REFERENCES

THE NORMAL BACKWARDATION THEORY

1. In 1930, Keynes provides an explanation on the relationship between spot and futures prices in commodity markets. This explanation is based on the function of transferring risks of the futures markets. It is the theory of normal backwardation. This theory supposes that long hedgers are more numerous than short hedgers. There is a structural market unbalance in commodity futures markets and a risk premium that rewards the speculators for the risk they undertake in order to restore the balance of the market.

Keynes, J.M., 1930. A Treatise on Money: The applied Theory of Money. London, Macmillan, vol. 2

2. In 1946, Hicks suggests that the market unbalance is due to the fact that a producer is more inclined to hedge than an industrial buying and transforming the commodity.

Hicks J.R., 1946: Value and Capital, London, Oxford Press

3. In 1958, Telser questions the normal backwardation theory. He claims that derivative markets are usually characterized by the presence of numerous speculators and the absence of barriers to entry. In such a market, according to him, there is no reason to think that the future spot price and the futures price will be different: the risk premium does not exist.

Telser L.G., 1958 : « Futures trading and the storage of cotton and wheat », *Journal of Political Economy*, vol. 66

4. Cootner (1960) replies that the spot and futures prices should be different because of the margin call mechanism.

Cootner P., 1960 : « Returns to speculators : Telser versus Keynes » *Journal of Political Economy*, n°68.

5. In 1960, Johnson says that:*«There is no distinction between the hedger and the «ordinary» speculator insofar as both are motivated by a desire to obtain a for-them optimum combination of E(R) and V(R) as determined by their respective utility functions»*. It is the first step towards the application of the CAPM for commodity markets.

Johnson L.L., 1959-1960: « The Theory of Hedging and Speculation in Commodity Futures », *Review of Economic Studies*, vol. 27, pp 139-151.

6. In 1973, Dusak uses the CAPM in order to test the normal backwardation theory on commodity markets. It is the beginning of numerous studies on CAPM and normal backwardation. These studies aim to test if speculators are rewarded for the holding of futures contracts.

Dusak K., 1973 : « Futures trading and investor returns : an investigation of commodity market risk premiums », *Journal of Political Economy*, vol. 81, n°6.

7. In 1987, Fama & French undertook a very extensive empirical study on 21 commodity futures markets. They checked whether futures prices rise during the life of the futures contracts.

Fama E.F., French K.R., 1987: « Commodity futures prices: some evidence of forecast power, premiums, and the theory of storage », *The Journal of Business*, vol. 60, n°1.

8. Working (1929-1931) also examines the behaviour of futures prices during the life of the futures contracts. He eliminates the influence of variations on the price level on his results and concludes that the theory of normal backwardation is not valid.

Peck A.E., 1977, Selected writings of Holbrook Working, Chicago Board of Trade

9. In 1986, Williams questions the normal backwardation theory. This theory is indeed centred on the function of transferring risk of the market. However, risk aversion is not sufficient in order to explain the huge and rapid changes observed in the basis (ie the difference between the futures and the spot prices).

Williams J., 1986 : *The economic function of futures markets*, Cambridge University Press.

THE STORAGE THEORY

1. Kaldor was the first to propose a definition of convenience yield. He defines this concept as the benefit that accrues to the owner of physical stocks: indeed, such an operator has the commodity at his' disposal, as soon as he needs it, and he doesn't have to bear the cost associated to frequent orders. Nor does he have to wait for delivery.

Kaldor N, 1939 : « A note on the theory of the forward market », *Review of Economic Studies*, vol. VIII, n°1, October.

2. Brennan (1958) completes Kaldor's analysis: he states that stocks give the possibility to benefit from an unexpected rise in the demand without having to wait for supply.

Brennan M.J. (1958). The supply of storage. American Economic Review, 47, 50-72.

3. Working (1949) relies on the presence of high fixed costs in storage activity and on the necessity to avoid a disruption of activity to explain the holding of stocks in backwardation.

Working H. (1949). The Theory of the Price of Storage. American Economic Review, n°31, December, 1254-1262

4. Through the concept of reserve yield, Weymar (1968) also refers to the presence of high fixed costs in production and processing activities in order to explain that phenomenon. He adds that there is a coverage yield which is due to the possibility to maintain a specific level of production.

Weymar H. (1968). *The dynamics of the World Cocoa Market*, MIT Press

5. Williams and Wright (1989) state that most of the time, the convenience yield is frequently overestimated, because stock data frequently reassemble heterogeneous stocks. This aggregation phenomenon explains partly why there are stocks in backwardation. The other part of the explanation is the following: for operators, holding commodity stocks in backwardation is the best way to reduce their "transformation costs" (namely their transportation, processing or selling costs).

Wright B.D. & Williams J.C. (1989). A theory of negative prices for storage. Journal of Futures Markets, 9(1), 1-14

6. In 1987 and 1988, Fama & French performed empirical tests on 21 commodity markets. They showed:

- that there is a seasonality in the behaviour of the convenience yield for agricultural commodities (1987)
- that the convenience yield evolves with the economic cycle for industrial commodities (1988).

Fama E.F., French K.R., 1987 : « Commodity futures prices : some evidence of forecast power, premiums, and the theory of storage », *The Journal of Business*, vol. 60, n°1.

Fama E.F., French K.R., 1988 : « Business Cycles and the Behavior of Metal Prices », *The Journal of Finance*, vol. XLIII, n°5

THE TERM STRUCTURE OF COMMODITY PRICES

1. One important characteristic of the behaviour of commodity prices is that there is a decreasing pattern of volatilities along the prices curve. Samuelson (1965) explains that phenomenon. As futures contracts reach their expiration date, they react much stronger to information shocks, due to the ultimate convergence of futures prices to spot prices upon maturity. These price disturbances influencing mostly the short-term part of the curve are due to the physical market, and to demand and supply shocks.

Samuelson, P.A. "Proof that Properly Anticipated Prices Fluctuate Randomly." Industrial Management Review, 6 (1965), pp. 41-49.

2. The first term structure model of commodity prices is the one proposed by Brennan & Schwartz 1985. It is a one factor model, where the state variable (the spot price) is characterized by a geometric Brownian motion.

Brennan M.J., and E.S. Schwartz. "Evaluating Natural Resource Investments." Journal of Business, 58 (1985), pp. 135-157.

3. The most famous term structure model of commodity prices is the two-factor model proposed by Schwartz in 1997. The state variables are the spot price and the convenience yield. The latter is mean reverting. Moreover, it is introduced in the dynamics of the spot price. Thus, the convenience yield appears as a stochastic dividend yield.

Schwartz, E.S. "The Stochastic Behavior of Commodity Prices: Implications for Valuation and Hedging." Journal of Finance, 52 (1997), pp. 923-973.

3. In 1991, Brennan performs empirical tests on several term structure models. He considers one factor models which are interesting because they can be seen as a first attempt to represent the convenience yield as a real option.

Brennan M.J. "The Price of Convenience and the Valuation of Commodity Contingent Claims", In D. Land and B. Φksendal, ed., Stochastic Models and Options Values. Elsevier Science Publishers, 1991, pp. 33-71

4. In 2000, Routledge, Seppi & Spatt propose a general equilibrium model where there is an assymetrical behaviour of the convenience yield, which is, in that case, an endogenous variable.

Routledge, B.R., D.J. Seppi, and C.S. Spatt. "Equilibrium Forward Curves for Commodities." Journal of Finance, 55 (2000), pp. 1297-1338.

5. Schwartz & Smith, 2000 propose a two-factor model where the state variables come from the decomposition of the spot price. This decomposition authorizes the distinction between the short-term variations affecting the spot price and a long-term equilibrium level of the prices.

Schwartz E.S., and J.E. Smith. "Short-Term Variations and Long-Term Dynamics in Commodity Prices." Management Science, 46 (2000), pp. 893-911.

6. Cortazar & Schwartz (2003) propose a three-factor model related to Schwartz (1997). In this model, the authors consider as a third risk factor the long-term spot price return, allowing it to be stochastic and to return to a long-term average.

Cortazar & Schwartz ES, Implementing a Stochastic Model for Oil Futures Prices. Energy Economics, 25 (2003), pp. 215-238

DYNAMIC HEDGING

1. Reflection on dynamic hedging in commodity markets began with the Metallgesellschaft (MG) case, in 1994. At that time, there was a debate concerning the hedge undertaken by MG. The question was: did MG hedge or speculate? Interesting comments on that case may be found in Edwards & Canters (1995) or in Culp and Miller (1994, 1995)

Culp C.L., Miller M.H. [1994], « Hedging a Flow of Commodity Deliveries with Futures : Lessons from Metallgesellschaft », *Derivatives Quarterly*, Fall, p 7-15.

Culp C.L., Miller M.H. [1995, a], « Metallgesellschaft and the Economics of Synthetic Storage », *Journal of Applied Corporate Finance*, Vol. 7, n°4, Winter.

Culp C.L., Miller M.H. [1995, b], « Hedging in the Theory of Corporate Finance : A Reply to our Critics », *Journal of Applied Corporate Finance*, Vol 8, n°1, Spring, p 121-127.

Edwards F.R., Canter M.S. [1995], « The Collapse of Metallgesellschaft : Unhedgeable Risks, Poor Hedging Strategy, or just Bad Luck ? », *The Journal of Futures Markets,* Vol.15, n°3, p. 211-264.

2. Another way to think about MG'strategy is to check whether this strategy was efficient or not.

● In 1997, Brennan and Crew compare the hedging strategy initiated by MG with other strategies relying on the models of Brennan and Schwartz (1985) and of Gibson and Schwartz (1990). They show that the strategies relying on the term structure models outperform by far that of the German firm.

Brennan, M.J, and N. Crew. "Hedging Long Maturity Commodity Commitments with Short-Dated Futures Contracts", In M. Dempster and S. Pliska, ed., Mathematics of derivatives securities. Cambridge: Cambridge University Press, 1997, pp. 165-190.

● The same year, Schwartz also calculate the hedge ratios associated with each of the three models he studied. However, he does not test the efficiency of the related hedging strategies.

Schwartz, E.S. "The Stochastic Behavior of Commodity Prices: Implications for Valuation and Hedging." Journal of Finance, 52 (1997), pp. 923-973.

● In 1999, Neuberger compared the performances of hedging strategies relying on the two-factor model developed by Schwartz in 1997 and on a new model. In this new model, no assumption is made on the number of variables, about the process they follow, or about the way risk is priced. The key assumption is that the expected price at which the long-dated contract starts trading is a linear function of the price of existing contracts (whereas in Schwartz' model, the futures price is a non-linear function of the state variables). While theoretically inconsistent with some models of the term structure of commodity prices, in practice this new model still gives good results.

Neuberger, A. "Hedging Long-Term Exposures with Multiple Short-Term Futures Contracts." Review of Financial Studies, 12 (1999), pp. 429-459.

● In 2000, Routledge, Seppi and Spatt calculate the hedge ratios associated their term structure model.

Routledge, B.R., D.J. Seppi, and C.S. Spatt. "Equilibrium Forward Curves for Commodities." Journal of Finance, 55 (2000), pp. 1297-1338.

REAL OPTIONS AND MINERAL RESERVES

1. The pioneer article on real option and mineral reserves is the one written by Brennan & Schwartz in 1985. There are several real options associated with the possession of the mine: the option to shut down the mine temporarily, the abandonment option, and the option to defer investment. With the parameters values they chose for simulations, the authors find that it is never optimal, under uncertainty, to close or abandon the mine. They also show how the option value changes with the volume of the reserve, with the initial amount to invest, etc

Brennan M.J., and E.S. Schwartz. "Evaluating Natural Resource Investments." Journal of Business, 58 (1985), pp. 135-157.

2. In 1997, Schwartz shows how much the value of a real option on a mine and the investment decision depend on the method used for the valuation of the net future cash flows associated with an investment project, namely the term structure model of commodity prices.

Schwartz, E.S. "The Stochastic Behavior of Commodity Prices: Implications for Valuation and Hedging." Journal of Finance, 52 (1997), pp. 923-973.

3. In 1997, Cortazar and Schwartz use a one-factor model based on mean reverting spot price, in which the convenience yield is variable and depends on the deviation of the spot price to a long-term average price. Using this model, they calculate the value of the field at different stages: before committing to the development during development, and during production

Cortazar and Schwartz "Implementing a Real Option Model for Valuing an Undeveloped Oil Field." International Transactions in Operational Research, 4 (1997), pp. 125-137.

3. In 2000, Schwartz and Smith apply their short-term/long-term model to a hypothetical real options problem. They consider two real options: the option to defer investment for a long-term project, and the development option for a short-term project.

Schwartz ES, and J.E. Smith. "Short-Term Variations and Long-Term Dynamics in Commodity Prices." Management Science, 46 (2000), pp. 893-911.

4. In 2001, Cortazar, Schwartz and Cassassus collapse price and geological-technical uncertainty into a one-factor model. Using this model, they determine the value of several options: flexible investment schedules for all exploration stages, and a timing option for the development investment. Moreover, once the mine is developed, there are closing, opening and abandonment options. The model is applied to the copper market.

Cortazar, Schwartz and J. Casassus. "Optimal Exploration Investments Under Price and Geological-Technical Uncertainty: a Real Options Model." R & D Management, 31 (2001), pp. 181-189.

REVIEWS
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Energy Economics
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INTERNATIONAL INSTITUTIONS
CFTC: Commodity Futures and Trading Commission
FIA: Futures Industry Association

FUTURES MARKETS
- LIFFE
- CBOT
- NYMEX
- LME
- CME
- ICE