Elasticity of Demand for Relative Petroleum Inventory in the Short Run

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Abstract

To better understand petroleum markets, the authors established the importance of the deviation of inventory levels away from a normal level, where the normal level is comprised of seasonal movement and a general trend. Since supply and demand for petroleum are less elastic to price in the short run than is inventory, it is this deviation or relative inventory level that plays the role of absorbing unexpected shifts in demand and supply. They demonstrated theoretically that the demand for relative inventory must be negatively related to price. They estimated the relative inventory levels and associated short-run price elasticity for several OECD countries and groups of countries, and found that short-run price elasticity of demand for relative inventory is negative and statistically significant, supporting the theoretical arguments. (JEL Q40)

Introduction

In this paper, the authors explored the importance of the deviation of inventories away from some expected or normal level in understanding petroleum markets. They refer to this deviation from normal as the relative inventory level. Since supply and demand for petroleum are less elastic to price in the short run than is inventory, it is this relative inventory level that plays the role of absorbing unexpected shifts in demand and supply. This observation stimulated exploring the price elasticity of demand for relative inventory levels theoretically and empirically. This paper describes why relative inventory level is an important variable to understanding petroleum markets and demonstrates theoretically that the demand for relative inventory must be negatively related to price. Then the paper estimates the short-run price elasticity of demand for relative inventories for several OECD countries and country groups and find it to be negative and statistically significant, supporting the theory they developed.

The petroleum market since the Gulf War exhibited several features that allowed the investigation of short-run petroleum market behavior in terms of supply, demand, and inventory. Over much of the time between 1991 and the present, the Organization of Petroleum Exporting Countries (OPEC) did relatively little to adjust production in order to accommodate consumption changes, and sometimes, when action was taken, it was either insufficient or excessive to stabilize prices. Thus, there was a fairly long period in which prices varied considerably. In particular, from 1996 to the present, prices exhibited large cyclical swings. As shown in Figure 1, monthly average West Texas Intermediate (WTI) crude oil spot price (nominal) dropped to nearly $11 per barrel early in 1999 and rose to a peak of nearly $35 per barrel towards the end of 2000.[1]

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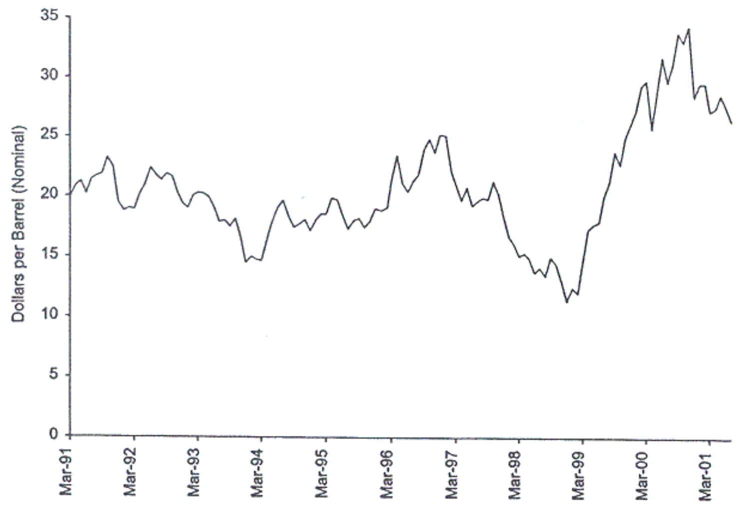

Figure 1: Western Texas Intermediate Spot Price

The level of petroleum inventories also varied considerably during the 1990s. Figure 2 shows the combined government and industrial inventories of both crude oil and petroleum products in all Organization of Economic Cooperation and Development (OECD) countries.[2] Two things can be observed from the figure. First, there appeared to be a seasonal pattern in the early 1990s when the WTI prices were relatively stable. Second, since 1996, a negative relationship between petroleum inventory and crude oil price is evident when WTI prices experienced large swings. As the crude oil price dropped from 1996 to 1998, OECD total inventories climbed to record levels in 1998. Later, when the price climbed to its peak in late 2000, total inventories declined. Intuitively, the authors suspect that the relationship between inventory and price was masked by the seasonal pattern in the early 1990s and that the seasonal pattern was overwhelmed by the large price swings since 1996. Thus, further careful analysis of petroleum inventory is needed to understand its relationship to WTI price.

The relationship between commodity inventory levels and spot prices has been theoretically as well as empirically studied for nearly a century.[3] There also have been many studies on petroleum demand and price elasticity of demand for crude oil and oil products in the mid to long run.[4] However, no previous studies on short-run price elasticity for petroleum inventory were available.

In this paper, the price elasticity of demand for petroleum inventory in the short run is investigated. A better understanding of the relationship between price and inventory was found by decomposing observed inventory movement into an expected component of normal seasonal movement and general trend and into an unexpected component that reflects responses to the short-run atypical variations in market supply and demand. This unexpected component is called the demand for relative inventory. The authors estimated the normal seasonal and trend components and relative inventory level for the Post Gulf War period from March 1991 to June 2001.

Elasticity of the demand for relative inventory with respect to WTI crude oil spot price was estimated for a number of countries, groups of countries, and regions in OECD for

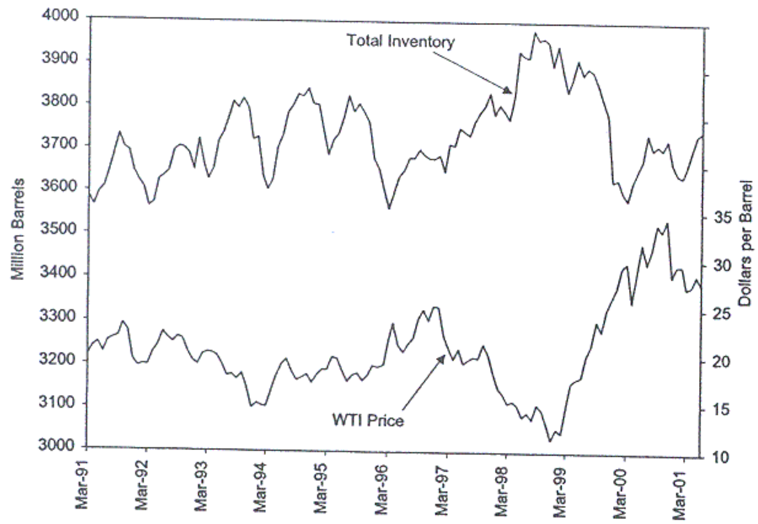

Figure 2: Total OECD Petroleum Inventory

the period of January 1996 to June 2001, during which the market experienced large price swings.[5] They found that the short-run demand for relative inventories of Group-Seven (G-7) countries (large size economies) is much less elastic than those of non-G-7 OECD countries (smaller size economies). This supports the intuitive hypothesis that, during times when crude oil prices are high and volatile, large countries are less sensitive to price changes and are more likely to have smaller percentage declines in inventory. This has the implication that poorer countries may back out of high-priced petroleum trading markets before wealthier countries, thus reducing the effective world demand for crude oil.

In the next section, a theoretical basis is developed to establish a negative relationship between crude oil price and demand for relative petroleum inventory. Section three presents the empirical results. It begins with a description of the data used in the study, their sources, and how the data were processed. Then, empirical results of elasticity at the country level and elasticity for groups of countries and regions are presented. The last section concludes the paper.

The Theory

The fundamental motivation to have petroleum inventory is much the same as that for other commodities. Petroleum inventory plays the role of smoothing operations on both the supply side and demand side and of hedging against price changes.[6] More specifically, inventory levels are determined in the short run by factors such as expected seasonality and general trends in production and demand as well as unexpected supply or demand shifts, and price changes caused by these shifts. There may also be other factors such as interest rates and changes in the cost of physical storage that may be important in the long run.

When dealing with the actual physical commodity (for example, the total of crude oil and petroleum products), we have two markets, the cash market and the storage market (with an embedded futures market). Each market has its own separate, yet related, supply and demand. The dynamic equilibrium defined by these two markets is depicted by the time trajectories of spot price, inventory, and convenience yield (the value price of inventory).[7] This paper focuses only on the cash market.

The cash market defines equilibrium spot prices and changes in inventory, denoted $I_t - I_{t-1}$ in period t where I denotes inventory level. In any period t, change in inventory is defined as supply, S_t, minus demand, D_t, $I_t - I_{t-1} = S_t - D_t$, or,

$$I_t \equiv I_{t-1} + S_t - D_t \quad . \tag{1}$$

Equation (1) is an identity holding for all periods and any crude oil price, assuming that the storable commodity suffers from no destruction or loss of inventory. However, both supply and demand are functions of price. It is assumed that supply and demand are independent of each other in the short run. In other words, $S = S(P)$ and $D = D(P)$. Since the three variables I, S, and D are related by (1), I is also dependent on price, or, $I = I(P)$. Thus, taking I_{t-1} to be pre-determined in period t, the equilibrium condition can be written as:

$$I_t(P) = I_{t-1} + S_t(P) - D_t(P) \quad . \tag{2}$$

Since normal seasonal movements and general trends in inventory exist for each country, or in aggregate for groups of countries and regions, it is necessary to define a normal level of inventory for each of them. Such a definition should recognize typical supply and demand characteristics. More specifically, demand for petroleum products is highly seasonal and is greatest during the winter months when countries in the Northern Hemisphere increase their use of distillate heating oils and residual fuels. Supply of crude oil, including both production and net imports, also shows a similar seasonal variation but with smaller magnitude. During the summer months, supply normally exceeds demand and OECD countries' petroleum inventories build; whereas during the winter, demand exceeds supply and inventories are drawn down. As a result, inventories typically demonstrate seasonality since inventory is a measure of the balance, or imbalance, between petroleum supply and demand.[8] If the market supply and demand is balanced over the period of a year, the increase in inventories during the summer will equal the decline in inventories during the winter. In brief, inventories will normally demonstrate seasonality because their build-ups and draw-downs reflect the seasonal imbalance between supply and demand as a result of the supply of crude oil showing less seasonal variation than demand. Long-term trends also exist, mainly due to the trends in government inventories, increasing economic activities, or new global conservation measures. Such trends are considered when defining a desired normal pattern. [9]

Consider that at any given time, t, there is a normal level of inventory reflecting the typical seasonal demand and supply as well as general trend movements in demand and supply. Letting * represent the normal level, we have, for a particular time t, from (1),

$$I_t^* = I_{t-1}^* + S_t^* - D_t^* \quad . \tag{3}$$

Note that $I_t{}^*$, $S_t{}^*$, and $D_t{}^*$ are independent of market price, P, and are determined empirically by historical information.

The relative level of inventory is defined as the deviation of the actual level from the normal level. Letting the prefix R mean relative level and subtracting (3) from (1):

$$RI_t = RI_{t-1} + RS_t - RD_t \quad , \tag{4}$$

where $RI_t = I_t - I_t^*$, $RS_t = S_t - S_t^*$, and $RD_t = D_t - D_t^*$. Referring to (2), equation (4) may also be re-written with each term explicitly expressed as a function of P, except RI_{t-1}, which is treated as pre-determined in period t:

$$\mathsf{RI}_t(\mathsf{P}) = \mathsf{RI}_{t-1} + \mathsf{RS}_t(\mathsf{P}) - \mathsf{RD}_t(\mathsf{P}) \quad . \tag{5}$$

Given I_{t-1} (and thus RI_{t-1}) as predetermined, (5) says that in the short run, demand for relative inventory, RI_t, responds to unplanned variations in the supply, RS_t, and unplanned variations in demand, RD_t. Inverting equation (5) to express price explicitly:

$$\mathsf{P} = \mathrm{f}(\mathsf{RS}_t, \mathsf{RD}_t) \quad . \tag{6}$$

Equation (6) says that market equilibrium price is determined by relative supply and relative demand because of the relationship between relative inventory, relative supply, and relative demand expressed by (4).

Equilibrium inventories may be disturbed by three exogenous factors: shifts in supply, shifts in demand, and shifts in the value of inventory (convenience yield). This paper focuses only on the first two.[10] Typical examples of shifts in supply for which $\mathsf{RS}_t < 0$ are OPEC production cuts or pipeline accidents. Examples of shifts in demand for which $\mathsf{RD}_t > 0$ are abnormal severe cold weather conditions or unexpected economic recoveries.

Note that any supply and demand shifts are directly translated into shifts in relative supply and relative demand because the normal levels of supply and demand are independent of price, that is, they are historically determined. In other words, we have $\Delta\mathsf{RS} = \Delta\mathsf{S}$ and $\Delta\mathsf{RD} = \Delta\mathsf{D}$ since $\mathsf{RS} = \mathsf{S} - \mathsf{S}^*$ and $\mathsf{RD} = \mathsf{D} - \mathsf{D}^*$ within a given time period t. Note that $\Delta\mathsf{S}$, $\Delta\mathsf{RS}$, $\Delta\mathsf{D}$, and $\Delta\mathsf{RD}$ are not the usual time differences between values in period t minus values in period $(t-1)$. Rather, it is the additional change within period t, taking the value in period $(t-1)$ as given. Therefore $\Delta\mathsf{S}^* = \Delta\mathsf{D}^* = 0$, that is, the normal levels stay always unchanged in period t since they are determined historically and are independent of current market conditions. (To avoid any possible confusion, subscript t has been omitted whenever Δ is used).

To see what happens to the relative inventory level when there is an unexpected decrease in supply or increase in demand in a particular period, we have from (5), taking RI_{t-1} as pre-determined:

$$\Delta\mathsf{RI} = \Delta\mathsf{RS} - \Delta\mathsf{RD} \quad . \tag{7}$$

Consider first the impacts of a shift in supply. Dividing both sides of (7) by $\Delta\mathsf{RS}$ yields:

$$\frac{\Delta\mathsf{RI}}{\Delta\mathsf{RS}} = \frac{\Delta\mathsf{RS}}{\Delta\mathsf{RS}} - \frac{\Delta\mathsf{RD}}{\Delta\mathsf{RS}} \quad , \tag{8}$$

where the shift in demand (the second term on the RHS) is due to the change in the market price caused by the shift in supply. To explicitly express the demand response to price, we re-write $\Delta\mathsf{RI}/\Delta\mathsf{RS} = (\Delta\mathsf{RI}/\Delta\mathsf{P})\cdot(\Delta\mathsf{P}/\Delta\mathsf{RS})$ and $\Delta\mathsf{RD}/\Delta\mathsf{RS} = (\Delta\mathsf{RD}/\Delta\mathsf{P})\cdot(\Delta\mathsf{P}/\Delta\mathsf{RS})$, recalling particularly (5). Thus, (8) becomes:

$$\left(\frac{\Delta\mathsf{RI}}{\Delta\mathsf{P}}\right)\cdot\left(\frac{\Delta\mathsf{P}}{\Delta\mathsf{RS}}\right) = 1 - \left(\frac{\Delta\mathsf{RD}}{\Delta\mathsf{P}}\right)\cdot\left(\frac{\Delta\mathsf{P}}{\Delta\mathsf{RS}}\right) \quad . \tag{9}$$

If there were no inventory or if inventory were not responsive to price changes, that is, $\Delta\mathsf{RI}/\Delta\mathsf{P} \approx 0$, we would have $0 = 1 - (\Delta\mathsf{RD}/\Delta\mathsf{P})\cdot(\Delta\mathsf{P}/\Delta\mathsf{RS})$ from (9), which implies $\Delta\mathsf{RD} = \Delta\mathsf{RS}$. In other words, demand would have to drop exactly the same amount of any supply loss in period t. To achieve $\Delta\mathsf{RD} = \Delta\mathsf{RS}$ when $\Delta\mathsf{RS} < 0$ and no usable inventories exist, price would have to increase significantly in the short run. However, in the real world, demand would rarely, if ever, accommodate one-hundred percent of the drop in supply in the short run. In other words, when inventories exist, the change in demand is observed to be smaller than the change in supply, $|\Delta RD| < |\Delta RS|$, in the short run. This is the case because many end users are unable or unwilling to alter their lifestyles, the production technologies involved, organizational structures, or other capital investments in the short run, unless the increase in price is so large that the cost of operating in status quo becomes greater than the cost of changing.

Assuming availability of usable inventories, one has, from (9) for $\Delta RD/\Delta RS < 1$, or $|\Delta RD| < |\Delta RS|$:

$$\left(\frac{\Delta RI}{\Delta P}\right) \cdot \left(\frac{\Delta P}{\Delta RS}\right) = 1 - \left(\frac{\Delta RD}{\Delta P}\right) \cdot \left(\frac{\Delta P}{\Delta RS}\right) > 0 \quad . \tag{10}$$

It can be concluded that $\Delta RI/\Delta P < 0$ from (10) since a decrease in supply increases price, that is, $\Delta P/\Delta RS < 0$.

Similarly, in the short run, an unexpected increase in demand for petroleum may not be fully accommodated by an increase in supply. Price would increase significantly if there were no inventory or if inventory did not respond to price changes. In reality, crude oil supply may not increase at all and petroleum product production may increase somewhat, resulting in a draw down of inventories of both crude oil and petroleum products to accommodate the increased demand and mitigate the increase in price in the short run. Using similar arguments to those made on the effect of a supply shift, it can be shown that $\Delta RI/\Delta P < 0$ when the source of the price change is the shift in demand.

Thus, the authors conclude that relative inventory is negatively related to price in the short run, irrespective of whether a price change is caused by an unexpected supply shift or an unexpected demand shift. In the next section, they empirically estimate the short-run price elasticity of demand for relative petroleum inventory in a number of OECD countries as well as regions and country groups.

The Data and Empirical Results

Petroleum inventories can be defined as the sum of government and industrial stocks of both crude oil and petroleum products. The authors carried out the analysis on the total of industry and government inventories, rather than industry only, because several countries appeared to have reclassified inventories between government and industrial categories. They also decided to investigate the behavior of demand for inventories for both crude oil and petroleum products because crude oil inventories at refineries are essentially exchangeable with product inventories in a monthly time frame, and even crude oil inventories located in distant places might only be a month from conversion to products.

Data for government and industrial inventories of crude oil and petroleum products for all OECD countries are available from March 1984 to the present, but the International Energy Agency (IEA) changed its data collection methodology in December 1990. The study on elasticity was limited to the period from January 1996 to July 2001 because, at the country level, the data appeared most consistent (that is, fewer one-time readjustments) from 1996 onwards. Furthermore, this time period contains some of the largest price swings and also avoids the Gulf War impacts on the market. The normal levels, however, were established using the data beginning in early 1991.

For crude oil prices, WTI spot price was used, which is considered a world marker price. Another price also viewed as a marker price is Brent. However, it was found that the two price series are highly correlated and move in very much the same pattern, with monthly WTI crude oil spot price being higher than Brent throughout the period, except for temporary daily or weekly price inversions.[11] These daily spot prices were obtained from Standard and Poor's Platts Data Service. Since OECD inventory data are only available monthly, the daily crude oil spot prices were aggregated to a monthly frequency.

In order to estimate a constant elasticity measure of the demand for relative inventory for individual OECD countries, the G-7 aggregate, non-G-7 aggregate, and each of the several regional aggregates, the authors first de-trended and de-seasonalized the log values of observed inventories to identify the normal levels in log form. Let D_k, $k = 2, 3, \ldots, 12$, represent the 11 monthly seasonal variables and T the trend variable. Let I_{it} be the observed total petroleum inventories in the i^{th} country, region, or group in period t. The following regression equation defines the normal and relative levels of the log values of total inventories in the i^{th} country, region, or group in period t:

$$\ln(I_{it}) = c_{i0} + c_{i1}T + \sum_{k=2}^{12} c_{ik} D_k + \text{residual}_{it} \quad , \tag{11}$$

in which c_{i0} , c_{i1}, and c_{ik}, $k = 2, \ldots, 12$ are estimated coefficients from the regression.

The normal level of demand for inventory, denoted $I_{it}{}^*$ for the i^{th} country, region, or group in period t, is empirically defined as:[12]

$$\ln(I^*_{it}) = [\ln(I_{it})]^* = c_{i0} + c_{i1}T + \sum_{k=2}^{12} c_{ik} D_k \quad , \tag{12}$$

and the demand for relative inventory level for the i^{th} country, region, or country group in period t, denoted by RI_{it}, is empirically defined as:[13]

$$\ln(RI_{it}) = \ln(I_{it}) - \ln(I^*_{it}) \quad , \tag{13}$$

where $\ln(I_{it}) - \ln(I^*_{it}) = \text{residual}_{it}$ in (11).

Regression results show statistically significant seasonal patterns and consistent trends in inventory for many OECD countries, regions, and country groups from the period beginning in March 1991 through June 2001.[14] The seasonality is particularly strong during the early years in the 1990s.[15] Later in the decade, the seasonality is often overwhelmed by the warm winters that limited the usual inventory draws and a large over-supplied market that was followed by an under-supplied market.[16]

Figure 3 shows the inventory trend and seasonality using the log values of total OECD inventory data from March 1991 to June 2001 in which relative levels, or the residual, are shown as the difference between actual and normal.

Comparing to WTI price shown in Figure 4 below, the negative relationship between relative inventory level and WTI price is obvious since 1996 and can be seen to a lesser extent in the early 1990s. This is particularly revealing when recalling that the negative relationship cannot immediately be observed between the inventory level and WTI price in the early 1990s in Figure 2.

To obtain the constant elasticity of demand for relative inventory for the i^{th} country, region, or group, the following regression equation was estimated:

$$\ln(RI_{it}) = a_i + e_i \ln(WTI_t) + \text{residual}_{it} + AR \text{ or } MA \text{ terms}^{17} \quad , \tag{14}$$

in which e_i is the elasticity.

Table 1 summarizes the results for the short-run demand elasticity of relative inventory for OECD total, G-7, non-G-7, and several geographic regions. These results are calculated for the period from March 1996 to June 2001 based on the relative inventory levels derived from the period of 1991-2001.

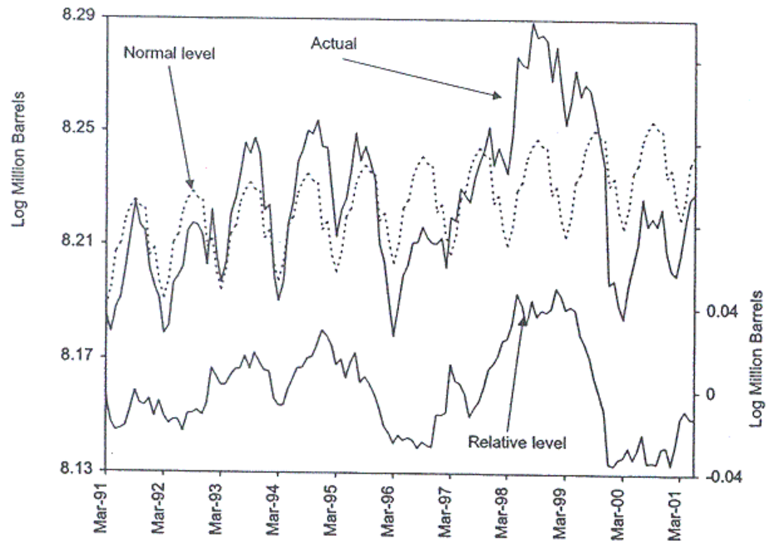

Figure 3: The Actual, Normal, and Relative Levels of Inventory*

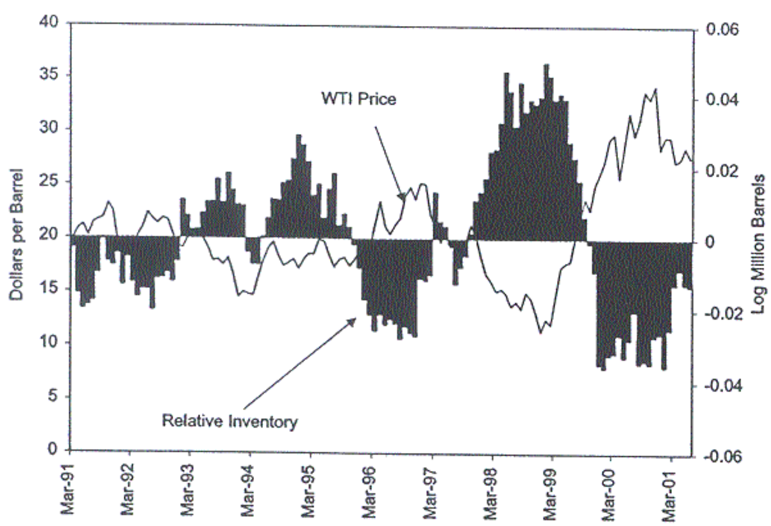

Figure 4: The Relative Inventory and WTI Price

Two things are readily observed. First, as expected, there is a significant negative demand response for relative inventory to price changes in the short-run, ranging from -0.026 to -0.110, which is supported by the theory they developed in the last section. Second, the main distinction in elasticity values is not among various geographical regions, but between the G-7 aggregate (-0.0263) and non- G-7 aggregate (-0.0827). As expected, G-7 dominates the total OECD's elasticity of demand for inventory (-0.0263).

At the country level, despite the fact that data are much noisier due to sudden shifts in inventories, Table 2 and the following scatter diagram demonstrate a positive relationship between the crude oil price elasticity of demand for relative petroleum inventory and the log value of GDP for a subset of OECD countries.[18] While the correlation may not look strong to the naked eye, the coefficient of correlation between log(GDP) and elasticity is 0.50 and significant at 94.7 percent.

TABLE 1
Group and Regional Elasticity

Region[a]	Elasticity	p-value
Total[b]	-0.0263	0.0401
G-7	-0.0263	0.0166
Non G-7	-0.0827	0.0006
Europe	-0.0578[c]	0.0033
Europe 2	-0.0389[c]	0.0700
N. Europe 10	-0.0571[c]	0.0122
N. Europe 8	-0.0437[c]	0.0877
Scandinavia	-0.1095	0.0019
S. Europe 5	-0.0409	0.0000
N. America	-0.0353	0.0116

[a]Regions are defined as follows: Europe 2 excludes U.K. and Ireland; N. Europe 10 includes Austria, Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Switzerland, and U.K.; N. Europe 8 includes Austria, Belgium, Denmark, France, Germany, Luxembourg, the Netherlands, and Switzerland; Scandinavia includes Norway, Sweden, and Finland; S. Europe 5 includes Spain, Italy, Portugal, Greece, and Turkey; and N. America includes Canada, the United States, and Mexico.

[b]The total excludes Czech Republic, Hungary, and Poland. Also note that Iceland and Slovak Republic have no petroleum inventory.

[c]Elasticity values are for the single period lagged for two months from the current month.

TABLE 2
Country Elasticity

	Elasticity	p-value	GDP (in Billions $)[g]
Austria	-0.0674	0.2390	231.92
Belgium	-0.1303	0.0000	253.51
Canada[a]	-0.0362	0.0611	634.38
France[b]	-0.0514	0.0332	1450.22
Ireland[c]	-0.0612	0.2940	82.74
Japan[c]	-0.0587	0.0609	4581.64
Luxembourg[d]	-0.1585	0.0044	18.50
Mexico[b]	-0.1069	0.0957	416.12
Netherlands	-0.1604	0.0025	393.68
Norway[e]	-0.1299	0.0185	153.09
Spain	-0.0330	0.0499	564.21
Sweden	-0.1810	0.0000	240.56
Turkey[a]	-0.0363	0.1536	191.29
United Kingdom	-0.0477	0.0001	1328.13
United States[f]	-0.0495	0.0001	8574.37

[a]The results for Canada and Turkey were derived by using a combined estimation for both the elasticity and normal (that is, de-seasonalized and detrended) inventory level using data from January 1996 to June 2001.

[b]The results for France and Mexico were derived for the one month lagged WTI crude price.

[c]The results for Ireland and Japan were derived for the industrial inventories only, excluding government controlled inventories.

[d]Luxembourg had only petroleum products inventories.

[e]Norway's elasticity is for the single period lagged for two months from the current month.

[f] While the United States' demand for relative inventories respond to both the current month price as well as last month price significantly, this is the elasticity for the current month only.

[g]See footnote a in Table B-1 in Appendix B.

Overall, results shown in Tables 1 and 2 and Figure 5 demonstrate that the demand for relative petroleum inventory is indeed significantly negatively related to spot price, indicating that, in the short run, relative inventory plays a crucial role of absorbing unplanned variations in the petroleum market. Moreover, they also show that, in the short run, large OECD countries, individually and in aggregate, appear to be less elastic than smaller OECD countries, individually and in aggregate.[19] This supports the intuitive hypothesis that, during times when markets have high, volatile crude oil prices, large countries are less sensitive to price changes, and are more likely to have a slower rate of change in inventory levels. This may imply that small or poor countries may back out of high-priced petroleum trading markets before big or wealthy countries, thus reducing the effective world demand for crude oil.

Conclusion

The authors focused on short-run petroleum cash market behavior in this paper. They found strong evidence to support the theoretical finding that it is inventory that plays the pivotal role in absorbing the unplanned variations in the petroleum market, since neither supply nor demand fully accommodate changes in price in the short run. One of the important concepts developed in this paper is the normal level and relative level of demand for inventory, where the former reflects the typical seasonal and trend movements and the latter the unexpected supply or demand shifts in the market. They derived a negative relationship

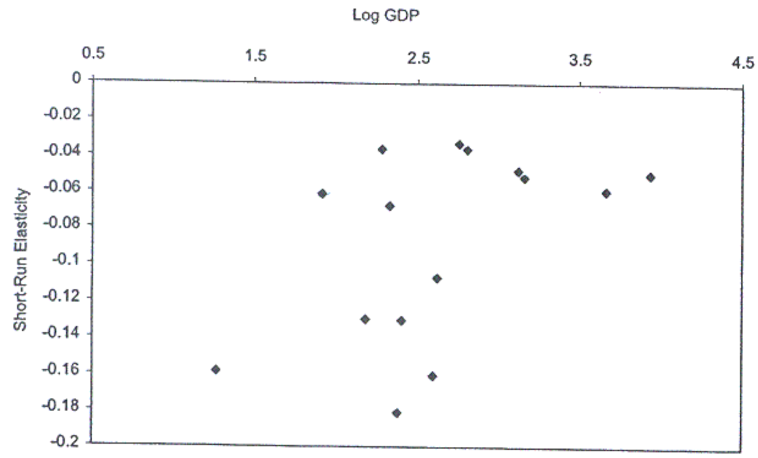

Figure 5: Relationship between Elasticity and GDP

between the demand for relative inventory and price and then empirically estimated the price elasticity of demand for relative inventory for a number of OECD countries as well as regions and groups of OECD countries.

APPENDIX A
De-Trending and De-Seasonalizing Results

The following table shows the trend results calculated for the combined government-controlled (if any) and industrial inventories of both crude oil and petroleum products during the period from March 1991 to June 2001, unless otherwise noted. Whenever necessary, dummy variables were used to reflect shifts in intercepts and trends.[20]

As can be seen from Table A1, most countries have significant trends over time, some positive and some negative. Overall, positive trends dominate among both G7 and non-G7 countries.

TABLE A1
Trend and Seasonality[a]

	Trend[b]	Note	Seasonality[c]
Total	0.0003 (0.0000)		Yes
G7	0.0005 (0.0000)		Yes
Non G7	0.0017 (0.0000)		Yes
Europe	0.0007 (0.0000)		Yes
Europe 2	0.0007 (0.0000)		Yes
N. Europe 10	-0.0002 (0.0042)		No
N. Europe 8	-0.0002 (0.0239)		No
Scandinavia	0.0011 (0.0000)		Yes
S. Europe 5	0.0019 (0.0000)		Yes
N. America	-0.0004 (0.0000)		Yes
Austria	0.0008 (0.0000)		No
Belgium	0.0004 (0.0284)		Yes
Canada	0.0032 (0.0000)	January 1996 to June 2001	Yes
France	0.0000 (0.5936)	March 1991 to September 1997	Marginal
	0.0012 (0.0021)	October 1997 to June 2001	
Ireland[d]	-0.0021 (0.0014)	January 1991 to December 1995	Yes
	0.0061 (0.0000)	January 1996 to June 2001	
Japan[e]	-0.0008 (0.0000)		Yes
Luxembourg[f]	-0.0076 (0.0000)	January 1992 to December 1995	Yes
	0.0013 (0.0000)	January 1996 to June 2001	
Mexico	0.0002 (0.3966)		Yes
Netherlands	-0.0004 (0.0337)		No
Norway	0.0085 (0.0000)	January 1991 to December 1995	Marginal
	-0.0021 (0.0000)	January 1996 to June 2001	
Spain	0.0035 (0.0000)		Yes
Sweden	0.0010 (0.0000)		Marginal
Turkey	0.0010 (0.0197)	February 1996 to June 2001	Yes
United Kingdom	-0.0007 (0.0000)		Yes
United States	-0.0005 (0.0000)		Yes

[a]For the definitions of geographical region, see footnote a for Table 1.

[b]Numbers in the parentheses are the p-values.

[c]Yes in this column means either the p-value for at least a single month or for all 11 seasonal variables taken as a whole is less than 0.1. Marginal means the p-values are just a little higher than 0.1.

[d]The results for Ireland were derived using industry crude oil and product inventories plus government product inventories. Government crude oil inventories inventories were not included because of the presence of large discrete changes with little variability otherwise.

[e]The results for Japan were derived for the industrial inventories only, excluding government controlled inventories.

[f]Luxembourg had only inventories of oil products and no crude oil inventory.

Seasonality of petroleum inventories has not been constant over time. For the various country groups, seasonality is prevalent in the period from 1991-95 and virtually non-existent in the period from 1996-2001 (see Table A2).

TABLE A2

Trend and Seasonality in Different Periods

	Trend[a]		
	1991 to 1995	1996 to 2001	1991 to 2001
OECD Total	0.00077 (0.0000)	0.00013 (0.5026)	0.00027 (0.0000)
G7	0.00060 (0.0000)	-0.00015 (0.4096)	-4.06E-5 (0.4753)
Non-G7	0.00164 (0.0000)	0.00142 (0.0000)	0.00172 (0.0000)
		Seasonality[b]	
	1991 to 1995	1996 to 2001	1991 to 2001
OECD Total	Strong	None	Yes
G7	Strong	None	Yes
Non-G7	Strong	None	Yes

[a]Numbers are the coefficients of linear trend and corresponding p-values are in parentheses.

[b]Yes means either the p-value for at least a single month or for all 11 seasonal variables taken as a whole is less than 0.1. Strong means the p-values are lower than 0.0001. Numbers in parentheses are p-values.

Figures 6 and 7, especially when compared to Figure 3 in the text, also show a stronger seasonality of OECD total petroleum inventories in the period from 1991-95 and weak (or even no seasonality) from 1996-2001.

The inventory time trends show certain interesting patterns as well (see Table A2). More specifically, the non-G7 group has a much larger growth rate in all periods than G7, and growth rates in the period from 1991-95 are larger than those in the period from 1996-2001.

APPENDIX B

OECD Countries and their GDP

GDP data were obtained from the International Monetary Fund [2002]. The original data were measured in nominal dollar terms. Although the exchange rates and differences in GDP definition make these numbers approximate, the rank of these OECD countries by size of economy is rather robust, with little variation in rank over a six-year period of time from 1995-2000. The values in Table B1 for each of the OECD member countries is based on a simple average of nominal GDP converted to dollars over the six years from 1995-2000, using the average exchange rates.

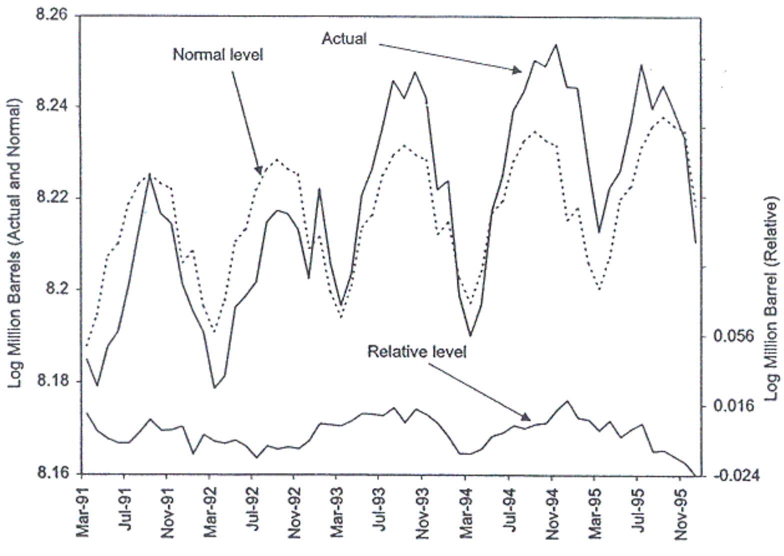

Figure 6: Strong Seasonality of OECD Total Inventory in Early 1990s

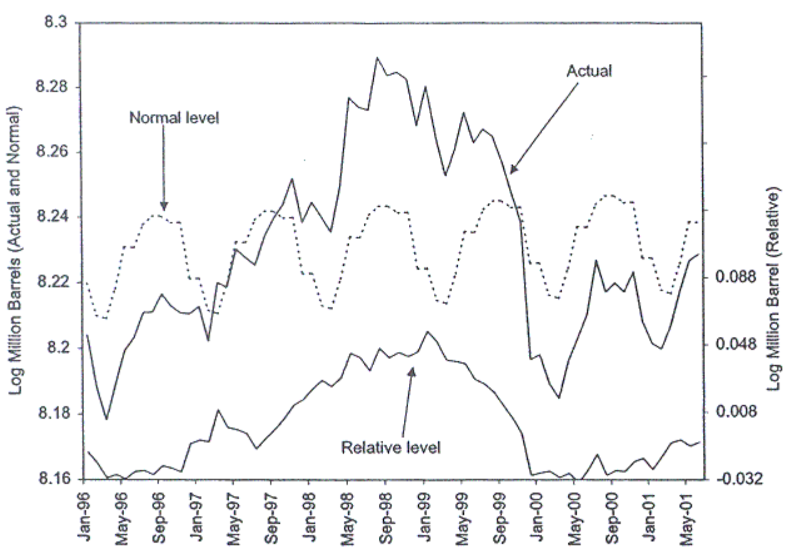

Figure 7: Weak Seasonality of OECD Total Inventory since 1996

TABLE B1
Average GDP in Billion Dollars[a] (in descending order)

United States	8574.37
Japan	4581.64
Germany	2176.99
France	1450.22
United Kingdom	1328.13
Italy	1157.96
Canada	634.38
Spain	564.21
Korea	444.39
Mexico	416.12

TABLE B1 (CONT)
Average GDP in Billion Dollars[a] (in descending order)

The Netherlands	393.68
Australia	387.18
Switzerland	269.89
Belgium	253.51
Sweden	240.56
Austria	213.92
Turkey	191.29
Denmark	174.22
Norway	153.09
Finland	124.90
Greece	120.69
Portugal	106.89
Ireland	82.74
New Zealand	58.21
Luxembourg	18.50

[a]In actuality, these numbers are indices. The authors took a simple six-year average and intentionally rejected converting nominal GDP in each year into base year constant dollars to avoid potential technical issues, such as inflation and exchange rate variations for each country.

Footnotes

[1]Unless otherwise stated, all prices are in nominal terms.

[2]The totals shown in this figure exclude the Czech Republic, Hungary, Iceland, Poland, and the Slovak Republic. Iceland and the Slovak Republic have neither crude oil inventory nor petroleum product inventory. The other three Eastern European members were new to OECD. The data for these latter three countries were incomplete in the early 1990s, and displayed large swings when first reported, raising the question of accuracy during the transition period in the mid 1990s. Their contribution to OECD total inventory is negligible.

[3]A detailed review of this body of literature is omitted here. Interested readers may refer to Pindyck [1994], Considine and Larson [2001], and the references in Ye, Zyren, and Shore [September, 2002; November, 2002).

[4]See for example, Arize [2000], Jones [1993], and Main [1981].

[5]It was not possible to calculate the elasticity for every OECD country due to data problems for several member countries.

[6]See, for example, Williams and Wright [1991].

[7]For detailed discussions on the dynamic equilibrium in the two markets, see Pindyck [2001].

[8]For empirical evidence to support these claims, see Ye, Zyren, and Shore [May, 2002].

[9]For more discussions on the normal inventory level and relative inventory, see Ye, Zyren, and Shore [May, 2002; November, 2002).

[10]The impacts of convenience yield will be addressed in a future work.

[11]The correlation coefficient between these two marker prices is about 0.99.

[12]For practical purpose, relative level is calculated from the difference between the log value of observed level and the log value of normal level rather than the difference between observed level and normal level. The statistical difference in resulting elasticity between the two definitions was found to be negligible.

[13]See the last footnote.

[14]In cases where there are obvious shifts in trend due to government policy changes or other unidentified reasons, one or more dummy variables are applied to break the trend into segments.

[15]See Appendix A for a summary of de-trending and de-seasonalizing results at country and region levels.

[16]Just as Iraqi crude oil re-entered the market in 1997 for the first time since Gulf War, the Asian financial collapse slowed world crude oil consumption growth, and crude oil production exceeded consumption for some time. OPEC also reduced production several times. Eventually the production cutbacks and Asia's recovery resulted in demand exceeding supply, which sharply reduced worldwide inventories in 1999.

[17]AR and MA terms may have been added to reduce residuals to white noise.

[18]For a list of OECD countries and their average GDP, see Appendix B, in which each country's GDP is based on a simple index that is the average of nominal GDP over six years from 1995 to 2000. Total petroleum inventory for each country is combined government-controlled (if any) and industrial inventories of both crude oil and oil products, unless otherwise noted.

[19]Country-level inventory data should be interpreted cautiously. In some cases, such as in Europe, countries do not act individually but depend on supplies and inventories from neighboring countries. In such cases, regional influences would be expected to filter down to country-level data, regardless of country size.

[20]In order to gain some knowledge for individual countries, we reviewed the relevant literature related to their petroleum markets. More specifically, for U.S. petroleum consumption behavior and oil price, see Arize [2000]; for Greek demand for energy, see Christopoulos [2000]; for demand elasticity of residential oil in Denmark, see Bentzen [1997]; for an analysis of offshore oil concessions in the Netherlands, see Smit [1997]; for gas and oil in Austria, see Melamid [1995]; for a study on the petroleum wealth of Norway, see Steigum and Thogersen [1995]; for macroeconomic responses to oil price changes in seven OECD countries, see Mork and Mysen [1994]; for government North Sea oil strategies in Denmark, Britain and Norway, see Andersen [1993]; for a comparative study of the UK, Norway, Denmark, and the Netherlands' petroleum fiscal systems, see Kemp [1992]; for Japan's energy strategy, see Morse [1992]; for Turkey's petroleum industry, see Buchanan et al. [1990]; for the U.S. demand for foreign crude oil, see Kohli and Morey [1990]; for Australian crude oil production, see Hogan and Naughten [1990]; for Norwegian petroleum reserve, see Flam and Moxnes [1987]; and for elasticity of demand for crude oil in the United States in 1929-41 and 1948-73, see Danielsen and DeLorme [1975-76].

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