices is consistent with the evidence in Tang and Xiong (2009) on the financialization of commodity markets and the possibility that investors in equity (domestic and foreign) and commodity positions affected price changes in futures markets. The influence of repo positions of US primary dealers is consistent with Etula (2010)'s finding that the risk-bearing capacity of large financial institutions affected returns in futures markets.

An important subgroup of the CFTC's "managed money" category is hedge funds. The growth in the net, and particularly the spread, positions of this category had a statistically significant effect on subsequent excess returns in oil futures markets. Brunetti and Buyuksahin (2009) argue that hedge funds had a stabilizing influence on volatility in futures markets between 2005 and 2009. I have not explored the impact of trader flows on volatility. However, in my analysis, for a comparable time period and in the presence of other flow variables, I find that the cumulative impact of managed-money spread trading over the prior three months tended to put upward pressure on futures returns.

My results on the impact of managed money positions are not necessarily inconsistent with prior findings. Many of the studies that have explored Granger causality between returns on futures positions and trader positions have focused on very short horizons (typically days). Examples are the Granger causality tests in Buyuksahin and Harris (2009) and Brunetti and Buyuksahin (2009). It seems likely that, if the flows of index investors and other trader categories affected futures prices, then these effects would build up over longer histories than just a few days. Put differently, the lead/lag patterns that might be useful for identifying short-term manipulation in futures markets are likely to be very different than the longer-term patterns that would naturally be associated with the ebbs and flows of herding-like behavior. Looking at position growth over longer histories than one week seems particularly relevant if, as many have argued, the massive swings in trader positions show substantial correlation with world equity indices, and that these position changes were partly induced by investors speculating on the implications of future growth of the world economy for commodity prices.

Increases in the growth rate index positions (as imputed by Masters) predict increases in futures prices at all maturities out to two years. In terms of both statistical significance and quantitative response, the impact of index flows is second only to the flow of spread trades by managed money. In both cases, the effects are largest on the short maturity contracts and they fall monotonically with maturity.

Two other notable results emerge from my analysis. First, the growth rate of positions held by the "swap dealer" category of the CFTC's COT report does not have predictive power for excess returns on futures in the presence of the other conditioning variables described above. This is not surprising given, as I discussed previously, the nature of this category and the fact that dealers' futures positions are based on their entire energy exposures.

Second, those who argue that the trading patterns of index investors and "managed money" were affecting futures prices often link these flows to speculation related to global economic growth. A relevant question then is whether measures of global economic growth also had predictive power for excess returns on futures. As a proxy for aggregate demand, I follow Kilian (2009) and Pirrong (2009), as well as many oil-market practitioners, and use shipping rates, namely, the Baltic Exchange Dry Index (BEDI). The growth rate of the BEDI over the previous three months does explain an additional $2-3\%$ of the variation in excess returns, and its coefficients are marginally statistically significant. However, its presence has very little effect on the explanatory power of the trader flow variables: they continue to explain most of the variation in futures returns.

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