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INDUSTRIALIZATION OF DERIVATIVE DESIGN: INTEGRATED RISK MANAGEMENT WITH THE FINANCIAL INFORMATION SYSTEM WARRANT-PRO-2

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INDUSTRIALIZATION OF DERIVATIVE DESIGN: INTEGRATED RISK MANAGEMENT WITH THE FINANCIAL INFORMATION SYSTEM WARRANT-PRO-2

Hans-Jörg von Mettenheim, Michael H. Breitner[1]

Abstract
Risk management is essential in a modern financial services industry. Derivative instruments like options have a particular status. Appropriate derivatives allow financial service providers to redistribute risks towards others. The process of creating customer tailored derivatives is not well-investigated today. With the financial information system (FIS) WARRANT-PRO-2 derivative prices are computed for given payments. The deviation, for example, from a predefinable Delta of an option can be minimized. Automatic creation of optimally synthesized options is very promising for buyer and seller. An example is presented to show the easy process of creating a customer tailored option.

1. Introduction and Motivation

Risk management is essential in a modern financial services industry. Financial markets enable institutions and households to select an acceptable level of risk in their transactions. Appropriate financial information systems (FIS) allow for the redistribution of risks towards others who are willing and able to assume them. FIS are a key element for financial management decisions.
Derivative instruments - derivatives, for short - have a particular status in the financial services industry, like options. Options allow agents to hedge against one-sided risks. Options give the right, but not the obligation, to buy (call option) or sell (put option) a certain underlying at a prespecified strike price at expiration (European style option) or at any time up to expiration (American style option). Common underlyings are, e.g., a certain amount of foreign currency, a certain number of bonds or shares or also a certain weight or volume of commodities, see [11, 18, 23, 26] for an introduction. Today, derivatives on various underlyings are traded worldwide around-the-clock. FIS and networks that link offices and markets permit immediate exchange of true market information (securities exchanges and "over the counter" (OTC) traders). Options lack flexibility under several aspects, however. Especially customized payout and risk profiles are difficult to realize and have to be tediously created manually. Calculation and optimization is often manual, subject to errors and time-consuming.

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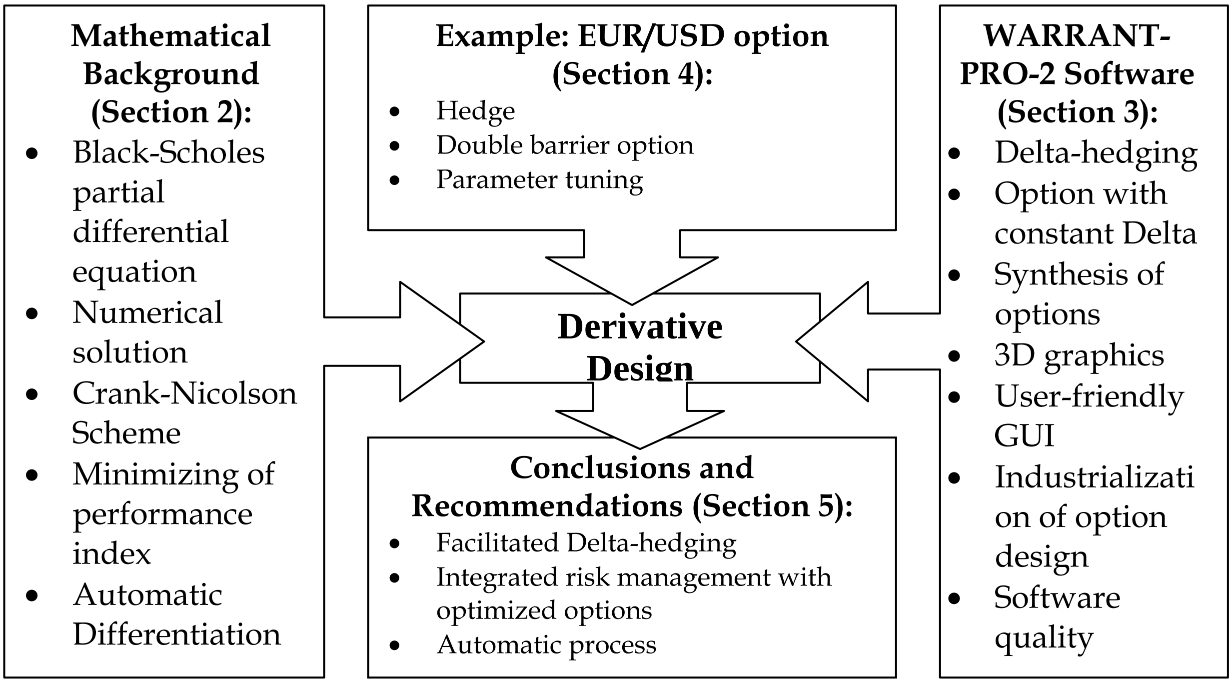

Figure 1: Steps towards industrialized derivative design.

The question arises: “How can a FIS help to design and optimize derivatives without manual intervention needed?” Usually, derivative experts working for banks, investment banks, insurance companies and fund companies “manually” design derivatives tailored to their own companies' or their customers' needs, see, e.g., [5, 6, 11, 18, 23, 24, 26]. These tailored derivatives usually are traded over the counter (OTC), i.e. not via exchanges or interbank security markets. The financial management decision process is not automated. Alternative methods are discussed in [8, 19].

Here we introduce a new software-based approach (WARRANT-PRO-2) using mathematical optimization for derivative design instead of intuition. WARRANT-PRO-2 is not only yet another software tool for derivative pricing. Our software sets the prices for customer-tailored OTC derivatives or optimizes cash settlements automatically. The software adds flexibility to the process of creating derivatives. Optimally-designed derivatives are important for both counter parties. They have the potential to transform the way how financial service providers can provide the market with new instruments. On the customer side, our FIS offers the possibility to check if the proposed OTC option really is a good deal, see [6, 7].

The customer wants to get the best price for his specific risk acceptance. For the issuer of an option, optimal pricing is vital. Otherwise, he could (and would) fall victim to arbitrage. While the risk for the customer is limited to the option premium, it is unlimited for the option issuer. The issuer usually hedges the risk. But for today's non-optimized options, hedging is cumbersome and costly. By providing options with nearly constant Delta, our FIS simplifies the hedging process for financial service providers.

The paper is organized as follows (see also Figure 1): Firstly, the mathematical toolkit is briefly introduced. This also includes the Black-Scholes partial differential equation. The relevance of Delta-hedging for financial service providers and customers is outlined. The software and methodology is introduced. Then an application is presented. Our example is a purpose-designed OTC option on the EUR/USD exchange rate. According to the special needs of a financial manager, an option is synthesized and the results are explained in detail. The paper ends with our conclusions, management recommendations and the outlook on future development of the FIS. Its potential to create new derivative markets in the financial services industry is outlined.

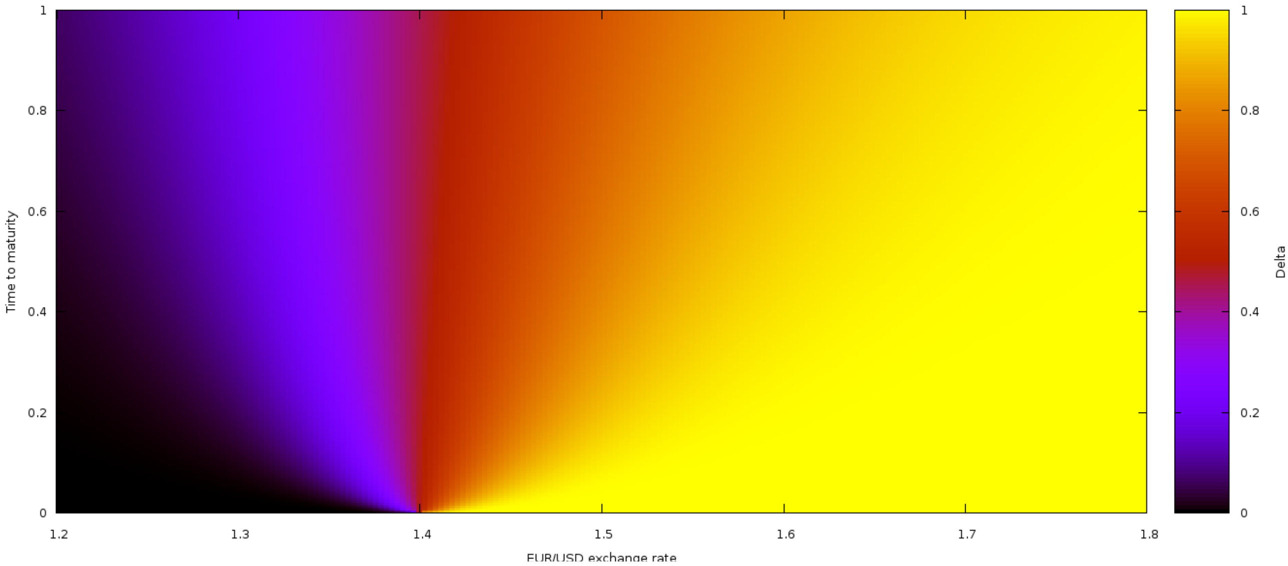

Figure 2: Delta is not constant. This figure illustrates the basic limitation of standard options. They require continuous rebalancing for hedging. Time to maturity is given in fractions of a year, EUR/USD exchange rate in USD per EUR. This plot was generated using the appropriate Black-Scholes formula and fitting it to historical volatility data.

2. Mathematical Background

The foundation of option pricing theory lies in the Black-Scholes partial differential equation. Solving this equation analytically is possible only for a limited number of cases, see [3, 4, 9, 10, 20, 21]. Common to these cases is that the payout profile is inflexible.

In the case of WARRANT-PRO-2, we want to obtain a constant Delta. Delta is a parameter of an option. It describes how the price of the option changes, when the price of the underlying changes. For someone wanting to hedge a portfolio with options a varying Delta is a disadvantage. Rebalancing the option position becomes necessary. This disadvantage also holds true for the position of the option issuer. If he wants to transform his so-called naked call into a covered call he has to buy the appropriate underlying. With varying Delta the number of entities he has to possess varies. High transaction costs are incurred, see [18]. We deliberately omit mathematical details here and provide only a rough overview of our method in the following paragraph. Further information is available in [6] and [8].

Creating an option with constant Delta involves finding a solution to the Black-Scholes partial differential equation which meets this or other additional optimization criteria. This is possible by a modification of the boundary conditions. Finding solutions for these generalized boundary conditions is only possible numerically, see [1, 12, 14, 15, 17, 25, 27]. Our software uses a finite difference method. The particular variant is the Crank-Nicolson scheme. It is a mixture of a forward and backward method. With the Crank-Nicolson scheme only few iterations are needed to find an accurate solution. The solution is finally found by minimizing the quadratic error on the solution space. We use the software library NPSOL for nonlinear problems. This library implements a fast general-purpose sequential quadratic programming (SQP) method. NPSOL finds solutions that are locally optimal. But very often these solutions are almost as good as the global optimum, see [13]. The optimization method uses not only gradients but also second order curvature information. The gradients are *not* calculated numerically. This is realized with Automatic Differentiation. Automatic Differentiation calculates *real* derivatives of given subfunctions in a program, see [2, 22].

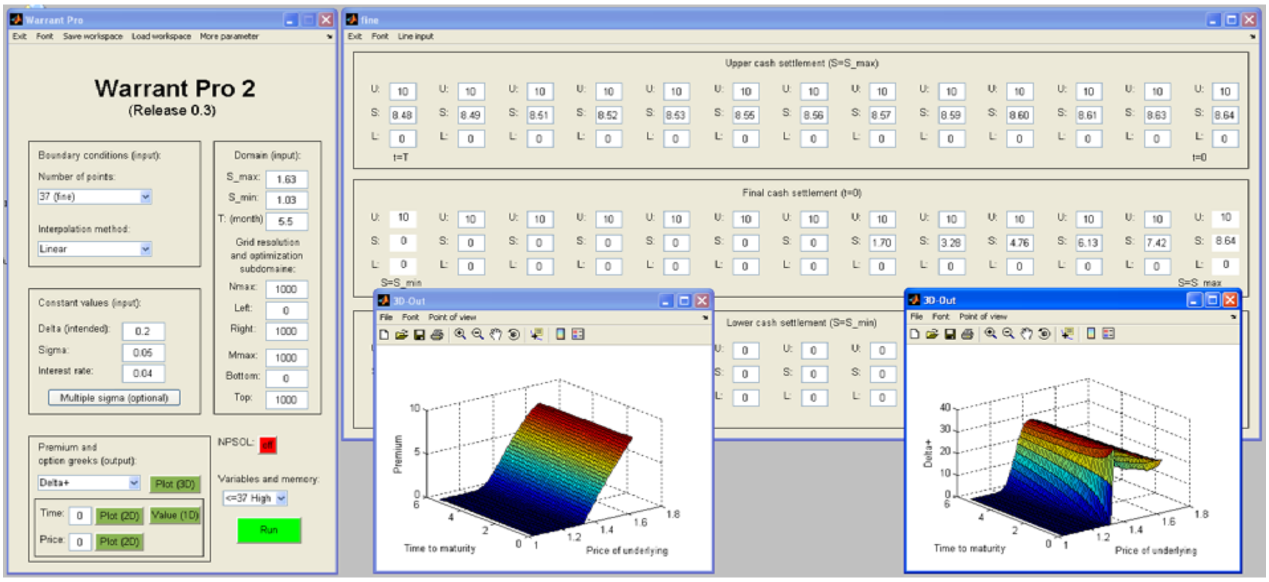

Figure 3: WARRANT-PRO-2's GUI (graphical user interface) helps to valuate and optimize arbitrary derivatives comfortably. 3-dimensional, interactive graphics enable one to check the settings, to understand the solution and to assess a derivative's value easily. Derivative data can also be retrieved for further analysis in external programs. A detailed example is computed in Figure 5 and Figure 6. See also the example in Section 4.

3. The WARRANT-PRO-2 Software

Today's software-(re)engineering is process-oriented, i.e. it is in subsequent (or sometimes parallel) phases which reduce complexity. Milestones allow the management to stop software-(re)engineering processes, to cut down or raise budgets and/or resources and to change requirements and schedules. Today's software-(re)engineering is based on software quality principles according to ISO/IEC 25051 and DIN EN ISO 9241, i.e.

- suitable, correct, secure and adequate functionality and interfaces for the integration into (often complex) IT-infrastructures,
- user-friendly documentation, easy self-learning possibilities, advanced ergonomics and high level of attractiveness,
- good maintainability with readable, changeable and testable source codes
- and high portability with easy installation, high compatibility with different hardware and operating systems and high convertibility.

In addition, conformity regarding standards and also best practices is important. Especially after the events on the financial markets starting in the summer of 2007, it is of relevance that software designed for the financial service industry has an appropriate quality level. With the FIS WARRANT-PRO-2, the software quality principles are implemented carefully.

Development of our FIS started in 1999 with the idea to optimize options numerically. Prototype Release 0.1 was completed at the end of 2000. The primary goal was to optimize cash settlements for European double-barrier options and warrants. The boundary conditions of the Black-Scholes equation were parameterized. Then the Black-Scholes equation was solved. As a performance index an option's deviation from a predefinable Delta was implemented. The first reengineering of the FIS (Release 0.1) started in the spring of 2002. Release 0.2 was completed in March 2003. The kernel was still coded in ANSI FORTRAN to assure easy portability. With an upgrade of the Crank-Nicolson scheme it became highly accurate. 10 to 20 times faster computation was achieved.

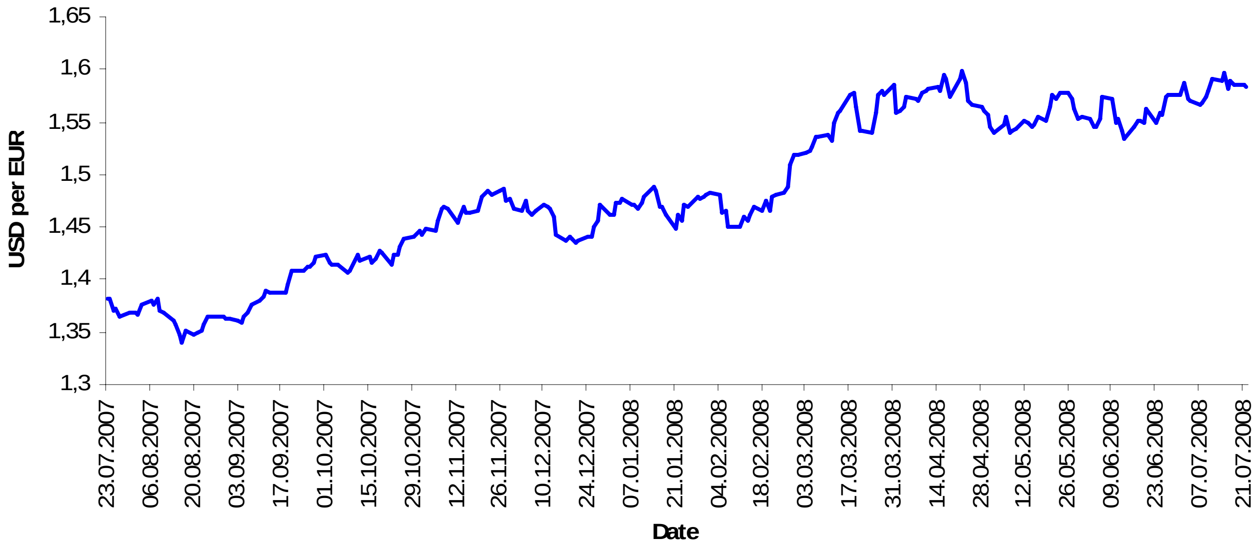

Figure 4: Chart of the EUR/USD exchange rate. – How will it continue from here on? Even if we don't know this, we can hedge foreign exposure using a custom designed derivative with constant Delta. (Source: Thomson Financial Datastream)

Discussions to implement a GUI began. Applications providing a GUI are more easily accessible for most users compared to a command line interface application. Finally, an interface using the MATLAB runtime library was created. The second reengineering of the FIS (Release 0.2) started in the fall of 2006. The actual Release 0.3 was completed in March 2007. The FORTRAN kernel is again 5 to 10 times faster due to code optimization and optimal compiler settings. A third reengineering of the FIS (Release 0.3), initiated by the first and second author, began in January 2008. On the GUI side, the FIS should run without proprietary GUI tools. The last release of the free Gnuplot software shows promising features and will be integrated as front-end to the FIS. Furthermore, additional features will be added allowing easy retrieval of previously optimized options.

Other steps have been undertaken on the computing side. Delta is only one of several possible performance indices. Current work aims at implementing the other option Greeks as well. In certain cases the optimized options have shown undesirable, i.e., volatile behavior on the boundaries. Research is directed into the implementation of a weighted scheme which smoothes out volatility on the boundaries. It is also of importance to tailor the FIS better for the needs of the financial services industry.

The methodology of our research and software development is the following, see also [16] on design-science research: we start with the very real problem of varying Delta in standard options (the relevant problem). Designing options with constant Delta is a promising research area. From this idea we create a mathematical model to improve the situation (application of a rigorous method): Numerical optimization of the Black-Scholes partial differential equation (search process in the problem environment). We implement the model (design an artifact) and check the result against real-life data (design evaluation). This allows showing the practical relevance of our FIS (research contribution). An analysis of errors demonstrates that the accuracy of our scheme is very good, see also the example application in the following section. The question whether our FIS is useable by novice users is also addressed: a GUI is programmed and extensive documentation is available (communication of research).

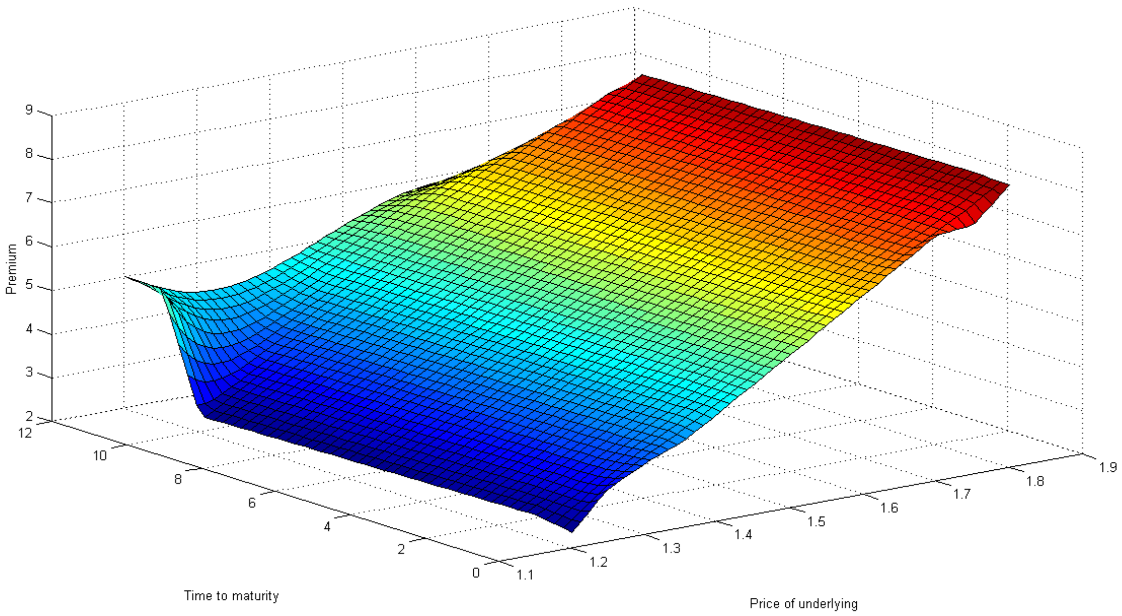

Figure 5: Optimized option for EUR/USD call, option premium. The option is optimized for time to maturity between 2 and 10 months. The gradient between 10 and 12 months is not relevant. Note that the payout in the optimization region looks almost like a "normal" option. The corresponding Delta is plotted on Figure 6.

4. Example: Design Process of a EUR/USD Option

To show the advantages of optimized options, imagine you are a financial manager at a European aircraft producer. Your company depends heavily on selling aircrafts internationally outside the Euro-zone. Let's say that due to long-ranging contracts with your customers the actual price of your sold aircraft is fixed in advance and not much of a concern for you. But the price that the customers will pay per aircraft is in US-Dollars (USD). A stronger USD, below an exchange rate of 1.60 USD per EUR, would be good for you, of course. But you fear that the economic slowdown will affect the USD even more. Your goal is to protect your company from the USD trading above 1.60. You want a safety margin of up to 1.80 USD per EUR and you want simplicity.

So you call your trusted bank and ask for a solution how to hedge an incoming payment of 100 million USD in 6 months. Immediately, you are offered a future. A future moves exactly like the underlying. But you recall that with a future the downside risk is also unlimited. You put forth this argument to the bank officer and he offers you an option. But a standard option is not what you want, either, because Delta is not constant. Finally, the voice at the other end of the phone says: "Wait a minute. We have a new integrated risk management tool. With that we can create customized options and optimize them for constant Delta." This sounds interesting to you.

But before you have time to think more about the technical details behind this tool, you already get an answer: a purpose-designed option with the payout profile seen in Figure 5. This looks to you almost like a "normal" option. After this you scrutinize Delta as seen on Figure 6. You notice that Delta is almost constant at 10. You also see that, towards the expiry date, Delta shows some spikes. But after evaluating the scaling of the axes you are reassured: an error of 0.004 % seems to you an acceptable risk.

How is this option created? Let's follow the process using the above-mentioned EUR/USD option. Firstly, WARRANT-PRO-2 needs some input from the user. For a currency option, the respective risk free interest rates in both countries are relevant. For the local currency Euro we take the ECB minimum bid rate for main refinancing operations, currently at 4.25 %. The equivalent for the USD

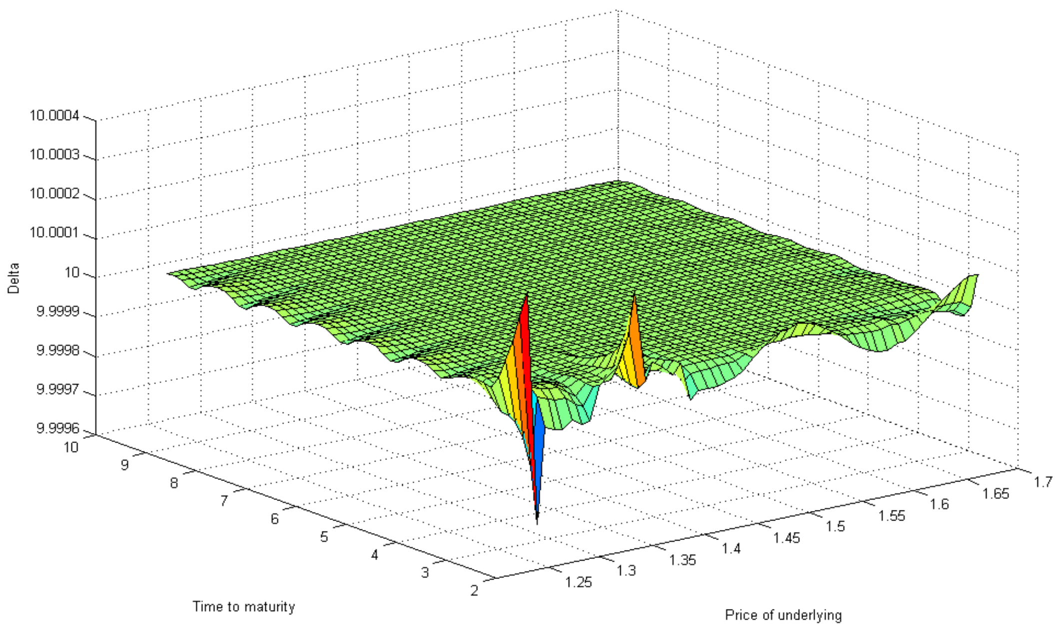

Figure 6: Optimized option for EUR/USD call. The target value is Delta = 10. The error is in the range of negligible 0.004 %.

is the Federal Funds Rate at 2.0 % as of July 2008. This actually gives us a *negative* continuous "dividend" of -2.25%. Moreover, we have to provide an estimation for the volatility of the EUR/USD currency pair. This estimation can be calculated using historical data. Another possibility is to take the implied volatility of real options traded on an exchange. In both cases we get a result around 11%.

We then enter a target optimization region. In the case of our option, we chose an underlying price between 1.20 USD per EUR and 1.80 USD per EUR providing a generous safety margin for the exchange rate to fluctuate. For time to maturity, we chose 12 months with optimization between 10 and 2 months. This means that we start with a time to maturity of 10 months, wait 6 months until we get our payment and sell the option with 4 months left till maturity.

Finally, a target Delta has to be provided. As we want to hedge our foreign exchange exposure with some leverage, we set an appropriate level of Delta=10. As you are on good terms with your bank and your company is a very good client, they invite you to see the tool. You notice that the optimization of the option only takes a few seconds. A dynamic 3D output is included with the calculation. It allows you to plot different parameters of the synthesized option, including the premium and Delta.

You dig further into the tool and find that the payout can also be set to a range or even to a fixed rate payout. With this, you can simulate and optimize almost every type of option. A binary payout is possible or a payout which occurs only in a certain range of the underlying price. You also like the feature that the option can be optimized for a set of different volatilities each weighted differently. This relieves you from the burden of providing just *one* estimate for volatility. If you are unsure, you can also provide a range.

The person of contact at the bank is a derivative expert. You ask him to explain the inside of his software in simple words. You learn that the Black-Scholes partial derivatives are solved for different parameters until the required conditions are met. Using the Black-Scholes equation avoids creating arbitrage opportunities for other market participants. You leave thinking, that math, after all, is quite a good thing to know, especially when it facilitates your foreign exchange management.

5. Conclusions and Management Recommendations

With the FIS WARRANT-PRO-2 the tedious process of issuing an option tailored to the customers' requirements can be automated and sped up considerably. The FIS was originally designed to optimize cash settlements in the financial services industry. However, it proves also very useful and comfortable for Black-Scholes value computations for derivatives *without* optimization. A stand-alone GUI provides interactive, 2- and 3-dimensional graphics of high quality. These outputs enable to evaluate and analyze a derivative’s value and the most important option parameters, the so-called option Greeks.

The upgraded Crank-Nicholson scheme is highly accurate and only several seconds of computing time are needed. In optimization mode, the gradient computation with automatic differentiation is most important to enable fast and reliable convergence of the SQP method. Here, the change of Delta is minimized. Other performance indices are currently implemented, too. We omit mathematical details but Section 2 lists the relevant literature.

In contrast to other tools used in financial institutions, our FIS is able to synthesize optimized options automatically. This offers the potential of creating a range of new derivative products because the manual process is eliminated entirely. The lacking feature of options, i.e., flexibility, can be overcome by computing options of almost all different risk profiles. An integration of the WARRANT-PRO-2 FIS into an institution's FIS would offer the unique possibility of creating customized options on demand. For the customer, this presents the opportunity of speeding up financial management decisions.

Our example using the EUR/USD exchange rate shows how a FIS for customer-tailored OTC derivatives can accommodate even the most special customer wishes. In the example, we create an option with constant Delta = 10 for an underlying price range of 1.20 to 1.80 USD per EUR and time to maturity between 10 and 4 months. The proceeding is as follows: the exogenous variables like volatility Sigma and interest rate r differential are given, the target Delta is entered. If required, the payout profile of the option can be customized, but this is optional. Upper and lower barriers and time to maturity are set; if necessary an optimization sub-region is also described. The following optimization is fully automated and graphics and tables are outputted directly.

Derivative design with a FIS is useful for both buyer and issuer. Key advantages are the followings: Hedging the option is possible without rebalancing when Delta is constant. It is therefore much easier to synthesize the option by holding the underlying. Also, the transaction costs are reduced. Additionally, the issuer does not have to assign traders to constantly monitor market and options. This tedious and boring job becomes obsolete and the financial institution can put the traders to work in other more interesting domains.

As our FIS also uses an easy to implement file-based interface, it can be integrated into the issuer’s risk management system directly. This is in contrast to pure GUI-based tools. Option pricing is a critical success factor in the risk management chain. As decision support tool the FIS can also be used to compare an optimized result to standard pricing by traders. In this case it doesn’t replace the trader but helps in assessing the correct pricing of a specialized OTC option.

The process of option creation no longer relies on semi-manual calculations. The risk of costly miscalculations is reduced. As options are optimized in an automated manner, the issuer rapidly becomes cost competitive in the domain of customized options. Share in this very lucrative business can be enlarged.

Buyer and issuer can use the fast results produced to improve there overall reactivity. They can check if market offers are fair. Overpriced options can be identified and singled out. Conversely relatively cheap options can be used for, e.g., arbitrage or simply for hedging purposes. Even for very special cases and requirements concerning the payout profile, a premium can be calculated.

Beside the already cited advantages we our FIS features the following important aspects: The program is easy to install, self-contained in one directory, available for Windows with installer and Linux. From the beginning the software is designed to be cross-platform. Access is possible via a user-friendly graphical user interface. Alternatively, a command line interface is provided for a maximum integration within already existing systems. Using the command line interface options can be created just-in-time or even automatically.

A range of new product ideas emerges:

- Automated pricing of OTC options without human intervention would allow increased liquidity and competitiveness for buyer and issuer.
- On special market conditions, options could be dynamically created based on the heuristics of what market participants expect.
- In cooperation with the insurance business, options on exotic underlyings could be created, like for example weather options.

The authors acknowledge that the current state of the FIS is only an intermediary state. A whole bundle of additional features is currently in discussion or actively being worked on:

- Integration of a comprehensive help system for novice users.
- Interface to data providers. This would allow matching calculated and real option prices. Historical volatility could be directly inferred from the data. Data would be automatically retrieved and input to the FIS.
- Output of a concrete strategy for synthesis of the customized options. These strategies would use other options, futures or (if available) the underlying directly.
- Special modes for different types of underlyings: shares, currencies, commodities, interest rates, real-life options.
- Combination modes: e.g. option on commodities priced in foreign currency, like an option on WTI oil, priced in USD for a buyer living in the euro-zone.
- Heuristic parameter settings for even more user-friendliness.

Our FIS offers integrated risk management. This is essential for a modern economy. The flexibility in creating customized options enhances liquidity, reactivity and the tool set which financial managers have at their disposal for hedging and risk mitigation.

WARRANT-PRO-2 is a tested beta-prototype. If you are interested in our software we cordially invite you to contact us. We would be glad to get additional ideas and feedback from new users, academics and practioners alike.

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