Journal of Econometrics 158 (2010) 95–107

Contents lists available at ScienceDirect

Journal of Econometrics

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

Modelling and measuring price discovery in commodity markets

Isabel Figuerola-Ferretti [a], Jesús Gonzalo [b,*]

[a] *Business Department, Universidad Carlos III de Madrid, Spain*

[b] *Economics Department, Universidad Carlos III de Madrid, Spain*

ARTICLE INFO

Article history:
Available online 12 March 2010

JEL classification:
C32
C51
G13
G14

Keywords:
Backwardation
Cointegration
Commodity markets
Contango
Convenience yield
Futures prices
Permanent–Transitory decomposition
Price discovery

ABSTRACT

In this paper we present an equilibrium model of commodity spot ($\boldsymbol{s}_t$) and futures ($\boldsymbol{f}_t$) prices, with finite elasticity of arbitrage services and convenience yields. By explicitly incorporating and modelling endogenously the convenience yield, our theoretical model is able to capture the existence of backwardation or contango in the long-run spot-futures equilibrium relationship, $\boldsymbol{s}_t = \boldsymbol{\beta}_2\boldsymbol{f}_t + \boldsymbol{\beta}_3$. When the slope of the cointegrating vector $\beta_2 > 1(\beta_2 < 1)$ the market is under long run backwardation (contango). It is the first time in this literature in which the theoretical possibility of finding a cointegrating vector different from the standard $\beta_2 = 1$ is formally considered.

Independent of the value of β_2, this paper shows that the equilibrium model admits an economically meaningful Error Correction Representation, where the linear combination of ($\boldsymbol{s}_t$) and ($\boldsymbol{f}_t$) characterizing the price discovery process in the framework of Garbade and Silber (1983), coincides exactly with the permanent component of the Gonzalo and Granger (1995) Permanent–Transitory decomposition. This linear combination depends on the elasticity of arbitrage services and is determined by the relative liquidity traded in the spot and futures markets. Such outcome not only provides a theoretical justification for this Permanent–Transitory decomposition; but it offers a simple way of detecting which of the two prices is dominant in the price discovery process.

All the results are testable, as can be seen in the application to spot and futures non-ferrous metals prices (Al, Cu, Ni, Pb, Zn) traded in the London Metal Exchange (LME). Most markets are in backwardation and futures prices are "information dominant" in highly liquid futures markets (Al, Cu, Ni, Zn).

1. Introduction

Futures markets contribute in two important ways to the organization of economic activity: (i) they facilitate price discovery; and (ii) they offer a means of transferring risk or hedging. In this paper we focus on the first contribution. Price discovery refers to the use of futures prices for pricing cash market transactions (Working, 1948; Wiese, 1978; Lake, 1978). In general, price discovery is the process of uncovering an asset's full information or permanent value. The unobservable permanent price reflects the fundamental value of the stock or commodity. It is distinct from the observable price, which can be decomposed into its fundamental value and transitory effects. The latter consists of price movements due to factors such as bid-ask bounce, temporary order imbalances or inventory adjustments.

Whether the spot or the futures market is the center of price discovery in commodity markets has for a long time been discussed in the literature. Stein (1961) showed that futures and spot prices for a given commodity are determined simultaneously. Garbade and Silber (1983) (GS thereafter) develop a model of simultaneous price dynamics in which they establish that price discovery takes place in the market with the highest number of participants. Their empirical application concludes that "about 75% of new information is incorporated first in the futures prices." More recently, the price discovery research has focused on microstructure models and on methods to measure it. This line of literature applies two methodologies (see Lehman, 2002; special issue in the Journal of Financial Markets), the Information Shares of Hasbrouck (1995) (IS thereafter) and the Gonzalo and Granger (1995) Permanent–Transitory decomposition (PT thereafter). Our paper suggests a practical econometric approach to characterize and measure the phenomenon of price discovery by demonstrating the existence of a perfect link between an extended GS theoretical model and the PT decomposition.

Building on GS, we develop an equilibrium model of commodity spot and futures prices where the elasticity of arbitrage services, contrary to the standard assumption of being infinite, is considered to be finite, and the existence of convenience yields is endogenously modeled as a linear combination of s_t and f_t satisfying the

* Corresponding author.
E-mail address: jesus.gonzalo@uc3m.es (J. Gonzalo).

0304-4076/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.jeconom.2010.03.013

standard no-arbitrage condition. The assumption of finite elasticity is more realistic since it reflects the existence of factors such as basis risks, storage costs, convenience yields, etc. Convenience yields are natural for goods, like art or land, that offer exogenous rental or service flows over time. It is observed in commodities, such as agricultural products, industrial metals and energy, which are consumed at a single point in time. Convenience yields and subsequent price backwardations have attracted considerable attention in the literature (see Routledge et al., 2000). Backwardation (contango) exists when prices decline (increase) with time-to-delivery, so that spot prices are greater (lower) than futures prices. By explicitly incorporating and modelling convenience yields, we are able to detect the existence of backwardation and contango in the long-run equilibrium relationship between spot and futures prices. In our model, this is reflected on a cointegrating vector, $(1, -\beta_2)$, different from the standard $\beta_2 = 1$. When $\beta_2 > 1\,(< 1)$ the market is under long run backwardation (contango). As a by-product of this modeling we find a theoretical justification for a cointegrating vector between log-variables different from the standard $(1, -1)$. To the best of our knowledge, this is the first time this has been formally considered in this literature.[1]

Independent of the value of β_2, this paper shows that the proposed equilibrium model not only implies cointegration; but it leads into an economically meaningful Error Correction Representation (see Engle and Granger, 1987). The weights defining the linear combination of s_t and f_t that constitute the common permanent component in the PT decomposition, coincide exactly with the price discovery parameters proposed by GS. These weights depend on the elasticity of arbitrage services and are determined by the liquidity traded in the spot and in the futures market. This result not only offers a theoretical justification for the PT decomposition; but it provides a simple way of detecting which of the two prices is long run dominant in the price discovery process. Information on price discovery is important because spot and futures markets are widely used by firms engaged in the production, marketing and processing of commodities. Consumption and production decisions depend on the price signals from these markets.

All the results produced in the paper can easily be tested, as may be seen directly from our application to London Metal Exchange (LME) data. We are interested in these metal markets because they have highly developed futures contracts. Applying our model to LME spot and futures data we find: (i) All markets with the exception of copper are backwarded in equilibrium. This is reflected in a cointegrated slope greater than one, and (ii) The futures price is information dominant for all metals with a liquid futures markets: Aluminium (Al), Copper (Cu), Nickel (Ni) and Zinc (Zn). The spot price is information dominant for Lead (Pb), the least liquid LME contract.

The paper is organized as follows. Section 2 describes the equilibrium model with finite elasticity of supply of arbitrage services incorporating endogenously convenience yields. It demonstrates that the model admits an economically meaningful Error Correction Representation, and derives the contribution of the spot and futures prices to the price discovery process. In addition, it shows that the weights of the linear combination defining price discovery in the PT metric correspond to the price discovery parameters proposed by GS. Section 3 discusses the theoretical econometric background of the two techniques available to measure price discovery, the Hasbrouck's IS and the PT of Gonzalo–Granger. Section 4 presents empirical estimates of the model developed in Section 2 for five LME traded metals, it tests for cointegration and the presence of long run backwardation ($\beta_2 > 1$), and estimates the contribution of the spot and futures prices to price discovery, testing the hypothesis of the futures price being the sole contributor to price discovery. A by-product of this empirical section is the computation of the unobserved convenience yields for all commodities. Section 5 concludes. Graphs are collected in the Appendix.

2. Theoretical framework: a model for price discovery in futures and spot markets

The goal of this section is to characterize the dynamics of spot and futures commodity prices in an equilibrium no-arbitrage model, with finite elasticity of arbitrage services and existence of endogenous convenience yields. Our analysis builds and extends on GS setting up a perfect link with the Gonzalo–Granger PT decomposition. Following GS and for explanatory purposes we distinguish between two cases: (i) infinite and (ii) finite elastic supply of arbitrage services.

2.1. Equilibrium prices with infinitely elastic supply of arbitrage services

Let S_t be the spot market price of a commodity in period t and s_t be its natural logarithm. Let F_t be the contemporaneous price of a futures contract for that commodity after a time interval $T - t > 0$, and f_t be its natural logarithm. In order to find the no-arbitrage equilibrium condition the following set of standard assumptions apply in this section:

- (a.1) No taxes or transaction costs.
- (a.2) No limitations on borrowing.
- (a.3) No cost other than financing a (short or long) futures position and storage costs.
- (a.4) No limitations on short sale of the commodity in the spot market.
- (a.5) Interest rates are determined by the process $r_t = \bar{r} + I(0)$ where $\bar{r}$ is the mean of r_t and $I(0)$ is an stationary process with mean zero and finite positive variance.
- (a.6) Storage costs are determined by the process $c_t = \bar{c} + I(0)$ where $\bar{c}$ is the mean of c_t.
- (a.7) The difference $\Delta s_t = s_t - s_{t-1}$ is $I(0)$.

If r_t and c_t are the continuously compounded interest rates and storage costs applicable to the interval from t to T, by the above assumptions (a.1)–(a.4), no-arbitrage equilibrium conditions imply

$$F_t = S_t e^{(r_t + c_t)(T-t)}. \tag{1}$$

Taking logs of expression (1), and considering $T - t = 1$,

$$f_t = s_t + r_t + c_t. \tag{2}$$

[1] Taylor (1988) and Vidyamurthy (2004) in the PPP and pairs trading literature respectively consider a cointegrating vector different from $(1, -1)$. However their approach is statistically rather than economically founded.