

Why do Firms Hold Oil Stockpiles?

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Abstract

Persistent and significant privately-held stockpiles of crude oil have long been an important empirical regularity in the United States. Such stockpiles would not rationally be held in a traditional Hotelling-style model. How then can the existence of these inventories be explained? In the presence of sufficiently stochastic prices, oil extracting firms have an incentive to hold inventories to smooth production over time. An alternative explanation is related to a speculative motive - firms hold stockpiles intending to cash in on periods of particularly high prices. I argue that empirical evidence supports the former but not the latter explanation.

Keywords: Petroleum Economics, Stochastic Dynamic Optimization

JEL Areas: Q2, D8, L15

1 Introduction

Since official records were first kept in the United States (U.S.), in 1920, private interests have consistently held significant inventories of crude oil. Over the course of the past few decades, these inventories have averaged around 325 million barrels per day. While these holdings have fluctuated some they have been remarkably persistent over the past 70 years, ranging from just over 215 million barrels to slightly less than 398 million barrels (see Figure 1). What motivates these inventories? One held view is that inventories are held for speculative purposes – betting on rapid price run-ups. An alternative explanation is that petroleum extracting firms would like to hedge against substantial swings in oil costs.¹

Neither explanation is compelling in a deterministic setting. In a deterministic world prices would have to rise at the rate of interest r to justify holding inventories.

An alternative, and I believe compelling, motivation is related to the concept of production

as a control variable in place of sales.

The firm's reserves at instant t are R_t and its inventory holdings are S_t . I assume the firm starts with no inventories. Reserves decumulate with extraction, while inventories accumulate according to the difference between extraction and sales:

$$\dot{R}_t = -y_t \quad (1)$$

$$\dot{S}_t = y_t - w_t \quad (2)$$

When it is actively extracting, the firm bears positive operating costs. I assume marginal extraction costs are positive, upward-sloping and weakly convex, with both total costs and marginal costs decreasing in R . A simple example of a cost function that has these features is

$$c(y; R) = A_0 + A_1 y^n = R^{-1} \quad (3)$$

which is adapted from Pindyck (1980). This function, which combines flow fixed costs with a power function of the rate of extraction that is proportional to the inverse of reserves, has two desirable features: There is a single, well-defined extraction cost, and extraction costs are

Denoting the market price of oil at instant t by P_t , the instantaneous rate of profits is

$$p_t = P_t[y_t - w_t] - c(y_t; R_t) \quad (4)$$

The goal is to select time paths of y and w so as to maximize the present discounted value of the flow of profits.

The firm's current value Hamiltonian is

$$H = P_t(y_t - w_t) - c(y_t; R_t) + \mu_t y_t$$

motion for the shadow values:

$$i = r + \frac{c}{R}$$

With the particular functional form in eq. (3), this condition reduces to

$$\dot{y} = y^r$$

where dz is an increment from a standard Wiener process. Convergence of the model requires that the trend in prices does not exceed r , the firm's discount rate: $\mu < r$.

mitigate abrupt changes in production that are induced by fluctuating demand. In the present case, this motive is offset somewhat by the overall expected downward trend in production associated with a non-renewable resource. Even so, the fundamental wisdom in the literature on inventories can be applied here, given enough variability in demand.

4 Empirical Analysis

The model presented above leads naturally to an empirical investigation. For production smoothing to motivate inventory holding, it must be the case that s^2

in total world output fell monotonically over the sample period from a high of 16.9% in 1986 to a low of 8.4%. It seems clear that individual U.S. producers were too small to influence the world price of crude. Second, Adelman (1995) argues that the Organization of Petroleum Exporting Countries (OPEC) has played a significant role in determining price during the last twenty years,

oil prices and production, to estimate a relation between y and the state variables R and P , at the monthly level.

The data on reserves, in millions of barrels, is reported as of 31 December in each calendar year from 1949 to 2007. Owing to the substantial find in Alaska in the summer of 1968 there is a

regression model can be interpreted as a Taylor's series approximation. One particular advantage of this specification is that the induced marginal effect of reserves upon extraction is linear. As such they map naturally into results at the level of the individual field-reservoir. If one is willing to draw an analogy between individual field-reservoirs and firms these results are directly relevant

sibility is that firms hold inventories in order to cash in on unanticipated price increases, whether they extract more or not in the face of such price increases. Such an explanation has much in common with the idea that wild gyrations in crude prices are related to (and perhaps even caused by) speculation. If such an explanation were correct, one would expect to see sharp increases in crude prices leading to clear reductions in inventories. Indeed, the correlation coefficient between crude stocks and prices is negative (-.241), and so is at least broadly consistent with this story. But closer examination reveals that crude stock levels and crude prices are not closely linked.

Figure 2 shows weekly crude stock and price levels, as ratios of their respective values at the start of 1986 (when weekly data is first available). Over this time period, there are dramatic swings in price: at one point, crude prices fell to below 50% of the initial level. More, prices have increased sharply, to over 550% of the initial level. But even with these dramatic swings in price crude stock levels are far less volatile; in fact, they are always within 20% of the

prices (as opposed to basing their decision on current levels or changes). Plausibly, such agents

5 Conclusion

In this paper, I present a model of firm behavior when oil prices are stochastic. In this framework, the firm has an incentive to hold inventories if prices are sufficiently volatile. Using data on monthly crude prices and privately-held U.S. inventories, I find evidence that there was sufficient volatility in crude prices over the period from early 1986 to late 2008 to motivate inventory holding. By contrast, the evidence that firms held inventories to speculate on price movements does not seem very strong. I believe the conclusion is that inventories are more likely to be motivated by attempts to smooth marginal production costs than by speculative motives.

My model assumes that the entire cost of production is born at the mine. In particular,

stockpiles.

Adding storage costs to the model also leaves the central result unchanged. While the

6 APPENDIX

Figure 1: U.S. Petroleum Stocks

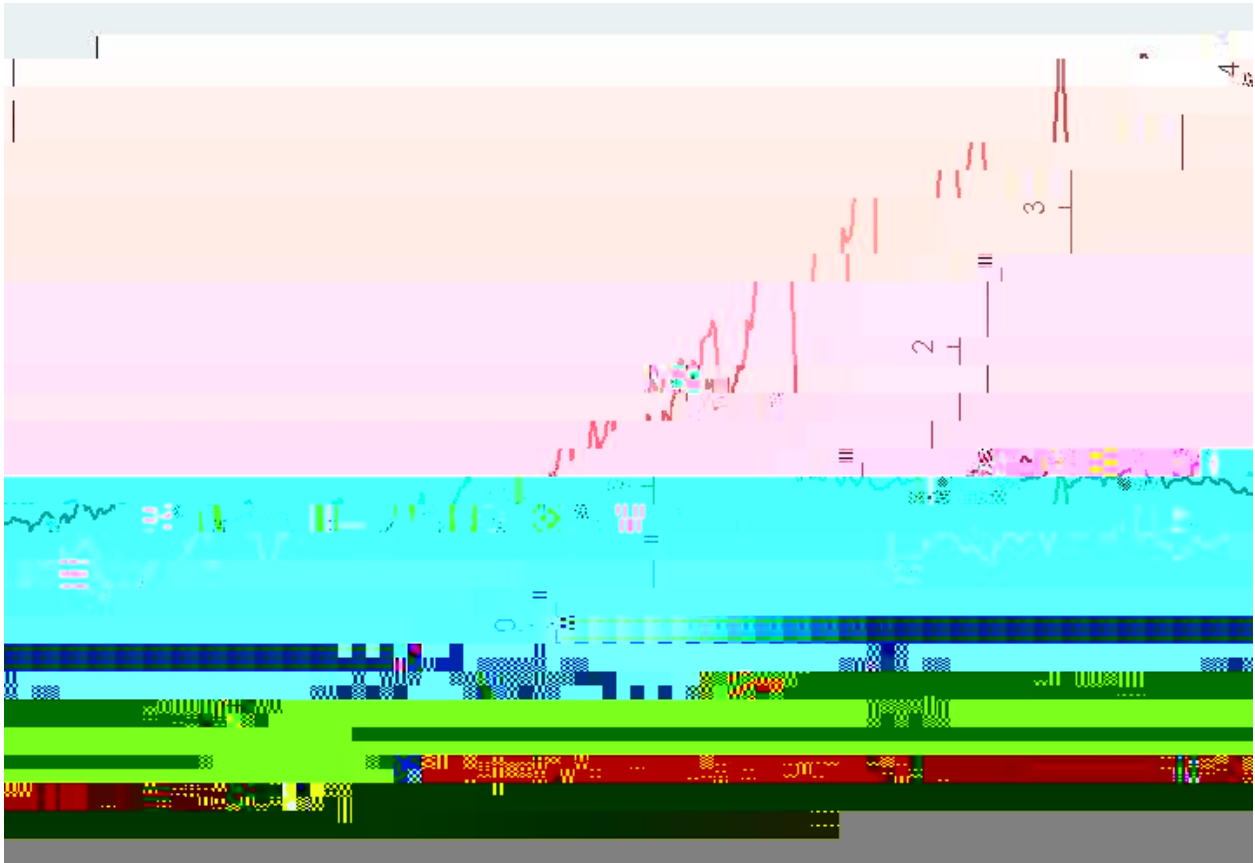


Figure 2: Crude Prices and Stocks

Table 1: Reserves as a function of exploratory drilling

variable	coefficient	stf1.entt-stating
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Pindyck, R. S. (1982). Uncertainty and the behavior of the firm,

Notes

1

piles are available including or excluding the U. S. strategic petroleum reserve (SPR). As the SPR is both publicly held, and hence motivated by political – as opposed to economic considerations – it seems clear that the data excluding the SPR is preferable for my purposes.

⁸ While the deposit was discovered in 1968 it is arguably true that the full extent of the find was not known for several months. As such, it would not impact the reported level of reserves until after 31 December 1968 and hence would not alter reported reserves for 1968.

⁹ An alternative approach is to use annual data to estimate a relation between extraction and

