Journal of Economic Dynamics & Control 75 (2017) 52–69

Contents lists available at ScienceDirect

Journal of Economic Dynamics & Control

journal homepage: www.elsevier.com/locate/jedc

On the behavior of commodity prices when speculative storage is bounded

Atle Oglend [a,*], Tore Selland Kleppe [b]

[a] Department of Industrial Economics, University of Stavanger, Norway
[b] Department of Mathematics and Natural Sciences, University of Stavanger, Norway

ARTICLE INFO

Article history:
Received 15 September 2015
Received in revised form
14 November 2016
Accepted 27 November 2016
Available online 2 December 2016

JEL Classifications:
Q02
Q11

Keywords:
Commodity prices
Storage
Capacity
Rational expectations

ABSTRACT

This paper investigates the implications of bounded speculative storage, storage bounded from below at zero and above at a capacity, on commodity prices. Binding capacity mirrors the non-negativity constraint on storage and leads to negative price spiking and higher volatility when the market is in deep contango, i.e. low current prices at high stock levels. With bounded storage there is no need to restrict storage to be costly to ensure a rational expectations equilibrium. This allows the model to cover a wide range of storage technologies, including free and productive storage. We also provide an alternative expression for speculative prices that highlights the key role of the storage boundaries. The competitive equilibrium price is the sum of discounted future probability weighted boundary prices. The boundary prices can be viewed as dividends on commodities in storage reflecting the realization of economic profits from storage.

1. Introduction

It is well known that speculative storage provides an efficient market based means to reduce price volatility in commodity markets (Miranda and Helmberger, 1988; Newbery and Stiglitz, 1981; Gouel, 2013a). Storage agents buy and hold commodities when abundant and sell when scarce, thereby smoothing the impact of supply and/or demand shocks on price movements. However, commodity stocks are not unconditionally freely disposable. For instance, if the commodity is scarce today, it cannot be augmented by borrowing from the future. This non-negativity constraint leads to prices that can be highly autocorrelated and "quiet" over long periods, but eventually spike upwards and increase in volatility as speculative stocks tend to zero. When this happens, price autocorrelation decreases as the shock smoothing effect of storage vanishes. The effects of the non-negativity constraint on commodity prices were analyzed in detail in Deaton and Laroque (1992, 1996, 1995).

This paper investigates the implications of fully bounded speculative storage on commodity prices. In addition to the non-negativity constraint, we consider speculative storage also bounded from above at a capacity constraint. All commodities have at any point in time a given upper bound on how much can be stored. For some commodities, such as different crops or metals for instance, storage capacity is cheap and flexible, requiring only available land and suitable protection. For other commodities, such as natural gas, animals, or water, the storage technology is often more complex and

* Corresponding author.
E-mail addresses: atle.oglend@uis.no (A. Oglend), tore.kleppe@uis.no (T.S. Kleppe).

http://dx.doi.org/10.1016/j.jedc.2016.11.007
0165-1889/

capacity more rigid. The US shale boom provides one recent example on the relevance of storage capacity on price dynamics. A largely unexpected increase in domestic availability of natural gas and oil led to tightness in both storage and transportation conditions. This was especially evident in Cushing, OK, the delivery point for the WTI oil futures (Büyükşahin et al., 2012). Full utilization of storage capacity contributed to a historic divergence between US domestic oil (and natural gas) prices and global energy prices. Water is another commodity where storage capacity is relevant (Xie and Zilberman, 2016). If water no longer "…exist in such quantities in lakes, rivers and streams, that no one need go without; everyone can take as much as he wishes from the water's edge" as stated by Walras as an example of a non-scarce commodity in his "Elements of Pure Economics", it becomes valuable in an economic sense, it has a market price and so is increasingly likely to be claimed as private property where decisions on capacity and its market price effect becomes relevant.

The topic of this paper addresses the question of how capacity for storage affects competitive price behavior. We show how the capacity constraint leads to price effects that mirror the non-negativity constraint on storage. If stocks in excess of capacity cannot be disposed off outside the market, prices will spike downwards and increase in volatility when storage hits full capacity utilization at the market level. As a consequence, revenues from positive supply shocks such as the shale-oil expansion in the US will be reduced. Bounded storage implies a U-shaped relationship between commodity price volatility and stocks, similar to what is predicted by Kogan et al. (2009) but then in relation to investment constraints in a production economy. Price volatility will be higher when the futures term structure is in strong backwardation or contango, similar to Carlson et al. (2007).

With both a non-negativity and a capacity constraint on storage, storage is completely bounded. The boundaries are important to the competitive equilibrium commodity price. The equilibrium commodity price when the zero-profit no-arbitrage restriction holds is the sum of discounted future boundary prices. The boundary prices are the probability-weighted prices that manifest when storage hits a boundary, that is, when the no-arbitrage restriction fails. When storage is not bounded and the no-arbitrage restriction holds, the expected profit of the marginal unit put in storage is zero. If the no-arbitrage restriction holds absolutely, and the commodity does not pay any dividends in storage, its value must be zero. However, in the competitive equilibrium the commodities value in storage must equal its market value. Assuming market price is not zero, the value of the commodity in storage must derive from future boundary outcomes, when speculative storage at the market level is at zero or full capacity and the no-arbitrage restriction fails. Speculative storage is valuable to the individual agent because of its bounded nature, i.e. the ability to sell when prices are abnormally high (storage bounded at zero at the market level) or buy when prices are abnormally low (storage bounded at capacity).

We introduce bounded storage in the competitive storage model. The competitive storage model is the primary economic model accounting for the price dynamics of storable commodities.[1] Completely bounding storage is a simple and straightforward way to extend the model to cover a broader range of commodity markets, markets that in the infinite capacity model are excluded due to parameter restrictions necessary to ensure the existence of a rational expectations equilibrium. With bounded storage, both free and productive storage technologies are allowed. Productive storage is relevant for instance for animal production where the commodity can grow in storage. By storage we mean storage in its most general term: the retention of stocks today for future marketing. Delaying harvest of a food commodity for instance is a storage decision. Productive storage gives rise to an explicit convenience yield on stock-keeping (Asche et al., 2015). This allows for positive storage under declining expected prices, something that is both empirically relevant and also necessary when pricing commodity based contingent claims (Gibson and Schwartz, 1990; Casassus and Collin-Dufresne, 2005; Casassus et al., 2013). The bounded storage model reduces to the conventional unbounded model at the limit of infinite capacity, and to a market with no speculative storage when capacity is zero. An added benefit of bounding storage is that numerical solutions to the model are quick and robust over a wide range of parameters. This allows a bigger parameter space to be explored when estimating the structural parameters. Even if capacity is not deemed relevant in the market analyzed, allowing for bounded capacity will tend to improve estimation procedures.

By bounding storage we are trading off a more restricted stock space for a more flexible storage technology. Whether restricting technology or stocks is relevant depends on the market in question. A benefit of bounding stocks is that it allows us to evaluate the restriction of costly storage often assumed for the storage model. Extending the range of storage technologies sheds some light on a predictive weakness of the competitive storage model highlighted by Deaton and Laroque (1992). The model with IID shocks and costly storage cannot fully account for the high autocorrelation commonly observed in commodity prices. A fix to the low autocorrelation problem is to introduce dependence in supply and/or demand shocks (Deaton and Laroque, 1996).[2] However, this leaves unexplained the source of the dependency. Not discounting the empirical relevance of shock dependence or the non-stationarity of observed prices, we demonstrate that if storage is cheap and capacity is high, speculative storage in a stationary environment with IID shocks can generate price autocorrelation in line with what is observed in actual data. Costly storage limits prices autocorrelation because it leads to frequent stock-outs; periods where the inter-temporal link between prices vanish. For instance, Routledge et al. (2000a) needs very low storage

[1] For some works on the competitive storage model and its economic relevance see e.g. Wright and Williams (1991), Deaton and Laroque (1992, 1995, 1996), Miranda (1998), Cafiero et al. (2011), Pirrong (2012), Geman and Smith (2013), Geman and Ohana (2009), Gorton et al. (2013), Gouel (2013b), Mitraille and Thille (2009).

[2] Cafiero et al. (2011) show that increasing the number of grid points the model is solved over better isolates the threshold where storage turns zero, and improves the model implied price autocorrelation.