A Price setting model of commodity markets*

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Abstract

Price fluctuations in some commodity markets are highly volatile price. It is generally understood that this subject falls within the domain of economics. However economics, the science of markets, fails to explain price fluctuations in the short time. We propose an alternative explanation in the form of a knowledge based model. The predictions of the direction of price movements made from this model are better than random choice, which is more than can be said of any other model.

1 Introduction

The prediction of the price of a commodity over the next few days is a task being performed by many people acting as agents. These agents work for genuine suppliers of the commodity, its users and for traders. If the commodity is an important one –such as crude oil – its price is of concern not

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only to these people but also to financial institutions, consulting agencies, analysts, scientists and the news media which speculate on changes in its price.

Since the price of important commodities is of interest to a wide spectrum of the society it becomes a social phenomenon, enacted by the behaviour of the many market participants each behaving according to certain rules. Knowing these rules, one can make good predictions of the direction of price changes having only limited knowledge of the structure of the entire phenomenon.

We show how such commodity markets work by identifying a set of rules that governs the decision process of the agents who are making the greater part of transactions. The rules use a representation of the market that is also used by the commodity futures market traders. This has little in common with the way markets are represented in economics. The application of these rules in a Knowledge-Based Model resulted in price predictions above the chance level.

For the application of our method we have chosen the largest commodity market, the oil market having a daily turnover of a few billion dollars. Since this market influences prices on other large markets such as the stock and gold markets, as well as other commodity markets, understanding the oil market helps to understand price developments in these other markets.

2 Understanding a market and a price

Markets are a mechanism for effecting the purchase and sale of assets and services in a relatively public manner. Thus, a market entails a way of carrying out transactions and some means of collecting and disseminating information on the terms of transactions, particularly price (Burns 1979). They facilitate the distribution of social wealth, convey information about the scarcity of goods and services, and set prices which allow a choice between alternatives. The social function of markets is to coordinate the decisions and behaviour of multitudes of individual economic agents so that the volume and quality of products bears a reasonable relation to the quantity and quality that consumers will buy, and that the price will be reasonable in relation to the costs of production. While markets are not the only method of such coordination – other methods of coordinating individual behaviours include published statistics, bargaining and negotiating, and hierarchic organizations (Simon 1981) – they are particularly in favour in the present social climate.

>From the practical point of view it is difficult to isolate a particular market for study. The extent of the oil market is quite diffuse. The meaning of the term 'oil market' depends on how boundaries are imposed, between what is considered a part of the system and what is background. In building a model of the oil market we were bound to characterize the system and its background in such a way that its resulting properties depended on the distinctions we made. This distinction process is recursively applied to the delineated system in order to distinguish its components and their properties and so on. The relation between components constitutes the system's organization (Maturana and Varela 1972). In these terms, we choose to see the oil market as four different markets: the global oil market which embraces all oil transactions, the international oil market, the spot oil market and the futures oil market.

In turn, the global world market may be viewed as a part of the world energy and raw material systems, which constitute an important foundation for the industrial system and current human civilization. At the other extreme, each sub-category is but an indicator for multiple types of agents revealing many types of task environments and behaviour.

Having in mind the many different understandings of the concept 'oil market', one can see that 'oil price' is also an ambiguous concept. For those who do not know the oil market, the oil price has a meaning of monthly or yearly average price. It is easy to plot such a price, along with some other economic categories such as demand (consumption) and supply (production), and draw demand and a supply curves on a Cartesian coordinate system.[1] Diagrams are the typical tools for reasoning in economics. The

[1] It is possible to assume the existence of long range demand and supply curves which help to deduce the behaviour of the global oil consumption. A price of about \$20 induces consumption to grow. The price of about \$30 decreases consumption to about 55 million barrels per day. At that point the oil glut causes price reduction to the previous level, and the cycle seems to start again. Yet, it is difficult to predict how long the particular part

reason for this was clear to Alfred Marshall in 1890: their use "requires no special knowledge, and they often express the conditions of economic life more accurately, as well as more easily, than mathematical symbols."

Rosing (1987) presented 68 projections of the oil price for 1990 and 61 for the year 2000 made by oil market experts at the World Oil Forum international conference in 1983 near Vienna. Upon such representations 'experts' frequently make inferences concerning price expectations. The increasing price trend depicted on the diagram was so steep that they expected it to continue, ignoring the information about falling oil prices for about a half of the year. With the price prediction for 1990 they all were wrong. The actual annual average price in 1990 was lower than the lowest predictions presented!

Those who know this market see the oil price as constantly fluctuating and never publicly known. Analysis of different price representations (according to the time period) suggests different understandings of the oil market and different causal maps of the factors supposed to determine this price. Depending on time horizons, the oil price changes are different; its daily change on the spot oil market can exceed 25%, the change of weekly average can be 30%, monthly 50%, and yearly 100%.

Market agents attend mostly to estimates of the price in the shortest time span; this is but one part of the oil market. The other prices (being averages) belong to the world of description and, as such, are not a part of the market system. The oil price is set in the international oil market where oil imports and exports are matched. That price is also a basis for the price in the global oil market which consists of all oil transactions across the globe and the domestic markets of all oil consuming countries. The price in domestic markets may differ from the international price due to local costs of production, transportation and import levies. From the point of view of the influence on the short term price, cash transactions in the spot oil market are the most important, although only about 10% of the internationally traded

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of the cycle will last, how large a price change will occur, and whether the intervention of some other factor will not disrupt the cycle totally. Consequently, though this type of analysis can contribute to the general description of the global oil market it is indifferent to understanding the working of the spot oil market because of the different time scale at which they operate. For example with the reduction of a time period to one month it is difficult to identify any demand and supply curves over time on the world base.

physical oil goes through it at the present time. However, the volume of oil transactions in this market is much bigger (about 50 million barrels per day) since the chain of middlemen between the producer and a refiner can be very long.

>From a theoretical point of view anybody can engage in oil transactions; practically only those who posses the large capital necessary for transportation, storage and refining of oil can do so. There is no such thing as an end-user demand for oil which economic theories need for the construction of a model to predict or account for an equilibrium price. The crude oil price is a matter of indifference to the average final consumer, who is usually purchasing gasoline, or gasoil. Conversion of oil into these products requires complicated technological processes which are indifferent to him. This wide area of consumer indifference between himself and oil producers is filled by governments, multinationals, and some independent oil companies. The relation between the price of crude oil in the spot oil market and the price of oil products on the final consumer market is quite tenuous. Price of oil is hardly following cost and there is no other commodity which has had such a big discrepancy between price and cost for such a long time. Forces defending the price of oil products (consuming-country governments) are determining the direction of price changes, so the price erosion may happen quickly, slowly, or never (Adelman 1972). This means that prices of oil products are largely independent of the crude oil price and that these do not convey any information about the scarcity of oil to a final consumer of oil products. Similarly prices of oil products do not convey any information to oil producers about changes in demand.

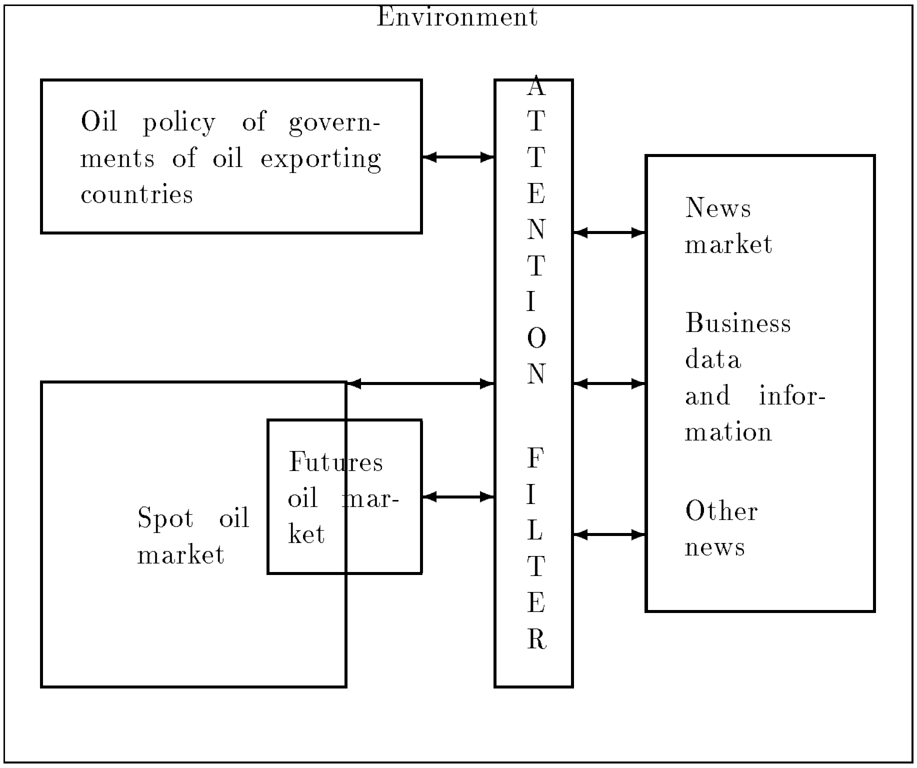
3 Representation of the oil market

What the spot oil market actually accomplishes is balancing the demand for oil and oil products with supply under market conditions which for many years now have been characterized as disorderly. These conditions assign an important role to price expectations which are determined by factors originating both in the market itself and in its environment. Under these circumstances, the most important factors in the environment which determine an agent's behaviour are the futures oil market and the media. These together constitute a system whose participants perform the following activities:

- on the spot oil market
  - either always exchanging oil for money (genuine suppliers) or money for oil (refiners),
  - both exchanging money for oil and oil for money, sometimes simultaneously (traders and speculators);
- on the futures market
  - hedging,
  - speculation;
- on the news market
  - spreading or generating and spreading rumours, news, comments and advice.

The phenomenon is shown schematically in Figure 1. The boxes shown inside the spot oil market represent the agents composing that market. Their different sizes reflect different volumes of oil these agents trade. The boxes outside the inner box represent salespersons of genuine oil producers (multinationals, oil exporting countries) or final users of crude oil (independent refiners). The boxes inside the inner box represent traders, i.e., agents who do not have their own oil production nor are final users of crude. The behaviour of these two groups differs greatly. Crude suppliers/users seek price stability, they ignore minor price changes, only a few of them hedge or speculate on the futures market. On the other hand traders gain on spot price fluctuations, they amplify price deviations as well as hedge and speculate on the futures oil market. They aim at any price difference and react to any rumour they attend to from inside or outside their box. The principle of their activity is buy low(er) and sell high(er). The futures market is an institution administering the less-than-zero-sum game of an almost infinite number of players. The rule of this game is to buy low and to sell high or to sell high and buy low. Only a small fraction of this market's turnover is a result of hedging physical transactions of refiners from the spot oil market.

Figure 1: Oil market structure



The high oil price fluctuation is the factor upon which the agents from inner box of the spot oil market and futures oil market base their activity. Contrary to the decision making process of genuine suppliers, which is based mostly on fundamental considerations, the agents' operations rely upon continuous search for information and use of technical analysis. In fact the level of the oil price is indifferent to them –it is only the changes that are important.

On the spot oil market, as on other markets which are not perfectly competitive, mutual expectations are very important. Agents are trying to anticipate expectations of the others (and hence their actions). That is why feed forward in such a market structure is especially destabilizing. A rising price creates the expectation that it will go higher still, hence induces buying and restrains selling. There then develops a game of economic 'chicken,' in which participants believe in their ability to change position just before the trend shift. Each agent tries to outguess its competitors; in this game an economic definition of rationality comes into question. What is destabilizing in such a situation is the absence of a belief in the existence of a long-run equilibrium price (Simon 1981). That lack of belief creates high uncertainty concerning the oil price, hence makes it necessary for economic agents to hedge their physical oil positions against possible price changes on the futures oil market.

4 Market agents' behaviour

Agents acting on the oil market recognize the market situation through analysis of the futures market price. That price is an array in which the spot price (immediate delivery) is the first element; further elements are the future prices for consecutive months up to 18 months ahead. It is supposed to reflect the price of oil in the physical market because of the mechanism of hedging. However, that price is not a 'price' as such; it is not a price which is paid for any type of oil or the oil futures contract. The price of a futures oil contract is only a part of the futures oil price and is determined by a commodity exchange taking into account mutability of the futures oil price. In this respect the futures oil price functions as a lottery number, and the price of futures oil contracts is the price of a lottery ticket. Agents monitor the price in a form suitable for their decision process. Some watch real time price, some attend to the snapshots in certain time intervals (every minute/hour), some only the opening or closing price or its daily average.

We found that in trading for the time period of from one to four days agents reduce the complexity of their task environment by resorting to technical analysis. Application of that analysis translates the complexity of the market into a representation consisting of a set of meaningful pictorial patterns. The tools for constructing these patterns, along with rules for their interpretation, appear nearly universal. They are independent of a country, language, commodity, and the causal maps of market agents. They constitute a part of a language, which allows different agents to communicate, and hence, act in the same cognitive domain. The crucial input is the futures oil price itself.

5 Conditions for transaction

Since the overwhelming majority of transactions on the oil market is a result of speculation, we explain when the transactions influence the price and what are the necessary conditions for those transactions to take place.

For the price to move in a certain direction, parties of the transaction must have the same belief of the expected direction of price change. The stronger that belief, the more and longer the price will move in the expected direction. In the situation when there is an agreement that the price will increase buyers are eager to pay more (because they expect the trend to rise) and sellers will offer only on a higher price because it is risky to make obligations for future delivery (issue contracts) now at a lower price, when the price is expected to rise. They may issue a contract but only at the price level (higher) at which their risk aversion to commit a loss is small enough.

Similarly when there is a common expectation that the price will decrease the seller is eager to increase sales and buyer will bid only at a lower level. What makes traders act, and act differently (buy and sell), is having the same expectation of the direction of a price change but different expectations of the length of the trend or the size of the price change. For example, both parties may have expectations that the price will increase, but one of them expects the price either to be increasing for a shorter period of time or to increase by a smaller amount than the other. In such a situation the party with shorter or smaller expectation will start to sell earlier or after the smaller price increase, creating a supply of contracts, and hence contributing to the price trend reversal.

In situations when the parties have different expectations of the direction of price change and the supply and demand for contracts is similar then transactions will be done at the present price level. The party expecting the price increase will go long and the party expecting the decrease will go short; they both will accept the current price. However, those transactions will be done only in the light of an expectation that the price will change and the parties will gain on their positions. A flat price and a lack of expectations for it change, undermine the very existence of a futures market. For speculators to operate on that market, and this market to exist, the existence of common expectations of price change is a must. What this says is that the price changes on modern commodity markets sustain these markets, and what causes those changes is the same expectation by the majority of agents of the direction of price change.

Then, like a herd, they all follow that trend, some buying and others selling, all believing that they will gain on the change. And the factor which helps traders to build their expectations in the same direction is the technical analysis. That is why the rules of technical analysis - as norms of conduct - influence market price behaviour.

6 The goal of the knowledge based model of the oil market

Knowledge based models are built around a very simple and incremental model structure that consists of a knowledge base (KB), capabilities to 'perceive' changes in the environment and an inference engine.

We focus our efforts on the first of these elements, that is, the construction of a KB for the model. The idea for applying KBs to modeling the oil market stems from the possibilities that Artificial Intelligence offers. It has developed conceptualizations for knowledge representation and tools for its manipulation which allow for the simulation of systems of a high complexity, e.g., with more than 10^{100} alternative states (Berliner 1989). AI models can represent and manipulate any piece of knowledge that market agents use, and the representation of the market in the Knowledge Base can be an isomorph to the full description of the phenomenon in a natural language.

The goal of our Knowledge-Based Model is to use the acquired knowledge about the spot oil market in order both to give an explanation of how the oil market works and predict the oil price. However, since the 'oil market' has many interpretations the task has to be stated more precisely with respect to what is to be modeled and what price is to be predicted and for which time period. For example, before an investment in exploration and extraction of a new oil basin is made, an historical annual average price is considered and the prediction is made for a decade ahead. This activity is made within the frame of industrial policy of the oil producing country or strategic planning department of the oil concern.

On the other hand, the refiner purchasing oil for refining process is interested in the current price level and its possible change within the next few days - for one to four days ahead. Our model deals with the latter price - the spot oil market price - the price of the market where physical oil is sold and purchased. This delineation brings the phenomenon to manageable proportions and releases the model from the treatment of the most speculative variables such as the strength of OPEC, the vagaries of Arab countries, discovery of new oil deposits, changes in technology, new sources of energy, etc., as endogenous. These variables - which are difficult to predict, the information about them being both scarce and unreliable - may enter the model as exogenous ones if and only if the information about them is attended to by the agents in the market. However, the operation of the spot oil market is not completely public, hence that market is strongly connected to the futures oil market which offers more information. Moreover the futures market, though not a 'real' oil market, has a possibility of converting futures contracts into crude oil, hence must reflect the spot oil market conditions. This is a reason to consider both these markets as intertwined entities and apply, in the model, the price of oil on the futures oil market for the prediction of the price on the spot oil market.

7 Assembling the knowledge base

The KB of the model consists of productions which were acquired from the behaviour of an individual agent (trader). The selection of rules is based on the result of the tests on historical general market data. The question may arise of whether there is any guarantee that these rules, induced from the past observations will hold in the future. Taking into account Georgescu-Roegen's novelty-by-combination and Prigogine's evolution of systems into new structures, the application of this method does not seem to be proper. However, we follow Popper's (1968) declaration that "the belief that the future will be like the past is, in fact, reasonable and it is perfectly reasonable to act on the assumption that it will, in many respects, be like the past, and that well-tested laws will continue to hold (since we have no better assumption to act upon)."

The fundamental problem faced in assembling the KB was to assure for it a high degree of correctness and of generality, so it could produce good predictions and leave only a small number of indifferent (unidentified) cases. However, these principles are in contradiction; each new rule affects both the coverage and the reliability of the KB. Generally, increasing coverage reduces reliability.

We have assembled the KB applying two different methods, relying on:

- rules trade-off, i.e., a rule's contribution to the performance of the whole KB,[2] and
- an index taking into account both a rule's correctness and the correctness of its contrary rule.

That KB with a highest reliability shall be included into the model of the oil market.

[2]That trade-off was calculated as the rate of the change in KB correct predictions to the change in the KB wrong predictions. That change refers to the performance of the KB before inclusion of the rule.

In the case of both methods the order in which rules are placed in the KB is very important. Since the KB is run against data (a record), the earlier a rule is placed on the list the higher is its chance to match the record (which could also meet antecedents of some other rules).

7.1 Selection of rules

In the selection of rules the method used was to include as the first rule the one that was the most often correct. Then all remaining rules were evaluated to find the one with the highest level of trade-off for the whole KB (combined in the KB at the position after rule one); this rule was selected as rule two. Then each remaining rule was evaluated (combined and placed after rules one and two) and the one with highest trade-off was selected as rule three, and so on. In this way the final order of selected rules was determined by a rule's trade-off, after inclusion in the rule base at the last position. Each rule contributed marginally to the KB as it was added (Figure 2).

The KB was build incrementally; after each amendment the predictability of the KB was evaluated using a LISP program specially written for that purpose.[3]

The final order of rules included into the KB by application of trade-off method is as follows:

1.	bottom-key-day-reversal1	9.	close=high
2.	bottom-key-day-reversal3	10.	expiration-day
3.	peak-key-day-reversal1	11.	peak-key-day-reversal2
4.	bottom-key-day-reversal2	12.	today-up
5.	peak-key-day-reversal3	13.	buy-signal
6.	bottom-key-day-reversal4	14.	bull
7.	peak-island-reversal	15.	bear
8.	sell-signal		

The use of a trade-off score as a discrimination factor instead of a rule's correctness means giving the priority to the rule's contribution to the reliability of the whole KB over correctness of individual rules. That is why the

[3] A standard output from the evaluation program is:
The knowledge base consists of 4 rules:
1. BOTTOM-KEY-DAY-REVERSAL1
2. BOTTOM-KEY-DAY-REVERSAL3
3. PEAK-KEY-DAY-REVERSAL1
4. BOTTOM-KEY-DAY-REVERSAL2

No of fired rules = 4
Total number of cases in data-base: 1629
The data-base GASOIL-DATA consists of 1614 good cases
Wrong rules predictions 13, i.e., 1%
Correct rules predictions 94, i.e., 6% of all good cases or 88% of all cases with the true LHS
Not matched by rules 1507, i.e., 93%

SUMMARY OF CORRECT RULE PREDICTIONS

Rule's name	Times fired	% of all correct predictions
BOTTOM-KEY-DAY-REVERSAL1	13	14
BOTTOM-KEY-DAY-REVERSAL3	14	15
PEAK-KEY-DAY-REVERSAL1	20	21
BOTTOM-KEY-DAY-REVERSAL2	47	50
Total	94	100

Change in correct predictions 47
Change in wrong predictions 8
The rate is 5.875

order of the rules selected by this criterion is different to the order of rules by their correctness. The application of this criterion is beneficial to the KB as a whole since some rules with individually high correctness have no positive influence on the KB at all. This happens because some rules have similar clauses, and hence fire on similar cases.

8 Results of the model simulations

Simulation is a technique for achieving understanding and for predicting the behaviour of a system. Since the spot oil market is a poorly understood system with only limited knowledge being available about the nature of the laws that govern its behaviour, it is particularly susceptible to simulation using a simplified computer model. That imitation is possible because distinct physical systems can be organized to exhibit nearly identical behaviour (Simon 1981). Since we are seldom interested in explaining or predicting phenomena in all their details, we do not have to know, or guess at all the internal structure of the system but only that part of it that is crucial to the abstraction. And the crucial part of the oil market that traders are interested in is the price.

Consequently our model is not meant to explain the working of the oil market in all its details. Our model is an artificial object (computer program) which imitates the real (the spot oil market) by turning the same face (presenting an oil price prediction) to the outer system. The outcome of our model, a prediction of the direction of a price change (increase, decrease, no-change), is selected not constructed. In this way the inference process avoids the chaining of rules and the derivation of intermediate steps. Instead the system searches in the KB for the first rule whose condition (given on the left hand side) matches the model's input, i.e., market conditions, and then gives a straightforward solution. In any case when system is unable to select an appropriate rule (in only 2% of cases), it informs us that no rule matches the input, and hence cannot give a price forecast.

The data used come from a single futures traders records for a period of a year, from 1984 to 1991, confirmed by published data. The rules that we have incorporated in the KB come from this trader.

Table 1: Knowledge Base Performance, as percentage

Rule's number and name		Reliability	Generality	Correctness
1.	Bottom-reversal1	100	1	1
2.	Bottom-reversal	93	2	2
3.	Peak-reversal1	90	3	3
4.	Bottom-reversal2	88	7	6
5.	Peak-reversal	87	8	7
6.	Bottom-reversal4	87	12	10
7.	Peak-island-reversal	84	16	13
8.	Sell-signal	83	21	17
9.	Close=high	82	28	23
10.	Expiration-day	81	32	26
11.	Peak-key-day-reversal2	81	34	28
12.	Today-up	79	42	33
13.	Buy-signal	79	45	35
14.	Bull	77	64	49
15.	Bear	74	98	73

The performance the KB, assembled by rules' trade-off index, on these data is presented in Table 1 and its pictorial representation in Figure 2.[4]

The inclusion of new rules into the KB steadily increases its generality but reduces its reliability. The inclusion of all 14 rules into the KB (after the first rule) has increased generality from 1% to 98% but decreased its reliability from 100% to 74%. With that generality the KB predicted correctly 73% of all cases.

The base rate is the chance of having a correct prediction by flipping a coin. If an increase is predicted, then the chance of the price increasing above today's price within the next four days is this base rate, here 69%. The base rate for predicting a decrease happens to be the same with the data for this

[4] Definitions:

- *Reliability* is a proportion of correct predictions among matched cases
- *Generality* is a proportion of matched cases among the all cases
- *Correctness* is a rate of correct predictions among to the all cases

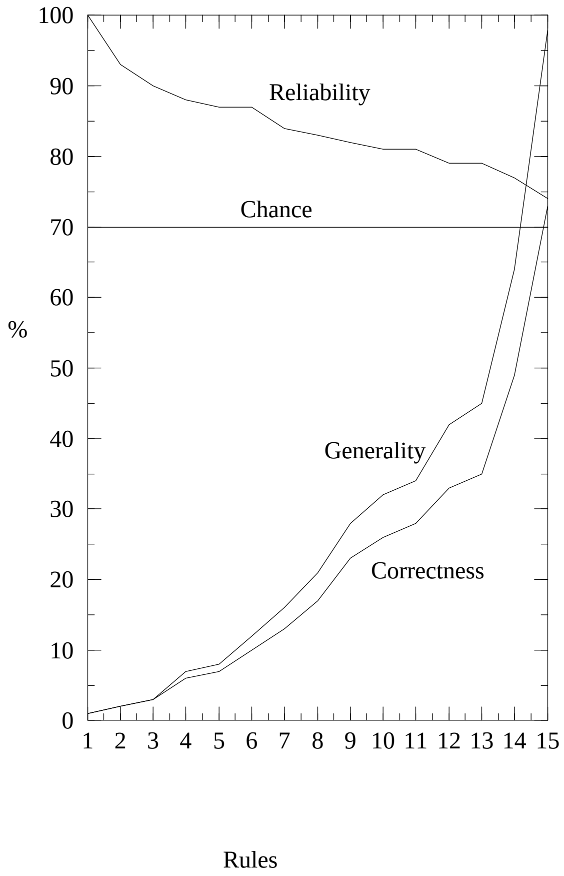


Figure 2: Knowledge Base Predictions (selection by trade-off index)

time period.

The most significant change in the performance of the KB occurred with the inclusion of the last two rules, that is, the Bull and Bear rules. They more than doubled the KB generality from 45 to 98% of all cases but decreased its reliability by five percentage points from 79% to 74%. The last rule, i.e., the 15th, alone brought the reliability down close to the level of the base rate; however, it increased the generality from 64% to 98%. The KB model's predictability, as well as the importance[5] of a particular rule, depends on

[5]The importance of a rule was defined as a proportion of its good predictions in the

Table 2: Data of other Commodity Markets

Commodity	Period	Number of cases	Base rate
Crude oil	1983-87	905	69.5
Live cattle	1989	160	71.5
Copper	1989	160	71.5
Wheat	1989	160	71.5

Table 3: Reliability and Generality of the Knowledge Base, after removing the two most general rules, as percentage

Commodity	Reliability	Generality
Gasoil	79	45
Crude oil	75	51
Live cattle	81	31
Copper	71	47
Wheat	76	38

the level of generality that is chosen.

9 Applicability of the model to other commodity markets

In the process of knowledge acquisition it was observed that some of the technical rules applied by the agent were applied to trading on different commodity markets. Also numerous 'how to trade' books prescribe the application of similar technical rules without discriminating among commodity markets. That is why we also tested our model on different data sets. The general description of the other data sets are presented in Table 2.

When the two most general rules were removed from the KB its reliability increased and the generality decreased for all commodities, as Table 3 shows.

total number of good predictions of the KB.

However, in the case of copper the reliability was still at the level of the base rate. Leaving aside the most general rules and considering only the more specific ones is adequate for the decision process of a trader who does not need to act every day but only when they recognize a pattern matching the highly reliable rules.

Not surprisingly the KB without the two most general rules fits best the data on which it was assembled, that is, the oil market. On that market it matched about a half of all cases with the correctness above 75%. In the case of live cattle the reliability was higher (81%), and in the case of wheat the same as for oil, yet the KB matched substantially less cases. For copper, the KB matched the similar proportion of cases as for oil, however, the reliability of prediction was at the level of chance. The differences may indicate that the knowledge contained in the KB (the rules and their order) has some knowledge items more appropriate for making good predictions on the oil rather than other markets.

There is a significant difference in the importance of individual rules in different commodity markets. Yet, it is true in the case of all analyzed commodities that three to four rules accounted for more than half of all correct predictions. The appropriate data (without the two most general rules) are presented in Table 4. The bottom-key-day-reversal rules contributed more than a fifth of all correct predictions in the case of each analyzed commodity. This indicates that some of the rules contained in the KB are generic rules for trading on futures markets absolutely alienated from specific features (fundamental factors) of any particular market.

The rules perform similarly on different markets and hence indicate that the basic principles of trading on futures commodity markets are similar. Those markets share only the name of the market with the real commodity, but the standard operating rules are the same. We may assume that these rules represent the most meaningful patterns attended to by traders in the technical analysis, and hence constitute the knowledge for making good price predictions that we are looking for. However, what makes the KB composed out of similar rules to perform differently on different commodity markets is the ordering of rules. That ordering is commodity specific.

Table 4: Importance of individual Futures Market rules, as percentage of all cases correctly predicted by the KB for the corresponding market

	Market:				
Rule:	Gasoil	Crude oil	Live cattle	Copper	Wheat
Peak-key-day-reversals	21			23	
Bottom-key-day-reversals	22	22	22	25	27
Close=high	15	15			
Sell-signal		11	14	13	24
Today-up	16	16	31	25	20
These five rules together	74	64	67	86	71

10 Conclusions

The results of the model's simulations of the oil price for the period of one to four days were quite good, both on European and American markets. The model's predictions were still better when the restriction of its high level of generality was waived. Then, out of the matched cases (45% of the total cases) almost 4/5 were correctly predicted.

The rules which performed best on all commodity markets are: peak-reversals, bottom-reversals, close=high, sell-signal, and today-up. Without taking into account the most general rules (bull and bear) they contributed above 2/3 of all correct predictions. Not all rules acquired from our agents performed well. Contrary to the believe of our agent and the trading community the RSI rules and island-reversal rules turned out to be quite weak. Their performance was below the chance level.

The composition of our KB assembled by the application of trade-off score as a discrimination factor - which takes into account a rule's contribution to the reliability of the whole KB instead of its individual correctness - is as follows:

1.	bottom-key-day-reversal1	9.	close=high
2.	bottom-key-day-reversal3	10.	expiration-day
3.	peak-key-day-reversal1	11.	peak-key-day-reversal2
4.	bottom-key-day-reversal2	12.	today-up
5.	peak-key-day-reversal3	13.	buy-signal
6.	bottom-key-day-reversal4	14.	bull
7.	peak-island-reversal	15.	bear
8.	sell-sign		

The model's predictive power was higher when the rules were applied to live cattle market, but significantly lower when applied to other commodities and markets such as copper and wheat. Yet, taking into consideration both the reliability and the generality of the KB, the model performed best on the oil market. This suggests that some technical rules and their ordering in the KB is commodity specific and results in better performance on some commodity markets than on others.

The alienation of both futures markets and media conveying information, from a real flow (trade) of commodities is one of the reasons for high price volatility. That volatility is further amplified by the transformation of the futures markets into the largest games for speculators. Unfortunately futures markets, though completely separated from real trade, are the only source of real time price information, not only for the majority of market agents i.e., speculators, but also for real economic agents who must take rational economic choices. Their rational decisions (as they see them) are based on rather weak technical rules which can be considered the only knowledge for making good price predictions in the oil market.

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