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AN INVESTIGATION OF SPECULATIVE INVENTORY BEHAVIOR IN THE U.S. PETROLEUM INDUSTRY

by

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CHAPTER I

INTRODUCTION

The world oil market conditions have undergone profound changes during the decade of the 1970's. It is generally agreed that the Organization of Petroleum Exporting Countries (OPEC) now controls the world price of crude oil and has become increasingly successful at controlling its own crude oil production levels.[1] Adelman comments: "The genie is out of the bottle, the producing countries have been extremely successful in using the weapon of a threatened concerted stoppage, and they cannot be expected to put it away."[2] This is a much different environment than what had existed for many decades prior to the 1970's, when crude oil prices and production levels were largely controlled by the multinational petroleum companies, most of which were based in the United States. Jorgenson points out that from 1950 to 1973:

> ...the real price of energy to the consumer...declined at a rate of 1.8 percent per year. While gross national product grew at a 3.7 percent rate per year, the consumption of primary energy sources--mainly petroleum, natural gas, and coal--was increasing at 3.5 percent per year.... The decline in real energy prices through 1973 continued a historical trend dating back atleast to the beginning of the Industrial Revolution.[3]

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[1]See Robert H. Rasche and John A. Tatom, "The Effects of the New Energy Regime on Economic Capacity, Production, and Prices," Federal Reserve Bank of St. Louis Review, Vol. 59, No. 5, May 1977, p. 7. Also see Edward W. Erickson, Stephen W. Millsaps, and Robert M. Spann, "Oil Supply and Tax Incentives," Brookings Papers on Economic Activity, Vol. 2, 1974, p. 460.

[2]M. A. Adelman, The World Petroleum Market (Baltimore: Johns Hopkins University Press, 1972), p. 257.

[3]Dale W. Jorgenson, "The Role of Energy in the U.S. Economy," National Tax Journal, Vol. 31, No. 4 (September 1978), p. 209.

1.1 The Current World Oil Market

Under the management of the multinational petroleum companies, real crude oil prices were gradually declining and hence, demand for crude oil was steadily increasing. Since 1973, the crude oil price trend has, of course, been dramatically reversed. After 1973, the oil importing nations began revising their attitudes toward the price of crude oil. Crude oil has long been regarded as a raw material, a factor input that is not directly consumable. Once the crude oil has been refined, the refined products are what consumers demand. Cheap energy has been thought of as absolutely essential for rapid economic growth. Prior to 1973, the industrialized oil importing nations generally believed the price of crude oil should be based on the costs of exploration, production, and transportation of crude oil, plus some reasonable return on investment for the crude oil producer.[4] World crude oil prices did roughly correspond to this sort of price before 1973. Obviously, this concept of crude oil price has not prevailed.

Allen writes:

> ...crude oil is a scarce substance, having a value independent of production costs. It is also one of the earth's fixed assets, exhaustible and not reproducible. Neither the companies nor economists, however, know its true value.... No way exists to compute, in theory or practice, crude oil real value.[5]

Hollander, Levine and Craig report: "The Harvard Energy Study... speculates that the value [of crude oil] may be two or three times

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[4]See Adelman, Chapters 1 through 3 for a detailed discussion of crude oil price theory relating to these costs.

[5]Loring Allen, <u>OPEC Oil</u>, (Cambridge: Oelgeschlager, Gunn & Hain, Inc., 1979), p. 115.

the current price."[6] The OPEC nations themselves are still searching for the "right" price for crude oil. At an OPEC meeting shortly after the Arab Oil Embargo, the Shah of Iran suggested that the price of crude oil should be "competitive with the cost of producing energy from other sources, such as oil shale and liquification or gasification of coal."[7] The OPEC meetings themselves, usually held twice a year, have become influences on the market price of crude oil. Allen discusses this:

> Since price is on the agenda, buyers to one degree or another, become convinced that the price is going to go up. The result is a surge in demand in the weeks and months immediately preceding the conference. Following the meeting, whether the price went up or not, demand falls off because buyers' inventories are high.[8]

Currently, evidence indicates that oil importing nations view crude oil as a scarce resource with a value of its own, almost like a precious metal: more is available but only at significantly increasing cost.

At the same time that OPEC has increased its market power, the domestic crude oil production rate for the United States petroleum industry has peaked out. At present, there appears to be nothing that could alter the trend toward decreasing domestic crude oil production through the 1980's. Already heavily dependent on crude oil imports from the beginning of the 1970's, the United States has little chance of reducing its dependence on oil imports through the 1980's. The United States petroleum industry and petroleum consumers already are and will

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[6]Lee Schipper, Jack M. Hollander, Mark Levine and Paul Craig, "The National Energy Conservation Policy Act: An Evaluation," Natural Resources Journal, Vol. 19, No. 4 (October 1979), p. 782.

[7]"Price of Crude Oil," Monthly Energy Review (June 1975), p. 5.

[8]Allen, p. 124.

continue to be seriously affected by events in the world oil market. Following the Arab Oil Embargo during 1973-1974, crude oil prices increased rapidly, domestic fuel "shortages" developed, and long lines at the gasoline pumps appeared. Again in 1979 after the Iranian Revolution and sharp cuts in Iranian crude oil exports, the "shortages" and gasoline lines re-appeared, while petroleum prices greatly increased. With crude oil prices increasing so rapidly during those time periods, the question has frequently been asked whether the domestic fuel shortages and gasoline lines were due to a real lack of available crude oil on the world oil market, or whether the bottlenecks were caused by deliberate stockpiling of crude oil by oil companies in order to speculate on future price increases.

The claim has often been made that such price speculation on crude oil inventories did take place immediately following the Arab Oil Embargo and the Iranian Revolution, and this aggravated the domestic fuel supply situation. Empirical research to substantiate this claim has been rather limited. Verleger argues that during 1979, the Department of Energy encouraged oil companies to build up their inventories of crude oil, and this reinforced or atleast indirectly sanctioned the price-speculative behavior that was already taking place.[9] However, Verleger did not offer a crude oil inventory behavior model to support his argument. Still, it is impossible to deny that world oil market conditions during 1979 certainly invited speculative crude oil inventory building in expectation of future price increases.

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[9]See Phillip K. Verleger, Jr., "The U.S. Petroleum Crisis of 1979," Brookings Papers on Economic Activity, Vol. 2, 1979, pp. 464-476.

1.2 Objectives and the Plan of Study

The primary objective of this study is to investigate the crude oil inventory behavior of the U.S. petroleum industry in the last five years in order to test the hypothesis that price speculation has been an important influence on crude oil inventory behavior, particularly in 1979, a period of rapidly increasing crude oil prices on the world oil market. As a secondary objective, this study will test the performance of various inventory behavior models on the gasoline, distillate fuel oil, residual fuel oil, and crude oil sectors of the U.S. petroleum industry.

Should the hypothesis of this study be accepted, this would have definite policy implications. If price speculation strongly influences crude oil inventory behavior during a period of rapid crude oil price increases, then it would appear that companies producing and importing crude oil would need little, if any, encouragement to build up crude oil inventories during such a time.

Immediately after the Iranian Revolution began, the Department of Energy was concerned that perhaps a crude oil shortage on the world oil market could persist for an unknown time period. At the time, it might have seemed prudent to encourage U.S. oil companies to build up inventories in order to meet future demand and for security reasons. However, if the crude oil shortage was not expected to persist, it would seem unwise to encourage oil companies to build up inventories when they will do so out of self interest as crude oil price increases accelerate. Inventory building reduces the amount of crude oil available to refiners, causing the now familiar problem of fuel shortages. The gasoline consumer feels the effect of a tight world oil market multiplied many times over.

In the case of the aftermath of the Iranian Revolution, the hypothesis would indicate that the U.S. gasoline shortage might not have been nearly so severe had the Department of Energy actually discouraged the oil companies from building crude oil inventories, especially if crude oil was available from sources other than Iran in sufficient quantities. The activity of building inventories itself will tend to fuel additional price increases and tighten the market even further. If the hypothesis is correct, it would seem inappropriate to encourage the oil companies to act in their own self interest by building crude oil inventories during a period of rapid price increases. In such a situation, a neutral stance on the part of the Department of Energy would be more than enough encouragement (excluding the situation where severe longterm shortage is anticipated).

The study contains four chapters. Chapter II provides a brief review of recent inventory investment theory, particularly that part most relevant to the petroleum industry. Chapter III discusses the models to be tested in the study, the methods of estimation used, and the data and data sources. Chapter IV gives the regression results and an in-depth discussion of them for each of the refined products mentioned above and crude oil.

CHAPTER II

INVENTORY INVESTMENT THEORY: A REVIEW

Inventory behavior has perplexed economists for the past several decades, and much of present inventory investment theory still remains woefully inadequate in providing a full, consistent explanation for many aspects of inventory behavior. However, several empirical studies have made important contributions toward gaining an understanding of inventory behavior. Various motives for holding inventories are presented in the next section, followed by brief sketches of different inventory investment theories that address some of these motives. In the last section, elements of inventory investment theory most applicable to the petroleum industry will be discussed.

2.1 Motives for Holding Inventories

Evans has suggested four motives for holding inventories: (1) the transaction motive, (2) the unanticipated sales or buffer-stock motive, (3) the backlog of demand motive, and (4) the speculative motive.[1] The transaction motive deals with the idea that business firms want to carry a certain amount of inventories because they do not wish to miss the opportunity to make sales. If items on the shelf run out, then sales are foregone. Business firms are assumed to have some expectations about their

[1]For a detailed discussion of these motives, see Michael K. Evans, Macroeconomic Activity (New York: Harper & Row, Publishers, Inc., 1969), pp. 202-204.

future sales, and firms will attempt to keep their inventories at a level consistent with those sales expectation.

The unanticipated sales or buffer stock motive is relevant to firms that cannot adjust their production schedules sufficiently to deal with changing sales patterns that might occur during the business cycle, and would often be unanticipated. In order to offset this lack of production flexibility in production levels, firms might build up extra inventories during periods of slack demand, which would cushion the firms during peak demand periods. Thus, firms could maintain a relatively constant production schedule and still meet peak demand levels.

The backlog of demand motive deals with firms that experience a continual build-up of backlogged orders. Those firms would take this as evidence of increasing demand, and so their sales expectations would also increase. This would cause firms to build up additional inventories. The backlog of demand motive will not be discussed any further in this study, since it is difficult to imagine how this motive could be applied to the petroleum industry, due to its nature and structure. This industry does not have anything akin to "unfilled" or "backlogged" orders for petroluem fuels or crude oil.

The speculative motive stems from two things: uncertainty about or fear of future supply shortage, and anticipation of rapidly accelerating price increases. A firm that believes one of its production inputs may not be available for a time in the future will stockpile as much of the input as possible, in order to safeguard the firm's continued operation. A consumer will exhibit similar behavior toward goods that are expected to be in shortage. Firms may build inventories during rapid price increases for two reasons: (1) they want to buy as much of the material as possible before the price goes up; (2) they know that what they have already purchased will increase in value as the price increases, and may provide a capital gain.

The inventory model developed by Metzler deals primarily with the transaction motive.[2] The most basic form of Metzler's model generally states that inventory investment in a given time period will equal the difference between the desired level of inventories in that period and actual inventories at the end of the previous time period. The desired inventory level is assumed to be directly proportional to the expected sales. This model also assumes that the entire difference between actual inventories at the end of the previous time period and present desired inventories can be made up in the given time period (usually one quarter).

Klein[3] and later Lovell[4] advanced the "flexible accelerator" concept.[5] They modified the assumption that the entire difference between actual and desired inventories could be made up (or adjusted) within one period. Instead, only a fraction of this difference could be adjusted within the given period. This fraction has often been called the inventory "speed

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[2] Lloyd M. Metzler, "The Nature and Stability of Inventory Cycles," Review of Economic Statistics, Vol. 23, No. 3 (August 1941), pp. 113-129.

[3] L.R. Klein, Economic Fluctuations in the United States, 1921-1941, Cowles Commission Monograph II (New York: Wiley, 1950).

[4] Michael C. Lovell, "Manufacturers' Inventories, Sales Expectations, and the Accelerator Principle," Econometrica, Vol. 29, No. 3 (July 1961), pp. 293-314.

[5] Ibid.

of adjustment" coefficient.[6] The "flexible accelerator" concept has aroused a considerable degree of controversy in recent years. Hay attacks this concept by arguing that it is not realistic to assume that firms will plan to adjust inventories by some fractional amount of this difference between the desired and actual levels. He states:

> ...if the only costs associated with the adjustment of inventories are those which result from any change in the rate of output which may be necessary to accomplish inventory adjustment, then it is the rate of production that will be adjusted imperfectly, and any failure of inventories to achieve their desired level will be simply a by-product of the inventory-sales-production relationship.[7]

If firms could plan the fractional amount of inventory adjustment they would make each period, this implies an unrealistically high degree of production schedule flexibility. Darling and Lovell both concede to the theoretical weaknesses of the "flexible accelerator" concept.[8]

Lovell developed an inventory model that incorporates both the transaction motive and the buffer stock motive, which is known as the Stock Adjustment Model.[9] In this model, inventory investment during a given period is assumed to be a linear function of the difference between desired and actual inventories, as discussed earlier, and the difference between expected sales and actual sales. The coefficient of the difference between expected and actual sales has been called the "production adaptation" coefficient,[10] and it is supposed to measure the degree of

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[6]See Lovell, pp. 295-300.

[7]George A. Hay, "Adjustment Costs and the Flexible Accelerator," Quarterly Journal of Economics, Vol.LXXXIV, No. 1 (February 1970), p. 142.

[8]See Paul Darling and Michael C. Lovell,"Inventories, Production Smoothing, and the Flexible Accelerator," Quarterly Journal of Economics, Vol. LXXXV, No. 2 (May 1971), pp. 357-362.

[9]See Lovell article in Econometrica cited earlier.

[10]Ibid.

production schedule flexibility. This coefficient is expected to lie between zero and one. If it is equal to one, then inventory investment is equal to the total difference between expected and actual sales. This implies a highly inflexible production schedule, because unanticipated sales must be made up entirely by depleting inventories. If this "production adaptation" coefficient is close to zero, then the production schedule is highly flexible. In that case inventory investment during the current period will be affected very little by unanticipated sales, since production can be quickly increased or decreased to match this difference.

The Stock Adjustment Model has been severly criticized by Feldstein and Auerbach.[11] Through empirical investigation, they consistently find that the estimated values of the "speed of adjustment" coefficient are extremely low, implying that during the given time period, firms are only able to adjust a very small amount of the total difference between desired and actual inventories. They reason that this is unrealistically low, and that the main problem facing firms is their inability to accurately forecast future sales. They find that frequently, the difference between desired and actual inventories only amounts to a few days' production of output, so that firms should have little difficulty in completely adjusting inventory levels within the given time period (one quarter). The firms' major difficulty lies in trying to determine the target level of production, in order to deal with unanticipated

[11] Martin Feldstein and Allen Auerbach, "Inventory Behavior in Durable-Goods Manufacturing: The Target Adjustment Model," Brookings Papers on Economic Activity, Vol. 2 (1976), pp. 357-408.

sales, which often plague them because of sales forecasting inaccuracy. Feldstein and Auerbach present the Target Adjustment Model, which differs from the Stock Adjustment Model primarily because of their assumption that inventories can adjust completely within one quarter, but the target level of production will respond very slowly to changes in the target level of inventories.[12]

The Stock Adjustment Model can accommodate the price-speculative motive by making desired inventories not only a linear function of expected sales, but also the rate of change in price. This desired inventory function can then be substituted back into the model. Empirical investigation has generally produced conflicting results as to how important price speculation is to inventory investment. Lovell comments:

> With regard to price hedging, I conclude that manufacturers do not successfully speculate or 'price hedge'although conceivably they tilt the composition of their stocks in an attempt to take advantage of rising prices of certain inputs.[13]

Others such as Klein[14] have found the change in price variable significant, indicating price speculative inventory behavior. Factors such as the particular sector of the economy studied and the time frame of the study seem to affect the results. Empirical investigations of inventory behavior during stable economic periods such as the 1960's generally do not find speculation to be significant. During more

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[12] Ibid., p. 365.

[13] Lovell, in a comment at the end of the Feldstein and Auerbach article, p. 400.

[14] L.R. Klein, "A Postwar Quarterly Model: Descriptions and Application," in Models of Income Determination (Princeton, N.J.: Princeton University Press, 1964).

inflationary periods such as the decade of the 1970's, price-speculative inventory behavior is more likely to be important.[15]

One factor that may tend to dampen the propensity to hold speculative inventories would be the carrying costs. Firms must pay for the storage space, provide for security, maintenance, and so on. If the firms borrow funds to build inventories, they must pay interest costs. If they use internal funds, they must give up the best alternative investment that could be made. Bechter and Pollock use the interest rate as a proxy for inventory carrying costs. They implicitly assume the other cost considerations mentioned above would remain relatively constant.[16]

Empirical studies prior to the 1970's generally found that interest rates do not have a significant effect on inventory behavior. Bosworth examined the finished goods sector and states that, "no direct role for monetary variables could be identified."[17] However, recent studies by Rubin[18] and Bechter and Pollock[19] have provided convincing evidence that inventory behavior can indeed be affected by interest rates. Both Rubin and Bechter and Pollock believe an inflation-adjusted interest rate, the nominal interest rate minus the rate of inflation, should be

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[15] See Evans, p. 211-214 for a more in depth discussion of this idea.

[16] Dan M. Bechter and Stephen H. Pollock, "Are Inventories Sensitive to Interest Rates?," Federal Reserve Bank of Kansas City Economic Review, (April 1980), pp. 18-27.

[17] Barry Bosworth, "Analyzing Inventory Investment," Brookings Papers on Economic Activity, Vol. 2 (1970), p. 213.

[18] Laura L. Rubin, "Aggregate Inventory Behavior: Response to Uncertainty and Interest Rates," Journal of Post Keynesian Economics, Vol.II, No. 2 (Winter 1979-80), pp. 201-211.

[19] Bechter and Pollock.

used as the proxy for carrying costs. In this way, the function for desired inventories can be expanded further by making desired inventories a linear function of expected sales, the rate of change in price, and carrying costs, measured as the inflation-adjusted interest rate.

Bechter and Pollock present a model that uses the inventory/sales ratio as the dependent variable. They also accept Feldstein and Auerbach's assumption that the difference between desired and actual inventories can be adjusted within one quarter. The actual inventory/sales ratio will then be a linear function of the desired inventory/sales ratio and some fraction of the difference between actual and expected sales. The desired inventory/sales ratio is a linear function of carrying costs, the expected trend in sales, and sales uncertainty. If carrying costs (interest rates) increase, then the desired ratio would decrease. If the expectation is that future sales will keep expanding, then the desired ratio will increase. If there is great uncertainty about future sales, usually because sales have been fluctuating quite drastically in the recent past, then the desired inventory/sales ratio will decrease.

2.2 Inventory Investment Theory Relevant to the Petroleum Industry

One might expect to find some obvious differences between the behavior of the petroleum industry inventories and the manufacturing industry inventories. Since petroleum fuels have virtually no substitute in the transportation sector, demand for petroleum has been perceived as fairly inelastic and more closely tied to the level of economic activity than anything else. As mentioned in the introduction, demand for petroleum had been steadily growing in the United States up until 1973. The petroleum industry has characteristically been more concerned about future supply than future demand. This is more and more the case as the U.S. becomes more heavily dependent on petroleum imports while at the same time having no good substitutes for petroleum products.

Petroleum inventories (or the inventory/sales ratio) would be expected to rise during the upswing of the business cycle and fall during a recession, just as demand for fuels would increase during economic expansion and decrease during a recession. However, the supply disruptions of the world oil market during the 1970's coupled with the dramatic petroleum price increases have changed the whole environment. Whatever the inventory level was prior to an oil embargo or other type of oil supply disruption, oil companies would certainly attempt to increase inventory levels during the shortage out of fear of continued shortage. Also, as crude oil prices accelerate, this invites price-speculative inventory holding. It would appear that carrying costs would affect inventory behavior in the petroleum industry only if the capital gains from the inventories, caused by increasing petroleum prices, did not exceed the carrying costs. Thus, it would seem that in the present environment, the petroleum industry would have an undeniably strong temptation to build speculative inventories, both from fear of future shortage, and in anticipation of rapidly accelerating petroleum prices. Petroleum inventories would certainly be affected by expected demand, as they have in the past, but during world oil market disruptions, the speculative motive would almost certainly be an important factor as well.

The Stock Adjustment, Target Adjustment, and Inventory/Sales Ratio Models discussed in Section 2.1 should be able to explain petroleum inventory behavior in terms of the transaction, buffer stock,and speculative motives for holding inventories. However, none of these models incorporates a variable that provides a means of measuring supply uncertainty in the petroleum industry. Such a variable would appear to be helpful in explaining speculative inventory behavior in the petroleum industry. The rate of change in price variable, included in some fashion in all three models, should indicate the importance of speculative inventory holding, but it may be difficult to decide how much of this speculation is due to anticipated price increase, and how much is due to fear of shortage. Still, shortage induced speculation should probably not be as persistent as price speculation. After a world oil market disruption, oil companies might fear shortage until they re-established crude oil supply sources. Once these sources are established, shortage induced speculation should subside. However,such a disruption might set off a trend of crude oil price acceleration that could last a year or more, leaving a very long period of opportunity for price speculation to take place. If the three models indicate the presence of speculation, then probably, only a small amount of that will be due to shortage induced speculation, and most of it will be due to price speculation.

The fear of crude oil shortage would be very closely tied to political factors, such as the perceived stability of the oil-exporting nations' governments. Since these perceptions can change very quickly, a mathematically defined variable that would accurately measure the fear of crude oil shortage might be very difficult to construct. This study does not attempt to incorporate such a variable into the models for reasons already discussed. The assumption is made that in the present environment, the shortage component of the speculative motive for building crude oil inventories would not be nearly as important as the price component.

CHAPTER III

INVENTORY MODELS, ESTIMATION METHODS, AND THE DATA

The first section of this chapter begins with a review of the three inventory models that will be used to study the petroleum industry. The methods of estimation used with the refined products considered in this study are discussed in the second section. The third section gives the methods of estimation used for crude oil, and the final section discusses the data and data sources used in this study.

3.1 Review of the Inventory Behavior Models

The models used to study the behavior of petroleum inventories are the Stock Adjustment Model, a simplified version of the Target Adjustment Model, and the Inventory/Sales Ratio Model that Bechter and Pollock developed. The inventory-holding motives most applicable to the petroleum industry would appear to be the transaction motive, the buffer stock motive, and the speculative motive. Each of the three models shows the effects of these motives on inventory behavior in different ways, and each of these models will be discussed separately.

The Stock Adjustment Model

The development of the Stock Adjustment Model begins with the basic Metzler model: desired inventories are a linear function of expected sales, i.e.:

$$I_t^d = a_o + a_1 S_t^e + u_t \qquad t = 1,2,\ldots n \tag{3.1.1}$$

I_t^d is the desired inventory level at the end of time period "t," S_t^e is the expected sales volume during time period "t," and u_t is the error term for time period "t." If the desired inventory level is also affected by carrying costs and changing prices, equation (3.1.1) may be written:

(3.1.2) $I_t^d = a_o + a_1 S_t^e + a_2 C_t + a_3 \Delta P_t + u_t \qquad t = 1,2,...n$

C_t represents the carrying costs during "t," and ΔP_t is the change in price during "t." All other variables are defined above.

The Metzler model generally accounts for the transaction motive. The buffer stock motive can be modeled by making the change in inventories a linear function of the difference between expected and actual sales, i.e.:

(3.1.3) $I_t - I_{t-1} = \lambda(S_t^e - S_t) + u_t \qquad t = 1,2,...n$

S_t is the actual sales volume during "t," and λ is the "production adaptation" coefficient. λ expresses the degree to which firms can change their production schedules in order to cope with unanticipated sales. Its value is expected to lie between zero and one. The lower the value of λ, the higher the degree of production schedule flexibility. If λ is zero, then the change in inventories is also zero, which means that when actual sales differ from expected sales, the difference can be made up entirely during time "t" by changing production, so that no additional inventory investment is needed. If λ is equal to one, then the production schedule and actual sales will be reflected completely in the change in inventories, or inventory investment.

As discussed earlier, the desired inventory level is a linear function of expected sales, as well as other factors. If actual sales have been increasing over time, then expected sales would also tend to increase, and so the desired inventory level would also increase. If expected sales are increasing fast enough, then the desired inventory level will be greater than the actual inventory level at the end of the previous time period. During the present time period, firms would attempt to narrow this gap by increasing inventory investment. This activity can be mathematically expressed as follows:

$$(3.1.4) \quad I_t - I_{t-1} = \delta(I_t^d - I_{t-1}) + u_t \qquad t = 1,2,\ldots n$$

The term δ is the "speed of adjustment" coefficient, which represents the speed with which firms can narrow the gap between actual and desired inventory investment levels. If δ is equal to one, firms are able to make the inventory investment necessary to totally adjust actual inventories to desired inventories within the time period "t." When δ is equal to zero, firms are unable to make any progress toward adjusting their actual inventory levels toward desired during the time period "t." The value of δ is also expected to lie somewhere between zero and one.

When both equation (3.1.3) and (3.1.4) are combined,the Stock Adjustment Model becomes:

$$(3.1.5) \quad I_t - I_{t-1} = \delta(I_t^d - I_{t-1}) + \lambda(S_t^e - S_t) + u_t \qquad t = 1,2,\ldots n$$

Making use of equation (3.1.2) in equation (3.1.5) we get:

$$(3.1.6) \quad I_t = \delta a_o + \delta b_o S_t^e + \delta b_1 C_t + \delta b_2 \Delta P_t + (1-\delta) I_{t-1} + \lambda(S_t^e - S_t) + u_t \qquad t = 1,2,\ldots n$$

In this form, all of the variables can be empirically identified except for expected sales, for which one must use some sort of measurable proxy.

Sales volume in the recent past is expected to have a strong influence on future sales expectations. In the most simplistic fashion, one could assume that expected sales in the next period are equal to the sales in the previous period, i.e.:

(3.1.7) $$S^e_t = S_{t-1}$$

One could also assume that expected sales would be best represented by a moving average of past sales, that is:

(3.1.8) $$S^e_t = \frac{S_{t-1} + S_{t-2}}{2}$$

This could be expanded:

(3.1.9) $$S^e_t = \frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}$$

A predicted sales variable may be used to model expected sales. Bechter and Pollock show a method for constructing such a variable.[1] The general approach involves fitting the actual sales data to an exponential time trend, then using the exponential function to predict future sales.

The Simplified Version of the Target Adjustment Model

The simplified version of the Target Adjustment Model is similar to the Stock Adjustment Model, but it contains the assumption that the "speed of adjustment" coefficient (δ) is equal to one. The simplified version of the Target Adjustment Model assumes that firms are able to completely adjust for the difference between actual inventories and desired inventories in one time period. If the assumption that δ is equal to one is imposed on equation (3.1.6), it becomes:

(3.1.10) $$I_t = a_o + b_oS^e_t + b_1C_t + b_2\Delta P_t + \lambda(S^e_t - S_t) + u_t \qquad t = 1,2,...n$$

All the variables have been previously defined. The primary difference

[1]See Appendix to Bechter and Pollock article, p. 27.

between equations (3.1.6) and (3.1.10) is that the variable for lagged inventories, I_{t-1}, has dropped out of equation (3.1.10). One obvious advantage of equation (3.1.10) over (3.1.6) as far as the estimation of coefficients is concerned, is the elimination of the lagged dependent variable from the right side of the equation. The Generalized Least Squares method can be used to estimate the parameters of equation (3.1.10) if there is serial correlation in the error terms.[2] This procedure cannot be used with equation (3.1.6) due to the presence of the lagged dependent variable on the right side of the equation, and therefore, the Ordinary Least Squares estimated coefficients will be biased.

The various proxies for expected sales discussed in this section will also be used in the simplified version of the Target Adjustment Model, and substituted for S_t^e in equation (3.1.10).

<u>The Inventory/Sales Ratio Model</u>

Rather than examining inventory levels, or change in inventory levels, this model looks at the behavior of the inventory/sales ratio over time. The model incorporates the Target Adjustment Model assumption that firms can totally adjust for the difference between actual and desired inventories within one time period. It asserts that the actual inventory/sales ratio is a linear function of the desired inventory/sales ratio and unanticipated sales, i.e.:

(3.1.11) $$(I/S)_t = (I/S)_t^* + \sigma(S_t^e - S_t) + u_t \qquad t = 1,2,\ldots n$$

$(I/S)_t$ is the actual inventory/sales ratio in time period "t," $(I/S)_t^*$ is the desired inventory/sales ratio in time period "t," and σ, a coefficient

2. For a concise explanation of this method see Henry Theil, <u>Principles of Econometrics</u> (New York; John W. Wiley & Sons, Inc., 1971), pp. 251-254.

similar to λ, the "production" adaption coefficient. The desired inventory/sales ratio is then a linear function of carrying costs, the expected sales trend, and sales uncertainty:

$$(3.1.12)\qquad (I/S)^*_t = \alpha - \beta C_t + \gamma(S^e_{t+1} - S_t) - \mu U_t + u_t \qquad t = 1,2,\ldots n$$

U_t is the sales uncertainty variable.[3] Substituting (3.1.12) into (3.1.11) gives:

$$(3.1.13)\qquad (I/S)_t = \alpha - \beta C_t + \gamma(S^e_{t+1} - S_t) - \mu U_t + \sigma(S^e_t - S_t) + u_t \qquad t = 1,2,\ldots n$$

S^e_{t+1}, the expected sales in the next time period, is assumed to be proportional to S^e_t, so that (3.1.13) reduces to:

$$(3.1.14)\qquad (I/S)_t = \alpha - \beta C_t + \omega S^e_t - \varepsilon S_t - \mu U_t + u_t \qquad t = 1,2,\ldots n$$

All variables have been previously defined and are now in measurable form, except S^e_t, which uses the predicted sales variable proxy computed by the Bechter and Pollock method.

3.2 Inventory Behavior of Refined Products: Methods of Estimation

The Stock Adjustment Model and simplified version of the Target Adjustment Model developed in the previous section are used on the gasoline, distillate fuel oil, and residual fuel oil data during the time period from August 1975 to August 1978, hereafter denoted as Period One. The regression equations listed below are based on the Stock Adjustment Model:

$$(3.2.1)\qquad I_t = \beta_o + \beta_1 S_{t-1} + \lambda(S_{t-1} - S_t) + \beta_4 I_{t-1} + u_t$$

$$(3.2.2)\qquad I_t = \beta_o + \beta_1 S_{t-1} + \lambda(S_{t-1} - S_t) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$$

$$(3.2.3)\qquad I_t = \beta_o + \beta_1 S_{t-1} + \lambda(S_{t-1} - S_t) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$$

$$(3.2.4)\qquad I_t = \beta_o + \beta_1 \frac{(S_{t-1} + S_{t-2})}{2} + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_4 I_{t-1} + u_t$$

[3]See Bechter and Pollock, p. 27 for explanation of this variable.

(3.2.5) $$I_t = \beta_o + \beta_1 \frac{(S_{t-1} + S_{t-2})}{2} + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$$

(3.2.6) $$I_t = \beta_o + \beta_1 \frac{(S_{t-1} + S_{t-2})}{2} + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$$

(3.2.7) $$I_t = \beta_o + \beta_1 \frac{(S_{t-1} + S_{t-2} + S_{t-3})}{3} + \lambda\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3} - S_t\right) + \beta_4 I_{t-1} + u_t$$

(3.2.8) $$I_t = \beta_o + \beta_1 \frac{(S_{t-1} + S_{t-2} + S_{t-3})}{3} + \lambda\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3} - S_t\right) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$$

(3.2.9) $$I_t = \beta_o + \beta_1 \frac{(S_{t-1} + S_{t-2} + S_{t-3})}{3} + \lambda\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3} - S_t\right) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$$

These models will be estimated for gasoline, distillate fuel oil, and residual fuel oil data during Period One. Equations (3.2.1), (3.2.2), and (3.2.3) use the proxy for expected sales given in equation (3.1.7). Equations (3.2.4), (3.2.5), and (3.2.6) use equation (3.1.8) as the expected sales proxy, and equations (3.2.7), (3.2.8), and (3.2.9) use equation (3.1.9) for the same proxy. Equations (3.2.1), (3.2.4), and (3.2.7) leave out the carrying cost and change in price variables. Equations (3.2.2), (3.2.5), and (3.2.8) add on the carrying cost variable, and equations (3.2.3), (3.2.6), and (3.2.9) add on the change in price variable as well. All variables in the above equations have been defined earlier. This provides a method of observing the influence of the carrying cost variable and change in price variable on the adjusted R^2's and t-ratios of the other estimated coefficients as each of the variables is added in. If the estimated coefficients are significant for either of these variables, then this would provide evidence of price-speculative inventory behavior during Period One.

For regressions of this type, one must be alert to the possibility of serial correlation in the error terms. Since all of these equations contain a lagged value of the dependent variable (I_{t-1}), the Generalized Least Squares method cannot be used in estimating the coefficients. The Ordinary Least Squares method of estimation is employed, and the h statistic is computed for each equation of the Stock Adjustment Model-type. The h statistic gives an indication of whether serial correlation in the error terms is present or not.

The winters of 1976-1977 and 1977-1978 included months that were abnormally cold for the entire nation. Therefore, another set of equations similar to Equations (3.2.1) through (3.2.9) is used, with the only difference between this set and the former set being the addition of a dummy variable. The dummy variable, labeled "Cold" with coefficient β_5, is set equal to one for the months of October 1976 through February 1977 and October 1977 through February 1978, and equal to zero for all other months. This new equation set is denoted (3.2.1C), (3.2.2C), and so on. It is expected that the particularly cold months would cause larger than normal increases in demand and depletions of stocks for distillate fuel oil and residual fuel oil.

The only difference between the regression form of the Stock Adjustment Model and the simplified version of the Target Adjustment Model as used in this study is the absence of the lagged dependent variable (I_{t-1}) on the right side of the equation. The regression equation set used for the simplified version of the Target Adjustment Model is the same as equation (3.2.1) through (3.2.9), except that "$\beta_4 I_{t-1}$" is deleted from each equation . The equations for the simplified version of the Target Adjustment Model will be given new numbers, corresponding to the Stock Adjustment Model equations. Equation (3.2.10) will correspond to equation (3.2.1) (except for the deletion of $\beta_4 I_{t-1}$). Equation (3.2.11) will correspond to equation (3.2.2), and so on. With the deletion of the lagged dependent variable from the equations, the Generalized Least Squares method can be used to correct for serial correlation in the error terms. This method is used with all simplified version of the Target Adjustment Model equations. If the estimated coefficients of carrying cost or change in price are significant, then this would indicate the presence of price specuàltion.

The dummy variable "Cold" is also added to the simplified version of the Target Adjustment Model equations, and in the same manner as with the Stock Adjustment Model equations, a new set of simplified Target Adjustment Model equations is generated with equation numbers (3.2.10C), (3.2.11C), and so on.

3.3 Price-Speculative Behavior of Crude Oil Inventories: Methods of Estimation

With crude oil, all three inventory behavior models discussed in Section 3.1 are used. The Stock Adjustment Model and Target Adjustment Model will first be used on Period One (August 1975-August 1978) crude oil data in order to estimate the coefficients of the independent variables during this relatively stable period of economic recovery. The Stock Adjustment Model regression equations used will be identical to Equations (3.2.1) through (3.2.9), but for the crude oil regressions, these equations will be re-numbered (3.3.1) through (3.3.9). Also, a fourth proxy for expected sales, the Bechter and Pollock predicted sales variable, will be used in the crude oil regressions. This will create three more Stock Adjustment Model equations, which will be labeled: (3.3.1B), (3.3.2B), and (3.3.3B). The Ordinary Least Squares method of estimation will be used with Stock Adjustment Model equations for the same reasons discussed in the previous section.

The simplified version of the Target Adjustment Model equation set for crude oil will be identical to equations (3.2.10) through (3.2.18), but will be re-numbered (3.3.10) through (3.3.18). Again, three more equations will be created with the addition of the Bechter and Pollock expected sales proxy. These equations will be labeled: (3.3.10B), (3.3.11B), and (3.3.12B). The Generalized Least Squares method can be used to correct for serial correlation of the error terms in the simplified Target Adjustment Model equation regressions for crude oil. The dummy variable "Cold" is not used with any of the crude oil equations, as the unusual weather does not appear to be that important, compared to the refined products.

Once the regressions on the crude oil data from Period One are estimated with the two models, the regression results are used on the Period Two data. Period Two is defined as a time of rapid crude oil price increases and supply uncertainty. It contains the months of August 1978 through November 1979. Periods One and Two will be discussed in more detail in the next section. Each of the equations with the estimated coefficients can be used to predict future crude oil stocks during Period Two simply by plugging the observed values of the independent variables during Period Two into those equations and calculating predicted stock levels. This procedure is used with each equation in both the Stock Adjustment Model equation set and the simplified Target Adjustment Model equation set; each equation thus generates a set of predicted end-of-month crude oil stocks during Period Two. Once the predicted stock levels are computed, they can be compared to the actual stock levels during Period Two. If the predicted stock level is subtracted from the actual stock level for each month, then this residual between the predicted and actual value represents factors that were not accounted for during Period One in the model, or factors that were accounted for during Period One, which have become either more or less important in Period Two. One obvious non-market factor that would make crude oil inventory behavior different during Period Two as compared to Period One is the Department of Energy's encouragement of the oil companies to build their crude oil inventories after the Iranian Revolution during late 1978 and on into 1979.

If oil companies were building up speculative inventories during Period Two but tended not to during Period One (when crude oil prices were relatively stable and the world oil market was not tight), then this difference between actual and predicted stock levels will be an approximation of the amount of speculative crude oil inventories being held. This study hypothesizes that price speculation became much more important in affecting crude oil inventory behavior during Period Two than in Period One. A significant part of the difference between actual and predicted stocks should be due to price speculation that was much more prevalent during Period Two than in Period One. If this is true, one should be able to find good correlation between the difference of predicted and actual stocks (hereafter tentatively labeled "estimated speculative inventories) for each month in Period Two and crude oil price behavior during the same months. The estimated speculative inventories could be regressed against the change in prices during Period Two and if the price coefficient was significant, this would be strong evidence of price speculation. In equation form, this regression appears as follows:

$$(3.3.19) \quad I_t^p - I_t = c_o + c_1 \Delta P_t + u_t \qquad t = 1,2,\ldots n$$

I_t^p is the predicted stock level; the other variables have already been defined.

If some of the unaccounted for factors that cause predicted stocks to differ from actual stocks are constant (such as the Department of Energy's encouragement to build up crude oil inventories in Period Two), they can be largely eliminated by taking the first differences of the estimated speculative inventories and regressing those against change in prices, i.e.:

$$(3.3.20) \quad (I_t^p - I_t) - (I_{t-1}^p - I_{t-1}) = d_o + d_1 \Delta P_t + u_t \qquad t = 1,2,\ldots n$$

All variables are defined earlier. This regression of first differences could also be done on the carrying cost variable as follows:

$$(3.3.21) \quad (I_t^p - I_t) - (I_{t-1}^p - I_{t-1}) = e_o + e_1 C_t + u_t \qquad t = 1,2,\ldots n$$

All variables are defined earlier. If estimated d_1 or e_1 values have right signs and significance , then this supports the hypothesis that price speculation was an important influence on inventory behavior during Period Two. Regressions are performed in this study using equations (3.3.20) and (3.3.21) with estimated speculative inventories generated from each equation in both the Stock Adjustment Model equation set and the simplified Target Adjustment Model equation set in order to test for the presence of the price-speculative motive for holding inventories during Period Two.

The Generalized Least Squares method will be used to correct for serial correlation of the error terms in regressions with equations (3.3.20) and (3.3.21) with estimated speculative inventories generated from the simplified Target Adjustment Model equation set. The Ordinary Least Squares method will be used for regressions of equations (3.3.20) and (3.3.21) with estimated speculative inventories generated from the Stock Adjustment Model equation set. The h statistic is reported in the Ordinary Least Squares regression results to indicate the presence of serial correlation in the error terms.

The third model considered in the study, the Inventory/Sales Ratio Model, is used on the crude oil data from Periods One and Two, but in a different manner than with the other two models. The Inventory/Sales Ratio Model given by equation (3.1.14) is regressed with crude oil data from Period One to get one set of estimated coefficients. Equation (3.1.14) is then regressed with crude oil data from August 1975 to November 1979, which combines both Periods One and Two. The estimated coefficients obtained with this regression are then compared to those of the first regression. If the hypothesis is correct, the coefficient for the carrying cost variable, C_t, should be more significant in the second regression than in the first. This is a less straightforward approach than simply regressing Period One with equation (3.1.14), regressing Period Two with the same equation, and then comparing the results. Since Period Two consists of only sixteen observations (months), and there were five parameters to be estimated in equation (3.1.14), the degrees of freedom would be quite small unless more observations were used. For this reason, Periods One and Two were combined for the second regression. The Generalized Least Squares method is used in estimating the coefficients of the equation (3.1.14) regressions. This method corrects for serial correlation in the error terms.

3.4 Data Sources and Considerations

This section begins by discussing some general data considerations appropriate to both the refined products and crude oil. Following this, specific details pertaining to each of the refined products and crude oil will be presented.

General Considerations

Monthly Energy Review published by the Department of Energy is the primary source of data for the study. The publication provides monthly observations of stock levels, approximate consumption, and prices for petroleum and other energy sources. Two time periods are defined in order to examine inventory behavior in the petroleum industry: Period One goes from August 1975 to August 1978; Period Two goes from August 1978 to November 1979. Period One is characterized by steady economic expansion and recovery from the 1974-1975 recession. Petroleum product prices were generally stable, and crude oil was in surplus on the world oil market. During Period Two crude oil and petroleum product prices rapidly increased and the world oil market became tight. These particular time periods were chosen because they are the most recent and the most relevant to the present environment. Also, the level of economic activity during both periods was not fluctuating but rather steadily increasing (although leveling off in the later part of 1979).

During Period One, petroleum inventory behavior would seem to be most affected by the transaction and the buffer stock (unanticipatied sales) motives. During Period Two, the speculative motive should become much more important. Time periods prior to 1975 were not considered, since the recession dominated the 1974-1975 time period, and prior to that, conditions in the world oil market were fundamentally different from the present: petroleum prices were, of course, much lower, and OPEC was not perceived as having the ability to control crude oil price or production.

Although quarterly observations have been generally used in inventory studies, monthly observations are used in this study, since the Monthly Energy Review provides that kind of data. Also, the two time periods defined for this study are too short to use quarterly observations. The monthly observations allow for sufficient degrees of freedom even though the time periods only cover a few years. This facilitates making a study of only the most recent years, eliminating those years during the recession and prior to the 1973 Oil Embargo.

All observed values for end-of-month stocks, monthly consumption, and average monthly prices of the different refined products and crude oil are reported as raw data in the Monthly Energy Review. No seasonal adjustment is done. In this study, the data for stocks, consumption, and price are seasonally adjusted by using the multiplicative decomposition method.[3] The crude oil raw data did not exhibit a very significant amount of seasonal fluctuation, but raw data for all three refined products did.

[3] For details see Bruce L. Bowerman & Richard T. O'Connell, Forecasting & Time Series (North Scituate, Mass.: Duxbury Press, 1979), pp. 223-232.

The variables contained in the three models used in this study are generally self explanatory, except for the carrying cost variable, C_t, and the change in price variable, ΔP_t. Bechter and Pollock define their carrying cost variable as "an interest rate adjusted for inflation."[4] It consists of the ninety day commercial paper rate in time "t" minus the annual percentage rate of change of prices during time "t." The carrying cost variable used in this study will be defined in the same manner. The ninety day commercial paper rate during each month of Period One and Two is collected from selected issues of the Federal Reserve Bulletin. The annual percentage change in price is determined by calculating the percentage change in the price of the petroleum product considered between the price given during month "t" and the price twelve months earlier. The specific prices of the various petroleum products are discussed later in this section. Since the annual percentage rate of change in the petroleum prices is often different from the overall inflation rate for the economy, the carrying cost variable (C_t) in this study does not really represent an inflation-adjusted interest rate. Instead, it gives some sort of indication as to whether price speculation would be profitable or not. If for a given month the value of the carrying cost variable is large and positive, then the commercial paper rate is high, and petroleum prices are not changing very much. If a firm must borrow money to purchase crude oil for stockpiling purposes, there will be significant interest costs. If the value of the carrying cost variable is negative, then the percentage

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[4] Bechter and Pollock, p. 25.

change in prices exceeds the commercial paper rate. A firm could borrow money to purchase crude oil, use the capital gains to pay the interest costs, and still make a profit. Alternatively, a firm could decide to sell its crude oil and lend the revenue out as commercial paper, or keep the crude oil stockpiled and get a better return on investment, depending on the value of the carrying cost variable. The change in price variable (ΔP_t) is simply the annual percentage change in price computed for each month, as discussed previously.

All end-of-month inventory levels (stocks) for gasoline, distillate fuel oil, residual fuel oil, and crude oil are reported in thousands of barrels in the Monthly Energy Review. The approximate consumption figures for each are reported in thousands of barrels per day. This can easily be equated to a monthly total consumption figure by multiplying the reported figure by thirty. Therefore, no distinction need be made in this study between "real" and "nominal" inventory levels or consumption, since the figures are given in physical and not monetary terms.

Refined Product Data

End-of-month inventory levels for refined products (gasoline, distillate fule oil and residual fuel oil) are defined as the summation of stocks held at refineries, bulk terminals, and pipelines where storage capacity exceeds 50,000 barrels.[5] These figures do not include stocks held by jobbers, dealers, independent marketers, and consumers.[6]

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[5] See Department of Energy (DOE) definition for Refined Petroleum Stocks in Monthly Energy Review (April 1980), p. 101.

[6] See same definition, same issue.

Undoubtedly, these stocks are quite large, but accurate statistics indicating their size are not available, so the Department of Energy end-of-month figure must be used as an approximation for total stocks. The monthly domestic sales or consumption figures for each of the refined products is also only an approximation. It is reported as the amount supplied, and is calculated by adding "domestic production, imports, and withdrawals from primary stocks and subtracting exports."[7] This figure basically represents the amount of refined product supplied to those agencies that sell the product to the end user, and therefore, it is only an approximation of how much product is actually sold and consumed.

The monthly price used for gasoline is the nation-wide average retail, full-service price per gallon for leaded regular gasoline. Since regular gasoline represented over half of the total amount of gasoline consumed during Periods One and Two, its price is viewed as being most representative.

For distillate fuel oil, the monthly average refiner's selling price per barrel to resellers and retailers for No. 2 Heating Oil is used for this study. Distillate fuel oil is used primarily as a residential space heating source and in making diesel fuel. Although demand for diesel fuel is expanding, residential space heating remained the dominant use for distillate fuel oil during Periods One and Two.

The average retail price per barrel for No. 6 Residual fuel oil is used as the monthly price for residual fuel oil. This fuel oil is

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[7] See DOE definition for Refined Petroleum Product Supplied in Monthly Energy Review.

used primarily as an energy source in the utility industry, and has been a substitute for coal.

Anytime monthly observations are used, as in this study, the accuracy of the data must be questioned. In addition to this problem, the end-of-month stocks and sales (consumption) statistics are only approximations in themselves. The advantage of using monthly observations is that it enables one to make a large number of observations in a relatively short period of time. This is of major importance since Period One is three years in length, and Period Two is only sixteen months in length.

Crude Oil Data

End-of-month crude oil stocks are defined as stocks "held at refineries, in pipelines, at pipeline terminals, and on leases."[8] Since crude oil itself has negligible demand as a final good and is basically a raw material, the Department of Energy figure as given should be a fairly accurate representation of actual end-of-month crude oil stocks. Crude oil sales (consumption) must be approximated by the amount of crude oil input to refineries for processing per month. This is reported in thousands of barrels per day, so must be multiplied by thirty to give the total crude oil consumption (or amount supplied to refiners) per month. This figure should give a fairly accurate approximation, since crude has very little use other than as a refinery input. The monthly price used for crude oil is the composite refiner acquisition cost per barrel. This is defined as: "the average of domestic and imported crude oil costs, and represents the amount of crude oil cost which refiners may pass on to their customers."[9]

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[8] Ibid., p. 99.

[9] Ibid., p. 101.

Since the Department of Energy figures for end-of-month crude oil stocks and monthly crude oil sales are expected to be fairly representative of the actual amounts, the crude oil data should be more reliable than the refined products data. However, the problem of inaccuracy with monthly statistics will still be present. Seasonal fluctuation of crude oil raw data is almost imperceptible in comparison to the very strong fluctuation patterns found in the refined products data.

CHAPTER IV

REGRESSION RESULTS FOR GASOLINE, DISTILLATE FUEL OIL, RESIDUAL FUEL OIL, AND CRUDE OIL

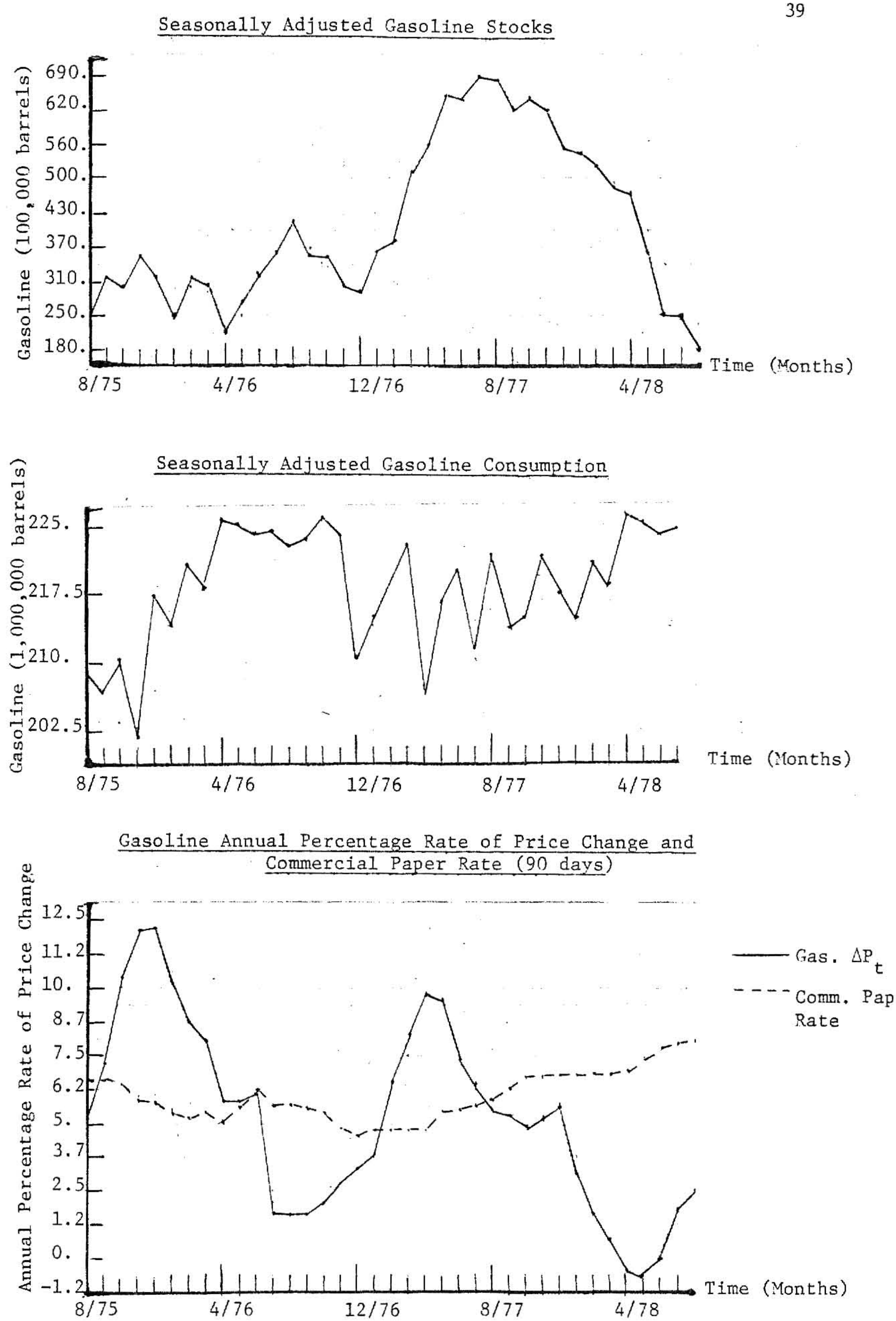
The coefficient estimates of the equation sets developed in Chapter III are presented in this chapter, along with graphical analysis of stocks, consumption, and percentage price change for gasoline, distillate fuel oil, residual fuel oil, and crude oil. Each of the refined products will be discussed in separate sections, followed by crude oil in the last section. Each section begins with a graphical analysis of the seasonally adjusted data for each fuel, and then the regression results of the same fuel are presented and analyzed.

4.1 Gasoline

Graphical Analysis

The graph depicting seasonally adjusted gasoline sales (consumption) on page 39 shows a great deal of fluctuation, perhaps due to inaccurate monthly data orother factors. However, the general trend shows a steady increase in sales for gasoline throughout Period One. Even after seasonal adjustment, the annual percentage changes in gasoline prices for each month during Period One show a repeating pattern with wide fluctuation. Still, the general trend is downward, indicating fairly stable gasoline prices. Seasonally adjusted gasoline stocks remain relatively stable until January 1977, when they build steadily, peaking around mid-year of 1977, and then decline for the rest of the period. One expects stock levels to build as demand for gasoline increases, but the

FIGURE 1


Seasonally Adjusted Gasoline Stocks
Gasoline (100,000 barrels)
690.
620.
560.
500.
430.
370.
310.
250.
180.
8/75
4/76
12/76
8/77
4/78
Time (Months)
Seasonally Adjusted Gasoline Consumption
Gasoline (1,000,000 barrels)
225.
217.5
210.
202.5
8/75
4/76
12/76
8/77
4/78
Time (Months)
Gasoline Annual Percentage Rate of Price Change and
Commercial Paper Rate (90 days)
Annual Percentage Rate of Price Change
12.5
11.2
10.
8.7
7.5
6.2
5.
3.7
2.5
1.2
0.
-1.2
8/75
4/76
12/76
8/77
4/78
Time (Months)
Gas. ΔP t
Comm. Pap
Rate

sales trend cannot explain the decline in stock levels that begins in mid-1977 and continues for the next year. Note that the percentage price change is also steadily declining throughout this same period, and it actually dips below zero at one point.

Under these circumstances, price speculation certainly cannot be ruled out as one of the causes for stock declines. If the real price of gasoline is falling, it does not seem prudent to build up inventories, at least for speculative motives. What is most surprising is to find that gasoline stocks were declining, even in the face of rising sales for gasoline. If price speculation was (that is, reverse price speculation) was in large part the cause for this, its influence must be recognized as important in determining gasoline inventory behavior.

Regression Results for Gasoline

The regression results for the Stock Adjustment Model equation set for gasoline are presented in Table 2 . The R^2's are quite high (.90), indicating good explanatory power of the models, but the h statistic indicates the possibility of significant serial correlation in equations (3.2.1), (3.2.4), and (3.2.7). In equations (3.2.2), (3.2.5), and (3.2.8) the estimated coefficients for carrying cost (C_t) are negative and significant at the five percent level. However, the estimated coefficients of expected sales and expected sales minus actual sales are insignificant at the five percent level in these equations, which is not consistent with theory. These estimated coefficients are also insignificant in equations (3.2.3), (3.2.6), and (3.2.9). In addition, there is strong evidence of a high degree of multicollinearity between the carrying cost variable and the change in price variable (ΔP_t) in these

TABLE 1

Stock Adjustment Model Equations
for Gasoline (Tables 2 and 3)

(3.2.1) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_4 I_{t-1} + u_t$

(3.2.2) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$

(3.2.3) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

(3.2.4) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1}+S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1}+S_{t-2}}{2} - S_t\right) + \beta_4 I_{t-1} + u_t$

(3.2.5) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1}+S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1}+S_{t-2}}{2} - S_t\right) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$

(3.2.6) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1}+S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1}+S_{t-2}}{2} - S_t\right) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

(3.2.7) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1}+S_{t-2}+S_{t-3}}{3}\right) + \lambda\left(\frac{S_{t-1}+S_{t-2}+S_{t-3}}{3} - S_t\right) + \beta_4 I_{t-1} + u_t$

(3.2.8) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1}+S_{t-2}+S_{t-3}}{3}\right) + \lambda\left(\frac{S_{t-1}+S_{t-2}+S_{t-3}}{3} - S_t\right) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$

(3.2.9) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1}+S_{t-2}+S_{t-3}}{3}\right) + \lambda\left(\frac{S_{t-1}+S_{t-2}+S_{t-3}}{3} - S_t\right) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

Equations (3.2.1C) through (3.2.9C) will correspond to the above equations except that the dummy variable and coefficient (β_5Cold) will be added to each equation.

Simplified Target Adjustment Model Equations
for Gasoline (Tables 4 and 5)

Equations (3.2.10) through (3.2.18) will correspond exactly to equations (3.2.1) through (3.2.9), only the lagged inventory variable and coefficient, $\beta_4 I_{t-1}$, will be deleted from each equation. Equations (3.2.10C) - (3.2.18C) include the dummy variable and coefficient (β_5Cold).
All of the simplified Target Adjustment Model equation regression results are corrected for serial correlation in the error terms.

TABLE 2
Gasoline Inventories on Motives to Hold Inventories
Period One, August 1975-August 1978
(Stock Adjustment Model)

	S_t^{e*} [a]	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.1)	(3.2.2)	(3.2.3)	(3.2.4)	(3.2.5)	(3.2.6)	(3.2.7)	(3.2.8)	(3.2.9)
Constant	66276.0	-67268.6	-39185.4	78991.4	-60841.4	-27464.7	72687.9	-65660.3	-37296.1
S_t^e	-.239 (-1.423) [b]	.306 (1.354)	.213 (.878)	-.286 (-1.608)	.292 (1.12)	.175 (.594)	-.258 (-1.355)	.319 (1.229)	.217 (.711)
$(S_t^e-S_t)$	.460 (2.949)	.209 (1.322)	.252 (1.545)	.441 (2.549)	.263 (1.563)	.294 (1.703)	.456 (2.667)	.269 (1.610)	.291 (1.693)
C_t		-966.62 (-3.187)	-1857.57 (-2.032)		-952.62 (-2.812)	-1752.97 (-1.792)		-935.83 (-2.874)	-1552.58 (-1.559)
ΔP_t			-1173.1 (-1.033)			-1096.15 (-.873)			-852.04 (-.656)
I_{t-1}	.941 (14.57)	1.005 (16.75)	.999 (16.62)	.931 (14.21)	.991 (15.79)	.984 (15.50)	.932 (15.32)	.988 (16.07)	.982 (15.67)
R^2	.8899	.9184	.9214	.8849	.9096	.9120	.8861	.9114	.9127
F	80.79	81.62	65.66	76.91	72.95	58.03	77.83	74.57	58.57
h	2.078	.565	.259	1.858	-.030	-.166	1.800	-.164	-.243

[a] S_t^{e*}, S_t^{e**}, and S_t^{e***} represent the expected sales proxies used in the equations listed directly below the symbols, where $S_t^{e*} = S_{t-1}$, $S_t^{e**} = \frac{S_{t-1} + S_{t-2}}{2}$, and $S_t^{e***} = \frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}$. These same proxies are also used for S_t^e in $(S_t^e - S_{t-1})$.

[b] Numbers in the parentheses are t-statistics.

TABLE 3

Gasoline Inventories on Motives to Hold Inventories, Including Dummy Variable
Period One, August 1975–August 1978
(Stock Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.1C)	(3.2.2C)	(3.2.3C)	(3.2.4C)	(3.2.5C)	(3.2.6C)	(3.2.7C)	(3.2.8C)	(3.2.9C)
Constant	63010.9	-68123.2	-364344.7	73925.8	-69044.4	-31817.8	64291.6	-80837.7	-47820.9
S_t^e	-.230 (-1.337)	.307 (1.338)	.201 (.815)	-.269 (-1.452)	.322 (1.199)	.191 (.642)	-.228 (-1.181)	.326 (1.404)	.257 (.836)
$(S_t^e - S_t)$	.467 (2.937)	.214 (1.323)	.271 (1.609)	.456 (2.546)	.281 (1.629)	.325 (1.828)	.481 (2.698)	.297 (1.743)	.330 (1.869)
C_t		-960.41 (-3.106)	-1992.6 (-2.088)		-963.36 (-2.810)	-1931.42 (-1.916)		-959.92 (-2.927)	-1730.27 (-1.710)
ΔP_t			-1369.56 (-1.143)			-1320.49 (-1.021)			-1059.30 (-.805)
I_{t-1}	.947 (14.16)	1.008 (16.29)	1.005 (16.32)	.938 (13.75)	1.00 (15.34)	.995 (15.23)	.941 (13.91)	1.002 (15.73)	.997 (15.48)
COLD	-921.07 (-.440)	-482.89 (-.262)	-1103.21 (-.577)	-940.60 (-.421)	-1230.37 (-.611)	-1677.50 (-.815)	-1296.90 (-.569)	-1794.17 (-.881)	-2059.84 (-.992)
R^2	.8906	.9186	.9224	.8856	.9108	.9141	.8874	.9138	.9158
F	59.01	63.21	53.47	56.15	57.17	47.89	57.14	59.35	48.94
h	2.026	.523	.075	1.782	-.206	-.468	1.668	-.501	-.676

See footnotes following Table 2.

TABLE 4

Gasoline Inventories on Motives to Hold Inventories,
Period One, August 1975-August 1978
(Simplified Target Adjustment Model)

	S_t^{e*} [a]	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.10)	(3.2.11)	(3.2.12)	(3.2.13)	(3.2.14)	(3.2.15)	(3.2.16)	(3.2.17)	(3.2.18)
Constant	307263.4	300780.4	303266.4	354731.2	351142.0	363615.6	471659.6	486288.3	492276.1
S_t^e	-.325 (-1.149)[b]	-.291 (-.99)	-.295 (-.973)	-.538 (-1.396)	-.521 (-1.126)	-.580 (-1.201)	-1.064 (-2.335)	-1.131 (-2.271)	-1.183 (-2.306)
$(S_t^e - S_t)$	.344 (2.123)	.332 (1.991)	.335 (1.933)	.377 (2.663)	.376 (2.424)	.386 (2.345)	.396 (2.963)	.399 (2.868)	.385 (2.595)
C_t		-355.98 (-.590)	-564.82 (-.239)		-169.47 (-.222)	-82.76 (-.031)		258.95 (.370)	1174.4 (.499)
ΔP_t			-223.54 (-.091)			34.75 (.013)			890.85 (.386)
R^2	.1665	.1726	.1697	.1878	.1805	.1728	.2315	.2289	.2279
F	3.30	2.22	1.58	3.70	2.28	1.57	4.67	2.97	2.14

[a] S_t^{e*}, S_t^{e**}, and S_t^{e***} represent the expected sales proxies used in the equations listed directly below the symbols, where $S_t^{e*} = S_{t-1}$, $S_t^{e**} = \frac{S_{t-1} + S_{t-2}}{2}$, and $S_t^{e***} = \frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}$. These same proxies are also used for S_t^e in $(S_t^e - S_t)$.

[b] Numbers in the parentheses are t-statistics.

TABLE 5

Gasoline Inventories on Motives to Hold Inventories, Including Dummy Variable, Period One, August 1975-August 1978 (Simplified Target Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.10C)	(3.2.11C)	(3.2.12C)	(3.2.13C)	(3.2.14C)	(3.2.15C)	(3.2.16C)	(3.2.17C)	(3.2.18C)
Constant	309770.1	302833.9	305594.8	338256.2	328009.2	341143.1	472817.8	479969.2	481433.2
S_t^e	-.332 (-1.153)	-.297 (-.991)	-.301 (-.98)	-.458 (-1.140)	-.409 (-.86)	-.478 (-.965)	-1.065 (-2.166)	-1.099 (-2.232)	-1.138 (-2.184)
$(S_t^e - S_t)$	.353 (2.130)	.339 (1.992)	.343 (1.949)	.364 (2.608)	.359 (2.385)	.370 (2.328)	.397 (3.005)	.398 (2.929)	.380 (2.610)
C_t		-339.85 (-.554)	-624.53 (-.261)		247.14 (.316)	21.50 (.008)		193.35 (.271)	1387.16 (.593)
ΔP_t			-305.76 (-.123)			222.98 (.086)			1177.74 (.510)
COLD	-2016.05 (-.707)	-1897.58 (-.652)	-1886.92 (-.635)	-478.22 (-.168)	-653.06 (-.222)	-1027.03 (-.337)	449.12 (.867)	381.16 (.139)	137.78 (.049)
R^2	.1753	.1804	.1797	.1964	.1917	.1847	.2395	.2374	.2371
F	2.27	1.71	1.31	2.53	1.78	1.31	3.15	2.26	1.74

See footnotes following Table 2.

equations. The simple correlation coefficients between these two variables were found to be over .9. This may be due to way the two variables were constructed.

The ninety day commercial paper rate remained quite stable relative to petroleum price changes during Periods One and Two. The graph on page 39 shows both the commercial paper rate and the percentage change in price for gasoline during Period One. When the percentage change in price is subtracted from the commercial paper rate, the remainder will still correlate strongly with the percentage change in price. For this reason, the regression equations for any of the refined products and crude oil that contain both the carrying cost variable and the change in price variable generally show that the estimated coefficients for these two variables have very large standard errors and values inconsistent with theory.

The estimated coefficient of lagged gasoline stocks (I_{t-1}) should be equal to one minus δ, the "speed of adjustment" coefficient (refer to Section 3.1, equation [3.1.6]). In equations (3.2.1) through (3.2.9), the estimated coefficients for the lagged gasoline stock variable are generally above .9, implying that the "speed of adjustment" coefficient is below .1, which is an unrealistically low value. The estimated coefficients for expected sales are generally positive, but not significant at the five percent level in the models shown in Table 2.

The addition of the "Cold" dummy variable to the Stock Adjustment Model equations (see Table 3) does not noticeably change the estimated coefficients of the other variables, and the estimated coefficients of the "Cold" variable are insignificant, indicating that unusually cold weather does not have an important impact on gasoline inventory behavior.

The regression results of equations (3.2.10) through (3.2.18) are presented in Table 4. This is the simplified Target Adjustment Model equation set. These results indicate the models in this equation set did not perform well for the gasoline data during Period One. The R^2 values are below .2 for equations (3.2.10) through (3.2.15), indicating very low explanatory power of the models. The estimated coefficient of the expected sales proxy variable is generally negative and insignificant at the five percent level. In fact, only the "production adaptation" coefficient estimates are significant at the five percent level in these equations ($\hat{\lambda}$).

Equations (3.2.16) through (3.2.18) give somewhat improved results, but R^2 values are still below .25. However, the expected sales coefficient estimates and the estimated "production adaptaion" coefficients are both significant at the five percent level. Equation (3.2.16) seems to perform better than any other equation in the simplified Target Adjustment Model equation set. This would indicate that price and carrying costs are not significant factors influencing gasoline inventory behavior.

The estimated coefficient of the expected sales proxy variable is negative throughout the entire simplified Target Adjustment Model equation set. One might assume that inventory levels and expected sales should be positively related. However, since the proxies for expected sales are based on lagged sales, stocks may be drawn down when lagged sales increase, especially if the "speed of adjustment" coefficient is less than one. However, this set of models asumes that the "speed of adjustment"coefficient is equal to one. When demand increases and firms are unable to replenish inventories completely during time period "t" (one month), the inventory levels may decrease when current sales are increasing.[1] The negative values for the estimated coefficient of the expected sales proxy in this equation set raise the suspicion that the assumption that the "speed of adjustment" coefficient is equal to one may not be valid in this case. Still, the low R^2 values throughout the equation set make it dangerous to draw any sort of definitive conclusions.

Table 5 shows the effect of adding the dummy variable "Cold" to the simplified Target Adjustment Model equation set. The results change very little, if any, and the "Cold" coefficient estimates are not significant, indicating negligible influence on inventory behavior.

It appears that neither the Stock Adjustment Model nor the simplified Target Adjustment Model perform well with the gasoline data during Period One. Data inaccuracy may be a major portion of the problem, as discussed earlier. The severe monthly fluctuations in the gasoline data for stock levels and sales, even after seasonal adjustment, may be due to data collection problems.

4.2 Distillate Fuel Oil

Graphical Analysis

Prices, stocks, and sales (consumption) for distillate fuel oil exhibit strong seasonal patterns, with prices and sales at highest levels during winter and lowest during summer, and stock levels increasing during

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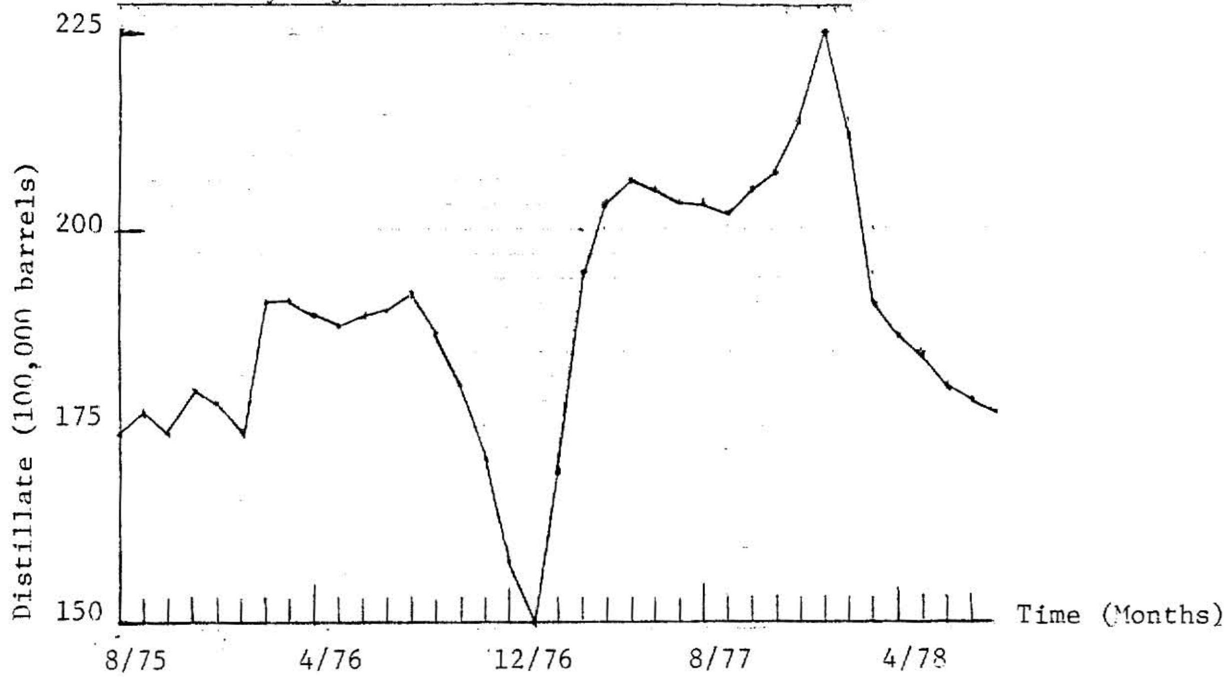
[1]See Rubin, pp. 204-205 for a similar explanation of this depletion effect.

FIGURE 2

Seasonally Adjusted Distillate Fuel Oil Stocks



Seasonally Adjusted Distillate Fuel Oil Consumption

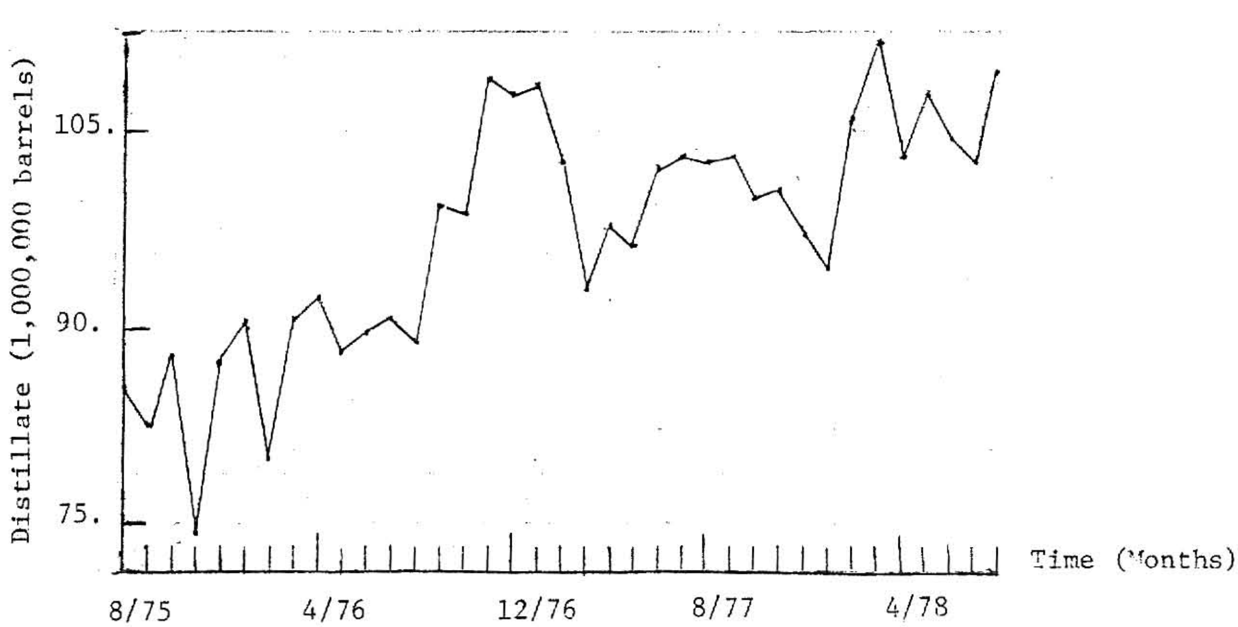
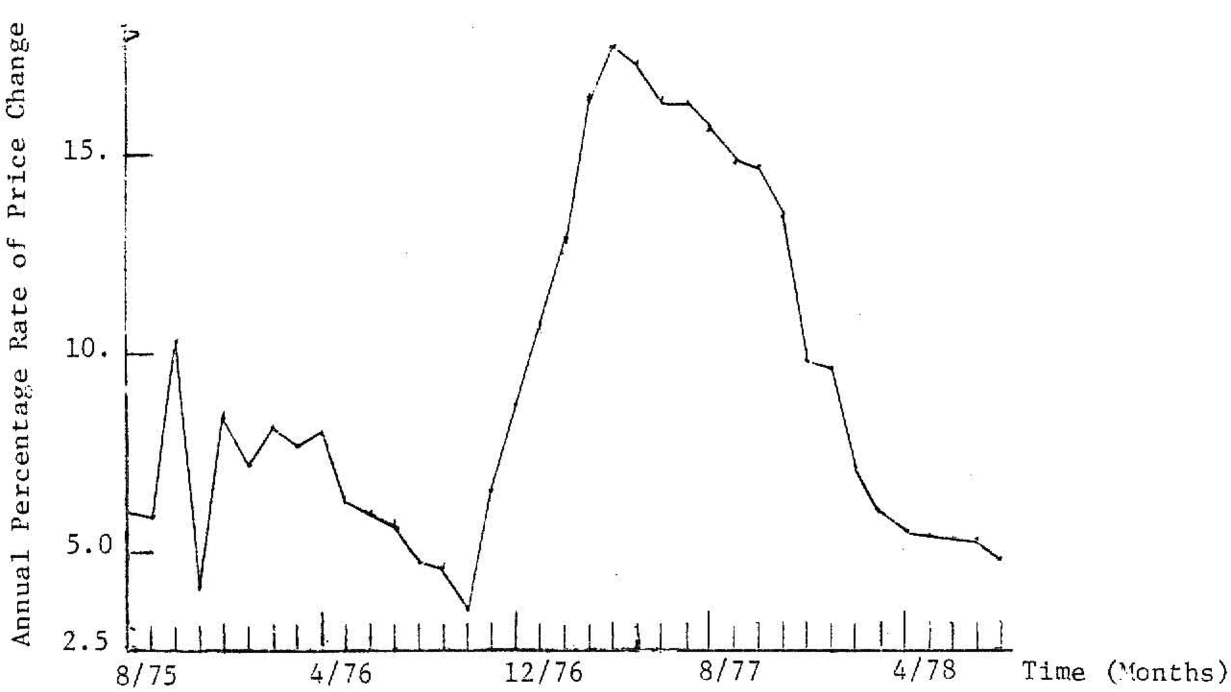


FIGURE 3

Distillate Fuel Oil Annual Percentage Rate of Price Change



the summer and early fall, then decreasing during the winter. As the graphs on pages 49 and 50 indicate, the seasonally adjusted distillate fuel oil data still exhibits a great deal of variation.

Stock levels show a dramatic decrease during the severe winter of 1976-1977, apparently due to the unusually cold weather. The percentage change in price shows a sharp acceleration of price increases beginning in the 1976-1977 winter and continuing well through 1977. High consumption of distillate fuel oil and high demand during the harsh weather may have sparked this acceleration. The percentage change in price peaked during 1977 and began a long decline extending through August 1978. This may explain the sharp decrease in stock levels beginning in January 1978, if companies decrease inventories as price declines.

The graph of seasonally adjusted consumption on page 49 shows noticeable peaks for the 1976-1977 winter and February-March 1978, periods of abnormally cold weather. The general trend of the consumption line is upward, demonstrating a growing level of consumption as the economy recovers from the recession of 1974-1975.

Regression Results of Distillate Fuel Oil

The regression results of the Stock adjustment Model equations are presented in Table 7. The R^2 values are quite high for all equations, but the h statistic provides evidence of serious serial correlation in the error terms through all these equations, except possibly equations (3.2.2), (3.2.5), and (3.2.9). Note that the estimated values for λ, the "production adaptation" coefficient, are greater than one in most of the equations. This is inconsistent with the theory, since λ is expected to

TABLE 6

Stock Adjustment Model Equations
For Distillate Fuel Oil (Tables 7 and 8)

(3.2.1) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_4 I_{t-1} + u_t$

(3.2.2) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$

(3.2.3) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

(3.2.4) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_4 I_{t-1} + u_t$

(3.2.5) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$

(3.2.6) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

(3.2.7) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}\right) + \lambda(S_{t-1} + S_{t-2} + S_{t-3} - S_t) + \beta_4 I_{t-1} + u_t$

(3.2.8) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3} - S_t\right) + \beta_2 C_t +$
$\beta_4 I_{t-1} + u_t$

(3.2.9) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3} - S_t\right) + \beta_2 C_t +$
$\beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

Equations (3.2.1C) through (3.2.9C) will correspond to the above equations except that the dummy variable and coefficient (β_5Cold) will be added to each equation above.

Simplified Target Adjustment Model Equations
For Distillate Fuel Oil (Tables 9 and 10)

Equations (3.2.10) through (3.2 .18) will correspond exactly to equations (3.2.1) through (3.2.9), only the lagged inventory variable and coefficient, $\beta_4 I_{t-1}$, will be deleted from each equation. Equations (3.2.10C) through (3.2.18C) include the dummy variable and coefficient (β_5Cold). All of the simplified Target Adjustment Model equation regression results are corrected for serial correlation of the error terms.

TABLE 7

Distillate Fuel Oil Inventories on Motives to Hold Inventories

Period One, August 1975-August 1978

(Stock Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.1)	(3.2.2)	(3.2.3)	(3.2.4)	(3 2.5)	(3.2.6)	(3.2.7)	(3 2.8)	(3.2.9)
Constant	47395.8	57586.7	69767.8	29992.9	41146.2	49588.6	29269.9	39534.3	41310.9
S_t^e	-.354 (-2.322)	-.405 (-3.098)	-.574 (-4.219)	-.234 (-1.859)	-.295 (-2.673)	-.391 (-2.802)	-.181 (-1.572)	-.244 (-2.367)	-.262 (-1.844)
$(S_t^e - S_t)$	.953 (4.493)	.893 (4.922)	.888 (5.358)	1.229 (6926)	1.132 (7.258)	1.086 (6.758)	1.284 (8.153)	1.184 (8.311)	1.172 (7.558)
C_t		-777.68 (-3.524)	2771.93 (2.003)		-619.98 (-3.343)	939.66 (.666)		-536.55 (-3.104)	-233.26 (-.165)
ΔP_t			4009.88 (2.593)			1793.13 (1.115)			352.51 (.213)
I_{t-1}	.936 (11.60)	.894 (12.83)	.785 (10.30)	.969 (14.87)	.929 (16.16)	.874 (11.56)	.947 (16.51)	.915 (17.74)	.905 (12.88)
R^2	.8213	.8749	.8991	.8838	.9161	.9197	.9063	.9297	.9298
F	45.97	50.71	49.92	76.03	79.15	64.10	96.78	95.88	74.19
h	2.878	2.150	2.374	2.360	1.591	1.838	1.859	1.016	1.140

See footnotes following Table 2.

TABLE 8

Distillate Fuel Oil Inventories on Motives to Hold Inventories, Including Dummy Variable
Period One, August 1975–August 1978
(Stock Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.1C)	(3.2.2C)	(3.2.3C)	(3.2.4C)	(3.2.5C)	(3.2.6C)	(3.2.7C)	(3.2.8C)	(3.2.9C)
Constant	48987.2	58739.5	75097.7	30691.5	41669.6	53195.9	30020.0	40158.8	43363.7
S_t^e	-.373 (-2.252)	-.419 (-2.953)	-.641 (-4.262)	-.243 (-1.774)	-.301 (-2.520)	-.433 (-2.709)	-.190 (-1.529)	-.252 (-2.264)	-.290 (-1.736)
$(S_t^e - S_t)$	.961 (4.433)	.899 (4.843)	.908 (5.449)	1.232 (6.790)	1.135 (7.107)	1.088 (6.686)	1.288 (7.987)	1.188 (8.134)	1.171 (7.429)
C_t		-775.90 (-3.458)	3167.62) (2.209)		-619.56 (-3.283)	1231.83 (.811)		-536.08 (-3.049)	52.35 (.033)
ΔP_t			4449.93 (2.778)			2127.14 (1.228)			561.88 (.310)
I_{t-1}	.936 (11.43)	.894 (12.63)	.774 (10.05)	.969 (14.63)	.929 (15.89)	.864 (10.99)	.947 (16.25)	.915 (17.45)	.899 (11.89)
COLD	921.98 (.321)	681.40 (.279)	2360.13 (1.036)	403.08 (.174)	306.46 (.153)	1191.39 (.565)	458.54 (.221)	387.32 (.212)	618.73 (.309)
R^2	.8222	.8735	.9030	.8839	.9162	.9206	.9065	.9291	.9301
F	33.48	39.29	41.88	55.19	61.19	52.17	70.29	74.19	59.84
h	2.717	2.210	2.343	2.369	1.602	1.878	1.840	1.009	1.184

See footnotes following Table 2.

TABLE 9
Distillate Fuel Oil Inventories on Motives to Hold Inventories
Period One, August 1975-August 1978
(Simplified Target Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.10)	(3.2.11)	(3.2.12)	(3.2.13)	(3.2.14)	(3.2.15)	(3.2.16)	(3.2.17)	(3.2.18)
Constant	329825.9	323910.1	260915.5	217213.0	233048.8	213200.0	215406.9	233463.4	189297.3
S_t^e	-1.480 (-4.904)	-1.437 (-4.758)	-1.066 (-3.387)	-.282 (-.637)	-.483 (-1.148)	-.725 (-1.923)	-.261 (-.567)	-.499 (-1.181)	-.655 (-2.098)
$(S_t^e-S_t)$	.890 (4.744)	.912 (4.767)	.780 (3.643)	.503 (3.009)	.608 (3.559)	.897 (3.119)	.550 (3.265)	.567 (4.745)	.574 (4.230)
C_t		-756.07 (-1.386)	3203.72 (.939)		-987.42 (-1.870)	5496.43 (1.714)		-1671.72 (-3.137)	7873.34 (3.193)
ΔP_t			4462.82 (1.238)			7016.25 (2.071)			9928.98 (3.830)
R^2	.4416	.4526	.3532	.3230	.3636	.3182	.2576	.5076	.5761
F	13.05	8.82	4.23	7.63	5.90	3.50	5.38	10.31	9.85

See footnotes following Table 2.

TABLE 10

Distillate Fuel Oil Inventories on Motives to Hold Inventories, Including Dummy Variable
Period One, August 1975-August 1978
(Simplified Target Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.10C)	(3.2.11C)	(3.2.12C)	(3.2.13C)	(3.2.14C)	(3.2.15C)	(3.2.16C)	(3.2.17C)	(3.2.18C)
Constant	330100.2	324464.6	258056.3	216946.3	232730.1	209975.7	215539.4	235023.6	192928.3
S_t^e	-1.480 (-4.817)	-1.440 (-4.683)	-1.056 (-3.264)	-.280 (-.621)	-.482 (-1.127)	-.727 (-1.885)	-.262 (-.556)	-.518 (-1.197)	-.750 (-2.385)
$(S_t^e-S_t)$	.892 (4.684)	.915 (4.704)	.776 (3.529)	.501 (2.935)	.606 (3.487)	.696 (3.010)	.550 (3.195)	.561 (4.556)	.549 (3.932)
C_t		-759.08 (-1.365)	3403.01 (.988)		-996.27 (-1.852)	5874.83 (1.823)		-1698.82 (-3.102)	8565.58 (3.513)
ΔP_t			4709.03 (1.291)			7467.54 (2.182)			10727.5 (4.152)
COLD	-185.19 (-.052)	362.91 (.100)	1279.14 (.303)	245.98 (.078)	650.38 (.201)	2119.78 (.472)	76.17 (.022)	793.19 (.321)	2377.43 (.853)
R^2	.4435	.4541	.3489	.3236	.3650	.3235	.2576	.5093	.5578
F	8.50	6.45	3.21	4.94	4.31	2.77	3.47	7.53	8.32

See footnotes following Table 2.

lie between zero and one. The estimated coefficients of lagged stocks, I_{t-1} (1-δ), are slightly lower than the results for gasoline. This implies that the "speed of adjustment" coefficient (δ) is larger for distillate fuel oil than for gasoline. However, estimated values of δ are still very low (.1-.15), suggesting very slow speed of adjustment. The estimated coefficients of the carrying cost variable (C_t) are negative and significant in equations (3.2.5) and (3.2.8). However, they are insignificant in equations (3.2.6) and (3.2.9). The addition of the "Cold" dummy variable does not drastically change the estimated coefficients of the other variables, as shown in Table 8. The estimated coefficients of the dummy variable are insignificant throughout the equation set, which does not support the contention that the harsh weather had an impact.

Table 9 shows the regression results of the simplified Target Adjustment Model equation set for distillate fuel oil. The R^2 values are usually below .5, although equation (3.2.18) has an R^2 equal to .57. The estimated coefficients of the expected sales proxy are negative and significant in equations (3.2.10) through (3.2.12) and (3.2.18). This may be due to the drawing down effect on stocks when lagged sales increase faster than stocks can be replenished. The estimates for λ are positive and significant throughout th equation set, but its value seems to decrease from approximately .9 with the expected sales proxy of S_{t-1}, down to around .5 with the three period moving average of lagged sales as the expected sales proxy. The estimates of λ are still noticeably higher than for gasoline, possibly indicating a lower degree of production schedule flexibility with distillate fuel oil in comparison to gasoline.

This seems consistent with the observation that U.S. refining capacity is weighted much more heavily toward gasoline production than distillate fuel oil. Adjustment of production schedules for distillate fuel oil could be very difficult. Supply shortfalls would probably be handled by increasing imports of distillate fuel oil, instead of changing production schedules.

The estimated coefficients of the carrying cost variable and change in price variable are insignificant at the five percent level, except for equations (3.2.17) and (3.2.18). The estimated coefficient of the carrying cost variable is negative and significant in equation (3.2.17), which is consistent with the theory and provides evidence of speculative inventory behavior in Period One. However, estimated coefficients of the carrying cost variable and change in price variable become positive in equations (3.2.12), (3.2.15), and (3.2.18), which is inconsistent. This may be due to multicollinearity between the two variables, as discussed earlier. Equation (3.2.10) yields the highest t-ratios for the estimated coefficient of the expected sales proxy variable and the estimate of λ, which indicates that the most important explanatory variables may be expected sales (the transaction motive) and expected sales minus actual sales (the buffer stock motive).

When the "Cold" dummy variable is added to the above equation set (see Table 10), R^2 values and estimated coefficients of the other variables change very little, and the dummy variable variable coefficient estimates are insignificant, which is somewhat surprising, since graphical analysis seemed to at least point toward the possibility that the unusually harsh weather may have influenced inventory behavior.

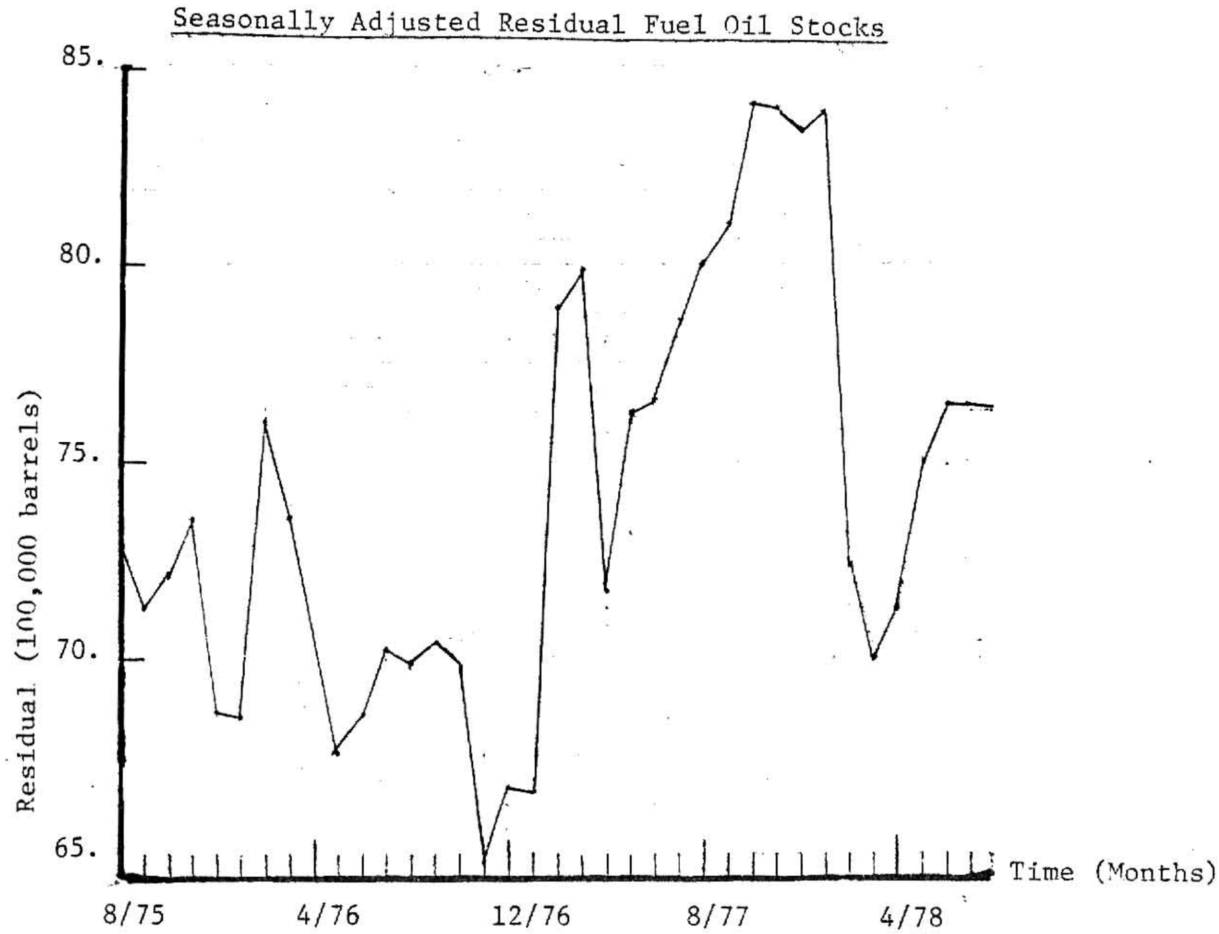
In general, the distillate fuel oil results do not support the contention that either of the two models used on the data are appropriate for distillate fuel oil inventory behavior. The same nagging doubts about the data accuracy must also be raised. Significant serial correlation greatly weakens the reliability of most of the results from the Stock Adjustment Model equations. However, the negative and significant values for estimated coefficients of the carrying cost variable in some equations from both of the models do provide evidence of speculative distillate fuel inventory behavior--even during a relatively stable period. Still, the long period of declining percentage changes in price during 1977-1978 may have invited speculation.

4.3 Residual Fuel Oil

Graphical Analysis

Utilities are the major consumers of residual fuel oil, and its use as a direct source for residential heating is rather limited. The consumption and stock level patterns (with raw data) do not show the same regular seasonal pattern that distillate fuel does, probably because residual fuel is not used directly in the residential sector. The seasonally adjusted data for sales (consumption) depicted in the graph on page 60 , show steady consumption growth throughout Period One. In contrast, the seasonally adjusted stock levels show a great deal of fluctuation. They show a large draw-down during the winter of 1976-1977.

FIGURE 4


Seasonally Adjusted Residual Fuel Oil Stocks
85.
80.
75.
70.
65.
Residual (100,000 barrels)
Time (Months)
8/75
4/76
12/76
8/77
4/78

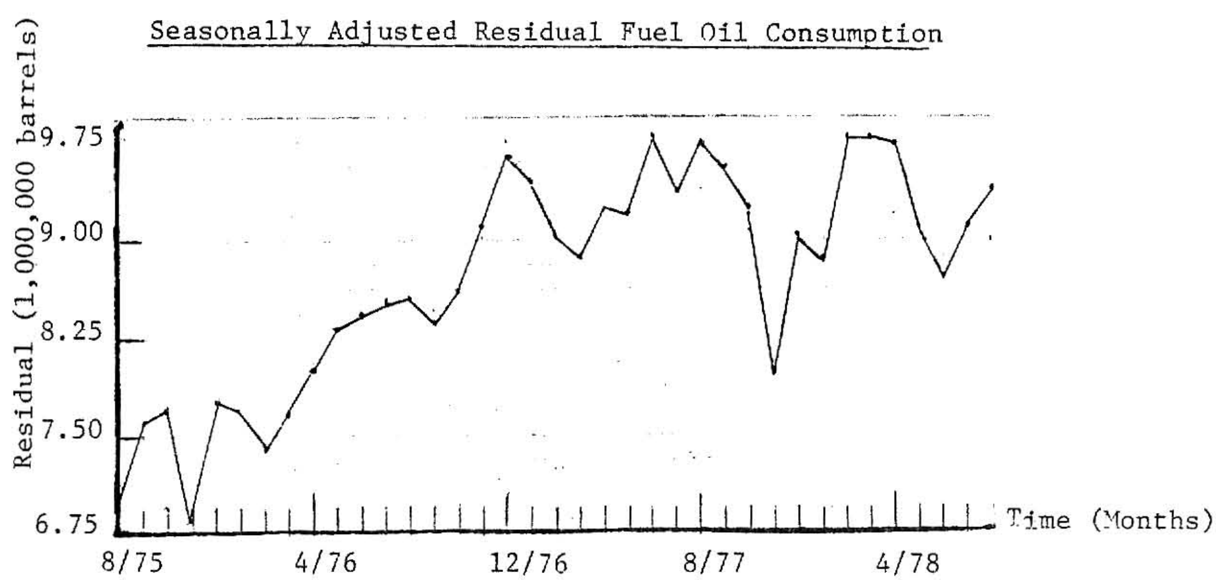
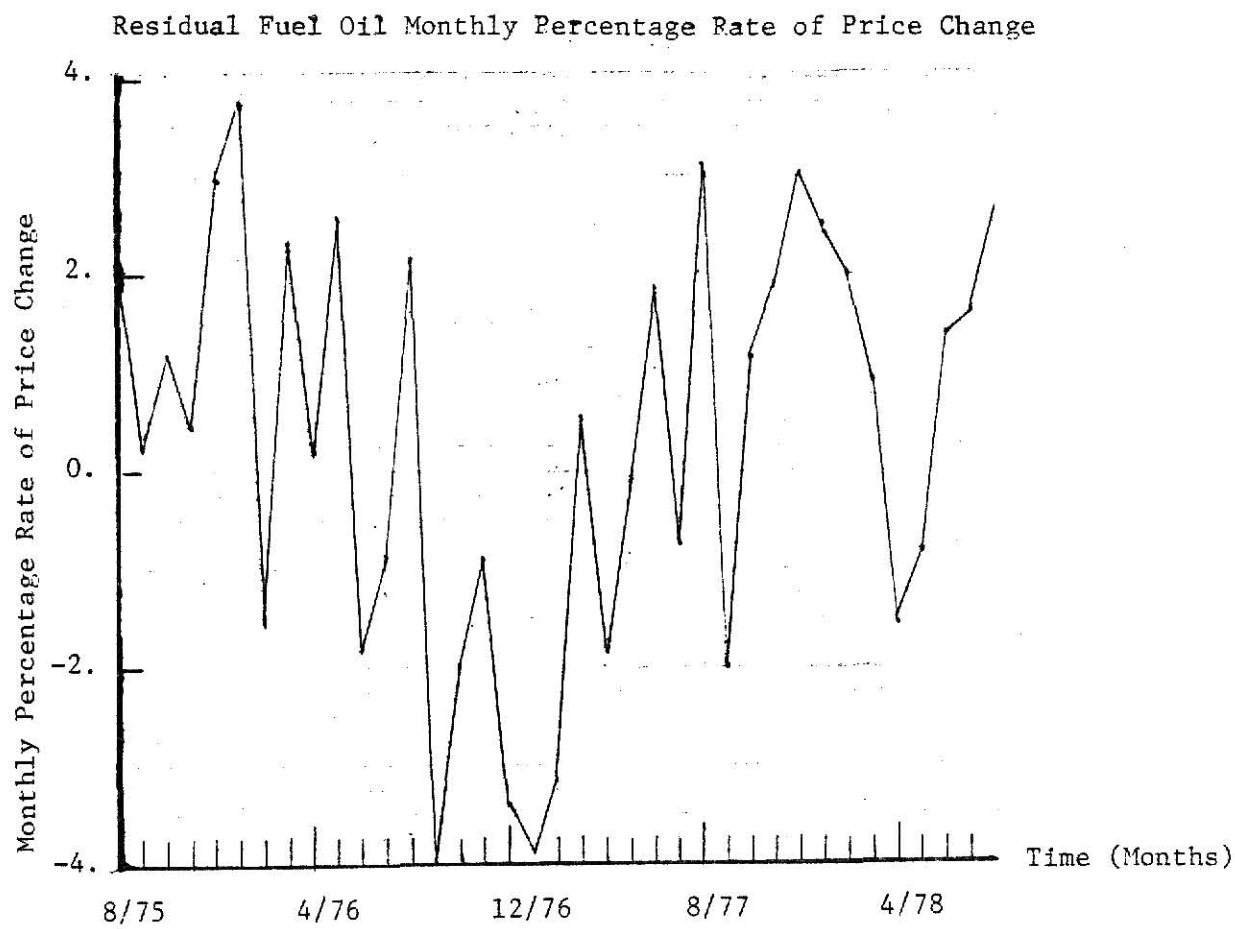

Seasonally Adjusted Residual Fuel Oil Consumption
9.75
9.00
8.25
7.50
6.75
Residual (1,000,000 barrels)
Time (Months)
8/75
4/76
12/76
8/77
4/78

FIGURE 5


Residual Fuel Oil Monthly Percentage Rate of Price Change
4.
2.
0.
-2.
-4.
Monthly Percentage Rate of Price Change
Time (Months)
8/75
4/76
12/76
8/77
4/78

The seasonally adjusted percentage change in price for residual fuel oil is computed as a percentage change in price from one month to the next month, instead of as an annual percent change for each month, since reliable monthly residual fuel oil price data was not available prior to July 1975. As the graph on page 61 shows, the percentage change in price remained quite small (fluctuating between plus and minus four percent), and did not show any dominant trend during Period One. For this reason, one would not expect to see any significant influence from prices on inventory behavior.

Regression Results for Residual Fuel Oil

The regressions results with the Stock Adjustment Model on residual fuel oil data are shown in Table 12 . These results show that the estimated values for λ, the "production adaptation" coefficient, and the coefficient of lagged inventories (I_{t-1}) are significant. No other coefficient estimates were significant at the five percent level. The coefficient estimates of lagged inventories are generally smaller than with the gasoline and distillate fuel oil results. The estimated values of δ, the "speed of adjustment" coefficient, range between .3 and .4, which is much larger than for the other refined products. This is consistent with the theory and indicates a higher degree of adjustment for inventories of residual fuel oil. Since demand for residual fuel oil is much lower than for other refined products such as gasoline or distillate fuel oil, it would be easier to replenish depleted stocks simply by importing more from Canada or Europe. Importing from Canada would especially enhance speed of adjustment.

TABLE 11

Stock Adjustment Model Equations
for Residual Fuel Oil (Tables 12 and 13)

(3.2.1) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_4 I_{t-1} + u_t$

(3.2.2) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$

(3.2.3) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

(3.2.4) $I_t = \beta_o + \beta_1 \left(\frac{S_{t-1} + S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_4 I_{t-1} + u_t$

(3.2.5) $I_t = \beta_o + \beta_1 \left(\frac{S_{t-1} + S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$

(3.2.6) $I_t = \beta_o + \beta_1 \left(\frac{S_{t-1} + S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

(3.2.7) $I_t = \beta_o + \beta_1 \left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}\right) + \lambda\left(\underline{S_{t-1} + S_{t-2} + S_{t-3}} - S_t\right) + \beta_4 I_{t-1} + u_t$

(3.2.8) $I_t = \beta_o + \beta_1 \left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3} - S_t\right) + \beta_2 C_t +$
$\beta_4 I_{t-1} + u_t$

(3.2.9) $I_t = \beta_o + \beta_1 \left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3} - S_t\right) + \beta_2 C_t +$
$\beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

Equations (3.2.1C) through (3.2.9C) will correspond to the above equations except that the dummy variable and coefficient (β_5Cold) will be added to each equation above.

Simplified Target Adjustment Model Equations
for Residual Fuel Oil (Tables 14 and 15)

Equations (3.2.10) through (3.2 .18) will correspond exactly to equations (3.2.1) through (3.2.9), only the lagged inventory variable and coefficient, $\beta_4 I_{t-1}$, will be deleted from each equation. Equations (3.2.10C) through (3.2.18C) include the dummy variable and coefficient (β_5Cold). All of the simplified Target Adjustment Model equation regression results are corrected for serial correlation of the error terms.

TABLE 12

Residual Fuel Oil Inventories on Motives to Hold Inventories, Period One, August 1975-August 1978)
(Stock Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.1)	(3.2.2)	(3.2.3)	(3.2.4)	(3.2.5)	(3.2.6)	(3.2.7)	(3.2.8)	(3.2.9)
Constant	12946.	10974.	10965.	15663.	14906.	14980.	19916.	17955.	18135.
S_t^e	2.514 (1.070)	1.877 (.712)	1.791 (.632)	3.915 (1.669)	3.652 (1.343)	3.824 (1.300)	4.693 (1.978)	4.099 (1.517)	4.366 (1.489)
$(S_t^e-S_t)$	11.32 (3.210)	11.05 (3.071)	11.02 (3.004)	11.54 (3.524)	11.43 (3.387)	11.49 (3.330)	11.38 (3.599)	11.24 (3.490)	11.32 (3.442)
C_t		210.98 (.561)	1153.52 (.125)		74.92 (.202)	-1482.82 (-.164)		169.07 (.480)	-2147.31 (-.242)
ΔP_t			931.33 (.102)			-1532.58 (-.172)			-2287.06 (-.261)
I_{t-1}	.729 (6.970)	.781 (5.580)	.778 (5.377)	.639 (6.289)	.659 (4.557)	.662 (4.477)	.553 (5.282)	.602 (4.074)	.604 (4.016)
R^2	.6827	.6861	.6862	.7091	.7095	.7098	.7177	.7199	.7206
F	21.52	15.85	12.25	24.37	24.68	24.85	25.42	18.63	14.44
h	-1.068	-1.356	-1.459	-.896	-1.301	-1.520	-.565	-.866	-1.116

See footnotes following Table 2.

TABLE 13

Residual Fuel Oil Inventories on Motives to Hold Inventories, Including Dummy Variable
Period One, August 1975-August 1978
(Stock Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.1C)	(3.2.2C)	(3.2.3C)	(3.2.4C)	(3.2.5C)	(3.2.6C)	(3.2.7C)	(3.2.8C)	(3.2,9C)
Constant	13362.	10994.	11031.	15865.	15020.	15019.	20343.	18165.	18230.
S_t^e	.081 (.992)	.063 (.698)	.060 (.623)	.129 (1.588)	.122 (1.319)	.127 (1.274)	.153 (1.871)	.137 (1.489)	.145 (1.459)
$(S_t^e-S_t)$	.378 (3.163)	.368 (2.980)	.386 (2.981)	.382 (3.459)	.383 (3.292)	.384 (3.237)	.382 (3.543)	.378 (3.395)	.378 (3.347)
C_t		210.20 (.517)	1172.54 (.124)		70.92 (.176)	-1472.67 (-.159)		161.61 (.424)	-2121.87 (-.233)
ΔP_t			952.66 (.102)			-1524.44 (-.167)			-2258.50 (-.251)
I_{t-1}	.727 (6.765)	.781 (5.177)	.777 (4.950)	.638 (6.121)	.658 (4.220)	.661 (4.134)	.550 (5.131)	.599 (3.766)	.603 (3.710)
COLD	251.78 (.194)	7.87 (.006)	26.04 (.018)	121.69 (.098)	42.83 (.032)	14.97 (.011)	264.92 (.217)	76.20 (.058)	35.58 (.026)
R^2	.6831	.6861	.6862	.7092	.7095	.7098	.7181	.7199	.7206
F	15.63	12.24	9.84	17.68	13.68	11.01	18.47	14.40	11.61
h	-1.114	-1.650	-1.830	-.875	-1.662	-2.129	-.522	-1.131	-1.625

See footnotes following Table 2.

TABLE 14
Residual Fuel Inventories on Motives to Hold Inventories
Period One, August 1975–August 1978
(Simplified Target Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.10)	(3.2.11)	(3.2.12)	(3.2.13)	(3.2.14)	(3.2.15)	(3.2.16)	(3.2.17)	(3.2.18)
Constant	84008.9	63036.2	57730.7	66130.0	53760.2	51625.9	58461.9	53350.7	51895.7
S_t^e	-.113 (-.742)	.129 (1.056)	.072 (.575)	.095 (.581)	.238 (2.017)	.185 (1.453)	.184 (1.110)	.242 (1.849)	.216 (1.538)
$(S_t^e-S_t)$	.279 (2.324)	.244 (1.712)	.245 (1.817)	.293 (2.478)	.383 (2.793)	.369 (2.724)	.184 (3.086)	.242 (3.533)	.216 (3.551)
C_t		-463.18 (-1.293)	20451.74 (1.528)		-657.23 (-1.964)	13256.37 (1.078)		-444.25 (-1.482)	7165.57 (.526)
ΔP_t			20661.77 (1.553)			13714.87 (1.078)			7552.04 (.559)
R^2	.1689	.1870	.2254	.2400	.3614	.3858	.3332	.4387	.4455
F	3.35	2.45	2.25	5.05	5.85	5.65	7.74	7.82	5.83

See footnotes following Table 2.

TABLE 15
Residual Fuel Oil Inventories on Motives to Hold Inventories, Including Dummy Variable
Period One, August 1975–August 1978
(Simplified Target Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}	S_t^{e***}	S_t^{e***}	S_t^{e***}
Equation	(3.2.10C)	(3.2.11C)	(3.2.12C)	(3.2.13C)	(3.2.14C)	(3.2.15C)	(3.2.16C)	(3.2.17C)	(3.2.18C)
Constant	848692.9	62601.8	57507.4	67720.3	53422.8	51915.5	60116.9	54006.1	52798.6
S_t^e	-.125 (-.816)	.128 (1.067)	.066 (.534)	.074 (.438)	.237 (2.077)	.180 (1.431)	.160 (.945)	.229 (1.764)	.202 (1.435)
$(S_t^e - S_t)$	.292 (2.411)	.279 (1.873)	.274 (1.963)	.304 (2.518)	.411 (2.931)	.392 (2.830)	.373 (3.192)	.431 (3.787)	.427 (3.696)
C_t		-615.55 (-1.667)	20775.8 (1.595)		-817.10 (-2.390)	12509.8 (.994)		-538.93 (-1.787)	6798.9 (.501)
ΔP_t			21081.9 (1.631)			13089.4 (1.052)			7268.1 (.546)
COLD	1605.2 (.838)	1877.0 (.975)	2102.7 (1.099)	1076.5 (.567)	1480.7 (.864)	1589.3 (.907)	1613.2 (.927)	1788.9 (1.177)	1831.5 (1.185)
R^2	.1882	.2346	.2676	.2482	.4119	.4067	.3511	.4817	.4846
F	2.47	2.38	2.19	3.41	5.25	3.98	5.41	6.74	5.26

See footnotes following Table 2.

When the "Cold" dummy variable is added to the Stock Adjustment Model equations (see Table 13), change in the estimated coefficients of the other variables is negligible, and the estimated coefficient of the dummy variable is insignificant.

The simplified Target Adjustment Model equations (Table 14) show a steady improvement in R^2 values as each successive proxy for expected sales is used, with the best results obtained using the three period moving average of lagged sales. The highest R^2 is still only .4455, meaning explanatory power of the simplified Target Adjustment Model is not strong. As expected from the graphical analysis, the estimated coefficients for the carrying cost variable and the change in price variable are not significant at the five percent level in any of the equations in this set. However, equation (3.2.14) does yield a negative value for the estimated coefficient of carrying cost and is significant at the 10 percent level. The estimated coefficient of the expected sales proxy variable is generally positive but not significant. The estimated values of λ are generally significant and range between .2 and .4, indicating a fair amount of production schedule flexibility with residual fuel oil. Since residual fuel oil is more or less a refining process by-product, this seems consistent. Its demand pattern and production schedule may follow gasoline's more closely than does distillate fuel oil. Thus, when gasoline refining is stepped up, more residual fuel will also be produced. Notice that the estimated values of λ are roughly equivalent to those found for gasoline.

The addition of the "Cold" dummy variable (Table 15) to the simplified Target Adjustment Model equations does improve the R^2 values.

The estimated coefficient of the dummy variable remains insignificant, but its t-ratios are much higher than with either of the other refined product regression results. Also, the t-ratios of the other estimated coefficients increase when the dummy variable is added. The estimated coefficient for the expected sales proxy is now positive, although still small (.2). In equation (3.2.14C), both the estimated coefficients for the carrying cost variable and the expected sales proxy variable are significant at the five percent level. The weather factor seems to be more important in explaining residual fuel oil inventory behavior than for the other two refined products.

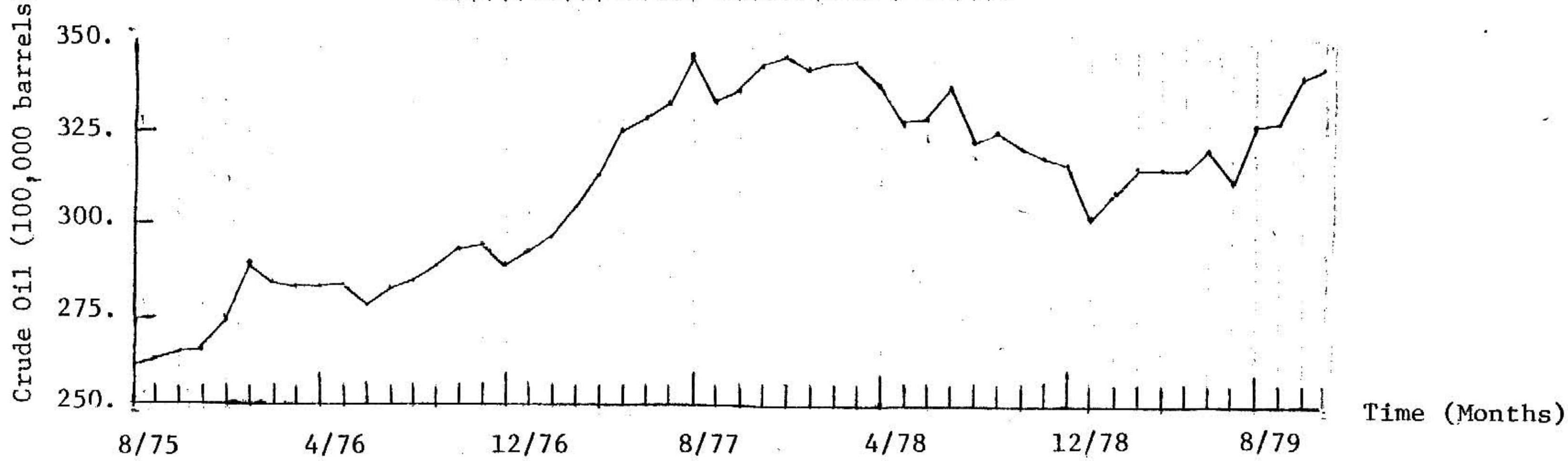
The simplified Target Adjustment Model performs better with residual fuel oil than with the other refined products, since the estimated coefficient of the expected sales variable is positive. The Stock Adjustment Model results conflict somewhat with those of the simplified Target Adjustment Model. Neither the dummy variable, carrying cost, change in price, nor even expected sales appear to be significant in this model with residual fuel oil. These types of conflicting results make it difficult to draw any definite conclusions about residual fuel oil inventory behavior.

4.4 Crude Oil

The crude oil regression results are much more extensive than for the refined products, so this section will include several parts. First, the graphical analysis of Period One and Two crude oil data will be presented, followed by the regression results from Period One. Then, the results of the estimation of speculative inventories during Period

FIGURE 6

Seasonally Adjusted Crude Oil Stocks



Seasonally Adjusted Crude Oil Inventory/Sales Ratio

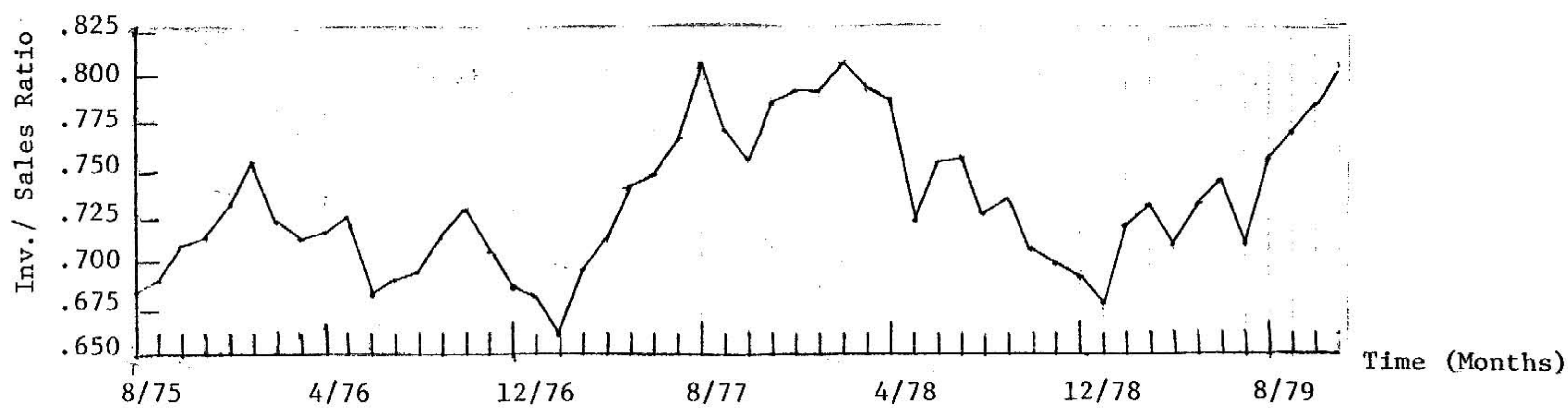


FIGURE 7

Seasonally Adjusted Crude Oil Consumption

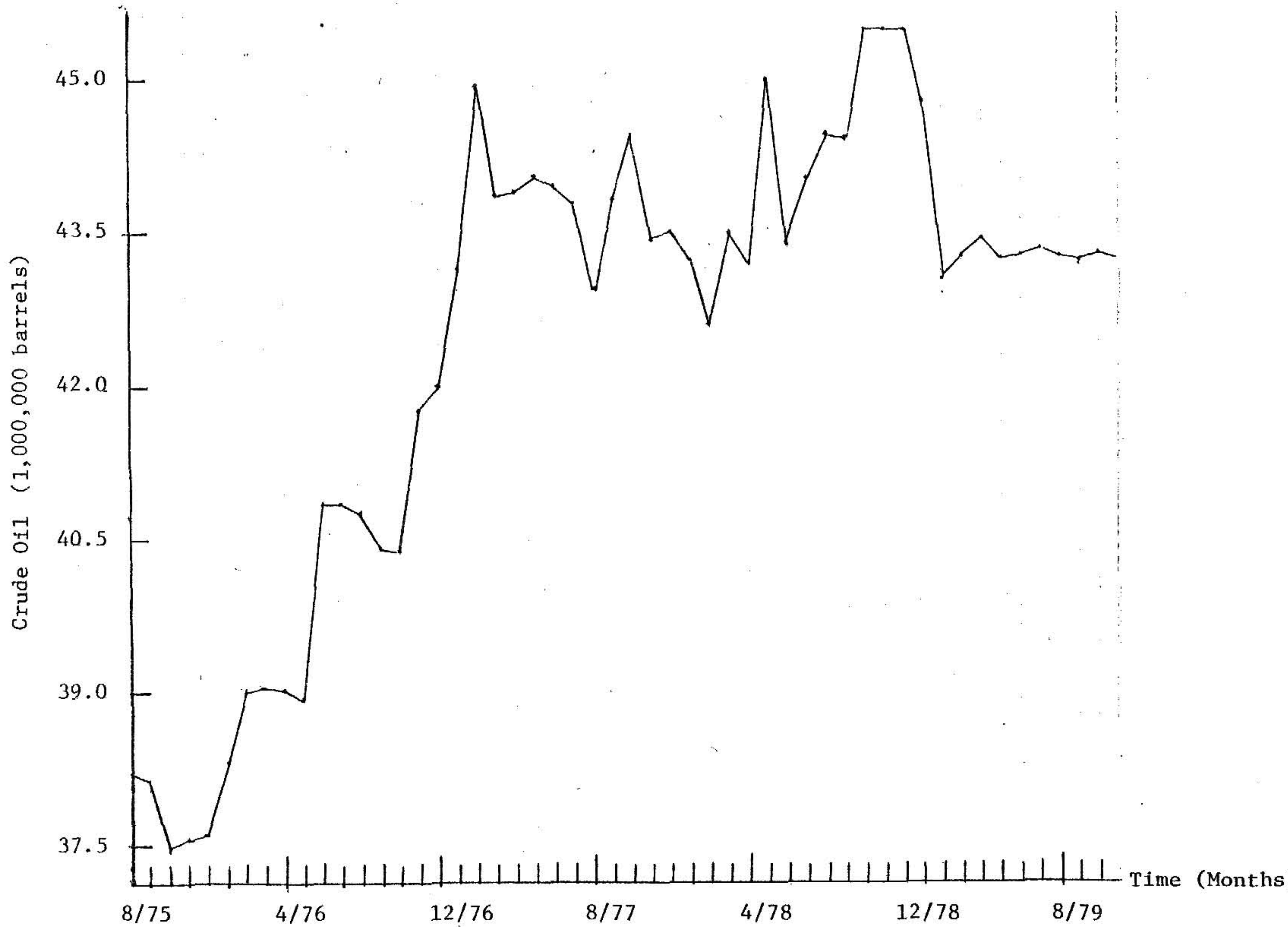
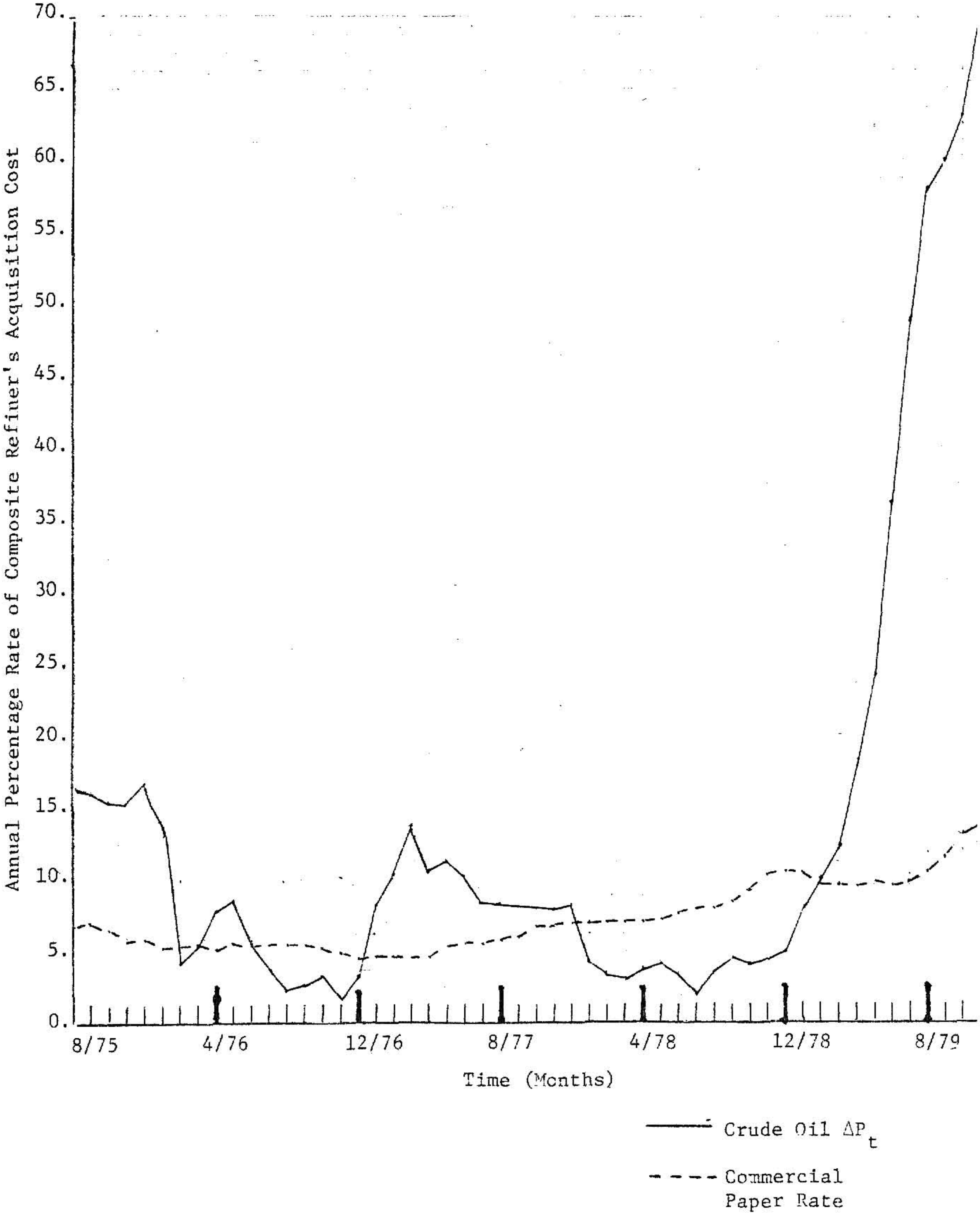


FIGURE 8

Crude Oil Annual Percentage Rate of
Composite Refiner's Acquisition Cost Change
and Commercial Paper Rate (for 90 days)



Two will be analyzed. Finally, the Inventory/Sales Ratio Model regression results for crude oil will be discussed.

Graphical Analysis

The seasonally adjusted crude oil data is graphically portrayed for both Period One and Period Two. As the graph on page 72 shows, the percentage change of composite refiner acquisiton cost took a downward trend until about November 1978, where it began taking an explosive growth pattern that continued through November 1979. This seems to parallel world crude oil market conditions during the same time, where world supplies of crude oil were relatively plentiful from the latter half of 1975 through most of 1978, until the Iranian Revolution, which virtually eliminated crude oil exports from Iran for a short time and drastically reduced them thereafter. The reduction of Iranian crude exports very quickly changed the world oil market from a surplus to a very tight market, and spot prices rose astronomically during late 1978 and 1979.

As the graph on page 71 shows, crude oil input to refineries (consumption) grew steadily from August 1975 up to November 1978, then dropped sharply and leveled off through 1979, making a definite break from the trend prior to November 1978. This parallels the percentage change in acquisition cost pattern, where crude oil input to refineries increases as percentage change in acquisition cost decreases, and then crude oil input decreases when the world crude oil prices start skyrocketing. As discussed in Section 3.4, crude oil input to refineries is used as a proxy for sales. In periods of stable crude oil prices and crude oil surplus on the world oil market, refineries would expect to get all the crude oil they desire. However, in periods where the world oil market is tight, refineries, especially independent ones, may not get all the crude oil they want, so "crude oil input to refineries" would indicate supply, but in all likelihood, crude oil demand would be much higher. When crude oil inputs to refineries begins to fall after November 1978, refinery demand for crude was undoubtedly much higher than crude oil inputs. The period of declining crude oil inputs also coincides with the appearance of long lines at gasoline pumps throughout the United States.

The graph depicting seasonally adjusted crude oil stocks (see page 70) shows a steady growth of crude oil inventories from August 1975 to March 1978, and then inventories begin declining on through December 1978. Again, they resume an upward trend starting in January 1979, continuing on through the end of Period Two. The first growth trend might be explained by the steadily increasing demand for crude oil during the post-recession period. However, the decline that follows cannot be accounted for by demand trends, because demand continues to increase at the same time inventory levels decline, until November 1978. When inventory levels start growing again after January 1979, crude oil supply (input to refineries) is severly reduced. As evidenced by gasoline pump lines, demand for crude oil during this time was much higher than supply. It would appear that speculative motives might offer a better explanation for the decline trend in stocks and subsequent growth trend (late 1978-1979), in contrast to the growing and then declining supply. It seems strange indeed to find the crude oil inventories growing after Decenber 1978 at the same time that crude oil inputs to refineries are declining. Since many of the independent refiners in the U.S. do not produce their own crude oil and must purchase it from oil companies that do produce (or import) it, the crude oil producers may have been making the most of an opportunity to build their own inventories, withhold supply, and possibly make petroleum prices go higher.

The ninety day commercial paper rate is plotted on the same graph with the percentage change in composite refiner's acquisition cost (see page 72). From January 1978 through January 1979, the commercial paper rate exceeds the percentage change of composite refiner's acquisition cost by two to three percent. This roughly coincides with the time period when crude oil inventories were declining, implying that petroleum companies had other investment options available that offered higher rates of return than stockpiles of crude oil during that time. From August 1975 to December 1977, the percentage change of composite refiner's acquisiton cost exceeded the commercial paper rate most of the time, indicating that companies with crude oil inventories were getting an attractive rate of return on their investment relative to other investment options, and stockpiling would be an attractive option. The time period after January 1979 would appear to be an important period of crude oil inventory speculation, where the percentage change of acquisition cost is substantially greater than the commercial paper rate. When everyone scrambles to increase their crude oil inventories during a time of rapid price increase, this makes a tight crude oil market even tighter, fueling even more price increases. Speculative increases in crude oil inventories seem perfectly consistent with the 1979 market environment; strong crude oil demand, restricted supply, and dizzying price increases.

Crude Oil Regression Results for Period One

The results of the Stock Adjustment Model equations are presented in Tables 17 and 18. The R^2 values are quite high (above .95), and h statistics are low, which implies that there is negligible serial correlation in the error terms. Equations (3.3.4) and (3.3.7) give the highest t-ratios for the estimated coefficients of expected sales and $\hat{\lambda}$. Both are positive and significant at the five percent level, conforming to theory. The estimated values of λ are generally less than .3 for most equations, indicating considerable production schedule flexibility. The carrying cost variable estimated coefficients are generally negative and highly significant in several of the equations, which is good evidence of the price-speculative motive for holding crude oil inventories. In the equations where the change in price variable is added, t-ratios decline and the estimated coefficients for the carrying cost and change in price variables become insignificant. The muti-collinearity problem discussed earier may be the cause for this result. The equations using the three period moving average as a proxy for expected sales seem to perform the best. These equations are (3.3.7), (3.3.8), and (3.3.9). In these equations, the estimates for $(1-\delta)$, the coefficient of lagged inventories, average around .8, so the estimates of δ, the "speed of adjustment" coefficient, are around .2. This would indicate a low speed of adjustment for crude oil inventories. Since importing is the only means of increasing the marginal supply of crude oil, the U.S. petroleum industry would be subject to the time constraints

TABLE 16

Stock Adjustment Model Equations
for Crude Oil (Tables 17 and 18)

(3.3.1) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_4 I_{t-1} + u_t$

(3.3.2) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$

(3.3.3) $I_t = \beta_o + \beta_1(S_{t-1}) + \lambda(S_{t-1} - S_t) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

(3.3.4) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_4 I_{t-1} + u_t$

(3.3.5) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_2 C_t + \beta_4 I_{t-1} + u_t$

(3.3.6) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2}}{2}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2}}{2} - S_t\right) + \beta_2 C_t + \beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

(3.3.7) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3} - S_t\right) + \beta_4 I_{t-1} + u_t$

(3.3.8) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3} - S_t\right) + \beta_2 C_t +$
$\beta_4 I_{t-1} + u_t$

(3.3.9) $I_t = \beta_o + \beta_1\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}\right) + \lambda\left(\frac{S_{t-1} + S_{t-2} + S_{t-3}}{3} - S_t\right) + \beta_2 C_t +$
$\beta_3 \Delta P_t + \beta_4 I_{t-1} + u_t$

Simplified Target Adjustment Model Equations
for Crude Oil (Tables 19 and 20)

Equations (3.3.10) through (3.3.18) will correspond exactly to equations (3.3.1) through (3.3.9), only the lagged inventory variable and coefficient, $\beta_4 I_{t-1}$, will be deleted from each equation.

All of the simplified Target Adjustment Model equation regression results are corrected for serial correlation.

TABLE 17

Crude Oil Inventories on Motives to Hold Inventories
Period One, August 1975-August 1978
(Stock Adjustment Model)

	S_t^{e*} [a]	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}
Equation	(3.3.1)	(3.3.2)	(3.3.3)	(3.3.4)	(3.3.5)	(3.3.6)
Constant	1904.1	-4296.2	3158.4	-7070.5	-10313.8	-5206.9
S_t^e	.099 (1.450)[b]	.068 (1.132)	.036 (.554)	.164 (2.523)	.125 (2.074)	.101 (1.504)
$(S_t^e - S_t)$	.247 (2.065)	.222 (2.115)	.248 (2.339)	.318 (3.068)	.272 (2.866)	.281 (2.923)
C_t		-634.2 (-3.129)	-2402.2 (-1.636)		-523.3 (-2.721)	-1657.9 (-1.184)
ΔP_t			-1828.9 (-1.125)			-1166.8 (-.818)
I_{t-1}	.867 (15.44)	.925 (17.56)	.979 (14.28)	.810 (14.94)	.870 (16.21)	.908 (12.78)
R^2	.9649	.9742	.9756	.9721	.9781	.9786
F	256.3	255.1	207.9	325.1	301.5	238.3
h	.969	.148	-.524	.311	-.429	-.885

[a] S_t^{e*} and S_t^{e**} represent the expected sales proxies used in the equations listed directly below them, where $S_t^{e*} = S_{t-1}$, and $S_t^{e**} = \frac{S_{t-1} + S_{t-2}}{2}$.

These same proxies are also used for S_t^e in $(S_t^e - S_t)$.

[b] Numbers in the parentheses are t-statistics.

TABLE 18

Crude Oil Inventories on Motives to Hold Inventories
Period One, August 1975-August 1978
(Stock Adjustment Model)

	S_t^{e***}	S_t^{e***}	S_t^{e***}	S_t^{e****}	S_t^{e****}	S_t^{e****}
Equation	(3.3.7)	(3.3.8)	(3.3.9)	(3.3.1B)	(3.3.2B)	(3.3.3B)
Constant	-13989.1	-15605.3	-10279.2	-14134.8	-25014.2	9164.1
S_t^e	.222 (3.334)	.177 (2.805)	.151 (2.178)	.150 (1.890)	.130 (1.856)	.078 (1.156)
$(S_t^e - S_t)$	.317 (3.450)	.273 (3.175)	.285 (3.257)	.177 (1.494)	.164 (1.565)	.271 (2.570)
C_t		-468.85 (-2.517)	-1632.63 (-1.227)		-609.3 (-3.074)	3606.6 (-2.988)
ΔP_t			-1196.6 (-.883)			-3029.9 (-2.512)
I_{t-1}	.755 (13.53)	.817 (14.34)	.858 (11.80)	.847 13.42)	.905 (15.37)	.982 (15.79)
R^2	.9754	.9801	.9806	.9665	.9748	.9794
F	369.6	331.6	263.3	288.8	280.8	266.3
h	.285	-.456	.932	1.813	1.124	-.567

[a] S_t^{e***} and S_t^{e****} represent the expected sales proxies used in the equations listed directly below them where $S_t^{e***} = \frac{S_{t-1} + S_{t-2} + S_{t-3}}{3}$, and S_t^{e****} is the predicted sales variable computed by Bechter and Pollock method, which is discussed in Section 3.1. Theses same proxies are also used for S_t^e in $(S_t^e - S_t)$.

[b] Numbers in the parentheses are t-statistics.

TABLE 19

Crude Oil Inventories on Motives to Hold Inventories
Period One, August 1975-August 1978
(Simplified Target Adjustment Model)

	S^{e*}_t	S^{e*}_t	S^{e*}_t	S^{e**}_t	S^{e**}	S^{e**}_t
Equation	(3.3.10)	(3.3.11)	(3.3.12)	(3.3.13)	(3.3.14)	(3.3.15)
Constant	83953.9	64281.5	-27288.2	-48419.1	-45802.2	-113361.8
S^e_t	.529 (3.048)	.578 (3.309)	.761 (4.968)	.853 (5.503)	.847 (5.432)	.912 (8.103)
$(S^e_t-S_t)$	-.175 (-1.156)	-.191 (-1.190)	-.273 (-1.489)	-.079 (-.625)	-.072 (-.494)	-.058 (-.346)
C_t		239.17 (.407)	3100.98 (.833)		60.89 (.113)	7016.19 (2.451)
ΔP_t			2793.82 (.742)			7098.88 (2.393)
R^2	.2410	.3009	.5276	.5160	.5296	.7707
F	4.92	4.31	8.10	15.99	10.88	23.53

See footnotes following Table 17.

TABLE 20

Crude Oil Inventories on Motives to Hold Inventories
Period One, August 1975-August 1978
(Simplified Target Adjustment Model)

	S_t^{e***}	S_t^{e***}	S_t^{e***}	S_t^{e****}	S_t^{e****}	S_t^{e****}
Equation	(3.3.16)	(3.3.17)	(3.3.18)	(3.3.10B)	(3.3.11B)	(3.3.12B)
Constant	-71136.7	-62773.2	-112095.9	-54129.6	-39524.2	-111942.1
S_t^e	.911 (6.365)	.892 (6.120)	.907 (9.309)	.860 (6.023)	.826 (5.305)	.942 (6.985)
$(S_t^e - S_t)$	.054 (.415)	.072 (.497)	.135 (.780)	-.213 (-1.094)	-.194 (-1.257)	-.263 (-1.483)
C_t		155.84 (.320)	7355.79 (2.777)		172.99 (.293)	3941.32 (1.179)
ΔP_t			7574.01 (2.688)			4065.06 (1.200)
R^2	.6051	.6065	.8460	.5431	.5221	.6906
F	22.22	14.39	37.07	18.42	10.93	16.18

See footnotes following Table 18.

of importing from OPEC nations, which involes a few months. This may be an explanationfor the low estimates of δ. The predicted sales proxy for expected sales (Bechter and Pollock method) is used in equations (3.3.1B), (3.3.2B), and (3.3.3B). These equations do not seem to perform any better than the equations using the other expected sales proxies. The h statistics for these three equations provide evidence that serial correlation of the error terms may be present, however.

In the case of the simplified Target Adjustment Model results (see Tables 19 and 20), equations (3.3.16), (3.3.17), and (3.3.18) perform the best. These equations use the three period moving average as the expected sales proxy. The estimates of λ are not significant in any of the equations of the simplified Target Adjustment Model. The estimated coefficients of the carrying cost variable and change in price variable are insignificant except in equations(3.3.15) and (3.3.18). However, both estimated coefficients are positive, which is not consistent with the theory. The multicollinearity problem may be the explanation for this result. The predicted sales proxy for expected sales in equations (3.3.10B), (3.3.11B), and (3.3.12B) does perform fairly well, but not quite as well as the moving average sales proxy.

The insignificant estimated values for λ in the simplified Target Adjustment Model regressions may imply that producing and importing oil companies can forecast future demand so accurately that the expected sales minus the actual sales variable itself is insignificant. Since petroleum products have few (in some cases none) substitutes and demand for them is highly inelastic, it might indeed be much easier to forecast future sales or demand in the petroleum industry than in other industries. As long as the economy is not in a recession, it is almost certain that demand for petroleum products (particularly fuel) will increase. There would appear to be very little sales uncertainty in the petroleum industry, in comparison to industries such as manufacturing, because people view the consumption of fuels such as gasoline as an absolute necessity in maintaining their standard of living. Insignificant estimated values for λ would be consistent with this explanation.

In contrast to this, the very low but significant estimates for λ in the Stock Adjustment Model equations would indicate a high degree of production schedule flexibility. Since crude oil imports are almost one half of total crude oil demand, and domestic crude oil production seems to have peaked during the 1970's, the interpretation of λ for the petroleum industry is ambiguous. Under these circumstances, it appears that crude oil "production" schedules could be changed only by increasing imports. Of course, actual domestic crude oil production during the 1970's has been declining and therefore has no room to adjust inventories through production changes. When the world oil market is in surplus, U.S. crude oil import levels might be quite flexible. This could be the case during Period One. In a tight world oil market, import levels would be very difficult to increase. Low estimated values for λ during Period One appear to be consistent with this explanation.

The Stock Adjustment Model and the simplified Target Adjustment Model both perform better with the crude oil data than with any of the refined products data for Period One. The R^2 values for the simplified Target Adjustment Model equations are generally much higher for crude oil data than the corresponding R^2 values for the refined products data. This may be due to the possibility that the crude oil data is more accurate and representative than the refined products data. The estimated coefficients of the carrying cost variable are significant in several of the Stock Adjustment Model equations, providing evidence that price speculation in inventory behavior is taking place even during Period One. However, the carrying cost variable is not significant in any of the simplified Target Adjustment Model equations, so perhaps it would not be prudent to draw any conclusions about the presence of speculative inventory behavior during Period One.

Results of Regressions from First Differences of Estimated Speculative Inventories in Period Two

As discussed in Section 3.3, the first differences of the residuals (the estimated speculative inventories) between actual end-of-month crude oil stock levels and predicted stock levels generated by each model are regressed against the change in price variable (ΔP_t) and the carrying cost variable (C_t). Recall that the reasoning behind taking first differences is to eliminate relatively constant factors that might influence speculative inventory behavior, such as the Department of Energy's encouragement of oil companies to build crude oil inventories during 1979. The equations used for the regressions with first differences (Section 3.3) are shown below:

(3.3.20) $$(I_t^p - I_t) - (I_{t-1}^p - I_{t-1}) = d_o + d_1 \Delta P_t + u_t \qquad t = 1,2,\ldots n$$

(3.3.21) $$(I_t^p - I_t) - (I_{t-1}^p - I_{t-1}) = e_o + d_1 C_t + u_t \qquad t = 1,2,\ldots n$$

All variables have been previously defined.

Tables 21 and 22 show the results for the Stock Adjustment Model estimated speculative inventory regressions. Table 21 shows the estimated coefficients for the change in price variable, and Table 22 shows the estimated coefficients for the carrying cost variable. The equation numbers at the top of each table represent the original equations from

TABLE 21

Regression Results of
First Differences of
Estimated Speculative Crude Oil Inventories on Price
Period Two, August 1978-November 1979
(From Stock Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}
Equation	(3.3.1)	(3.3.2)	(3.3.3)	(3.3.4)	(3.3.5)	(3.3.6)
Constant	-10.88	-973.76	-580.23	-681.01	-1365.2	-1106.8
ΔP_t	5.474 (.043)	-58.74 (-.418)	-43.91 (-.303)	30.63 (.244)	-26.49 (-.206)	-18.34 (-.139)
R^2	.0001	.0144	.0076	.0049	.0035	.0016
F	0.	.17	.09	.06	.04	.02
h	-4.014	-3.980	-3.922	-3.926	-3.898	-4.124

	S_t^{e***}	S_t^{e***}	S_t^{e***}	S_t^{e****}	S_t^{e****}	S_t^{e****}
Equation	(3.3.7)	(3.3.8)	(3.3.9)	(3.3.1B)	(3.3.2B)	(3.3.3B)
Constant	-1122.2	-1657.7	-1384.3	-353.71	-1216.9	-716.86
ΔP_t	43.89 (.347)	-9.638 (-.075)	-1.558 (-.012)	11.84 (.090)	-51.10 (-.373)	-33.35 (-.228)
R^2	.0100	.0005	0.	.0007	.0115	.0043
F	.12	.01	0.	.01	.14	.05
h	-4.100	-4.139	-4.374	-4.256	-3.828	-9.463

See footnotes following Tables 17 and 18.

TABLE 22

Regression Results of
First Differences of
Estimated Speculative Crude Oil Inventories on Cost
Period Two, August 1978-November 1979
(From Stock Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S^{e**}
Equation	(3.3.1)	(3.3.2)	(3.3.3)	(3.3.4)	(3.3.5)	(3.3.6)
Constant	-1526.6	17.91	-985.5	-402.5	-1607.3	-1265.8
C_t	62.11 (.425)	-6.921 (-.049)	46.92 (.311)	-32.87 (-.252)	28.37 (.212)	20.08 (.147)
R^2	.0149	.0002	.0080	.0053	.0037	.0106
F	.18	0.	.10	.06	.04	.13
h	-3.749	-4.015	-3.923	-3.784	-3.898	-4.259

	S_t^{e***}	S_t^{e***}	S_t^{e***}	S_t^{e****}	S_t^{e****}	S_t^{e****}
Equation	(3.3.7)	(3.3.8)	(3.3.9)	(3.3.1B)	(3.3.2B)	(3.3.3B)
Constant	-1122.3	-1745.5	-1389.29	-1694.17	-259.46	-1010.47
C_t	43.89 (.347)	10.34 (.077)	2.130 (.016)	54.21 (.380)	-13.37 (-.098)	36.28 (.238)
R^2	.0100	.0005	0.	.0120	.0008	.0040
F	.12	.01	0.	.14	.01	.06
h	-4.120	-4.139	-4.375	-3.866	-4.114	-3.788

See footnotes following Tables 17 and 18.

TABLE 23

Regression Results of
First Differences of
Estimated Speculative Crude Oil Inventories on Price
Period Two, August 1978-November 1979
(From Simplified Target Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}
Equation	(3.3.10)	(3.3.11)	(3.3.12)	(3.3.13)	(3.3.14)	(3.3.15)
Constant	-3268.2	-2959.5	-3282.9	-2861.59	-2783.1	-4142.6
ΔP_t	157.70 (2.358)	181.63 (2.611)	164.67 (1.807)	157.60 (1.738)	163.37 (1.787)	88.30 (.661)
R^2	.2842	.3275	.1891	.1886	.1972	.0326
F	5.56	6.82	3.26	3.02	3.19	.44

	S_t^{e***}	S_t^{e***}	S_t^{e***}	S_t^{e****}	S_t^{e****}	S_t^{e****}
Equation	(3.3.16)	(3.3.17)	(3.3.18)	(3.3.10B)	(3.311B)	(3.3.12B)
Constant	-3343.7	-3173.1	-4889.4	-3647.4	-3431.9	-4381.5
ΔP_t	175.63 (1.975)	192.45 (2.070)	103.45 (.822)	161.30 (2.285)	177.03 (2.440)	110.24 (1.173)
R^2	.2452	.2631	.0533	.2717	.2984	.0895
F	3.90	4.29	.68	5.22	5.95	1.38

See footnotes following Tables 17 and 18.

TABLE 24

Regression Results of
First Differences of
Estimated Speculative Crude Oil Inventories on Price
Period Two, August 1978-November 1979
(From Simplified Target Adjustment Model)

	S_t^{e*}	S_t^{e*}	S_t^{e*}	S_t^{e**}	S_t^{e**}	S_t^{e**}
Equation	(3.3.10)	(3.3.11)	(3.3.12)	(3.3.13)	(3.3.14)	(3.3.15)
Constant	-1749.6	-1222.8	-1716.0	-13338	-1203.8	-3319.3
C_t	-163.34 (-2.322)	-188.94 (-2.588)	-171.78 (-1.799)	-16377 (-1.727)	-170.05 (-1.780)	-93.58 (-.67)
R^2	.2781	.3236	.1877	.1867	.1459	.0334
F	5.39	6.70	3.23	2.98	3.17	.45

	S_t^{e***}	S_t^{e***}	S_t^{e***}	S_t^{e****}	S_t^{e****}	S_t^{e****}
Equation	(3.3.16)	(3.3.17)	(3.3.18)	(3,3.10B)	(3.3.11B)	(3.3.12B)
Constant	-1634.2	-1307.0	-3917.1	-2090.4	-1734.7	-3317.7
C_t	-182.61 (-1.986)	-200.59 (-2.09)	-109.41 (-.837)	-166.58 (-2.235)	-183.62 (-2.402)	-113.91 (-1.152)
R^2	.2473	.2668	.0552	.2630	.2918	.2684
F	3.94	4.37	.70	5.00	5.77	1.33

See footnotes following Tables 17 and 18.

which the estimated speculative inventories are generated. All the regressions with the Stock Adjustment Model estimated speculative inventories show very high absolute values for the h statistics, indicating that serial correlation in the error terms is seriously affecting the coefficient estimates. The Ordinary Least Squares method is used on the regressions with the first differences of the estimated speculative inventories from the Stock Adjustment Model equations. Standard errors for the estimated coefficients of the carrying cost variable and change in price variable are seriously affected by serial correlation, and all estimated coefficients are insignificant. Judging from these results, either the Stock Adjustment Model does not perform well for prediction purposes, or change in price and carrying cost are not significant factors influencing inventory behavior during Period Two. The latter conclusion is not consistent with the graphical analysis presented at the beginning of this section, or with the simplified Target Adjustment Model results discussed below.

Tables 23 and 24 show the regression results for the simplified Target Adjustment Model estimated speculative inventories. Table 23 shows the estimated coefficients for the change in price variable, and Table 24 shows the estimated coefficients for the carrying cost variable. The tables for these results are arranged in the same manner as Tables 21 and 22. Referring to Table 23, the regression results with the estimated speculative inventories from equations (3.3.10), (3.3.11), (3.3.17), (3.3.10B), and (3.3.11B) show that the estimated coefficients for the change in price variable are significant at the five percent level. The R^2 values are very low, as expected with regressions of first differences. The estimated speculative inventories from equations

(3.3.10) and (3.3.11) give the highest t-ratios for the change in price variable estimated coefficients, and all equations give positive values for this coefficient, which is consistent with the theory. Results from equations (3.3.12), (3.3.15), (3.3.18), and (3.3.12B) do not yield significant coefficient estimates for the change in price variable. This is not surprising, since these original equations contain the multicollinearity effect between the carrying cost and change in price variables. Excluding these equations, the results do show a significant, positive relationship between the first differences of the estimated speculative inventories and the change in price. This makes a strong case for the hypothesis that the price-speculative motive for holding crude oil inventories is important during Period Two.

The regression results of first differences against the carrying cost variable (C_t) are shown in Table 24. The regressions with first differences of estimated speculative inventories from equations (3.3.10), (3.3.11), (3.3.17), (3.3.10B), and (3.3.11B) show that the estimated coefficients of the carrying cost variable are negative and highly significant. It is interesting to note that the first difference regressions from equations (3.3.11) and (3.3.11B) yield the highest t-ratios for the estimated coefficient of the carrying cost variable. Those original equations already contained the carrying cost variable, though its estimated coefficient was not significant in either equation. The fact that the estimated coefficients of the carrying cost variable are negative and highly significant in the Table 24 results may indicate that inventory speculation is taking place to a much greater extent during Period Two.

TABLE 25

Estimated Speculative Crude Oil Inventories from Equation (3.3.11), for Period Two (August 1978-November 1979)

Date	End-of-Month Crude Oil Stocks (1000 barrels)	Estimated Speculative Inventories[a] (1000 barrels)	Percent of End-of-Month Stocks
8/78	323845.	3927.	1.2
9/78	325782.	3264.	1.0
10/78	321229.	-3201.	-1.0
11/78	318031.	-10526.	-3.3
12/78	314219.	-14205.	-4.5
1/79	302537.	-23782.	-7.9
2/79	309249.	-10443.	-3.4
3/79	315655.	2591.	.8
4/79	314164.	-98.	-.03
5/79	314406.	-435.	-.1
6/79	321470.	14165.	4.4
7/79	312028.	5358.	1.7
8/79	327809.	21715.	6.6
9/79	328502.	26185.	8.0
10/79	340595.	40436.	11.9
11/79	343038.	43178.	12.9

[a]The estimated speculative inventory figure for each month is equal to the end-of-month crude oil stock level minus the predicted stock level. The predicted crude oil stock level is computed from the inventory model, equation (3.3.11).

The estimated speculative inventories for Period Two generated from the simplified Target Adjustment Model equation (3.1.11) are shown in Table 25. Notice that beginning in June 1979, the estimated speculative inventories tend to grow larger each month through November 1979. During the spring and summer months of 1979, gasoline pump lines were present in several areas of the United States. This table provides a strong indication that the gasoline shortages during that time may have been due to oil companies increasing their speculative holdings of crude oil inventories. During June through November 1979, the percentage increase in composite refiner acquisition cost ranged from thirty-five to almost seventy percent, as spot market prices for crude oil soared and partial de-regulation of domestic crude oil prices proceeded. There appears to be a convincing case for the conclusion that the large increases in crude oil inventories through 1979 were in large part a response to the price-speculative motive.

Regression Results for the Inventory/Sales Ratio Model

Recall the Inventory/Sales Ratio Model equation from Section 3.3:

$$(3.3.\ \ ) \quad (I/S)_t = \alpha - \beta C_t + \omega S_t^e - \varepsilon S_t - \mu U_t \qquad t = 1,2,...n$$

All variables have been previously defined. A graph of the inventory/sales ratio for crude oil during Period One and Two is shown on page 70. The regression results of this model for Period One and also for the combination of the two periods are shown on Table 26. The graph will be discussed first, followed by the interpretation of the regression results.

From the graph, it is apparent that the inventory/sales ratio pattern looks similar to the pattern of crude oil inventories during the same time period. The inventory/sales ratio remains fairly steady,

TABLE 26

Regression Results for
Crude Oil Inventory/Sales Ratio Model
(Corrected for Serial Correlation)

Period One (August 1975-August 1978)

$$(I/S)_t^{a} = .5781 - .0000994C_t + .0000542S^e_t - .0000418S_t - .21483U_t$$

$$(3.654)^{b} \quad (-.074) \quad (3.996) \quad (-3.538) \quad (-1.611)$$

$R^2 = .3982$ F = 4.70

Period One + Period Two (August 1975-November 1979)

$$(I/S)_t = 1.120 - .000824C_t + .000000482S^e_t - .0000454S_t + .028U_t$$

$$(6.755) \quad (-1.515) \quad (1.768) \quad (-3.018) \quad (.279)$$

$R^2 = .4429$ F = 8.74

[a] All variables have been previously defined. For definitions see Section 3.1.

[b] Numbers in parentheses are t-statistics.

although declining slightly from August 1975 to February 1977. It begins to increase up until early 1978, and then starts a year-long decline. By January 1979, the inventory/sales ratio resumes an upward trend through the end of Period Two.

There appears to be a lagged response between the percentage change in composite refiner's acquisition cost and the inventory/sales ratio, at least during 1978 and 1979. The percentage change of composite refiner's acquisition cost declines from March 1977 to August 1978, while the inventory/sales ratio declines from February 1978 to January 1979. The percentage change in composite refiner's acquisition cost increases very rapidly beginning in December 1978 and continuing on through the end of Period Two. The inventory/sales ratio begins climbing in January 1979, continuing on an upward trend thereafter. This last increase in the inventory/sales ratio is in contrast to the declining supply of crude oil during that time. More curiously, the inventory/sales ratio seems to decline from August 1975 to February 1977 while demand for crude oil is growing. The inventory/sales ratio exhibits almost a bi-annual cycle during the observed time period: declining in 1976, climbing in 1977, declining in 1978, and again climbing in 1979.

The regression results of the Inventory/Sales Ratio Model for Period One are presented in Table 26. The estimated coefficients of current sales and the expected sales proxy are significant at the five percent level. All other estimated coefficients are insignificant. The estimated coefficient of the current sales variable is negative, showing the depletion effect of higher current sales on the inventory/sales ratio. The estimated coefficient of the carrying cost variable, C_t, is negative, which is consistent with the theory, but it is insignificant. The estimated coefficient of the sales uncertainty variable is also negative, which is theoretically consistent, but it too is insignificant. This would indicate that during Period One, the primary factors influencing the inventory/sales ratio were expected and current sales (the transaction motive); sales uncertainty and price speculation seem to have had a negligible influence.

In the petroleum industry, sales uncertainty is low because the demand for petroleum products such as gasoline, heating oil, and residual fuel oil is less volatile than in other industries, such as manufacturing. Many of the petroleum products are necessities for consumers. Except for periods of extreme weather conditions, it should be relatively easy to predict sales. Hence, one would expect the sales uncertainty variable to be insignificant in crude oil inventory behavior.

Table 26 also shows the regression results for the Inventory/Sales Ratio Model during the combined periods (August 1975-November 1979). In this case the only variable that is significant at the five percent level is the current sales variable. The estimated coefficients of the expected sales and the carrying cost variables are significant at the ten percent level. The estimated coefficient of the sales uncertainty variable is insignificant, which is consistentwith earlier results. The estimated coefficient of the current sales variable is negative, as is the estimated coefficient of the carrying cost variable, which is consistent with theory. The remarkable improvement in the t-ratio of the estimated coefficient of the carrying cost variable between the Period One results and the combined periods results is an indication that price speculation may become a much more important factor influencing the inventory/ sales ratio when Period Two is added to the regression study. This is in general agreement with the findings from the simplified Target Adjustment Model for crude oil.

As discussed earlier, the sales uncertainty variable would be of doubtful relevance to the petroleum industry. Uncertainty in this industry during the last decade has focused on supply, not demand. As U.S. dependence on imported crude oil increases, supply uncertainty will become even more important. A more appropriate uncertainty variable for the petroleum industry would have to be a variable which will capture this growing uncertainty about future crude oil supply. A supply uncertainty variable might help in explaining inventory/sales ratio behavior by dividing the speculative motive into its two parts: supply uncertainty and future expectations about prices. None of the models used in this study can account for this kind of separation. The results obtained in this study do show a strong correlation between crude oil inventory behavior and price change during Period Two. This would certainly support the hypothesis that price speculation has taken place in crude oil inventory behavior during Period Two.

CONCLUSIONS

This study used three different models in order to examine inventory behavior in the petroleum industry: the Stock Adjustment Model, a simplified version of the Target Adjustment Model, and the Inventory/Sales Ratio Model. Only the first two were used on the refined products studied, but all three were used on crude oil in order to test the hypothesis that speculative inventory behavior has taken place recently in the petroleum industry. In addition, refined products were studied only during August 1975 to August 1978. Crude oil was studied from August 1975 to November 1979.

For the refined products, the results of the study were inconclusive. The Stock Adjustment Model and the simplified Target Adjustment Model provided conflicting results during the period studied. It is suspected that the monthly data observations are very inaccurate, which may have adversely affected the overall results for the refined products.

For crude oil, the results show strong evidence that especially during 1979, price speculation had a major impact on crude oil inventory behavior. From August 1975 to August 1978, change in crude oil price seemed to have a negligible effect on inventories. However, during 1979, rapid price increases provided a strong incentive to stockpile crude oil, and a significant relationship can be found between change in price behavior and inventory behavior for crude oil. The speculative crude oil inventories estimated in this study began increasing dramatically during mid-1979, about the same time many parts of the United States were suffering from gasoline shortages.

Since oil companies were encouraged to stockpile crude oil by the Department of Energy during 1979 (because of the supply uncertainties created by the Iranian Revolution), it is difficult to tell how much of the inventory stockpiling by the oil companies was due to enthusiastically carrying out the Department of Energy guidelines, or to price speculation. It may not be important to know, because it is clearly in the interests of the oil companies to stockpile crude oil during times of rapid price increases.

The study indicates that during the most recent surge of crude oil price increases, inventories and the inventory/sales ratio also increased. One could deduce from this that during a time of escalating crude oil prices, oil companies will tend to stockpile crude oil with or without encouragement from any outside agency, because of the obvious incentive to speculate. It may be necessary for the Department of Energy to use caution before providing guidance on inventories to oil companies when the world oil market is tight and crude oil prices are rapidly increasing.

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AN INVESTIGATION OF SPECULATIVE INVENTORY BEHAVIOR
IN THE U.S. PETROLEUM INDUSTRY

by

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

The primary objective of this study is to investigate the crude oil inventory behavior of the U.S. petroleum industry in the last five years in order to test the hypothesis that price speculation has been an important influence on crude oil inventory behavior, particularly in 1979, a period of rapidly increasing crude oil prices on the world oil market. As a secondary objective, this study tests the performance of two different inventory behavior models on gasoline, distillate fuel oil, and residual fuel oil during a period of relatively stable prices and increasing demand: August 1975 to August 1978.

The study discusses segments of recent inventory investment theory most relevant to the petroleum industry and then reviews the inventory behavior models used on the crude oil data and the data from the refined products mentioned above. The Stock Adjustment Model and a simplified version of the Target Adjustment Model were used with the refined products studied. Both of these models and the Inventory/Sales Ratio Model were used with crude oil.

For the refined products, the study yielded inconclusive results, because the Stock Adjustment Model results tended to conflict with the simplified version of the Target Adjustment Model results. Serious doubt was cast on the reliability of the refined products data, since monthly observations were used and the consumption and end-of-month stock level figures could not be compiled accurately.

For crude oil, the data appeared to be more reliable. The crude oil study was divided into two periods: August 1975 to August 1978 (Period One) and August 1978 to November 1979 (Period Two). Estimated coefficients for the Stock Adjustment Model and simplified version of the Target Adjustment Model were determined for Period One (a time of stable prices and increasing demand). These models were then used to predict stock levels during Period Two (a time of increasing crude oil prices and stable demand). Estimated speculative inventories were determined by subtracting actual end-of-month stock levels from the predicted stock levels for Period Two. The Inventory/Sales Ratio Model coefficients were estimated for Period One, and then compared to the estimated coefficients for the combination of Period One and Two.

The results indicate that although the behavior of crude oil prices did not tend to influence crude oil inventory behavior during Period One, price behavior did have a significant influence on inventories during Period Two. This suggests that during periods of rapid crude oil price increase, oil companies will tend to speculate by stockpiling crude oil in anticipation of receiving capital gains from future price increases. This could have definite implications for Department of Energy policies toward oil-producing and importing companies.

After the Iranian Revolution created a tight world oil market, the Department of Energy encouraged domestic oil companies to build crude oil inventories during 1979. This may have indirectly sanctioned speculative behavior on the part of the oil companies, which in turn reduced crude oil runs to refineries and caused gasoline shortages in mid-1979.

The results of this study suggest that in a future tight world oil market, the Department of Energy should be more cognizant of the natural tendency of the oil companies to act in their own interests by stockpiling crude oil when its price is rapidly increasing. The oil companies should not need any encouragement to increase crude oil inventories under those circumstances.