A Note on the Presence of Inconvenience Yields in Bulk Commodity Markets

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A Note on the Presence of Inconvenience Yields in Bulk Commodity Markets

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Abstract

The presence of a strong contango in the term structure for thermal coal implies a highly negative convenience yield. This paper examines the conditions that lead to negative convenience yields for bulk commodities. We show that convenience yields for bulk commodities are dominated by the effect of oversupply rather than the combined effect of increases in inventory costs and decreases in the volatility of the underlying cash commodity. Producers clearly prefer to stockpile the commodity rather than adjust production in response to a contraction in demand. The data also reveals the inverse relationship between convenience yields and inventory levels is more significant when convenience yields are negative and deferred forward contracts are less volatile than near maturity contracts. We also demonstrate that the effect of convenience yield monotonically diminishes with maturity.

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1. Introduction

The ability to trade financially settled contracts for seaborne thermal coal has undoubtedly increased the efficiency of the global coal market. Annually more than 560 million tones of coal are traded on the seaborne market and the growth in the volume of forward contracts for this commodity since 2002 has enabled producers and consumers of thermal coal to smooth out fluctuations in price exposure. This capability is critical for European power production where a liquid market in forward power price contracts also exists. Over 180 million tones of thermal coal is imported to Europe annually from the producing regions of South Africa, Colombia, Indonesia and Russia and consumers are able to hedge their exposure through coal swap contracts whose prices are subsequently tracked via a number of key price indexes. Thermal coal is a strategic resource which is primarily used for power production, although it is also required for cement manufacturing and small amounts are used for other industrial purposes. The security of supply of thermal coal is critical for the efficient operation of Europe’s electricity market. The purpose of this study is to analyse the spot and forward market for thermal coal and provide estimates of convenience yield and volatility through time, while correcting for major sources of seasonality. I argue that the observed convenience yield is a surrogate for the volatility level in the thermal coal spot market and changing dynamics in the supply of, and demand for, the commodity. This study further shows that convenience yields can rapidly swing to become negative during periods of excess supply translating into a significant added cost for the commodity producer. The results show that a negative convenience yield, which generally occurs during periods when producers stock excessive inventory, are effectively dominated by the effects of oversupply rather than the combines effects of an increase in inventory costs and a decrease in the volatility of the underlying cash commodity. It is argued that the costs of a negative convenience yield incurred by a producer are less than the total costs associated with reducing production, meaning that producers have a financial incentive to continue to produce coal and stockpile for extended periods. A thorough examination of the emergence of negative convenience yields and their behaviour in the bulk commodity markets over time has not been conducted and this study attempts to clarify our understanding of such dynamics.

2. Commodity Markets and Thermal Coal

Because a commodity can be consumed, its price is a combination of future asset and current consumption values. However, unlike financial derivatives, storage of energy products is costly and sometimes practically impossible. Physical ownership of the commodity carries an
associated flow of services and the agent has the option of flexibility with regards to consumption; no risk of commodity shortage. On the other hand the decision to postpone consumption implies a storage expense. Thermal coal producers operate in an environment where production cannot be altered easily and the supply response to changes in demand is notoriously ‘sticky,’ meaning that production generally continues at the same rate for 6-12 months despite large short-term positive or negative changes in demand.

In equilibrium, backwardation implies that immediate ownership of the physical commodity entails some benefit or convenience which deferred ownership (via a long forward position) does not. This benefit, expressed as a rate, is termed the ‘convenience yield’. A convenience yield is natural for goods, like art or land, that offer exogenous rental or service flows over time. However, substantial convenience yields are also observed in bulk commodities, such as coal which are consumed at a single point in time. Intuitively, the convenience yield corresponds to the dividend yield for stocks.

The ‘theory of storage,’ see Brennan (1958), explains convenience yields in terms of an embedded timing option. In particular, the holder of a storable commodity can decide when to consume it. If it is optimal to store a commodity for future consumption, then it is priced like an asset, but if it is optimal to consume it immediately, then the commodity is priced as a consumption good.

Thus, a commodity’s spot price is the maximum of its current consumption and asset values, explained at length in Routledge, Seppi, and Spatt (2000). In contrast, forward prices derive solely from the asset value of the deferred right to consume after delivery. Inventory decisions are important for commodities because, by influencing the relative current and future scarcity of the good, they link its current (consumption) and expected future (asset) values. This is unlike equities and bonds where outstanding quantities are fixed. This link is imperfect, however, because inventory is physically constrained to be nonnegative. Inventory can usually be added to keep current spot prices from being too low relative to expected future spot prices. However, once the aggregate discretionary inventory of a commodity is driven to zero, its spot price is tied solely to the good’s (high) ‘immediate use’ consumption value. Thus, ‘stock-outs’ break the link between the current consumption and expected future asset values of a good. The result is backwardation and positive convenience yields. In contrast, oversupply of a commodity in the form of excessive discretionary inventory will have the reverse effect and drive the consumption yield towards zero and even negative resulting in a strong contango market.
The production cycle of energy commodities produce very distinctive behavior in commodity prices. When forward prices are a fair reflection of expected future prices, the expected forward return will be zero. When hedging demand is particularly strong, however, a discrepancy will arise as hedgers may be willing to accept a less favorable forward price in return for being able to fix their forward exposure. When hedgers on balance sell (buy) forward this puts downward (upward) pressure on the forward price. The result is a forward price which is lower (higher) than the expected future price and which therefore offers buyers of the forward contract a positive (negative) premium.

Seaborne thermal coal, along with most commodities, enjoyed high prices and experienced significant volatility in the lead up to the global financial liquidity crisis in late-2008. In 2009 prices reverted to historical levels in response to the slowdown. However despite the recession and the relatively subdued economic outlook in Europe, the forward price for thermal coal on the seaborne market was traded at a strong premium to spot prices during 2009. The dynamics of the coal forward curve during 2009 were very similar for the other two major seaborne coal indices. Both the delivered price of coal to Northwestern Europe and the free-on-board price for coal traded through Newcastle, Australia experienced very similar conditions. The magnitude of the contango and the persistent negative convenience yield were therefore not confined to a specific geography during this period. The changing dynamics of the relationship between spot and forward prices for bulk commodities will be explored through the concept of the convenience yield with respect to the extreme conditions experienced in 2009.

3. Data and Observations

The main indexes used for the trading, clearing and settlement of thermal coal, jointly calculated and published by Argus and IHS McCloskey, are the API2 and API4 indexes. The API 2 index is the international price benchmark for coal imported to northwestern Europe. The API 4 index is the international price benchmark for coal exported from the Richards Bay terminal in South Africa. The API4 forward curve is constructed as an average of the Argus FOB Richards Bay assessment and McCloskey’s FOB Richards Bay marker for coal with certain minimum quality specifications.

The strong contango in the term structure for thermal coal during 2009 was highlighted by large inventories of thermal coal held by the world’s major producers who continued production at pre-2008 rates. Forward contract prices for delivery 12-24 months forward for coal remained at historically high levels while spot prices fell. Coal producers incur high costs
in rapidly varying production in response to demand conditions and as such generally maintain production at a given level until a sustained structural change in demand is observed. The most appropriate proxy used in this study of Atlantic coal prices in the European market is the API4 index. This index is used instead of the API2 index (delivered coal price index to Northwestern Europe) because it is more representative of the true cost of coal as a consumption good, it is immune to changes in the forward freight market and it is also immune to supply alternatives from producers that enjoy a freight cost advantage into Europe. The implied inclusion of freight costs in the API2 index are difficult to extract in a meaningful way and therefore a true FOB forward curve is a better representation for this analysis.

The API4 forward curve was strongly in contango during the first half of 2009. The large degree of difference between forward and spot prices is historically rare. Figure 1 shows a sample of the API4 forward curves on four dates from late-2008 to mid-2009. While these curves merely represent a snapshot of the term structure for coal prices on these dates the analysis below will highlight the magnitude of the contango relative to historical levels.

![API4 Forward Prices for 4 Dates](image)

Figure 1

Figure 2 shows the API4 price differential between 12-month and 1-month prices at weekly intervals from 2003-2011. The 1-month forward contract is used here to represent spot prices since this is the nearest tenor available for the trading of physical bulk commodities, given the inherent lag in delivery. The behaviour of the 12-1 month differential shows that periods of ‘large’ contango characteristics have reverted back to more ‘normal’ contango features when
the differential reaches a particular cap. The differential is historically capped at around US$5/t over this tenor.

This phenomenon is more apparent in the next figure. Figure 3 shows the 24-month and 1-month price differential for API4 as a percentage of spot prices. The level of the cap is very pronounced from Jan 2004 - Sep 2008. It appears that historically, upon reaching the differential cap level of about 15 percent of spot prices after a period of time, the differential tends to reverse. The capped differential is a temporary phenomenon sustained for short periods of time followed by a rapid reversal to a smaller level or zero. The timing of each reversal is not predictable. The rapid reversion is due to varying factors some of which are discussed below. This reversion however ceased to occur in late-2008 where the differential continued to widen and at its height in June 2009, the differential as a percentage of spot was greater than 60%.

We now focus on the price dynamics leading up to the height of the differential in mid-2009. Figure 4 shows the 12m-1m FOB RB contango(+)/backwardation(-) relationship against spot prices from 2003-2009. The 12m rate is used here as a proxy for the longer end of the curve.
since the 12-month and 24-month forward prices are highly correlated (correlation > 0.89 for 2003-2011) and 24-month tenor contracts were relatively illiquid prior to 2005. The two characteristics as described above are evident in this illustration; Firstly, periods of high contango are followed sharply by backwardated curve conditions and secondly, the degree of the differential implying contango is historically capped at around 10-15%. It is also evident that higher spot prices usually relate to periods of higher volatility.

Weekly estimates of convenience yield have been calculated following Brennan (1986). The convenience yield $Y(t,T)$ is simply computed via the relationship

$$F(t,T) = (S(t) + C(t,T) - Y(t,T))e^{r(T-t)}$$

where $S(t)$ is the current spot price, $C(t,T)$ is the present value of storage costs to store one tonne of coal from time $t$ to $T$, $F(t,T)$ is the forward price at time $t$ which expires/settles at $T$ and $r$ is the risk-free rate. In a normal market forward prices should exceed spot prices by an amount that is equivalent to interest costs and storage costs and any deviation from this is explained via the so-called convenience yield. This quantity is a marginal spread component which can be modelled as an option on a positive spread component between spot and forward prices.
Figure 5 illustrates the daily implied convenience yield at the 12m tenor for 2003-2009. This was computed using API4 12-month forward and API4 spot prices (1-month contracts used as a proxy), 12-month US Treasury bond yields and actual storage costs at Richard’s Bay Coal Terminal (RBCT). We also make a quality adjustment to the coal at a depletion rate of 240kcal/kg per 6-month period, which acts as a linear price discount for a parcel of coal. No other quality adjustments were made. A non-zero storage cost does not greatly alter the observed behaviour in the implied convenience yield curve over time, since storage fees are a small portion of the total cost of thermal coal (US$2-3/t annually).

If the convenience yield is high enough, the observed forward price will be less than the spot price. This occurs quite frequently in oil and gas markets where the premium for immediacy is very real. If however, this relationship does not hold and the forward price is much higher than spot when taking into account high working capital costs (funding and storage), the convenience yield may in fact be negative. The observed quality adjusted 12m forward yields from March-September 2009 were about 21%. With a very high working capital funding rate of 900 basis points (bp) and storage costs of 500bp the convenience yield over this period is about -700bp, indicating that it is actually inconvenient to hold coal to the order of about US$6-8/t per year. For a coal producer with 3 million tonnes of coal stock held in inventory, this represents significant annual loss in addition to storage and working capital costs in a strong contango market. Figure 6 displays the 24-month convenience yields using the same data sources and adjustments as for the 12-month yields from 2003-2009.

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Storage costs incurred at a constant rate until full stockpile capacity is reached. Added capacity though compacting and alternative storage options are available at a higher cost however full capacity was not reached at mine and port stockpiles at any time during 2003-2011. Warehousing and insurance costs do not experience much temporal variability and are included in storage cost assumptions. Working capital costs are embedded in the forward price.
Figure 6

It is apparent from these figures that convenience yields historically fluctuate around a non-zero value, assuming constant storage costs. Assuming a 900bp credit spread (an extreme value) over the risk-free rate to cater for working capital under distressed market conditions in 2008/09 the 24-month implied convenience yield is still significantly negative. This adjusted time series is shown in Figures 7 and 8 for the 12-month and 24-month tenors.

Figure 7

The magnitude of the implied convenience yield adjusted for working capital and storage costs suggests that a significant element of inconvenience was associated with storing coal for future use during 2009.
Figure 9

Figure 9 shows implied convenience yields against contango(+)/backwardation(-) market characteristics for 2003-2009. The degree of contango/backwardation behaviour is represented as a proportion of the API4 spot price. This graph superimposes the magnitude of the contango against the implied convenience yield for 2003-2009 in order to demonstrate that convenience yields have rarely been negative since the establishment of the traded market for coal, and when these yields were negative producers sold down stocks at or below spot rates to avoid incurring excess costs. Note that over the period 2003-09 coal production for sale on the API4 index remained relatively steady.

Figure 10 displays the same general features except the line graph in this case represents the differential between implied convenience yields and Government bond yields at the 24-month tenor.
The volatility of the 12-month contract tenor relative to spot prices was also examined. While historically, the volatility during 2009 does not appear to serve as a useful predictor of structural changes in the market, it is apparent that swings in convenience yield combined with falling bond yields translated into higher long-tenor price variability. Figure 11 shows that daily price volatility as measured by the 60-day rolling standard deviation of changes in the 12-month API4 forward contract prices for 2003-2009.
4. Analysis of Convenience Yields in the Thermal Coal Market

It has been suggested that the convenience yield is inversely related to inventory levels, see Milonas and Henker (2001). When producer and consumer inventories are at capacity, it suggests that there is a low scarcity of the commodity today relative to the future. There is no benefit in stockpiling inventory further and therefore selling stocks forward is a rational decision. As such we would expect forward prices to be higher than spot prices. But the extreme spread between spot and forward prices during 2009 implies that holding stocks over the 12-24 month period incurred significant cost.

To fully analyse the spot and forward market for bulk commodities, it should be noted that forward market price ‘signatures’ can't be relied upon to distinguish speculative from fundamental demand while inventory may be un-measurable, especially if it takes the form of withheld production. However for the thermal coal market during 2009, production at the major mines continued at pre-2008 levels and the volume of forward and spot coal trades on API4 contracted only slightly. Speculator and inventory impacts were therefore minimal.

So what are the implied constituents of the convenience yield for a thermal coal producer and the effect on thermal coal prices? I propose that a negative convenience yield is notionally a spread for the shadow price on storage capacity, and volatility in the spread may increase the profitability of adding capacity. In addition, there may be more than one type of convenience yield to consider – for instance, there is convenience associated with holding a commodity to benefit from upside volatility in spot prices and spreads, and there is also convenience associated with storage itself, enabling profit from trades that are expected to benefit from downside volatility in spot prices and spreads. A positive convenience yield can be best represented as a long position in an embedded call option on the commodity. Conversely a negative convenience yield can be represented as a short position in an embedded call option on the commodity. As volatility increases, the value of the short position manifest as a negative convenience yield also increases.

It is incorrect to assume, out of context, that rising inventories means an overhang of supply that translates into lower prices until the market clears. Note that forward and futures markets are priced on the principle of equivalence. In a perfectly balanced market, a consumer is indifferent between buying a physical commodity now and storing it for later consumption, and buying it for future delivery and letting the producer pay for the storage costs. This situation also known as full carry, seldom applies in practice. The world's thermal coal consumers, mainly power producers and cement manufacturers, cannot afford to run out of
inventory and they therefore pay for the ‘convenience’ of having excess supplies available. This yield can be viewed as the commodity buyer’s insurance payment for supplies. It also represents the producer’s cost of hedging by selling forward contracts for the commodity. For bulk commodities such as coal where the cheapest place of storage is generally with the producer, the convenience yield measure could be quite high. But negative convenience yield means negative insurance costs for consumers, and that in turn means they can buy coal, pay for all of its storage costs and hedge it by selling the coal forward. The consumer owns an embedded call option on their hedged commodity in storage.

Although non-discretionary inventories may have convenience value, it appears that it is the discretionary inventory that determines the real trade-off between current and future consumption value. The focus of this analysis now turns to stocks held in inventory in excess of those committed to production processes, which we proxy for by eliminating the long term component of base load port stocks at Richard’s Bay Coal Terminal. Seasonal variation in coal trade volumes is not pronounced in the API4 index as thermal coal can be sold to markets other than Northwestern Europe. However the base load component is assumed to represent committed inventory and is simply eliminated in the analysis.

![Richard’s Bay Port Inventory Thermal Coal 2003-2009](image)

**Figure 12**

The theory of storage predicts a negative relationship between convenience yields and inventories. Table 1 shows the results from the following regression:

$$c_t = a + b Inv_t + \varepsilon_t$$  \hspace{1cm} (2)

where $c_t$ is the convenience yield at time $t$ and $Inv_t$ is the discretionary component of inventory extracted as described above. The column $Inv$ contains the slope coefficients of the inventory level and the columns labeled $t$ are the t-statistics calculated using Newey and West
standard errors using up to 26 lags. My results are qualitatively similar at other lags as given in the Table.

The convenience yield-inventory relationship is significant and negative for seaborne thermal coal. For seaborne thermal coal over the period 2003-2009, up to 31 per cent of the variation in the convenience yield can be explained by inventories. These results suggest that the convenience yield is highest when inventories are low; that is to say, the benefit of holding inventories is greatest during periods of relative scarcity or heightened demand.

<table>
<thead>
<tr>
<th></th>
<th>Inv</th>
<th>t</th>
<th>Adj R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>12m API4 (0m)</td>
<td>-0.0326</td>
<td>-6.07</td>
<td>0.17</td>
</tr>
<tr>
<td>12m API4 (3m)</td>
<td>-0.0274</td>
<td>-5.17</td>
<td>0.30</td>
</tr>
<tr>
<td>12m API4 (6m)</td>
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<td>-4.97</td>
<td>0.31</td>
</tr>
<tr>
<td>24m API4 (0m)</td>
<td>-0.0637</td>
<td>-7.46</td>
<td>0.16</td>
</tr>
<tr>
<td>24m API4 (3m)</td>
<td>-0.0373</td>
<td>-4.10</td>
<td>0.23</td>
</tr>
<tr>
<td>24m API4 (6m)</td>
<td>-0.0325</td>
<td>-3.87</td>
<td>0.22</td>
</tr>
</tbody>
</table>

**Table 1: Regressions of Convenience Yields on Discretionary Inventory Levels**

This table contains the results from regressing convenience yields on the discretionary component of inventory levels. All storage data are studentized. The column Inv contains the slope coefficients of the inventory level. The column labeled t is the t-statistics calculated using Newey-West.

The same regression was conducted over the period Dec 2008-Nov 2009 and the results are provided in Table 2. The inverse relationship between convenience yields and inventory levels are clearly more significant over 2009 than at any time in history, and the adjusted R-square result indicates that the historically high inventory levels explained up to 83 per cent of the convenience yield of thermal coal for the Atlantic market.

<table>
<thead>
<tr>
<th></th>
<th>Inv</th>
<th>t</th>
<th>Adj R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>12m API4 (0m)</td>
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<td>-9.31</td>
<td>0.83</td>
</tr>
<tr>
<td>24m API4 (0m)</td>
<td>-0.2616</td>
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<td>0.82</td>
</tr>
</tbody>
</table>

**Table 2: Regressions of Convenience Yields on Discretionary Inventory Levels in 2009 Only**

This table contains the results from regressing convenience yields on the discretionary component of inventory levels in 2009. All storage data are studentized. The column Inv contains the slope coefficients of the inventory level. The column labeled t is the t-statistics calculated using Newey-West.

In efficient pure contango markets the convenience yield should be close to zero. If inventory levels are small relative to the amount consumed of the commodity, the risk of a supply shock raises the convenience yield. If such risks are high enough, it is expected that the forward
market will revert to a backwardated market, often suddenly. Under such conditions, it is also possible that arbitrage conditions may weaken or may even break down.

During 2009 the forward market for power declined sharply and hence thermal coal demand contracted by up to 12 per cent in Europe. European power producers rely heavily on imports of thermal coal. The above results give support to the hypothesis of Brennan (1958) that the convenience yield is a negative function of inventory levels. Yet it also provides support for the hypothesis that negative convenience yields, which occur during periods when producers stock excessive inventory, are dominated by the effect of oversupply rather than through the combined effects of an increase in inventory costs and a decrease in the volatility of the underlying cash commodity.

Another explanatory variable for analysing the seaborne coal market behaviour is the so-called Samuelson effect, see Samuelson (1965). When the contracts are first traded and are far away from maturity (2+ years), they are thinly traded and exhibit low volatility. As the maturity nears, both trading volume and volatility increase. Typically the spot coal contract (for delivery within the next 3 months) is both the most liquid and the most volatile. Specifically spot contracts are usually used for balancing week-to-week needs and consequently exhibit high volatility and high volume. Thus, the term structure of coal forward volatility is usually monotonically decreasing. For the following analysis, the levels of liquidity in spot, 12-month forward and 24-month forward contracts remained relatively high over the period 2003-2009, although 24-month forward contracts were relatively illiquid prior to 2005. Despite the real decline in power production in the major importing centers in 2009, no adjustment for liquidity was conducted for this analysis.

Deferred forward contracts should be less volatile than near maturity contracts because as a contract draws nearer to maturity producers and consumers are forced to react more quickly to information shocks, while forward and spot contract prices converge at maturity. Fama and French (1987) and Milonas and Henker (2001) have provided empirical support to this hypothesis for a variety of commodities and financial assets. To validate this hypothesis for bulk commodities, forward contract prices must increasingly correlate strongly with spot prices as maturity nears. The convenience yields should also decrease in both absolute terms and as a proportion of spot prices as maturity nears. This behaviour has been discussed above and is presented in Table 3. These results show a steadily decreasing convenience yield as maturity nears and therefore supports this argument.
As the convenience yield diminishes with maturity due to the closer movement of forward to spot contract prices, the correlations of convenience yields in thermal coal is expected to generally decrease also. The behaviour of the correlations shown in Table 4 supports this hypothesis and indirectly supports the existence of the maturity effect in bulk commodity markets.

These results demonstrate a number of points. Firstly, negative convenience yields for bulk commodities are dominated by the effect of oversupply rather than the combined effect of increases in inventory costs and decreases in the volatility of the underlying cash commodity. Producers clearly prefer to stockpile the commodity rather than adjust production in response to a contraction in demand, implying that the costs of a negative convenience yield are less than the costs associated with changes to production capacity. Furthermore we have shown that a negative convenience yield can be represented as a short position in an embedded call option on the commodity. Secondly, the inverse relationship between convenience yields and inventory levels is more significant when convenience yields are negative than when positive. This is caused by the dominant impact of oversupply rather than increases in inventory costs or decreases in the volatility of the commodity. Thirdly we demonstrated that the Samuelson
effect holds for bulk commodities. Deferred forward contracts are less volatile than near maturity contracts because as a contract draws nearer to maturity, producers and consumers are forced to react more quickly to information shocks and forward and spot contract prices converge at maturity. Finally we demonstrated that the convenience yield diminishes with maturity due to the closer movement of forward to spot contract prices and that the correlation of convenience yields in bulk commodities monotonically decrease also.

5. Concluding Remarks

The wide contango in the thermal coal market implied highly negative convenience yields during 2009 which represented a significant departure from history. This reversion allowed for an examination of the relationship of convenience yields in bulk commodities, using the thermal coal market as a proxy. The implied added cost of storing coal, earning producers an inconvenience yield the forward market during 2009, was preferred to changes in production capacity. Under these conditions a speculator could sell a forward contract in the hope that the spot price at maturity will be below the forward price. In contrast, hedgers and especially electricity producers buy forward contracts at a premium price to reduce the market risk of their fuel input. But there may also be other hedgers who need to sell forward contracts to reduce their market risk. Whether the risk premium is positive or negative depends very much on the structure of the market participants and their strategies.

The observed dynamics of the thermal coal market in 2009 implies that hedging behaviour should dominate speculator behaviour. It is difficult to assert that this is the case based on the available data. Nevertheless from this analysis the so-called inconvenience yield appears to dominate the trading dynamics of the forward curve driven by supply overhang and significant long positions in spot volume. The potential for highly negative convenience yields in the bulk commodities market demonstrates that trading behaviour is greatly dependent on the term structure of the forward market and a producer’s capacity to absorb excessive inventory reduces bulk commodity supply fluctuations.
References


