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Theory of storage, inventory and volatility in the LME base metals

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ABSTRACT

The theory of storage, as related to commodities, makes two predictions involving the quantity of the commodity held in inventory. When inventory is low (i.e. a situation of scarcity), spot prices will exceed futures prices, and spot price volatility will exceed futures price volatility. Conversely, during periods of no scarcity, both spot prices and spot price volatility will remain relatively subdued. We test these predictions for the six base metals traded on the London Metal Exchange (aluminium, copper, lead, nickel, tin and zinc), and find strong validation for the theory. Including Chinese inventories reported by the Shanghai Futures Exchange strengthens the relationship further. We also introduce the concepts of excess volatility, inventory-implied spot price and inventory-implied spot volatility and illustrate some applications.

Introduction

The aim of this paper is to examine the six base metals traded on the LME (aluminium, copper, lead, nickel, tin and zinc), and examine the relationship between price, volatility and the quantity held in inventory, for both the spot and future markets. A relationship, believed to exist for many storable commodities, is predicted by the *Theory of Storage*. Firstly we review briefly the base metals and future trading. We then review the theory of storage and its literature across a number of commodities. Next, we review our data and discuss choices for the units of inventory. In our 'Results' section, we present our results for the relationship between price and inventory, and then for the relationship between volatility and inventory. We discuss some application in the 'Discussion' section followed by a conclusion.

Base metals and futures trading

Firstly, we review the base metals, futures markets (particularly the London Metal Exchange) and the existing literature on the theory of storage.

The base metals

Unlike the precious metals such as gold and silver, which are often purchased for investment rather than commercial use, the base metals are all notable for their industrial uses, principally in automobiles (aluminium, nickel), packaging (aluminium, tin), building and infrastructure construction (aluminium, copper, nickel, zinc), electronic and electrical components (copper, lead, tin) and many other applications.

Prices of the base metals vary according to their rarity and extraction costs, ranging from around $25,000 per tonne (nickel, tin), through $10,000 per tonne (copper) down to around $2500 per tonne (aluminium, lead, zinc), observed in mid-2011. They are typically traded on the LME in the form of bars, rods or ingots, with the exact contract specifications being tailored to the typical requirements of industrial users, and at high purities in excess of 99.8%.

Unlike many commodities, the base metals show negligible seasonal variation in their supply and only minor seasonal variation in demand (related to slight variations in construction activity across the northern hemisphere year), simplifying their analysis. They are easily storable at relatively low cost (typically $<5\%$ of their value p.a.), and unlike agricultural commodities, suffer negligible degradation over time, again simplifying their analysis.

Futures markets

Commodity markets typically have greatest liquidity in futures markets rather spot markets, which allows participants to 'lock in' a price in advance, for example a farmer may wish to fix a price for his harvest long before harvest time, or a construction company may wish to fix the price of copper they will use some months hence. On any given trading date 't', a number of futures contracts are traded, one for each maturity date T_1 to T_N. Typically maturities range from 1 month to several years into the future. The purchase of a futures contract obliges the owner to pay on the

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maturity date T_i, $i \in \{1,...,N\}$, the market price $F(t,T_i)$ to the seller, and in turn (s)he will receive one contract's worth of commodities.[1] Typically futures are traded on an exchange, and margin payments will be payable between the trade date t and the maturity date T_i to minimise the counterparty risk born by each side. For some commodities, spot markets exist with immediate delivery required. In their absence, the price of the futures contract which is the soonest to expire (the so-called 'front month' contract) is considered a proxy for a spot price.

The London Metal Exchange

London has been the world hub of metal trading for centuries, in an area near to the former Royal Exchange. Ad-hoc metal trading was replaced with a formal exchange with the founding of the London Metal Exchange in 1877. The LME has remained the centre of world metal trading ever since. Despite competition from COMEX in the US, and the Shanghai Futures Exchange (SHFE) in China, it remains for now the most liquid venue for trading of base metals.

The LME's trading structure is somewhat unique, resulting from its long history. Several times a day, open-outcry 'ring' trading sessions occur, with traders located physically in a seated circle or ring, with only a single metal traded per brief and intense 5 minute session. Electronic trading is also available during an extended business day, and telephone trading is available 24 h per day, with all trades reported and settled through the LME (2011a).

Unlike most commodity exchanges where futures contracts are typically deliverable in fixed months, with only occasional 'expiry' of contracts, the LME trades constant maturity contracts. On each trading day, contracts for delivery in 2 days ('spot'), 3 months, 15 months and 27 months are traded. The 3-month contract is most liquid, and was originally introduced because it took that long for tin from South-East Asia, or copper from Chile, to arrive by ship to London (Bloomberg, 2011).

The LME maintains a worldwide network of over 600 warehouses which are owned by third parties and must conform to certain specifications set by the LME. Although counterparties of a futures or spot trade are free to arrange bilaterally the delivery of metal from seller to buyer, they can also deliver to or take delivery from an LME warehouse. The warehouses are chosen to be at sources of demand rather than supply, ensuring that the buyer has immediate access to the metal he has purchased (LME, 2011b). However, to date, China does not allow warehouses in its territory to become LME-registered[2], and metal for Chinese delivery is typically shipped from Singapore or South Korea. Total inventory figures are published daily.

Commodity inventories and the theory of storage

Commodities are categorised as storable or non-storable. Non-storable commodities include those where storage methods exist but are prohibitively expensive (in particular, the case of electricity) and where the commodity is the provision of a service (as in the shipping industry). The vast majority of commodities are storable. They are stored for several reasons:

- As a buffer against uneven or seasonal supply, as in the case of agricultural commodities, which have been stored in silos as early as 10,000 years ago.
- As a buffer against uneven demand, as in the case of most energy commodities, which are typically used more in winter for heating, and midsummer for cooling.
- As a buffer against any other supply or logistical disruption, which would otherwise necessitate the expensive pause of an industrial process.
- In recent years, for investment purposes within physically-backed ETFs.
- For arbitrage reasons, if any, as described later.

The theory of storage applies to any commodity that can be physically stored and makes two main predictions, both related to the quantity of the commodity held in inventory (also known as stocks, a term we avoid due to its confusion with equity markets).

Prediction 1: the relationship between spot and futures prices

When there is a situation of scarcity (low inventory), spot prices will rise as purchasers bid whatever is necessary to secure supply. The effect will be less pronounced in longer term futures, since market participants know that higher price will, in the long term, stimulate increased supply and allow for a rebuilding of inventory. The effect, with *spot price* > *futures price*, can be extreme, and is known as 'backwardation'. An example of backwardation in the crude oil futures market is shown in Fig. 1, taken from the time of high oil demand and rapid price rises in 2007. Oil contracts that mature (expire) in 40 or more months are priced around $76, whereas those expiring within 1 month (so called 'nearby') futures are priced as high as $89.

Conversely, when supplies are ample, spot prices can become depressed with respect to futures prices. However, this effect, with *spot price* < *futures price*, termed 'contango', is usually less pronounced. At a certain point, the possibility of so-called 'cash and carry arbitrage' emerges, whereby a risk-free profit can be obtained by buying the commodity in the spot market, simultaneously selling a futures contract at a higher price, and storing ('carrying') the commodity until the delivery date of the futures contract. This possibility limits the degree of contango for storable commodities. This effect is asymmetrical—we cannot move a quantity of commodity from the future to the present, therefore there is no economic limit on the strength of backwardation imposed by storage. However, given sufficiently high spot prices, some consumers will cancel or postpone their demand, or possibly substitute their demand to another commodity. This weaker economic argument provides some limit to the strength of backwardation.

Prediction 2: the relationship between spot and futures volatilities

In conditions of scarcity, not only will spot prices be elevated, but they will also experience elevated volatility. This is because in a tight market, any news about short term supply, demand or inventory will have a large impact on the spot market. However,

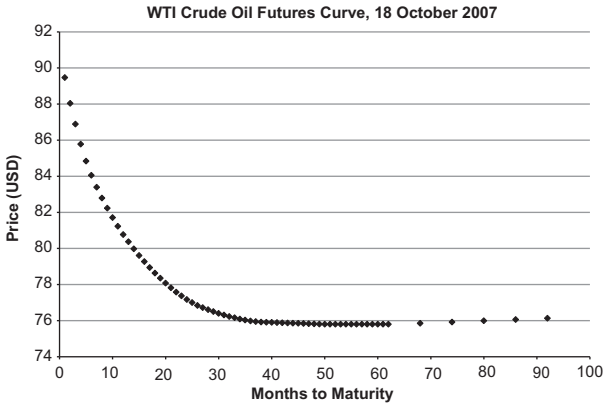

Fig. 1. Extreme backwardation in the crude oil market, 2007.

[1] Typically there may be some small lag comprising several business days between maturity of the contract and the delivery date, but this is irrelevant in the present context.

[2] At the time of writing, the sale of the LME to Hong Kong Exchanges and Clearing Limited is proposed. If approved, this would likely allow the LME to add Chinese warehouses to its global warehousing system.