Pricing Efficiency and Arbitrage in the EU ETS Carbon Futures Market

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INTRODUCTION

Climate change represents a threat to our current way of life, a considerable policy challenge, as well as new investment opportunities and risks. Most countries have signed and ratified the Kyoto Protocol (UNFCCC, 1998) in an attempt to slow down and stabilise the pace of climate change. Through limits on greenhouse gas (GHG) emissions and carbon trading the Protocol allows GHG abatements to occur in those sectors of the economy in which they are achievable at least cost.

Even though the US and Australia have not ratified the Protocol, and are thus not required to actively participate in carbon trading, the international carbon market transacted in excess of US$30 billion in 2006. Most of the volume was recorded on the European Union’s Emission Trading Scheme (EU ETS), the world’s largest mandatory carbon trading program. Launched on 1 January, 2005 EU ETS has grown at an unprecedented rate with the total value of transactions conducted in 2006 in excess of US$24 billion, compared to US$8 billion traded in 2005.

In this article we review some of the findings presented in Milunovich and Joyeux (2007) who address two questions related to the pricing efficiency of the EU ETS futures contracts. First, they ask if there is a stable long-run relationship between the EU ETS carbon spot and futures prices, and interest rates. This question is of fundamental importance because it seeks to establish if the EU ETS carbon futures contracts are effective hedging instruments.
Second, they aim to test a stronger assumption by asking the following: If the answer to the first question is yes, is the long-run link between carbon spot and futures prices, and interest rates given by the no-arbitrage cost-of-carry model? Thus, this question aims to determine if there is a possibility of profitable arbitrage opportunities between the carbon spot and futures prices.

The empirical methodology used in the study is based on econometric cointegration analysis and Granger causality tests. The dataset consists of EU ETS carbon emission allowance spot and futures prices and interest rates and covers the June 2005 – November 2006 time period.

**THEORETICAL LINKS BETWEEN SPOT AND FUTURES PRICES**

In theory, and for assets that allow arbitrage between spot and futures markets, futures contracts can be priced according to the cost-of-carry model. If $F_{T,T}$ is the current price of a futures contract that expires in $(T-t)$ years and $S_t$ is the current spot price, the cost-of-carry relation links the spot and futures prices in the following way:

$$F_{T,t} = S_t e^{r(t - T)}$$  \hspace{1cm} (1)

where $r$ is a risk-free interest rate and $\delta$ can be thought of as either a dividend yield in the case of a dividend paying stock, or a convenience yield in the case of a commodity.

The cost-of-carry model thus posits that the futures price should equal the spot price, adjusted for the opportunity cost of holding a spot position, ie. the interest foregone, less a dividend/convenience yield. Because the cost-of-carry model is derived from a no-arbitrage condition that results in a risk-free portfolio (see for example Hull, 1997), the relevant discount rate (ie. $r$) is the risk-free rate. In a perfectly efficient and frictionless market the pricing relationship expressed in Eq. (1) should hold at every instant over a futures contract life (Stoll and Whaley, 1990).

However, when applied to an imperfect market with frictions such as transaction costs, stochastic interest rates, et cetera the no-arbitrage condition will hold in the long-run but not necessarily in the short-term. After taking natural logarithms Eq. (1) can be expressed as a long-run cointegrating relation of the following form:

$$f_t = \delta (T-t) + \delta (T-\delta) + \eta_t$$  \hspace{1cm} (2)

where $\eta_t$ is a stationary zero-mean innovation term whose variance is determined by the extent of market imperfections. Note that the terms in brackets of the above equation represent a reverse time trend that start at $T$ (years to maturity) and end at zero as $t$ approaches $T$. In order to test the cost-of-carry model Eq. (2) can be re-written as:

$$f_t = a_5 + b_5 T + \delta (T-t) + \eta_t$$  \hspace{1cm} (3)

The following hypotheses can then be tested:

- **H.1.** Eq. (3) forms a cointegrating relationship, ie. $\eta_t$ is stationary.
- **H.2.** $a = b = 1$ ie. restrictions implied by the cost-of-carry model.

The above hypotheses H.1 and H.2 have the following interpretations. Should both H.1 and H.2 hold, then there exists a long-run relationship between the carbon spot price, the carbon futures carbon price and interest rates that is consistent with the cost-of-carry model. This finding would also imply that the futures market is efficient in the sense that there are no profitable arbitrage opportunities between the spot and futures prices and that the futures contracts are suitable risk mitigation instruments.

On the other hand, an alternative finding would be to discover that the hypothesis H.1 holds while H.2 does not. In this situation, although Eq. (3) would represent a cointegrating relationship the conclusion would be that while the three markets are linked in the long-run, the relationship is not provided by arbitrage activity and hence arbitrage opportunities persist in the market. Nonetheless, even though arbitrage opportunities may exist in this case, the futures contracts can still be used effectively for risk management purposes.

Lastly, the failure to find any type of long-run relation between the spot and futures carbon prices and interest rates would mean two things. First, it would mean that the futures contract price is independent of the underlying spot price and thus should not be used for hedging. Second, it would raise the possibility of profitable arbitrage opportunities in this market.

Table 1 presents a summary of Johansen, Mosconi and Nielsen (2000) cointegration rank analysis that are effectively tests of cointegration as given by H.1.

**TABLE 1. COINTEGRATION TESTS**

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>p-value</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 2006 futures contract does not form a cointegrating relationship with the spot contract and interest rates</td>
<td>0.0000</td>
<td>Rejected</td>
</tr>
<tr>
<td>Dec. 2007 futures contract does not form a cointegrating relationship with the spot contract and interest rates</td>
<td>0.0000</td>
<td>Rejected</td>
</tr>
<tr>
<td>Dec. 2008 futures contract does not form a cointegrating relationship with the spot contract and interest rates</td>
<td>0.482</td>
<td>Not Rejected</td>
</tr>
</tbody>
</table>

Given the test statistics presented above, Milunovich and Joyeux (2007) establish the existence of long-run links between the December 2006 and December 2007 futures contracts, the carbon spot price and interest rates. On the other hand, they note that the December 2008 futures contract does not form a long-run link with the other two variables. Tests of the cost-of-carry hypothesis (ie. H.2) are presented next.

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1. $(T-t)$ is calculated as the number of days to expiry divided by 360.
COST-OF-CARRY TESTS

In order to conduct a test of the cost-of-carry model (ie. H.2.) Milunovich and Joyeux estimated cointegrating vectors for each of the Dec 2006 and Dec 2007 futures prices and the carbon spot price and interest rate. Their specification of the cointegrating relations includes linear trends, restricted to the cointegrating vectors, and a trend break dated from January 2006 until the end of the sample. Their results from this test are presented in Table 2.

<table>
<thead>
<tr>
<th>Futures Contract</th>
<th>Parameter estimates</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec 2006</td>
<td>1.003</td>
<td>0.791</td>
</tr>
<tr>
<td></td>
<td>(256.774)</td>
<td>(0.811)</td>
</tr>
<tr>
<td>Dec 2007</td>
<td>0.991</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>(135.013)</td>
<td>(4.906)</td>
</tr>
<tr>
<td>Dec 2008</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

Even though Milunovich and Joyeux were unable to reject the null of the cost-of-carry relation between the December 2006 futures price, the spot price and the interest rates based on a joint likelihood ratio (LR) test presented in the above table, they argued that this finding was most likely due to the large standard error associated with the interest rate variable. In particular, according to the estimates presented in Table 2 the interest rate variable was not statistically different from zero at any conventional level of significance, implying that interest rates did not play a role in the cost-of-carry model.

This finding is inconsistent with the theory of arbitrage and the authors thus cautiously conclude that although the December 2006 futures contract price, the spot contract price and the risk-free interest rate are linked in the long-run, the long-run relation is not given by the arbitrage activity.

In the case of the December 2007 carbon futures contract the cost-of-carry restriction is strongly rejected based on both the joint LR and individual t-ratio tests. Milunovich and Joyeux therefore conclude that although there is a long-run link between the December 2007 futures price, the spot price and interest rates, the link is not provided by the cost-of-carry model.

CONCLUSION

In this article we have summarised some empirical results on the pricing efficiency of the EU ETS carbon futures market published in Milunovich and Joyeux (2007). As illustrated their findings indicate that none of the three carbon futures contracts that they examine are priced according to the cost-of-carry model. This result raises the possibility of arbitrage opportunities in the EU ETS market and should be tested further.

Although the December 2006 and December 2007 prices do not adhere to the cost-of-carry model, they are found to form long-run links with the carbon spot price and interest rates and can thus be regarded as effective risk mitigation instruments. The December 2008 contract, on the other hand, does not form such a relation and it is suggested that this contract should not be used for hedging pre-2008 exposures in the spot market. The December 2008 contract could instead be used for hedging post January 2008 carbon exposures that fall in the Phase II period (2008-2012) of EU ETS.

REFERENCES

Hull, J 1997, Options, Futures, and Other Derivatives, Prentice Hall, Upper Saddle River, NJ