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Bulk dry maritime freight prices and oil prices: Projection estimates with random discount rate

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ABSTRACT

Using the theory of price formation through intertemporal discrimination, we study with a particular attention the randomization discount rate of prices on time series related to maritime transportation prices and oil prices related to the period January 1985 to May 2013. We demonstrate that this assumption permits to obtain external limits which provide a more accurate estimate of price regression, which display a significant volatility.

1. Introduction

The study of statistical properties of time series, limited mainly to financial series (assets and indices), is the object for several years of intense research. These studies are conducted, in general, in order to establish economic forecasts of the prices or, more rarely, to conduct an econometric analysis to characterize the stochastic processes of these series.

Let's consider a sequence P_t , realization of a random value at instants *t*. If P_t , has been widely studied as a stock index, we propose to review the case of P_t, prices of goods or services. We have chosen to dedicate our work to dry bulk P_t^T and oil prices P_t^p .

This choice is explained by the importance of these prices in international trade. It is also justified by difficulties in identifying long term variations of these prices (Hummels) [6].

The treatment of these series raises two kinds of issues: first it is rare to have a series of input data over a long period; secondly and most importantly, most series are non-stationary. The latter problem makes it impossible to forecast it with extrapolation obtained by regression calculations.

Various mathematical, statistical and numerical treatments have been developed with some success to solve these issues. We can recall the techniques derived from Garch or cointegration [7], should one be interested in economics or temporal properties of the series.

It is demonstrated that the sequences of the price of transport P_t^T and oil P_t^p are non-stationary and that differences which are deducted from the series are almost stationary.

1 Monopoly

The approach to price formation in the intertemporal theory of discrimination has been proposed by several economists [2, 3, 4, 5, 8, 9] and is treated more completely by [1] in specific cases of cost and inventory functions.

First, we take a few results established for firms in a monopoly situation.

We consider a company in a situation of monopoly over a period ΔT consisting of several periods of time *t*. In order to set its prices p_t and production levels x_t, the company maximizes its profit function Π_t.

$$\underset{\{C\}}{\text{Max}}\ \Pi_t = p_t(q_t) - C(x_t) - B(s_t), \qquad (1)$$

where {C} summarizes the constraints. The ratings are presented as follows: q_t denotes the sales volume (demand), s_t the volume of stock, $C(x_t)$ the production cost function and $B(s_t)$ the function of storage cost. The system of equations of the model as proposed by Blinder [1] is written as follows:

$$\begin{aligned} p_t &= a_0 - a_1 q_t + \eta_t, && \text{(2a)} \\ C(x_t) &= c_0 + c_1 x_t + c_2 x_t^2, && \text{(2b)} \\ B(s_t) &= b_0 + b_1 s_t + b_2 s_t^2 && \text{(2c)} \end{aligned}$$

where all coefficients are assumed positive. The shock η_t in (2a) is a random process which one knows the characteristics.

2.1 Price shock without storage

To take into account the random nature of the price function, we introduce a price shock. It retains the previous expressions (2a) and (2b) where the random shock η_t is an AR (1) process

$$\eta_t = \rho\ \eta_{t-1} + \varepsilon_t \qquad (3)$$

given ε_t as a white noise and ρ a coefficient such that $0 \leq \rho < 1$. The system solution is then written

$$\Delta_1 = x_1 - q_1 = -\frac{\Delta_0}{2}\frac{1-r}{1+r} - \frac{\eta_1 - r\eta_2}{2a_1(1+r)}, \qquad (4)$$

with $\Delta_0 = \frac{a_0}{a_1} + \frac{c_1}{c_2}$.

It is therefore interesting to make several simulations of the equation (4) and deduce the first moment $< \Delta_1 >$ and the variance $\sigma^2_{\Delta_1}$.

Simulations were performed for a number of samples of 10^4, given two extreme values of ρ = 0.01, and 0.99 determining the AR(1) of η.

On figure 1, we represent the average values and variance of Δ_1 depending on the discount rate r. The values of the coefficients chosen here are $a_0 = 1$,

$a_1 = 1$, $c_0 = 1$, $c_1 = 0.5$ and $c_2 = 0.25$.

We note on the curve (*a*) that the average value remains negative for chosen values of parameters and independent of *r*. On the curve of variances (*b*), we notice that there is a value of $r \cong 0.66$ incurring a minimum value for the variance.

The chosen point of view, i.e. the time series analysis of aggregated data, does not allow us to distinguish between different carriers or oil producers. Hence we cannot calculate the average value on the data and we are therefore forced to work on trade in monopolistic situations.

We show [7] that the Blinder's theory established for monopolistic situations is satisfactory to understand the dynamic variations in average values of transport and oil's prices.

2.2 Average prices in average period

As another application of the formalism of the intertemporal prices' theory, we will show that it adequately reflects the average of prices.

The equation for p_t contains random variables. Therefore, we can but study it on average values of any order. The simplest is the order 1, that is to say the average value.

We first consider a series grasped over an average period of about 25 years and start from equation (2a) written for two periods t = 0 and t, where q_t expresses demand that we can get through a r_t. coefficient update.

Suppose that r is a random variable such that it is constant on a sub-period of t, but random on t, $r_1 = r_2 = ... = r$. Then

$$q_t \sim \frac{q_0}{r^t}, q_0 \neq 0. \qquad (5)$$

Suppose that r obeys the uniform distribution $\frac{1}{2\sigma}U\left[r_0-\sigma, r_0+\sigma\right]$, such as $r_0 \le 1$ and $0 \le \sigma \le 0.2$. We get

$$\langle q_t \rangle = \frac{q_0}{2\sigma}\left((r_0+\sigma)^{1-t}-(r_0-\sigma)^{1-t}\right) \qquad (6)$$

then

$$\langle q_t \rangle \approxeq q_0 + q_0\left(1+k\ t^2\right). \qquad (7)$$

k being a parameter depending on r_0 and σ. To calculate the average value of the shock η_t, we follow the model defined by the equation (3) written with the form

$$\eta_t = \rho^t + \sum_{l=0}^{t}\rho^l \varepsilon_{t-l} \qquad (8)$$

As the shock is related to the price, a positive value, then the noise ε_t has to be positive. That is why we take for ε_t, an uniform rule over [0,1]. The average value is finally given with

$$\langle \eta_t \rangle = \rho^t\langle \eta_0 \rangle + \frac{1}{2}\frac{1-\rho^t}{1-\rho} \qquad (9)$$

which allows to write, by putting the terms (7) and (9) in the average value of the equation (2a)

$$< p_t >= a_0 + a_1 < q_t > + < \eta_t >= \alpha + \beta e^{-\gamma t} + \delta t^2 \qquad (10)$$

The coefficients being stated depend on the initially chosen values.

2.3 Rule of demand of transportation rates

First, we intend to check the form adopted for the rule of demand.
As the use of non-stationary series led to erroneous conclusions, we start by making these by-difference-considered series stationary

$$\Delta P_t = P_{t+1} - P_t, \qquad (11)$$

whose stationarity is checked through the criterion of autocorrelation functions (ACF).[1] As to the relation between transport's prices (dry bulk) and demand, it depends on the definition of transport's demand.

We consider that the demand- or the sales' volume - is reflected by the transport's capacities. On figure 2a, this rule is confirmed either by the continuous line which is a regression line whose equation is

$$\Delta P_T = -0.023\ \Delta C_T + 296 \qquad (12a)$$

or by the exponential whose equation is

$$\Delta P_T = 990^{-0.0001\Delta C_T} - 700 \cong -0.1\Delta C_T + 290. \qquad (12b)$$

[1] We admit that an ACF slowly decreasing and whose values (except for the value at origin) are out of the confidence interval (±0.05 in this study) defines a non stationary process. On the contrary, an ACF quickly decreasing and whose values (except for the value at origin) are in the confidence interval (±0.05 in this study) defines a stationary process. The series' stationary identity is checked by the auto-correlation functions. The majority of ACFs' points is within the internal ±0.1.

The coefficients of the rule of demand in equation (2a) may be identified by $290 \leq a_0 \leq 296$, and $0.02 \leq a_1 \leq 0.1$.

When storage is absent, we consider that the transport's capacities mobilized by ship-owners are the best approximation of the quantities transported. Carried goods are inseparable from the transport's capacities mobilized by the ship-owner to transport them. Ship-owners are, in a quasi-monopolistic situation, as stated in [7]. Therefore, the transport's capacity may, as a first approximation, be used as a proxy for transport's demand.

Another way is to choose, as a variable grasping the sales' volume, the transport's capacity reported to the volumes of transported goods, referred to by ΔI_C. [7]
This approach allows mirroring the level of use of transport's capacity. It is therefore a more relevant proxy of demand.

We also observe a decreasing relation between transport's price and transport's demand as stated above.

On figure 2b, this rule is checked either by the continuous line which is a regression line, with equation

$$\Delta P_T = -\,6.17\ \Delta I_C - 4.4 \qquad (13a)$$

or by the exponential whose equation

$$\Delta P_T = 800^{\,-0.014\,\Delta I_C} - 1000 \cong -11.2\ \Delta I_C - 200\,. \qquad (13b)$$

Hence we can identify the coefficients for the rule of demand in equation (2a) by $-200 \leq a_0 \leq -6$ and $4.4 \leq a_1 \leq 11$.

This relation may be economically read: The higher the transport's demand, grasped through the transport's capacity used by the ship-owners, the more the transports' sector makes economies of scale, the more it optimizes its production tool, the more it increases the size of ships, and the lower the prices it offers for the transportation of a given quantity.

2.4 The rules of transportation rates and oil's prices

The goal of this section is twofold. First, it is to check that the prices' rule as stated in the beginning of the section 2, is true for transportation and oil.

Second, it is to provide extrapolations for short-term prices.

The rule deduced from the calculations has two components. The first refers to the initial model. The second is driven from the additional proposal stating that the actualization coefficient is made random.

The rule that we defined is represented in figures 2. The coefficients used in this law have been numerically seized to the data. The units of all the coefficients are price's units, price per unit of time or without dimension for γ. Hence we do not provide but indicative values.

Thus, for the variations of oil's prices $\alpha = -4$, $\beta = 4$, $\delta = 0.8\ 10^{-4}$, $\gamma = 0.001$ equivalent $\rho = 0.999$, and for the variations of transport's prices $\delta = 1.25\ 10^{-2}$, the other coefficients being unchanged.

We observe that in high times, the prominent term is the quadratic term in t whereas the first two terms of (11) are important when approaching short times. The quadratic term determines the long-term previsions, except for the assumptions set out at the start of this study: monopolistic situation and shortage of stocks.

In figures (3), the variations of average monthly prices $\Delta P_t = P_{t+1} - P_t$ of oil and transportation data (black dots) have been represented in function of the dates when the points were entered. The extreme data ($\pm 3\sigma$) are excluded from this regression.

We observe that for both series, the theoretical figures are in a reasonably good accordance with the true data. Then the rules that have been represented happen to be satisfactory. Hence they open the window to extrapolations. The extrapolations that may be driven of these rules may be considered as reliable.

In addition, since we are dealing with stationary data, a linear regression (usual method of least squares) may be calculated for the prices of:

Oil :

$0 \le \Delta P_t^p \le 5 \quad : \Delta P_t^p = 0.0135\, t$ (14a)

$-7.5 \le \Delta P_t^p \le 0 \quad : \Delta P_t^p = -0.0135\, t$ (14b) ,

Transportation :

$0 \le \Delta P_t^T \le 750 \quad : \Delta P_t^T = 2\, t$ (15a)

$-750 \le \Delta P_t^T \le 0 \quad : \Delta P_t^T = -2\, t$ (15b) ,

The lines are drawn in figures 3. They allow reducing the confidence interval for the previsions of short-term prices.

However, it is relevant to draw lines with a high confidence interval when dealing with highly volatile series. The rule derived from the Blinder model may be used for previsions that are less risky than those obtained by a simple regression.

If we consider that variations have the same trend, then, for the considered period taking into account equations (14)-(15), the relation of dependence of both series is

$$\Delta P_t^T \simeq 150 \Delta P_t^p \qquad (16)$$

The proportionality coefficient being dependent on the chosen units. Here we have picked up the unit “barrel per ton”.

Regarding the estimate of prices over a short term period (horizon h), we can extrapolate theoretical curves, i.e. either those deduced from the regression or those obtained through calculation. As such for transportation price,

a) $P_{t+h}^T = P_t^T \pm 500$ (17a)

b) $P_{t+h}^T = P_t^T \pm 1000$ (17b)

Similarly for oil prices

a) $P_{t+h}^p = P_t^p \pm 5$ (18a)

b) $P_{t+h}^p = P_t^p \pm 10$ (18b)

for $h > 0$ and so as the error is null for $h = 0$ for two series P_t^p and P_t^T (prices are in \$).

We summarize in the dashboard below the quality of predictions (17) and (18) compared with actual data

Serie	Initial Prices [a]	Estimation	Actual Prices [b]
Transportation	1060	$560 \leq P_h{}^T \leq 1560$	698
Oil	105	$100 \leq P_h{}^p \leq 110$	102

a: The initial dates for transportation prices is December 2012 and March 2013 for oil prices;
b: The estimation date is January 2013 for transportation prices and April 2013 for oil prices.

We see in figures 3 that uncertainty increases with time: the long-term forecast involves considerable uncertainty. However, the uncertainties that can tend to infinity as h takes great values, it is clear, first, that the values of h must remain low and secondly, the defined uncertainties relate only to the period time studied here.

3. Conclusions

The important result that we wish to emphasize is that the inter-temporal price theory is verified in a satisfactory way for the series of average values, at least in the case of series considered here. These time series relate to monthly average price of oil and transport for the period 1985 − 2010.

This result must be included provided that the time series have been made stationary, for instance by difference.

We adapted an economic model proposed by Blinder, to describe time variations of average prices for transportation and oil. This model is based on two basic assumptions:

(i) the price law is a decreasing linear function of demand;
(ii) prices are subject to additive shocks, which are random stationary process of AR(1)

We have proposed in this work to randomize demand through the discount factor r_t by a uniform law of assumed known variance, in order to approximate actual data.

Very simplified calculations whose constants were determined based on the data entered, led to show that the effects due to fluctuations in demand are dominant in the long term.

This result confirms the determining role of demand in the medium term, in the variation of prices, compared to random shocks. This result, applied to oil and transportation prices, seems consistent with our understanding of these sectors.

Although it is very difficult to make predictions, especially when a process shows volatility, extrapolations are reasonably possible within a horizon of a few months if we assume a wide interval of confidence.

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