# Real Options Valuation of Highly Uncertain Investments:

# Are UMTS-Licenses Worth their Money?

by

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## Abstract

We adopt a real options approach to analyse the value of recently auctioned UMTS-licenses, focussing on Germany as the largest European market. For that purpose we develop a real options model with an abandonment as well as a growth option. Not having an appropriate underlying security of the options, we pursue an indirect approach by assuming a stochastic process for the number of mobile phone users. As we also take account of the optimal option exercise, we have to rely on numerical analysis rather than on closed form solutions. Our real options model enables us to value the flexibility inherent in the UMTS investments. On the basis of a sensitivity analysis it turns out that two variables are crucial for a positive expected value of the investments: the initial customer base of a mobile phone company as well as the realised net cash flows per user.

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# Non-technical Summary

Real options modelling is currently revolutionising decision making and valuation processes across corporate America and among leading corporations around the world. It is a new and powerful valuation and strategic decision-making paradigm when investment projects are to be undertaken in highly uncertain environments. The real options approach captures the value of managerial flexibility to react to future developments with the benefit of better information. Traditional techniques like discounted cash flow analysis do not take this potential value of managerial flexibility into account. Thereby, a potentially large part of the value of an investment project is neglected and investment decisions are heavily distorted. In contrast to the traditional techniques, the real options approach builds upon the methods developed in option pricing theory. This not only allows to quantify the value of managerial flexibility but also provides a challenging new way of thinking.

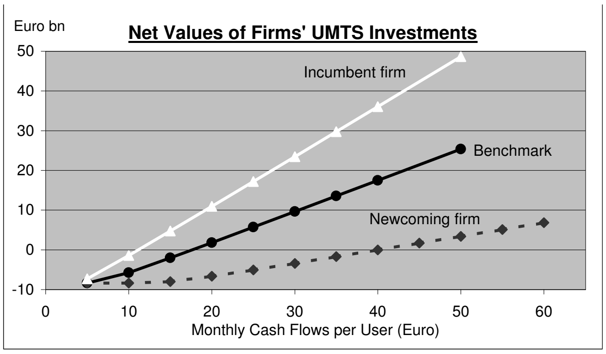
We employ this new valuation technique to address one of the largest investments undertaken by a group of companies, the investment in UMTS-licenses. Focussing on the auction of UMTS-licenses in Germany, our basic question is whether the licenses can ever be worth their money. We then analyse for which licensees this is most likely to be the case. The general model we develop here is applicable to a larger number of valuation problems. Therefore, our study can easily be used as a starting point to evaluate highly uncertain investments other than UMTS, such as R&D projects or e-commerce investments.

The development of a real options model allows us to capture and quantify the uncertainty as well as the potential flexibility associated with the new mobile phone technology. We thereby allow both for an abandonment option and a growth option. It turns out that the latter is the more important option associated with the UMTS-licenses. It stems from the fact that UMTS enables the operators to potentially exploit the spectrum of transmissions by supplying further applications. Adding both option values to the conventional value of discounted cash flows gives us a comprehensive and complete picture of the UMTS investments and avoids

neglecting crucial elements in their valuation.

We show that for the average license, the growth option is often the decisive factor: in its absence, the total net value of the investment is negative and the telecom firms do not earn the money they have spent. In the benchmark case, the net value of the investment amounts to Euro -1220 million in the absence of the growth option. Including the option, our analysis shows that investing in UMTS-licenses may indeed create value for the firms' shareholders as the net value increases to Euro 1824 million. With a detailed sensitivity analysis for the underlying parameters, we are able to identify the value drivers, of which the cash flow generated per user is the most important.

By allowing for different starting points of the telecom firms in our asymmetric scenario, we identify the initial number of users as the second main value driver. Whereas for the incumbent firms (such as T-Mobile and Mannesmann Mobilfunk) the investment pays off in most of the scenarios, almost the opposite is true for the newcoming firms in the German telecommunication market (e.g. Group G3 and to a lesser extent MobilCom). For them, a lot of effort will be necessary to earn the initial investment outlays. Even with rather large cash flows per user the total net value (including the growth option) is negative (see chart). With these results, implications for the firms' future strategies can be readily inferred.




By pursuing our real options analysis, we are able to shed a new light on the value of UMTS-licenses. With better information on the underlying parameters, our approach can be used to improve this new valuation technique even further. In addition, it provides a perfect tool and starting point to address related valuation problems.

# 1 Introduction

Given the speed of technological progress, it is often very difficult to assess the value of investments in high-tech industries such as the telecommunication industry. For the outside observer it seems as if a significant number of investments are undertaken without a precise quantitative approach. Very often relative valuation methods are used or simple multiplicative methods are employed. This becomes quite obvious in the course of merger activities. Projects or firms are valued relative to the value of their competitors. Alternatively, sales multiple valuations (e.g. number of customers times the implicit value of a customer) are employed. All these very crude and often misleading measures are used since the correct method, namely a properly designed contingent claims analysis, seems to be difficult to implement.

Besides a high degree of uncertainty, a high degree of future flexibility is inherent in these types of investment. We show that these difficulties can be resolved and apply a real options approach to one of the most widely discussed investments in the telecommunication area, the investment in UMTS-licenses. The development of a real options model allows us to capture and quantify the uncertainty as well as the potential value of flexibility associated with the new mobile phone technology. The value of flexibility stems from the fact that this new technology enables the operators to potentially exploit the spectrum of transmission by supplying further applications. In the UMTS market, operators will introduce the most profitable applications first, like multi-media messaging and news and information services. In addition to these early applications, there exists the option to expand into further application if the customer base has evolved properly and the new applications can be expected to generate sufficient cash flows.

In order to capture these characteristics, we develop a model containing a combination of an abandonment with a growth option. Our approach differs from many other real option models (see e.g. Micalizzi 1999) by using an indirect way to model the value of the inherent option. Since there is no appropriate traded security which we may use as an underlying, we have to solve a more difficult valuation problem. Among other things, we can not make use of a closed form solution (e.g. the Black-Scholes formula) but rather have to rely on numerical procedures. However, letting the number of users follow the stochastic process has the advantage of using a variable which is easily observed and verified. To model the stochastic process, we apply a standard Cox et al. (1979) multiplicative binomial approach. From a methodological point of view and with respect to the focus of the analysis, Schwartz/Moon (2000) and Schwartz/Zozaya-Gorostiza (2000) who use a least-square Monte Carlo valuation approach developed by Longstaff/Schwartz (1998) are the studies most closely related to ours. We apply our approach to the specific case of UMTS-licenses in Germany, allowing the licensees to operate this technology potentially until 2020. By pursuing an extended sensitivity analysis we investigate the most crucial parameters for the value of the investments under consideration.

We show that two variables affect the total value of the investment particularly: the initial customer base of a firm and the net cash flows generated per user. With regard to the former variable it turns out to be very helpful to distinguish between incumbent and newcoming firms. Incumbents can build on a fairly established customer base and hence have better chances to gain a larger market share than a newcoming firm. Consequently, the net value of a licence substantially differs between the two types of firms. Our valuation approach can therefore not only be used to analyze the value of the UMTS-licenses but, by pointing to the crucial value drivers, also serves as an important starting point for a properly designed management strategy for the owner of UMTS-licenses.

The paper is organized as follows: in the next section we outline the basic structure of our real options model. In section 3, we use our approach to analyze the potential value of UMTS-licenses, focusing on the German market. We thereby distinguish between the symmetric and the asymmetric case, the latter taking account of differing starting points among the telecom companies. In section 4, we provide a brief discussion of further extensions to our approach and conclude the analysis.

## 2 A Simple Model of Two Real Options

The starting point of our modelling approach is that the number of users adopting the new technology follows a stochastic process. In the base model, the representative user is assumed to generate at least a given amount of revenues using the available services. Subtracting variable costs from revenues gives us the cash flows per user in each period. These cash flows per user have to be contrasted with a total fixed cost per firm in each period under consideration. This implies that total cash flows per period may decline to a negative value, which forms the basis of our abandonment option. Whenever expected future net cash flows (cash flows per user times number of users minus costs) become negative, it is sensible to abandon the project altogether. This flexibility during the life of the project creates additional value – the value of the abandonment option.

Initially, the project is started with the most promising applications of the new technology and with the option to expand these applications into new fields by investing a certain amount (in marketing, technological developments etc). This creates a growth option: the firm has the option to raise future cash flows by expanding in these usages (which, by the way, also may increase fixed costs per period). This flexible investment strategy is undertaken if it creates value, the value of the growth option.

A vital point of our approach is that it is the number of users, $U$, which follows a stochastic process, and not a traded security which would serve as an underlying. We assume the number of users to follow a geometric Brownian motion in any small time interval $dt$

$$dU = \alpha U dt + \sigma U dz \tag{1}$$

with $\alpha$ being the drift rate of the number of users. $\sigma$ reflects the instantaneous standard deviation of $U$, and $\Delta z$ is an increment of a standard Wiener process. The above continuous diffusion process can be approximated by an equivalent discrete-time process with the same first two moments (see Trigeorgis (1996), p. 321). The stochastic process lasts for $T$ periods. In the discrete-time case we divide $T$ by the number of steps $N$ in order to get the discrete time intervals $\Delta t = T/N$. Within each time interval, $U$ follows a Markov random walk with drift. With probability $p$ it increase from $U$ to $u \cdot U$ and with the complimentary probability $(1-p)$ it decreases to $l \cdot U$ (with $u = 1/l$). The expected number of user in period $t+1$ is $U_{t+1} = U_t e^{\alpha \Delta t}$, hence

$$U_t e^{\alpha \Delta t} = puU_t + (1-p)lU_t \tag{2}$$

Using the definition of the variance it must hold that

$$pu^2 + (1-p)l^2 - [pu + (1-p)l]^2 = \sigma^2 \tag{3}$$

Taking the conditions $u = 1/l$, $\Delta t = T/N$ together with Eqs. (2) and (3) yields[1]

$$\begin{aligned} p &= \frac{e^{\alpha T/N} - l}{u - l} \\ u &= e^{\sigma \sqrt{\Delta t}} \\ l &= e^{-\sigma \sqrt{\Delta t}} \end{aligned} \tag{4}$$

This allows us to express the number of users at time $t$ as a function of the starting number of users, $U_0$,

$$U_t(i) = U_0 u^i l^{t-i} \tag{5}$$

where $u$ and $l$ are given in equation (4). The index $i$ refers to the number of increases realised up to this point.

We are now in a position to define the net cash flow stream. By assumption, the representative user generates revenues (net of variable costs) $X$. In addition, firms have to take their fixed cost expenses ($F$) into account. Therefore, we get for total net cash flows in period $t$ with $i$ increases in the number of users (and $t-i$ steps downward) starting from $U_0$:

$$C_t(i) = U_t(i)X - F \tag{6}$$

[1]See for a detailed discussion of a related derivation Hull (2000), chapter 16.

If the project is continued throughout the growth period (from $t = 0$ to $t = T$) under all eventualities, we can define the expected value of the project at any point $(t, i)$ recursively as

$$EV_t(i) = C_t(i) + [pEV_{t+1}(i+1) + (1-p)EV_{t+1}(i)]\, e^{-r} \tag{7}$$

for $0 \leq t \leq T - 1$. This value consists of the current period's cash flows and the expected present value as of the subsequent period, in $t + 1$. By noting that the number of users is stationary after $T$ and therefore net cash flows stay the same between $T$ and the final period of the project, $T^*$, we can calculate the expected value of the project at point $(T, i)$

$$EV_T(i) = \sum_{\tau=T}^{T^*} C_T(i) e^{-r(\tau-T)} \tag{8}$$

as the sum of discounted cash flows in the remaining periods.[2] With the project value at the end of the growth period being hence defined, we will be able to calculate the expected project values of earlier periods by recursion, using equation (7).[3] Ultimately, this gives us the expected project value in the initial period, $EV_0(i = 0)$.

Carrying the project through all bad realization is, however, not always an economically optimal decision. Instead, it is value-maximizing to abandon the project if (and only if) the foreseen value of the project at a certain point $(t, i)$ is negative. Taking this into account, gives us a new expression for the (optimal) expected value of the project which already takes this kind of flexibility of management into account:

$$\tilde{EV_t}(i) = C_t(i) + \max\left\{pEV_{t+1}(i+1) + (1-p)EV_{t+1}(i), 0\right\} e^{-r} \tag{9}$$

for $0 \leq t \leq T - 1$, and

$$\tilde{EV_T}(i) = C_T(i) + \max\{\sum_{\tau=T+1}^{T^*} C_T(i) e^{-r(\tau-T)}, 0\} \tag{10}$$

[2]Strictly speaking, this is no 'expected' value any more, as any uncertainty about future cash flows has been resolved at $t = T$.

[3]Technically, this was done by means of a fairly simple routine programmed in Visual Basic.

Consequently, the total value of the abandonment option can be derived as

$$AO_0 = E\tilde{V}_0 - EV_0 \tag{11}$$

Right from the starting point of the project, firms have the possibility to expand the existing applications into new fields. By investing $Z$, new applications can be acquired and used by the customers. This generates additional revenues but also additional costs. Whereas net cash flows increase by a factor $m$ ($m > 1$) with the new set of applications, fixed costs per period now amount to $nF$ ($n > 1$). In case this growth option is exercised new cash flow in each period $t$ read as:

$$C_t^N(i) = U_t(i)mX - nF \tag{12}$$

Hence, the additional net cash flows per period which stem from exercising the growth option are

$$\Delta C_t^N(i) = C_t^N(i) - C_t(i) \tag{13}$$

Investing $Z$ in $t$ leads to these additional cash flows starting from $t+1$ until $T^*$, the end of the project.

Exercising the growth option is only sensible until the last period of the growth process: a firm, having reached period $T$ without having exercised the growth option yet, will know its future cash flows completely. It will then either immediately exercise the option, or not exercise it at all. The value of the growth option in period $T$ can hence be expressed as

$$GO_T(i) = \max\{E\tilde{V}_T^N(i) - E\tilde{V}_T(i) - Z, 0\} \tag{14}$$

where

$$E\tilde{V}_T^N(i) = C_T(i) + \max\{\sum_{\tau=T+1}^{T^*} C_T^N(i)e^{-r(\tau-T)}, 0\} \tag{15}$$

defines the expected value of the project after an expansion into the new applications in $T$. Similarly, for earlier periods ($0 \leq t \leq T-1$) this value, including the abandonment option, is defined as

$$
\begin{aligned}
E\tilde{V}_t^N(i) = \quad C_t(i) \quad &+ \max\left\{p\left(E\tilde{V}_{t+1}^N(i+1) + \Delta C_{t+1}^N(i+1)\right)\right. \\
&\left. +(1-p)\left(E\tilde{V}_{t+1}^N(i) + \Delta C_{t+1}^N(i)\right), 0\right\} e^{-r}
\end{aligned}
\tag{16}
$$

For the remaining points in time, i.e. from $t = 0$ to $T - 1$, we have to take into account that waiting (that is to postpone exercise of the growth option) is a valid alternative. Therefore, we have to balance the value of immediate execution against the value of later execution. The value of the growth option can thus be written as:

$$
GO_t(i) = \max\left\{E\tilde{V}_t^N(i) - E\tilde{V}_t(i) - Z, (pGO_{t+1}(i+1) + (1-p)GO_{t+1}(i))e^{-r}\right\} \tag{17}
$$

Combing (9) and (17) yields the total value of the entire cash flow stream:

$$
TV_t(i) = E\tilde{V}_t(i) + GO_t(i) \quad . \tag{18}
$$

Again, we are thus able to derive the total value in the initial period, $TV_0(i = 0)$, numerically by recursion.

# 3 Valuation of UMTS-Licenses

## 3.1 Facts behind the German UMTS-Licenses

### 3.1.1 What is UMTS all about?

Universal Mobile Telecommunication System, or UMTS, represents the third generation mobile transmission technology. This new technology will enable high speed, high quality mobile multimedia applications. UMTS allows an increase in transmission speed of up to 2 Mbps (which is almost 200 times the speed of today's GSM technology). UMTS not only provides significant improvements with respect to the currently prevailing GSM technology, but also with respect to the intermediate GPRS and EDGE technologies. In contrast to the latter, the main difference is not in speed capabilities but rather in its efficient use of the transmission spectrum which allows a larger set of potential applications with UMTS. This increase in spectrum is the main value of the new technology: it allows to supply, besides the volume of oral communication services, a large set of multi-media services. From the current point of view, one can distinguish seven potential areas of applications: oral communication, mobile orientation support (e.g. electronic city maps), transmission of games and news, multi-media messaging, m-commerce, video-transmission and access to the internet via mobile phone. It is expected that the mobile phone operators will start with the first four applications and keep the option to expand into the other applications.

### 3.1.2 The German Auction

The German government allocated licenses to operate UMTS in Germany through a multi-period sealed-bid auction. The UMTS-licensees are allowed to operate a mobile phone service on the basis of the UMTS-standard until 2020. Of the two stages of the entire auction only the first one was economically important. In this first stage 120MHz of paired spectrum have been sold in twelve blocks. Since each bidder could bid for either two or three blocks, the total number of licenses was not predetermined. With two or three block licensees, respectively, the number of potential licensees ranged between four and six. The number of paired blocks each participant in the auction was bidding for was of vital strategic importance. Depending on the final number of blocks, four, five or six firms would have had to split the future German market. A crucial feature of the auction was that a bidder could never increase the number of blocks he was bidding for over time. That is, a firm bidding for two blocks once could never bid for three blocks anymore. This – and the foreseen impact on the division of the entire market – gave a strong incentive to bid for three blocks, especially for the incumbents.

Initially twelve bidders backed by individual firms or groups of firms submitted to participate in the German auction. Of these twelve only seven finally entered the auction process. The group of bidders was quite heterogenous, consisting of basically four incumbent firms (the two market leaders with their operating systems D1 and D2 as well as networks E1 and E2 with a smaller customer base) and three entrants (Group 3G, Mobilcom Multimedia and Debitel).

After 11 days and a total sum of all bids of almost Euro 40 billion, one of the bidders, Debitel, dropped out of the race. However, since the market leaders, Mannesmann Mobilfunk and Deutsche Telekom, were bidding for three blocks the auction continued. After 3 further days and a lot of gossip regarding implicit cooperation among the two market leaders (explicit cooperation was strictly forbidden under the greatest possible sanction: the exclusion from the bidding process) the auction finally came to an end. To the surprise of many observers the entrants did not drop out of the race and the incumbents finally surrendered. The incumbents decided to bid only for two blocks at the cost of an emerging 6-competitor-market. The total sum of bids amounted to Euro 50.5 billion. Due to the symmetric outcome of the bidding process each of the six licensees had to pay more than Euro 8.3 billion.

As already mentioned, the group of licensees is quite heterogenous. This can be illustrated best by looking at the number of mobile-phone customers these companies or groups of companies had at the end of the year 2000. The two market leaders, Deutsche Telekom MobilNet and the Vodafone subsidiary, Mannesmann Mobilfunk both had almost the same number of customers, 19.1 and 19.2 million, respectively (see FAZ 2001). In contrast, Viag Intercom (belonging to British Telecom) and E-Plus (subsidiary of the Dutch telecom company KPN) could rely only on 3 million and 6.6 million customers, respectively. MobilCom, which has been regarded by some observers of the auction as the most aggressive bidder, will start from a relative small customer base with 4 million customers at the end of 2000. It can, however, rely on the financial ressources of its strategic partner, France Telecom. The sixth licensee, the consortium G3, consisting of the Spanish Telefonica and the Finnish Sonera have to start with basically no initial customer base (and experience of the German market). They are usually considered as being the weakest in the market. These numbers clearly indicate that the starting position of the different licensees is highly asymmetric, a point we will exploit later in our analysis.

## 3.2 The Symmetric Case

In order to evaluate UMTS-licenses with the help of our model outlined in section 2, we have to specify the parameters underlying the real option model. We start by looking at the symmetric case. For this purpose, we assume that all firms owning a UMTS-license are ex-ante in the same position, that is, they all start with the same number of customers and have the same potential to acquire new customers. Furthermore, in the symmetric set-up, all firms have the same cost structure. Therefore, we basically analyze the value of the average UMTS-license. In the next subsection, we recognize that there are important asymmetries in the German market for mobile phones, which may very well lead to different values for the different licensees.

In order to specify our parameters we proceed in two steps. First, we introduce a group of parameters which we leave unchanged throughout all our calculations in this subsection. For a second group of parameters, we start with a benchmark case. We then perform sensitivity analyses in which we alter the parameters of this second group, departing always from the benchmark case. By choosing our parameters we follow the idea that we want to ask for situations in which it is most unlikely for the UMTS-licenses to pay off. For that reason, we tend to choose for our first group of parameters a rather optimistic version. If the UMTS-licenses are not profitable against this scenario this is obviously bad news and implies, among other things, that the licencees should think very hard about possibilities to improve the rate of return of their investments.

With the first group of parameters, we determine the starting point and the expected end-point for the group of users (customers) belonging to each firm. Given a total population of approximately 65 million people being 14 years or older and an assumed penetration rate of 100%, the final number of customers will approach 65 million.[4] Considering the experience of recent trends in the mobile phone market in Germany, a period of 4 years for the switch of all users to UMTS seems to be rather realistic. Figures for the growth of users of conventional mobile phones of more than 80 % (for the entire market) lead us to such an estimate. Furthermore, we start with one million users per firm in the initial period (i.e. 2002). This is the group of users which is willing to switch technologies very easily. The number of initial users chosen is identical to the number of users having adopted mobile phones with wireless application protocol (WAP) rather shortly after its introduction (see FAZ 2001).

The initial and expected final number of users together with the assumption on the growth period (4 years) then leads us to a trend (growth) rate of 81% per year. In our computation we divide the four years into monthly steps. Since the number of users obviously does not follow a deterministic path, we combine a very optimistic and a very pessimistic case in order to compute the stochastic component of the development of the number of users. In the optimistic case, the licensee captures 50 percent of the entire market, whereas in the pessimistic scenario the market share drops below 1 percent. This gives us for our stochastic process an annual standard deviation of 25 percent. The drift rate and the standard deviation remain unchanged after execution of the growth option. The fixed costs per period stem from the rental of the necessary telecommunication infrastructure. With a total cost of Euro 5 billion and an annual rental rate of 12 per cent, the fixed costs amount to Euro 600 million per year.[5] Finally, we set the cost to exercise the growth option to Euro 1 billion.

With respect to the second group of parameters, we define a benchmark case and

[4]Given that, due to business customers, a significant proportion of persons are users in more than one function, this does not seem to be too unrealistic.

[5]Obviously this is a rather crude approximation of the underlying economics. Considering these costs as fixed rather than sunk costs is justifiable if, in case of a negative development of market shares, the equipment can be shifted to a firm gaining market shares. This latter firm then needs the equipment in order to provide the technological base for the larger-than-average number of customers.

then pursue a sensitivity analysis. For the interest rate, the benchmark is, as already mentioned, 12 percent. We assume that the UMTS-licences will be in place for 15 years, i.e. almost until their legal end (the year 2020). This implies that there is a period of 11 years with zero growth, starting at the end of the growth period (i.e. in 2006). The benchmark realization of cash flows per users is defined with reference to actual cash flows generated in the current generation of mobile phones and is thus set to Euro 20. This value includes an increase in net cash flows which seems justified given the expectation of new applications with UMTS. Recent estimates by Forrester Research (2001) support this benchmark assumption, as the group predicts gross revenues per year and customer to be around Euro 440. With respect to the growth option and the related possibility to expand the applications to new ones, we adopt a factor of 1.5 by which cash flows as well as fixed costs increase. The proportional increase of cash flows and fixed costs is for simplicity only. Table 1 gives an overview over all parameters used in our benchmark case.

Table 1: The Parameters of the Benchmark Case

| First Group | | Second Group | |
|---|---|---|---|
| growth period | 4 years | interest rate (p.a.) | 12 % |
| initial number of users | 1 m | monthly cash flows per user | Euro 20 |
| standard deviation (p.a.) | 25 % | no growth period | 11 years |
| drift rate (p.a.) | 81 % | cash flow growth factor | 1.5 |
| fixed costs (p.a.) | Euro 600 m | fixed cost growth factor | 1.5 |
| price of a license | Euro 8.4 bn | | |
| exercise cost | Euro 1 bn | | |

We are now in the position to use our theoretical model and calculate the value of the UMTS-license for the benchmark scenario. Table 2 reports the results.

The numbers in Table 2 reflect the value of the cash flows discounted to the investment period (2000) minus the initial investment outlay (Euro 8.35 billion) for

Table 2: Valuations (in Euro Million) in the Benchmark Case

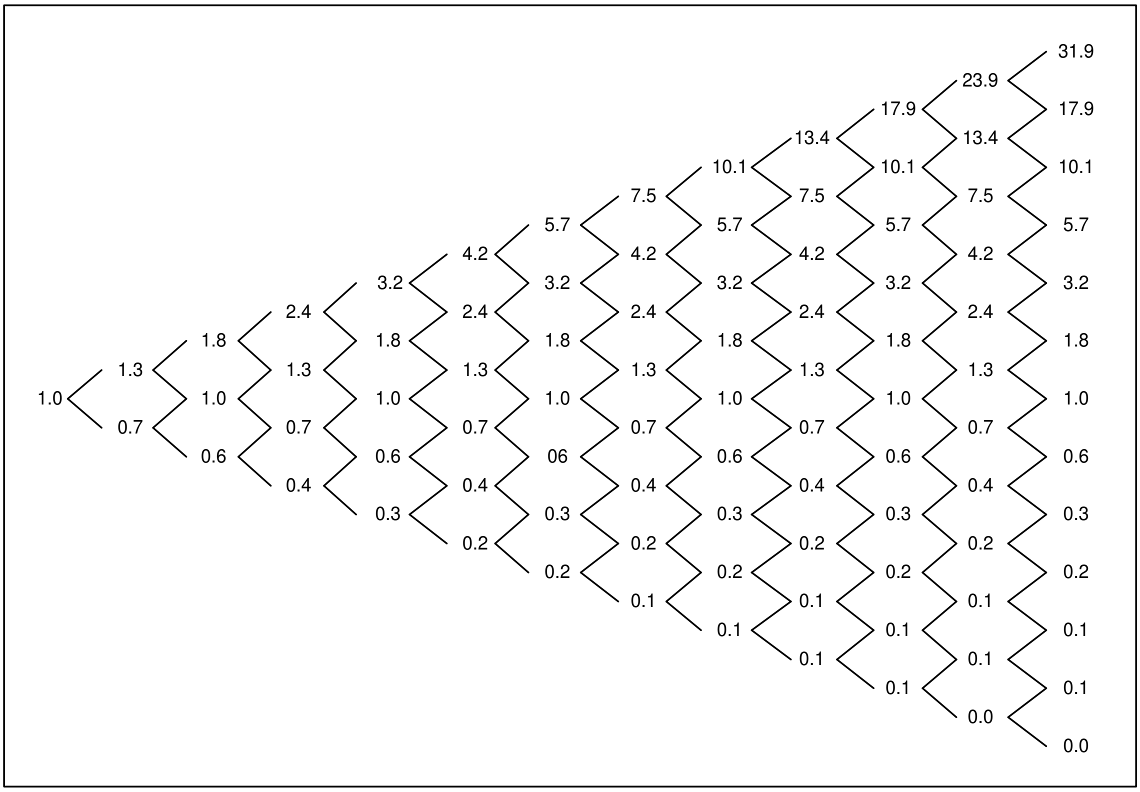
| Simple Valuation | Value of Abandonment Option | Total Net Value (with Growth Option) |
|---|---|---|
| -1220.3 | 0.12 | 1824.1 |

each firm. The numbers indicate that the abandonment option is of little value (in the benchmark case it has almost no value at all). This is due to the high drift rate and the assumption of 1 million customers in the initial period for the symmetric case. In contrast to the abandonment option, however, it turns out that the existence of the growth option is crucial for a positive value of the entire investment. The possibility to increase the stream of cash flows by fifty per cent has in many situations a positive net present value and therefore leads to an exercise of the growth option.

To understand the details of the process better, we depict the development of the number of users as well as the value and optimal exercise of the growth option in two graphs, reporting only each fourth step. Looking at the graphs, one has to keep in mind that the probability of downward steps is much lower (0.17) relative to upward steps (0.83). This is a consequence of the high drift rate underlying the assumed stochastic process. The low probability of a reduction in the number of users is also the reason for the very low value of the abandonment option. In contrast, due to the high probability of upward steps, the growth option is weighted with high probabilities and therefore rather valuable. A look at Figure 2 reveals that the growth option is typically not exercised immediately (the lower value 1 in Figure 2 indicates exercise of the option) as it pays off to wait another period. Waiting has the advantage that more information becomes valid, thereby increasing the expected value of exercising the growth option. That is, the expected value of exercising the option immediately is initially lower than the value of waiting for some uncertainty to be resloved.

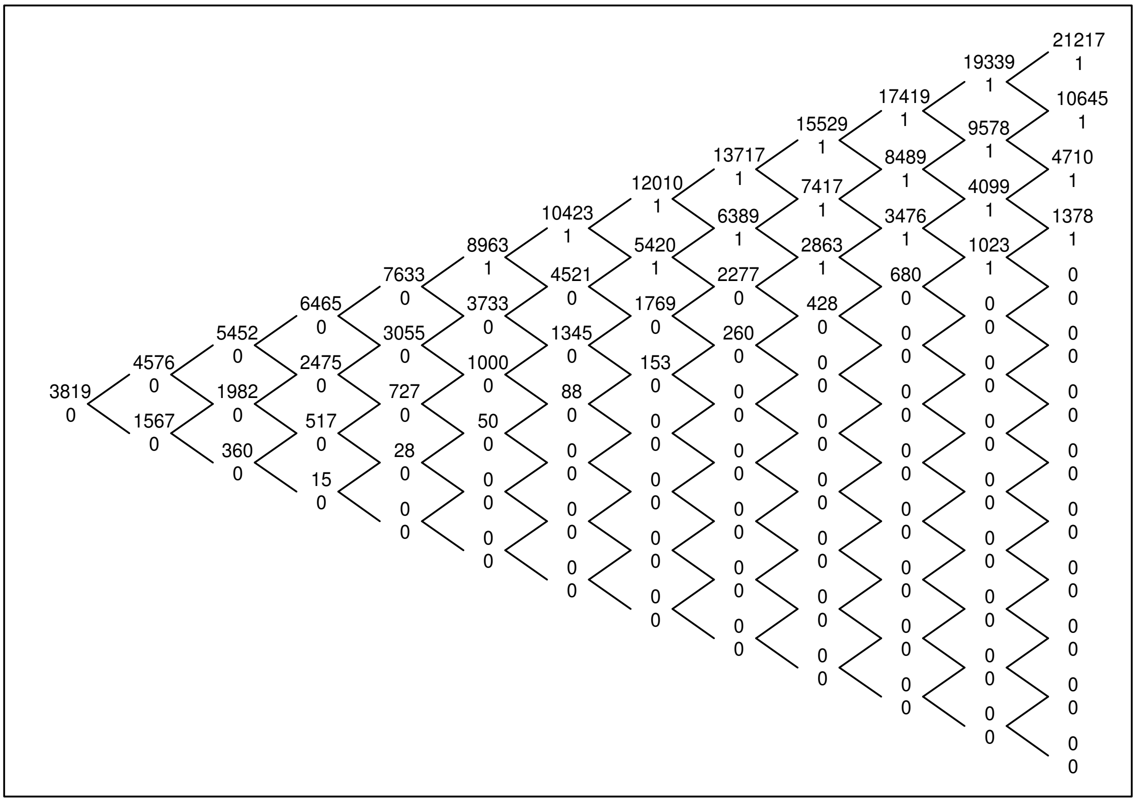
In order to pursue a sensitivity analysis of our results, we now alter the para-

Figure 1: The Evolution of the Number of Users in the Benchmark Case




meters of our second group stepwise. That is, we keep all other parameters in line with the benchmark case and investigate the resulting values for a range of different realisations of a single parameter. With respect to the cash flows per users we allow for a range of Euro 5 to 35. Given that these are cash flows net of variable costs and since we allow cash flows to increase by 50 percent in the growth option, this implies that net cash flows per user may increase to Euro 52.5 per months, which is quite an extreme value. On the other hand, we consider Euro 5 per user and month to be the lower bound. Obviously, the value of the license without the growth option as well as the growth option value itself increase significantly with cash flows per users. Since with low values of the cash-flow-per-user variable the abandonment option has a positive value this increase is initially more than proportionally. For higher cash-flow-per-user numbers, the value increases proportionally. The critical number

Figure 2: The Value of the Growth Option (Million Euro) and Optimal Exercise



for the overall value (including the growth option) to become positive is between Euro 15 and 20, Euro 17.6 to be precise.

Higher interest rates lead to a decrease in the value of cash flows realized in later periods. Hence, the value of the investment as well as the option value decrease. It turns out that the options (the abandonment as well as the growth option) are exercised earlier since the value of waiting decreases with an increase in the rate of interest. Keeping all other variables at the level of the benchmark case, the cut-off level is 14.2 per cent. For lower (higher) values the total value is positive (negative).

Altering the length of the no-growth period is basically an approximation of modelling a technological breakthrough. The assumption that the UMTS technology will last, from an economic point of view, until 2016 is, to say the least, optimistic. Given the past speed of change in this area, an earlier replacement of this technology

Table 3.1: Varying Cash Flows per User

| Cash Flows per User (Euro) | Net Value without GO (Million Euro) | Value of GO[a] (Million Euro) | Total Net Value (Million Euro) |
|---|---|---|---|
| 5 | -8385.3 | 43.3 | -8350.8 |
| 10 | -6491.4 | 899.7 | -5774.1 |
| 15 | -3862.4 | 2299.8 | -2029.0 |
| 20 | -1220.3 | 3818.9 | 1824.1 |
| 25 | 1422.6 | 5381.1 | 5712.4 |
| 30 | 4065.6 | 6967.7 | 9620.2 |
| 35 | 6708.5 | 8571.7 | 13541.9 |

[a]The value of the growth option is always calculated for the start of the project (2002) rather than for the period in which the UMTS-auction took place and the license had to be paid (2000).

is quite likely. An argument against the replacement, however, is the large size of the investment and the incentive structure underlying the potential R&D race. This implies that, due to the profit destruction effect, the incumbent firms have very little incentive to undertake R&D and adopt a new technology. Furthermore, they have a strong incentive to strategically defer new technological development which is not too difficult, given the network externalities prevailing in this sector. But despite these arguments a shorter length of the no-growth period is worthwhile to consider. A glance at table 3.3 reveals that the length of the no-growth period is important for the licenses having a positive value. Whereas in the absence of the growth option the value is always negative, the total value becomes positive if the no-growth period exceeds 7.4 years.

As our previous discussion revealed, the growth option is crucial for a positive net present value of the UMTS-licenses. For the growth option, in turn, the factor at which cash flows and fixed costs increase after the execution of the option (i.e. after having extended the business into the new areas) is vital. This variable only affects

Table 3.2: Interest Rates

| Interest Rate | Net Value without GO (Million Euro) | Value of GO (Million Euro) | Total Net Value (Million Euro) |
|---|---|---|---|
| 0.04 | 6901.5 | 7474.9 | 13812.4 |
| 0.08 | 1929.4 | 5282.8 | 6458.5 |
| 0.12 | -1220.3 | 3818.9 | 1824.1 |
| 0.16 | -3278.0 | 2816.1 | -1185.2 |
| 0.20 | -4660.7 | 2113.4 | -3193.1 |

Table 3.3: Length of No-growth Period

| Period Length (Years) | Net Value without GO (Million Euro) | Value of GO (Million Euro) | Total Net Value (Million Euro) |
|---|---|---|---|
| 3 | -4968.2 | 1473.7 | -3793.4 |
| 5 | -3693.1 | 2269.8 | -1883.7 |
| 7 | -2676.6 | 2906.1 | -359.9 |
| 9 | -1866.3 | 3414.0 | 855.3 |
| 11 | -1220.3 | 3818.9 | 1824.1 |
| 15 | -294.7 | 4399.0 | 3212.1 |

the value of the growth option. The critical cash flow factor at which the total value turns into positive territory is 1.25. That is, given our benchmark case, the firms need at least a potential increase of 25 percent in order for the UMTS-investment outlays to pay off.

The overall point of our sensitivity analysis is that basically all variables (of our second group) are important for a positive net present value. However, the cash-flow-per-user variable appears to have the highest impact on the total value (and its fluctuation) given its uncertainty relative to the other benchmark parameters.

Table 3.4: Increase of Cash Flows (and Fixed Fosts) with Growth Option

| Growth Factor | Net Value without GO (Million Euro) | Value of GO (Million Euro) | Total Net Value (Million Euro) |
|---|---|---|---|
| 1.2 | -1220.3 | 1085.0 | -355.4 |
| 1.4 | -1220.3 | 2900.3 | 1091.8 |
| 1.6 | -1220.3 | 4739.3 | 2577.8 |
| 1.8 | -1220.3 | 6584.0 | 4028.5 |
| 2.0 | -1220.3 | 8430.9 | 5500.8 |
| 2.2 | -1220.3 | 10278.8 | 6973.9 |

## 3.3 The Asymmetric Case

We now depart from our symmetric scenario and allow for asymmetries between the different licensees. This reflects, among other things, the notion that the mobile phone market is characterized by the existence of network externalities. These network externalities are on the one hand due to technological reasons (a firm which has more users will build more transmitters and achieves thereby a higher degree of reachability) and on the other hand economic factors prevail, such as optimal pricing strategies (lower prices of intra-net calls compared to calls across different firms' nets). Therefore, firms with a better starting position are more likely to succeed later on, compared to newcoming firms. Given that there are switching costs (or simply convencience losses) when switching from one firm to another while adopting the new technology, it is most likely that firms such as T-Mobile and Mannesmann Mobilfunk start with a larger number of initial customers. They will hence be able to gain customers more easily, as compared to newcoming firms without an established customer base.

We proceed in two steps: in the first step, we analyze the value of UMTS-licenses for newcoming firms with a lower number of initial customers and therefore also with a lower expected market share. In a second step we turn to the incumbent telecom companies and their UMTS-licenses. Hence, we start with a larger than average customer base and allow for a larger than average expected number of users.

For a newcoming firm (e.g. Group G3), the initial customer base is assumed to be rather low. We therefore start from a modified benchmark case with an initial number of 0.5 million users. In order to end up with an expected number of users below industry average, we reduce the drift rate and the standard deviation in the benchmark case for the newcoming firm to 75 percent and 23 per cent, respectively. These new numbers lead to an expected number of 4.8 million users (a market share of 8 per cent). In the most optimistic scenario 12 million customers will be using the services of the company under investigation. Combining these numbers with the remaining benchmark parameters outlined in table 1 yields the following results: in the absence of the growth option, the value of the UMTS-license amounts to Euro -7103.3 million. Since the growth option has rather little value (Euro 575.0 million), the total value amounts to Euro -6644.9 million. We also find that the abandonment option has a small, but positive value (26.1 million Euro). Overall, the gross value of the investment falls significantly short of the initial investment outlay. Under which circumstances will this broad picture change, or, when will we observe positive net present values for the newcoming firms? We try to answer this question by investigating the effects of a variation in the cash flow per user variable. It turns out, however, that in our initial cash-flow-per-user range total values remain always negative. Only if we increase it to over a rather unrealistic 40.0 Euro (i.e. with the growth option to 60.0 Euro) do we enter positive territory. Table 4 illustrates the relationship between cash flows per users and the project value for an extended range of this variable.

Obviously, reducing the length of the no-growth period even worsens matters. If we extend the no-growth period to 15 years, i.e. the legally given official maximum, we still do not get a positive value. But even if the technology would last forever net present value of the investment remains negative for the newcoming firm. Pretty much the same pattern emerges when pursuing a sensitivity check for the interest

Table 4: Cash Flows per User and Total Value for Newcomers

| Cash Flows per User (Euro) | Net Value without GO (Million Euro) | Value of GO (Million Euro) | Total Net Value (Million Euro) |
|---|---|---|---|
| 10 | -8385.3 | 9.9 | -8377.4 |
| 20 | -7103.3 | 575.0 | -6644.9 |
| 30 | -4789.1 | 1744.2 | -3398.6 |
| 40 | -2455.9 | 3060.5 | -16.1 |
| 50 | -121.9 | 4424.3 | 3405.1 |
| 60 | 2212.2 | 5813.8 | 6846.9 |

rate. Even if we decrease the interest rate to zero per cent, the total value remains still negative. These rather strong results are the outcome of the low customer base assumed in our benchmark scenario for the newcoming firms. Somewhat surprisingly, we find that we have to increase the cash flow and fixed cost factor associated with the growth option by more than 400 percent in order to get a positive number for the total value of the investment. This, too, is due to the low customer base, which reduces the leverage created by the growth option.

Given that we take our starting position as well as the stochastic time path of the number of users for granted, it turns out to be rather difficult for newcomers to earn their initial investment outlays. Our analysis suggests that there are only two alternatives for newcoming firms to turn their UMTS-investments into a success. Either they push hard in order to get a larger customer base (via marketing, better services, prices, etc) and/or they try to extract larger cash flows per user. Among the problems associated with such a strategy is that these two instruments are not independent of each other but are most likely to be negatively correlated. That is, trying to grasp a larger customer base e.g. via marketing bears the risk of a substantial increase in costs and hence lower cash flows per user. Increasing cash flows per user (via pricing), in turn, may deter new customers. Therefore, these firms have to find a delicate balance between these two partially contradicting approaches.

For incumbent firms it is (almost by definition) much easier to achieve a positive total value from an ex-ante point of view. We start from an initial customer base of 2 million, admittedly an optimistic assumption. We chose the parameter such that an incumbent firm captures an expected market share of 25 percent at the end of the growth period. In the most optimistic scenario the incumbent has 50 percent of all users as customers.[6] This yields a drift rate of 70 per cent and a standard deviation of 21 percent

Our modified benchmark case for the incumbent results in a net project value of Euro 4997.0 million in the absence of the growth option and in Euro 10948 million with the growth option. The growth option is therefore worth Euro 5951.0 million in discounted terms. The sensitivity analysis for the cash flows per user is depicted in table 5 and shows that the cut-off level is significantly below Euro 15 per user and month.

The table reveals that for already rather moderate levels of cash flows per user (Euro 15 per month and above), the growth option is important but not vital for an incumbent. Given that cash flows are at least this size, the incumbent telephone companies may end up with a positive net-present-value investment in UMTS even if the growth opportunity vanishes in thin air for some reason. This case may be due to the shortcoming of the corresponding technologies and/or overestimates of the degree of the growth potentials.

Unlike the situation of the newcomer, the effect of the parameters of our second group are not as important as the impact of cash flows per user on total value, at least for values within sensible ranges. A main reason for this is that the value

[6]This latter scenario might be called overly optimistic. However, our purpose was to consider quite an optimistic case with regard to the evolution of the customer base. This then reveals the lower range of parameters giving us still a positive total value. Furthermore, technical reasons restrict us in the choice of the standard deviation as we have to take the consistency restriction of the Cox et al. (1979) approach into account. For that reason, our chosen standard deviation represents, *ceteris paribus*, a lower bound.

Table 5: Cash Flows per User and Total Value for Incumbents

| Cash flows per User (Euro) | Net Value without GO (Million Euro) | Value of GO (Million Euro) | Total Net Value (Million Euro) |
|---|---|---|---|
| 5 | -7567.3 | 341.6 | -7294.9 |
| 10 | -3397.6 | 2484.7 | -1416.8 |
| 15 | 799.7 | 4935.6 | 4734.3 |
| 20 | 4997.0 | 7465.0 | 10948.0 |
| 30 | 13391.6 | 12643.3 | 23470.7 |
| 50 | 30180.9 | 23166.6 | 48649.1 |
| 60 | 38575.5 | 28431.7 | 61241.0 |

remains positive even in the absence of the growth option. With respect to the length of the no-growth period we find that the total value (including the growth option) remains positive if the length is reduced to three years. That is, a replacement of UMTS in 2009 obviously reduces the value of the licenses but it does not make them a negative net-present-value investment for incumbent firms. This however depends crucially on the realisation of the other parameters as specified. Finally, since the total value of the investment is already positive in the benchmark case excluding the value of the growth option, it is obvious that the cash flow factor does not contribute anything to the sign, but only to the (positive) level of the project value.

The second major parameter from an incumbent's point of view is the discount rate. One needs, however, quite large rates of interest to jeopardize the positive net present value of the UMTS-license. The critical interest rate level is slightly above 22.7 percent. In a nutshell, we can state that, given our assumptions on the evolution of the number of users, matters look pretty good for incumbent firms. The main risk stems from low cash flows per user – and from overly optimistic assumptions about the development of the customer base.

# 4 Final Remarks

Our analysis has been designed as a quantitative investigation of the potential of one of the most costly (and also most uncertain) investments undertaken by a group of companies in recent business history. We argue that due to inherent uncertainties, i.e. the risks and chances of the investment, and the fact that the licensees may provide a larger number of potential fields of application, a traditional cash flow analysis falls short of taking all these aspects properly into account. By modelling the valuation of German UMTS-licenses as compounded real options we take all these aspects into account. We focus on two particular options: an abandonment option and a growth option, i.e. the possibility to expand business into new directions if the number of users evolves positively. Since the number of users is the natural candidate for the stochastic process over time, we can not rely on conventional option pricing formulas, such as Black-Scholes, to compute the value of our options but have to rely on numerical analysis.

In the course of the numerical analysis, the relevant issues of UMTS-licenses from the point of view of the licensees are clearly revealed. It turns out that besides the relative position of the individual licensees relative to the competitors (especially with respect to the initial number of users), the cash flow generated by each user is a vital variable. We show that in our rather optimistic benchmark case, 20 Euros per user and month are sufficient to get an investment with positive net present value. Our sensitivity analysis reveals, however, that for a number of parameter constellations, the existence of the growth option is not only important but crucial for enabling the licensees to earn their initial investment outlays in the future.

One of the main messages of our analysis is, however, that while it is most likely that the investment will pay off for an incumbent firm, it will be a real uphill battle for the newcoming firms. Only if the latter are able to achieve very considerable growth rates in the number of users they will have a chance to come close to break-even. Our analysis suggests that they have at best a chance to make small profits but at the same time face a high probability of significant losses.

Obviously, our model and the numerical analysis rest on a number of debatable assumptions. First and foremost, we treated the cash flows per users as constant over time and exogenous. This assumptions rests on the objective to leave the model as simple as possible. Allowing the cash flows to vary of time (and to follow a second stochastic process) and depend on the actions of firms is a clear way to potentially improve our analysis. The risk of doing this is to introduce a certain degree of arbitrariness which we tried to avoid with our explicit sensitivity analysis. Furthermore, we could as well ask whether our fixed costs (i.e. the infrastructure outlays) are indeed fixed rather than sunk costs. In summary, there are a number of ways in which future research can improve our present, first step towards an explicit valuation of a highly uncertain investment and its inherent flexibility.

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