# Understanding the Valuation of Swing Contracts

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## Introduction

Contracts for the purchase and sale of gas which provide some flexibility about the timing of delivery have been commonplace in the natural gas industry for many years. Possibly bundled with constraints about overall minimum and maximum take amounts, these contracts are alternatively known as take-or-pay, variable base-load factor, or swing contracts [1]. Interestingly, they have been around long before their optionality content was fully appreciated and, even when such content was truly understood, the techniques used for pricing them often did not adequately take into account some important features of these contracts. As a result, the embedded options were sometimes mispriced, if not neglected altogether.

Given the practical importance of this type of contract in the natural gas market, and possibly its future role in the emerging electricity market, it is our goal in this paper to describe some of the crucial features of these contracts, and to provide some insights into the main ingredients that, in our opinion, ought to be incorporated into a consistent pricing scheme. As we shall see, the appealing and easy-to-understand specifications of many of these contracts actually hide a structure which is quite complex and difficult to value.

We will describe swing contracts in terms of a generic underlying commodity, although in the examples we will refer to the natural gas market conventions and terminology. The reader should keep in mind, however, that the described framework is more general and can be applied to electricity, oil, and similar "continuously available" commodity markets. For sake of clarity we will start with a very simple contract, and will add complexity to its specifications layer by layer, to clarify the interplay of the added features and to gain some intuition about the proper way of incorporating them into a pricing methodology.

## The swing contract

The basic starting point is a contract guaranteeing one of two parties periodic delivery of a certain amount of commodity (the nominated amount) on certain dates in the future, within a given delivery period, at a stipulated constant price (the strike price). The contract thus provides some protection against day-to-day price fluctuations from inception to expiration of the contract. Protection is full if the strike price agreed upon is fixed when entering the contract; protection is only partial, if the strike price is linked to the value of the spot price at the beginning of such period. As an example, consider a utility interested in purchasing 10,000 MMBtu of gas per day for the month of February. The purchasing price could be a published monthly index to be known after bid week at the end of January, a fixed price to be set now, or some combination of these two possibilities. To be as specific as possible in our example we will assume that the price to be paid for gas is fixed at $2.00/MMBtu. Depending on the choice of the strike, pricing of this basic structure can depend on the particular modeling of the index [2] and on the settlement provisions (is gas going to be paid day by day when delivered, or all together at the beginning or at the end of the month?), but it is a simple exercise since the contract can be thought of as a monthly strip of daily forwards. For this reason we will refer to this as the strip component of the contract.

But what if the party purchasing the commodity wants to have extra flexibility with the same price protection? In particular the strip described above might cover the expected base load only, but an additional amount of commodity might be needed on a certain number of delivery dates, although it is not evident now exactly when these dates might occur. More generally the party might want the option to change ("swing") the amount delivered from the nominated amount to a new amount, on a short notice, for a limited number of times [3]. We will call this the option component of the contract.Continuing with our specific example, the utility might expect that on fifteen days during the month its actual need for gas might be different, say 4,000 or 15,000 MMBtu instead of the contracted daily 10,000 MMBtu. The change might be required because of demand fluctuations due to weather changes, and expected high storage costs, or because of particular spot price expectations. For whatever reason, the utility might want to purchase the strip together with fifteen swing rights to alter the nominated amount to either one of two new stipulated levels, in this case 4,000 or 15,000 MMBtu for the same fixed price of $2.00/MMBtu. In the natural gas market, typical contracts involve daily swings where one swing right applies to the amount of gas delivered on the following day, and only a single swing can be exercised on each day. What is the fair value of these rights and what is an appropriate framework within which to price this structure? Note that the swing rights are clearly options: the utility can choose but it is not contractually obliged to swing on any day. But these options are "coupled", since exercising one swing on a particular day prevents exercise of other swings on the same day [4]. The options are American in character, i.e. the exercise dates are not predetermined and can be selected at will by the utility, depending on market conditions. Once the utility has bought these options, its non-trivial task during the delivery month is then to identify an optimal exercise strategy which responds to changing market conditions.

To price the swing rights we are going to make the usual assumptions that a liquid market for these options and for the underlying physical commodity is in place, that players in this market make decisions in order to maximize their profits, and that transaction costs are negligible. Although some of the assumptions might be questionable especially in new developing markets, they nevertheless provide a good starting point for a general quantitative analysis.

Let's consider first two relatively simple special cases: the first case, where a single swing right is purchased ("one-swing"), and the second case, where the number of swings is equal to the number of delivery dates within the delivery periods ("full-swing"). Such limiting cases are important because they provide important benchmark values for the more general case discussed below. Returning to our example again, the one-swing contract can be viewed as the option to either purchase an amount X (5,000 MMBtu) , or to sell back to the provider an amount Y (6,000 MMBtu ) at the price of K ($2/MMBtu), on any day in February. This is similar to what is known as an American chooser option [5] and can be priced similarly: a tree [6] is used to model price dynamics and evolution of the option price. The option price at the end of February (on the day preceding the last delivery day according to our conventions) is uniquely determined by the spot price level on that day. Computing backward in time along the tree allows one to decide, on each day when exercise is permitted, whether it is economically convenient to exercise the swing right (for instance, by calling the 5,000 MMBtu if the spot price is above the strike, and selling the gas on the spot market if it is not needed), or whether the swing option is worth more if left unexercised. Working backward in the tree to the present day provides the desired option value.

The above shows that a one-swing right exercisable at a specific point in time is essentially equivalent to a chooser option. But it does not deal with the question of interactions between multiple swing rights, nor the timing of the swing decisions. However, it makes clear that a chooser option value can be used as a useful benchmark for the one-swing contract. Another benchmark comes from considering all possible swing rights, i.e. a swing every day.

The crucial point in analyzing the full-swing case is that the optimal exercise strategy is trivial. Since one and only one swing can be exercised on any delivery date, whether or not one ought to be exercised on a particular date only depends on its exercise value. In other words the full-swing is very similar to a strip of European chooser options [7] that can be valued by analytic methods.

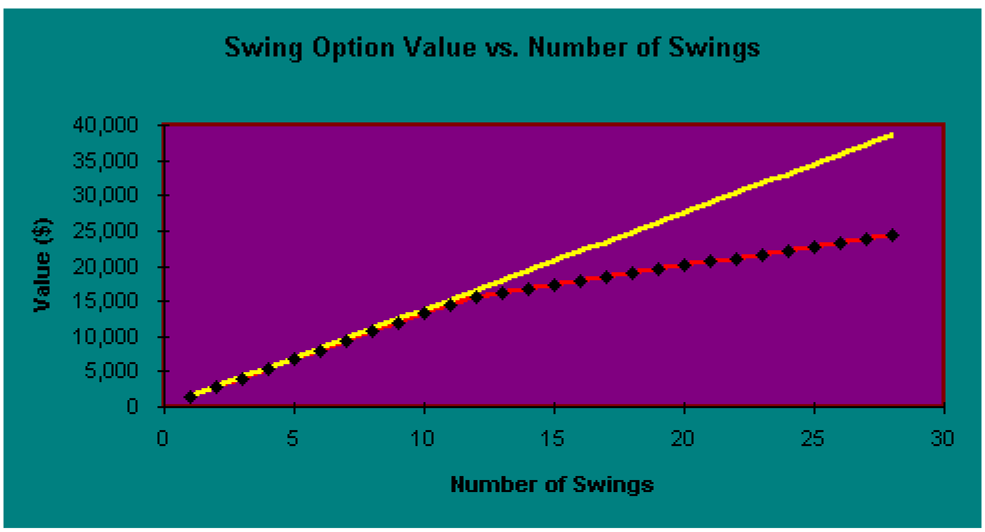
The intermediate case, involving a limited number of swing rights, is the most interesting in practice, but also by far the most complex to value. Again, a tree method is appropriate to solve for the optimal exercise strategy for each of the swings owned. But now, because of the previously mentioned coupling between the different swings, all the swings have to be treated at once.

Another way to appreciate the nature of the problem is to consider which parameters, at any point in time and in particular during the delivery period, must be specified to fully define the option component of the contract. Clearly, the number of swing rights left unexercised, let's call it n, is a crucial piece of information which depends on the exercise strategy followed up to that point in time. As a result, at each tree node we have to keep track of the option component value as a function of the possible values of n, and in each case separately compute exercise and option values. Note, however, that any exercise decision couples nodes corresponding to n and n-1, since exercising one right reduces the number of swings not yet exercised by one.

Up to now the contract specifications we have described did not set any total volume constraint (for the whole delivery period). In reality, the customer holding the swing rights is frequently required to take at least a minimum amount and/or to not exceed a maximum amount over the delivery period. These "must take delivery" provisions are often attached to contracts under the form of penalties that must be paid at expiration of the contract if predetermined overall volume constraints are not met. Penalties make the option component strongly path-dependent, since whether or not to exercise a swing right on a given day will now depend not only on the market conditions for the day, and on the number of days to expiration, but also on decisions made in the past which affect the volume still deliverable.

The contract thus might specify a maximum and a minimum total amounts, say M and m, respectively, to be delivered over the total time period. A selected penalty provision quantifies the costs associated with a violation of the constraints; "unit penalty" and "buy back" penalty provisions are common in the natural gas industry. Let's again go back to our example and assume that the contract also stipulates that the utility must take a total of 210,000 MMBtu. With a buy-back provision this would imply that if the utility, by the end of February and following exercise of its swing rights, bought say 8,000 MMBtu less than m (210,000 MMBtu), it will have to buy the 8,000 MMBtu back from the provider at a unit price of Max(K-S, 0), where K is the unit strike price ($2) and S is the spot market price at expiration. If a unit penalty instead is specified (say $10/MMBtu), this would force the utility to pay $80,000 (=8,000(10) for the violation of the "minimum take" requirement.

It is convenient at this point to examine the actual costs of the option component in a few specific cases similar to the example discussed so far. In the following graph we plot the value of the swing component of the contract specified above [8], as a function of the maximum number of swing rights available to the utility. For sake of comparison we have also plotted a straight line corresponding to the product of the option component for one-swing multiplied by the number of swings.




(The FEA SWING add-in software for Excel 5.0c was used to create the graph.) Several comments about this graph are in order. (1) A complete leveling-off of the swing contract price is never achieved in spite of the minimum take requirement; since the utility can swing both up and down in volume, all swings can be effectively used while avoiding penalties. (2) The price for any number of swings is always below the straight line, representing multiples of the one-swing values. This is always true, and reflects the fact that multiple swings cannot be exercised on the same day: the optimal exercise date for the first swing (hence a maximal price) cannot be used for the other swings. (3) The strip component has zero value if the gas is paid for daily when delivered. The total value of the contract then reduces to that of its option component. (4) Let's consider the price in the case of fifteen swings, which is about $17,200. This corresponds to the up-front fair premium the utility should pay for the swing rights. Another equivalent way to pay for the option would be to agree on a higher price for gas by increasing the strike, so that the new contract (strip + option component) be equal to zero. A calculation shows that, in this case, the strike price should go to $2.06: the utility should expect to pay, in this particular case, about $0.06/MMBtu. But swing rights may be more or less expensive, depending upon market conditions. (5) the option would be cheaper if the strike were to be set equal to the index, because of the reduced price protection provided in this case. Still, the cost then would be about $11,000, or, equivalently, the index should be increased by about 1.8%, about $0.04/MMBtu, to pay for the option value.

## Variations

The variety of swing contracts actually traded is even richer than the one discussed so far. A swing right might allow the owner to change the amount delivered to any value within a certain range, as opposed to two discrete up and down levels. In principle, when no penalties are present and according to our assumptions, it will always be economically convenient, however, to swing to one of the boundaries in the range. The problem reverts then to the one discussed above.

A different type of swing right allows the owner to change the amount of commodity received not only on the following delivery date, but until expiration or exercise of another swing right (we can think of this as a swing right on the nominated amount). This swing is much more costly since the owner can take advantage of pronounced price movements for several delivery dates with the exercise of a single right. The cost can be reduced by requiring that changing the nominated amount from a minimum to a maximum value can only occur in a number of smaller discrete steps, sometimes called ratchets, to be taken one at a time. To give an example, the utility might nominate 10,000 MMBtu for daily delivery, and buy swing rights that would allow it to change this value to either 15,000 or 5,000 MMBtu. Or it could buy swing rights allowing to decrease or increase the nominated value by 1,000 MMBtu each time a right is exercised.

In all these cases the tree method outlined above can be generalized to provide a proper valuation. A single contract might encompass several delivery periods. For instance, a utility might buy 10,000 MMBtu at monthly index for six months in the future, with the option to swing a certain number of times each month. This assures that the strike price be reset at the beginning of each delivery month to the new monthly index. Clearly this contract can be valued as a six-months strip, where the striplets are the monthly contracts previously described. To complicate things further, a new layer of volume constraints can be set up for the whole strip. So, in the previous example, a minimum take requirement of 250,000 MMBtu on average per month, might be added to an already existing 220,000

MMBtu minimum per month. Valuation in this case becomes very difficult and time consuming, because the individual monthly striplets become coupled and cannot be valued separately. It is our belief, however, that the insights provided by a deep quantitative understanding of the basic monthly contracts described above will help developing accurate approximate solutions in even the hardest cases.

In conclusion, the use of "swings" can add useful flexibility to contracts in the natural gas and electricity markets. When flexibility is sold it will decrease the cost of the underlying commodity, when it is bought it will increase it. A proper valuation and hedging of these contracts, however, provides considerable challenges, even when relatively simple one-factor models are employed to describe the evolution of the underlying price. We will discuss some of the issues relevant to hedging swing contracts in a separate article.

## Footnotes

- 1. See V. Kaminski and S. Gibner, Exotic Options, in Managing Energy Price Risk, Risk Publications.
- 2. A reasonable approach is to reduce bid week to a point in time (the actual length of bid week has indeed been shrinking considerably in past years), and to relate the expected value of the index to the value of a traded gas future contract.
- 3. An interesting alternative possibility is that the party long the strip might be willing to give away some flexibility to reduce its costs. In other words this party wants to be short the swing option.
- 4. For a much stronger "coupling" see later on when penalties and total monthly delivery constraints are introduced.
- 5. See M. Rubinstein, "Options for the Undecided", RISK, April 1991. Note, however, that albeit similar in spirit, the one-swing American chooser specifications differ somewhat by those described by Rubinstein.
- 6. See Hull-White, Options, Futures, and other Derivatives Securities, Prentice Hall for a better discussion of general tree methods.
- 7. If the specification of the contract only allows up (or down) swings in volume, chooser options should be replaced by calls (or puts).
- 8. We valued the contract on January 1, 1997 and have assumed, for that day, a February future price and a strike price of $2/MMBtu, an annualized February spot price volatility of 40% and a 6% risk-free rate. The penalty provision is "buy-back". All the other parameters were specified in the text.

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