Justifying Information Technology Investments: Balancing the Need for Speed of Action With Certainty before Action

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Abstract

Technological innovations create an increasing sense of strategic uncertainty. Executives are concerned about failure to implement the infrastructure that they might need and the opportunity costs that this might entail as a result of missed market opportunities. They are equally concerned with avoiding any unnecessary investments in technology infrastructure in support of market opportunities that do not arise. The trade-off between the desire for speed and the desire for certainty before acting requires a methodology for justifying contingent investments in assets that may be required and for enabling rapid deployment of these assets when required. We develop a general functional form for an investment decision that permits numerical computation of the value of an investment that enables the future deployment of a strategy under a range of conditions

1. Introduction

Technological innovations in shopping, distribution, and entertainment that outstrip consumers' ability to adopt them, cultural and military conflicts polarized by recent events in the middle east, and unprecedented stock market volatility combine to create an increasing sense of strategic uncertainty. Executives are concerned about failure to implement the infrastructure that they might need and the opportunity costs that this might entail as a result of missed market opportunities. They are equally concerned with avoiding any unnecessary investments in technology infrastructure in support of market opportunities that do not arise. They are trading off the desire for speed (*"we have no time to waste"*) with the desire for certainty before acting (*"we have no resources to waste"*). They feel they need to be prepared for anything that does happen, while avoiding expensive investments to prepare for events that do not occur. They require a methodology for justifying contingent investments in assets that may be required and for enabling rapid deployment of these assets when required.

We develop a general functional form for an investment decision that permits numerical computation of the value of an investment that enables the future deployment of a strategy under a range of conditions. The set of conditions includes environmental factors such as the behavior of customers, and game theoretic factors, such as the actions of competitors. Unfortunately, the general form makes it virtually impossible to derive a closed form solution; although we may be able to develop distributions for *individual parameters*, such as customer adoption rates, we cannot provide any general functional form for the *benefits* that can be expected from implementing a strategy. However, we extend the general functional form for the investment decision through what we consider an *elegant ad hocery*, using the general form as a harness into which we can plug computer simulations or numerical approximations for the benefits from strategies under specified conditions.

Maintaining flexibility while withholding expensive full commitment is key to maximizing profits under rapidly changing business conditions; this is facilitated by initially laying the groundwork for future actions through what we might have called ***strategy-enabling partial investments***. These partial investments cost less than complete acquisition of necessary resources. Importantly, they enable speed of action when the appropriate course of action can be determined and allow delaying full spending on necessary investments until it is clear which investments are required. These investments are properly viewed as ***strategic options.***

2. Review of the Literature

An option is simply the right to obtain an asset at later time, at a pre-specified price (call) or the right to sell an asset at a later time, at a pre-specified price (put). The value of an option is largely driven by uncertainties concerning the future value of this underlying asset.

A **financial option** is the right to trade a **financial asset** at a future time and at a predetermined price. Financial options are valued based on the history, particularly the history of price volatility, of the underlying asset, using a formula due to Fischer Black and Myron Scholes [1973].

In its purist sense, a **real option** is the right to trade a physical asset, such as real estate or manufactured durables such as aircraft, at a future time and at a

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predetermined price[1]. These are not "common value" in the sense that a one airline may want or need replacement aircraft more than another, or one firm may have a greater use for a piece of land than another. The greater the volatility in demand, the more valuable the option to take delivery without delay. [Myers 1984]. [Amram and Kulatilaka 2001]

A **strategic option** represents a **capability to deploy a selected strategy**. Rather than being purchased, these capabilities are synthesized by making the investments that will be needed for rapid deployment of the strategy later, if and when it is desired[2].. Strategic options are context-specific rather than common-value; a strategy based on customer relationship management and individualized service will have different value for chains like the Ritz Carlton or the Inter-Continental than it would for more mass-market chains like Marriott Courtyard or Holiday Inn.

History is unable to offer much guidance when attempting to value strategic options: the first airline to develop an online distribution strategy was not able to predict either the benefits from customer adoption or the potential losses from retaliation from travel agents concerned with the loss of business. There is no history of price or volatility, nor are there reasonable surrogates (there was no known distribution for the pricing strategies employed by Capital One or the regulation that will be applied to the insurance industry in the face of improved genetic testing. The variance of value is heavily contingent on timing and on actions of competitors (*c.f.*, [Kamien and Schwartz 1978] Katz and Shapiro 1987]).

IT investments can also be considered as **strategic IT options**. MIS faculty have studied the idea that investments in IT need to be valued and justified since at least the early 1970s. Some systems could clearly be justified because they were necessary to the timely conduct of business. Others were more subjective, and required valuing the information produced by the systems [Emery 1974]. Dos Santos [1991] applies real options theory to making IT investments, dividing the investment into two stages and treating the first stage as an option on the speedy deployment of the second. Kulatilaka and Perotti [1998] study investment in technology options in the presence of competition, and determine that in the presence of competition options are exercised sooner but total benefits to innovators are reduced (due to competition). Zhu [1999] studies IT options, rather than technological options more generally, and derives similar results. Huchzermeier and Loch [2001] apply a sequential decision analysis framework to a multi-stage investment process and use dynamic programming to determine the options value.

Perhaps the earliest work directly related to the valuation technique we use is statistical decision analysis, pioneered by Raiffa and Schlaifer in the 1960s [Pratt, Raiffa, and Schlaifer, 1965] [Raiffa, 1970]. Their idea was simple but powerful: analyzing *ex ante* the effects of taking a sequence of decisions, and allowing the combination of actions made based on previous decisions and the evolving state of the world to create a decision tree.

Some things may be needed in one scenario and unnecessary or even dangerous in another. These contingent possibilities, those things that we can identify **now** as possibly useful at a **later** time, yield the most interesting investment decisions. Increasingly, scenario analysis is used to predict the range of possible future environments, so that the range of systems they will require can be determined in advance (*e.g.,* Clemons [1995]).

3. Sequential Decision Making and Strategic *Chunkification*

Some systems investments can be divided into segments, tasks, or chunks that can be implemented sequentially. Development of the initial tasks can be undertaken early, perhaps immediately, and surely before there is certainty that the full project will be required. Later tasks can be undertaken when the state of the future (the emergent scenario) is clearer, or perhaps, is revealed with certainty. If the investment in the early tasks is limited, and if the investment in these tasks will result in a substantial **reduction in response time** to complete the entire systems implementation process when necessary (e.g. as a response to competitor actions), these early tasks can be viewed as strategic options. The cost of implementation of the early tasks can be viewed as an *option premium*; the benefits from rapid completion of systems development, such as early market share gains resulting from early deployment, can be considered the benefits from *exercising an option that is in the money*.

We can be more specific. Consider preparation for a future strategy, where the act of preparing requires two tasks, which require investments I1 and I2, and which have duration L1 and L2.

- The options premium, or the **cost of the option**, can be estimated by estimating I1, the cost associated with the investment needed to complete the first task.
- The **value of the option** will be most difficult to estimate in a meaningful fashion. It is determined by the value of the sequence of investments I1 at T1, I2 at T2, compared to the value of both investments made beginning at T2. While this

[1] Many researchers also include in this category actions that enhance strategic flexibility, such as learning or initial experiments with early market entry; we find it useful to make a distinction between real options as we have defined them, and strategic options, which we introduce in the next section; we trust this will cause no confusion among our readers.

[2] Other authors in the strategy area, particularly Bowman and Hurry [1993], Mitchell and Hamilton [1987], and Kogut [1991] have used the term strategic option much as we have here.

value cannot actually be determined, business simulation modeling can be most effective, when factors such as response time and adoption rate of customers, and the value of first mover advantages, can be incorporated. This will be explored in more detail in section 7.

The **reduction in response time** will frequently be close to L1, the time required to complete implementation of the first task and thus the duration of the first phase; only rarely will strategic uncertainty be reduced, and the state of the emergent scenario be revealed, faster than this. (Assuming that both tasks would need be performed sequentially, the eventual completion of sequence {I1,I2} when needed would be accelerated by L1 if the first task were performed in advance, before it was required.) Thus, the value of advanced preparation can be determined by calculating the value of the difference between the optimal strategy **ß*(θ,t)** that would be pursued with the enabling investment I1 completed in advance if the state of the world were revealed to be **θ** at time **t** and the best alternative strategy **ß** in **θ** that could pursued if I1 had not been completed. This computation needs to be performed, integrating over probability distributions for state of the world **θ** and the time at which it is revealed.

4. Valuation in Precision Pricing Strategies

4.1 An Attacker with Differential Pricing

We consider the credit card industry at the time at which precision pricing was first introduced. The **Attacking Bank** (AB) launches its differential pricing strategy and begins to attract high balance revolvers. **Creative Bank** (one of two dominant players) has various strategic responses available to it. The **Other Bank** (OB) simply ignores changes in the industry. We compare the strategies that CB may follow, and, in particular we compare them to the profits enjoyed by OB. Thus, L1 is the time it would take to develop the software and expertise needed to deploy the differential pricing strategy employed by the Attacking Bank and I1 is the cost of doing so. L2 is the time taken to deploy this strategy once I1 has been completed and I2 is the cost of doing so (L2 is almost instantaneous and cost I2 almost zero). The option value of I1 is the incremental value of being ready to deploy differential pricing if attacked, conditioned by the timing and likelihood of attack.

4.2. Analysis of Alternative Strategies for Defenders — The *Status Quo* and the Value of Preserving It

A casual analysis suggests that neither incumbent bank would want to do move to differential pricing;; with all customers initially being charged the maximum allowed under usury laws, cutting prices for some customers would not be matched by offsetting increases for others, and thus should inevitably reduce the profits for the entire industry. In the base case or *status quo* scenario, before the entry of AB, CB and OB each have 5-year earning streams with NPV of $16.943 million.

Consider what happens if CB engages in data mining and differential pricing, changing its pricing strategy for its existing customer base but not offering a balance transfer product to attract new customers away from OB. We assume that since they receive no immediate reward for doing so, customers do not transfer from OB to CB. NPV of CB's earning stream is reduced to $15.24 million while OB remains at $ 16.94 million. (Appendix 1 describes how these numbers are calculated. Appendix 2 provides calculations for some combinations of the parameters that determine the value the profit stream produced by various strategies.) Continuation of the *status quo* strategy of figure 1 is preferable, and this strategy offers no reason for either bank to disturb the status quo.

We now consider CB's introducing defensive differential pricing to protect its own best accounts along with an aggressive balance transfer product to attract the best customers from OB, just the strategy that AB would have pursued if left an opening in the market. However, any attack on OB's customers base by a major incumbent competitor, following a strategy that looked like the initiation of a price war, would have received an immediate response. Not surprisingly, both banks earned more under the *status quo* scenario than they do when either attempts to introduce the strategy pursued by AB.

4.3. Inevitability of Attack and the Need for Careful Response

This comfortable oligopoly enjoyed by CB and OB could not continue. Figure 1 shows what happens when AB enters the industry with a strategy based upon data mining and differential pricing, effectively targeting the most attractive customers in the credit card portfolios of its competitors; neither CB nor OB is prepared to respond immediately. The competitive situation of both CB and OB deteriorates after AB's entry and the results are unacceptable for both defending banks. This analysis was done under conditions favorable to defenders, with customers exhibiting only slow response to the attacker's offers; even under conservative assumptions, failure to respond to AB's attack is unacceptable for CB.

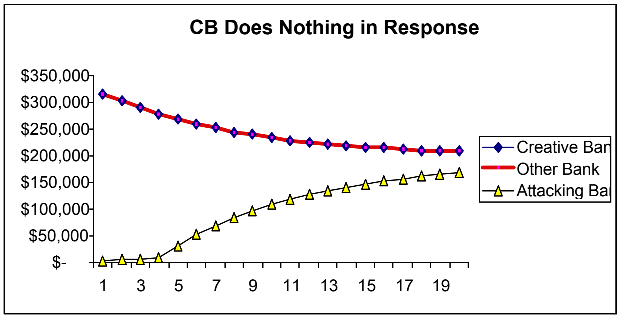

Figure 1—AB begins its attack; neither CB nor OB responds. NPV of profits of both incumbent banks are reduced to $10.94 million, while AB enjoys profits of $7.82 million.

4.4. Analysis of Alternative Strategies for Defenders — The Range of Alternatives and Conditions Determining Success

CB does have a range of strategies available to it:

- **DP** — (Differential Pricing only) Roll out data mining and differential pricing as quickly as possible (8 quarters), but do nothing in the short term to protect market share until data mining is available
- **CPDP** — (Cut Prices immediately while preparing for Differential Pricing) Cut prices for all accounts now to halt erosion of market share, while once again implementing data mining as quickly as possible, within 8 quarters
- **MODP** — (Match Offers while preparing for Differential Pricing) Do not cut prices for any customers initially, but match the offers customers have received, for any customers who call to transfer their balances to AB, while once again implementing data mining as quickly as possible

A number of factors influence the attractiveness of each of these strategies. Principal among them are the following two:

- The **in play ratio** (**IP**) , that is, the rate at which customers consider switching their balances among banks simply because they have been offered a better rate.
- The **retention effectiveness ratio** (**RE**) , that is, the percentage of customers who cancel their planned balance transfers from CB to AB when CB matches the offers that they have received.

4.5. Analysis of Alternative Strategies for Defenders — Specific Scenarios

We will initially consider only strategies for defenders that are not based on their developing the infrastructure and performing the advanced training and other forms of preparation that are required to launch differential pricing. We make this assumption since both incumbents were able to determine that their own deployment of differential pricing and their competitor's inevitable response to it would damage both of them; thus, an investment in preparing for differential pricing would have negative value.

Assigning specific values for the parameters described above allows us to calculate the implications for CB of each of the three strategies that could be used in response to attack from AB. Assuming initially that IP is a relatively high 50% and retention effectiveness is only 25%, figures 2-4 illustrate the results of deploying each of these three strategies for these specific values. Clearly, for these parameter values CB's best strategy would be CPDP; that is, it should cut prices for all its existing customers immediately, to avoid losing its most profitable accounts to AB, and it should then implement informed differential pricing when it is able to do so, after 8 quarters.

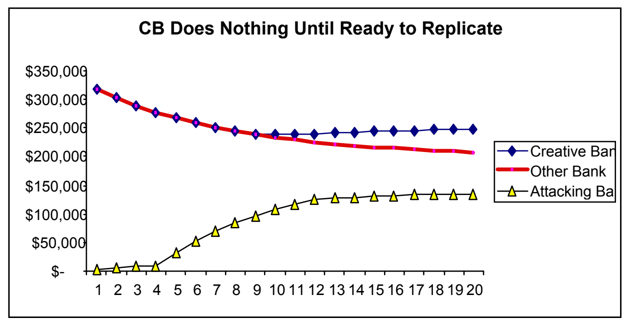

Figure 2—AB begins its attack. OB does nothing. CB begins to prepare to match AB's strategy, but does nothing until its infrastructure is available. Clearly this works better than OB's strategy, but with high IP ratio it results in the loss of too many good accounts to AB before CB is ready to implement differential pricing. The NPV of CB's 5-year earnings is reduced to $12.94 million. This is better than OB's strategy of doing nothing, which results in NPV of earnings being reduced to $10.94 million, but CB still loses too many good accounts before it is ready to act.

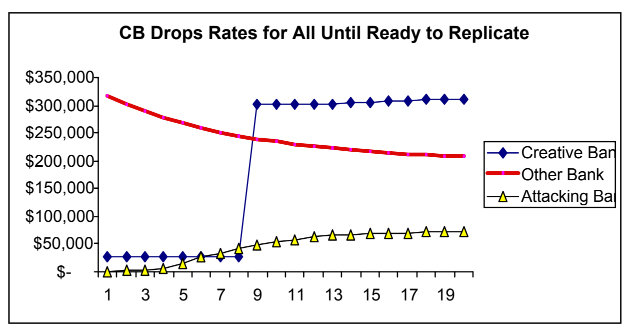

Figure 3—AB begins its attack. CB responds by dropping its prices for all customers to avoid any loss of its good accounts to AB. With High IP the large majority of CB's best accounts would have left in the two years it takes CB to replicate AB's strategy and this defensive move preserves all of these accounts. The NPV of CB's earnings is preserved and CB earns $13.74 million, but the short-term impacts may be unacceptable. Once again, OB earns $10.94 million. AB earns $3.35 million.

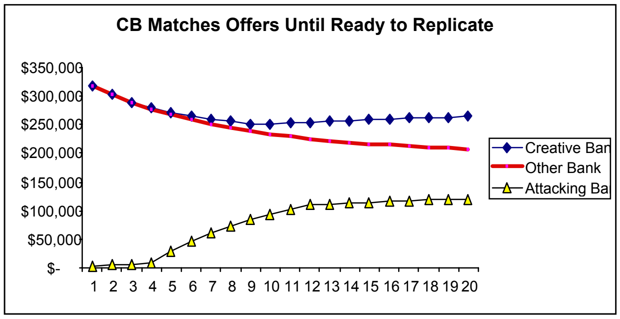

Figure 4—AB begins its attack. CB responds by attempting to match the offers that its best customers receive from AB. With high IP, many of CB's accounts are at risk each month, but with low RE matching their offers is rarely effective in persuading customers to remain with CB. CB earns $13.63 million, while OB once again earns $10.94 million. This strategy is less profitable for CB than dropping rates for all customers but the short-term effects are better.

The selection of CB's best strategy depends upon the values assumed for IP and RE. Reducing IP to 25% and increasing RE to 75% changes the value of CB's earnings. Under DP, CB begins to prepare to match AB's strategy, but does nothing until its infrastructure is available. Over the long term CB does better with this strategy than OB, but it does reduce CB's profits and the NPV of 5-year earnings are $14.43 million for CB and $11.77 million for OB. AB earns $4.22 million. Alternatively, CB can employ CPDP in response to AB's attack, immediately dropping its prices for all customers to avoid any loss of its good accounts to AB. With low IP and high RE, this is unnecessarily costly, and reduces NPV of 5-year earnings to $14.00 million, below those available to CB with strategy DP. OB continues to earn $11.77 and AB earns $2.53 million. Finally, CB can employ MODP, matching the offers that its best customers receive from AB. With NPV of 5-year earnings of $15.70 million this strategy is more profitable than DP or CPDP, and is better than the strategy followed by OB, which continues to earn $11.77 million. AB earns $1.95 million. Under low IP and high ER MODP is the preferred strategy. With slow loss of accounts, there is limited pressure for CB to act immediately. Moreover, with a high probability that matching offers will be effective, CB should cut prices only for those customers who begin to initiate the process to transfer their card balances to AB.

4.6. Investing in Strategic Flexibility: Calculating the Value Of Advance Preparation for Differential Pricing

Ignoring attack would be unacceptable for CB, while premature deployment of differential pricing dramatically reduces CB's profitability. There is another strategy, investing in preparation for data mining, and deploying it rapidly if and when a new entrant attacks. The value of this strategy-enabling partial investment can only be determined by examining the situation that would have obtained had the investment not been made. Let us do a specific calculation before presenting the general functional form, and let us assume that as in figures 2-4 the IP is 50% and RE is 25%. The best alternative available to CB if it were to be attacked without advance preparation was shown to be deployment of CPDP. Let us examine one more strategy, CB's early investment in preparation for data mining (PDP), to enable rapid deployment of differential pricing **if and when** CB is attacked. This strategy is shown in figure 5; clearly, this is vastly preferable to the three alternatives shown in figures 2-4.

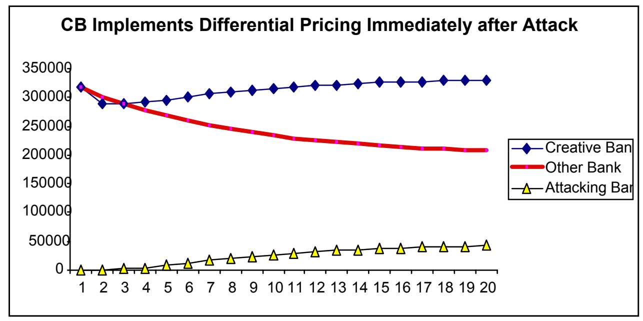

Figure 5—Rapid deployment of differential pricing enables CB to respond to attack from AB.

With NPV of 5-year earnings of $16.63 million and acceptable short term profitability this is clearly the best strategic choice, better than those shown in figures 2-4, and better than the corresponding figure of $10.94 million earned by OB. The incremental value of the investment in preparation is $4.25 million — the difference between the value of this strategy and the value of the best alternative, which was shown in figure 2.

Comparison of NPV(PDP) to the alternatives under each combination of parameter values allows us to calculate the value of advance preparation, assuming these parameter values and assuming that an attack does materialize.

However, we do not know IP or RE, and we cannot be sure if or when an attack will materialize. The timing of attack is determined by AB, a hostile opponent. The values of IP and RE will only be known at the time of attack, and will be determined in part by environmental conditions and in part by strategic business decisions made by AB. Consequently, calculating the value of advance preparation as a strategic option requires developing and using probability distributions for IP, RE, and the time at which attack occurs.

Assuming that IP and RE were known, the value of advance preparation as a function of probability of attack at time t could be computed from the following:

(1) Value (Advance Preparation) =

$$\int_{t_0}^{t_n} p(t)\left\{ \begin{array}{l} NPV(PDP,t) \\ -\max\left[NPV(DP,t), NPV(CPDP,t), NPV(MODP,t)\right] \end{array} \right\} dt$$

Here, p(t) represents the probability of new entrant AB's attack at time t, and NPV(Strategy$_ß$,t) represents the NPV, at the present time, of strategy Strategy$_ß$, if attack occurs at time t. The integral is over time, from the lower to the upper bounds of the time period under consideration. ß represents the set {DP, CPDP, MODP} Of course the values of NPV(DP,t), NPV(CPDP,t), and NPV(MODP,t) depend upon the values of IP and RE. Hence, the complete functional form becomes:

(2) Value (Advance Preparation) =

$$\int_{t_0}^{t_u}\int_{IP_L}^{IP_U}\int_{RE_L}^{RE_U} p(t)\,p(IP)\,p(RE)\left\{ \begin{array}{l} NPV\ (PDP\ ,t) \\ -\max\left[\begin{array}{l} NPV\ (DP\ ,t,IP,RE\ ), \\ NPV\ (CPDP\ ,t,IPRE\ ), \\ NPV\ (MODP\ ,t,IP,RE \end{array} \right] \end{array} \right\} dRE\ dIP\ dt$$

Here, p(IP) and p(RE) represent the probability distributions assumed for these variables, which must be integrated over the bounds of their distribution. The functional forms of NPV(Strategy$_ß$,t,IP,RE) have been extended to incorporate the dependence of the value of each strategy ß upon the environmental context in which it is deployed, for ß in {DP, CPDP, MODP}.

For example, let us assume the following:

- The probability of attack is 90%, with a distribution that places greater weight on early entry
- IP has a discrete distribution that places 25% probabilities on the values of 25% and 75% and the remaining 50% probability on 50%.
- RE has a discrete distribution that places 25% probabilities on the values of 25% and 75% and the remaining 50% probability on 50%.

This enables us to calculate an expected value \$1.88 million for the strategic option created by advance preparation. (These calculations are described in appendix 3.) Comparing the value of this strategic option to the cost of advance preparation allows us to determine if the investment is worth making.

5. Conclusions

This paper makes a modest contribution to our ability to evaluate strategic options in information technology infrastructure. It shows how a systematic determination of sources of strategic uncertainty can lead to a functional form of valuation, which can be solved numerically even if it is not amenable to closed form analysis.

No simple, general, closed-form solution exists for the class of strategic options that we are exploring here. Black-Scholes and other option valuation models enjoy the mathematical simplicity at the cost of restrictions on the underlying stochastic processes of assets' future value. Our approach is to derive a general form as far as we have been able to derive and, perhaps, as general as any likely to be developed. Whether our technique is labeled sequential decision analysis for the value of strategy-enabling partial investments, or analysis of IT investments as strategic options, is of little importance. This technique makes a modest contribution to allowing the decision maker to structure what he or she does know about the impact of an expected strategy, even in the complete absence of historical data on the value of the payoff from the investment. Consequently, this technique makes a modest contribution towards allowing decision makers to evaluate investments in supporting strategy as strategic options.

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Appendix 1

With the assumptions that follow below it is possible to derive the following:

- The expected profitability of customers in the total population, as they evolve over time.
- The market share of each bank, both in total and by expected profitability of population subgroups, as they evolve over time.
- The profitability of each bank, over time.

A.1. Assumptions

Assumption 1: Each individual customer carries a month balance of b_i, while the distribution of b_i in the population is *f(b)*. The distribution *f(b)* is uniform between *0* and *B*.

Assumption 2: Each individual faces the possibility of bankruptcy at any time, which can be modeled as a Poisson process. The rate of bankruptcy for individual *i* is λ_i (per quarter), while the distribution of λ over individuals in the population is $g(\lambda)$. The distribution $g(\lambda)$ is uniform between *0* and $\boldsymbol{\Lambda}$. Customers who have declared bankruptcy are not dropped from the bank, but they are offered **secured cards**, which reduce the bank's risk, and they are charged a higher interest rate, which the bank uses for its high-risk customer base.

Assumption 3: An individual's probability of bankruptcy is not correlated with the individual's outstanding card balance, and thus b_i and λ_i are independent.

Assumption 4: Before implementing a differential pricing strategy, banks do not maintain information about individual customers. After the implementation, the bank knows each individual's b_i and bankruptcy history for the past year.

Assumption 5: Before implementing a differential pricing strategy, and in the absence of any information on which to base pricing decisions, both banks charge customers the same interest rate of r_s (per quarter).

Assumption 6: The implementation of a differential pricing strategy by an incumbent bank has a defensive component aimed at reducing or eliminating loss of the most profitable customers to a new entrant attacker. For customers with a balance of more than *k* who have not filed for bankruptcy in the past year, the bank will offer an attractive rate of r_n. For customers with a bankruptcy filing in the past year, r_p is offered. For the rest of the customers, the rate will stay at r_s. The interest rate for high-balance customers is lower than the rate that was offered to all customers before differential pricing, which in turn is lower than the high-risk rate offered to customers who have had a recent bankruptcy filing.

Assumption 7: Implementation of a differential pricing strategy — either by a new entrant bank or by one of the incumbent banks following an aggressive differential pricing strategy — calls for the bank to offer r_l as the balance transfer rate for a year to a new customer, followed by r_n for subsequent periods. The balance transfer interest rate is lower than the rate for subsequent periods, which in turn is less than the rate that was offered to all customers before differential pricing. Balance transfer products are only offered to new customers with a balance of more than *k*. If a customer goes bankrupt after switching banks, the customer's the rate will be raised to the high-risk rate of r_p.

Assumption 8: The two incumbent banks (CB and OB) are identical and initially split the market by half. All banks face a discount rate of r_f

Assumption 9: Without loss of generality, the market size is normalized to 1.

Assumption 10: The in-play ratio limits the speed with which customers will accept offers and switch banks, even when offers are as attractive as those being employed by the attackers here. Only *I%* customers are considering switching in each quarter.

Assumption 11: Retention-effectiveness is limited. When a bank matches the interest rate that a competitor offered one of its high-balance customers as an incentive to motivate a balance transfer, the matching counter-offer will be effective only *R%* of the time.

Assumption 12: Differential pricing cannot be implemented immediately. It takes a bank *L* periods to develop the infrastructure needed to implement a differential pricing strategy.

A.2. Expected Bankruptcy

Lemma 1: (expected bankruptcy of the general population) Individual i, with bankruptcy arrival-rate λ_i, has the probability of avoiding bankruptcy in a given quarter of $e^{-\lambda i}$. Integrating across the general population, the expected rate of customers avoiding bankruptcy in any given quarter is:

$$C_q = \int_0^{\Lambda} \frac{e^{-x}}{\Lambda} dx = \left(\frac{1-e^{-\Lambda}}{\Lambda} \right) \quad (1)$$

Lemma 2: (expected bankruptcy of customers with and without bankruptcy history in the past year) The unconditional expected rate of customers avoiding bankruptcy in a given year is:

$$C_y = \int_0^{\Lambda} \frac{e^{-4x}}{\Lambda} dx = \left(\frac{1-e^{-4\Lambda}}{4\Lambda} \right) \quad (2)$$

We then calculate the conditional distribution of λ for customers who have avoided bankruptcy in the past year:

$$P_{-}(\lambda) = \frac{\int_0^{\lambda} \frac{e^{-4x}}{\Lambda} dx}{\int_0^{\Lambda} \frac{e^{-4x}}{\Lambda} dx} = \frac{1-e^{-4\lambda}}{1-e^{-4\Lambda}}$$

Therefore, the density function is:

$$p_{-}(\lambda) = \left(\frac{1-e^{-4\lambda}}{1-e^{-4\Lambda}} \right)' = \frac{4e^{-4\lambda}}{1-e^{-4\Lambda}}$$

Thus, the conditional expected non-bankruptcy rate for customers without bankruptcy in the past year is:

$$C_{q-} = \int_0^{\Lambda} \frac{4e^{-5\lambda}}{1-e^{-4\Lambda}} dx = \frac{4(1-e^{-5\Lambda})}{5(1-e^{-4\Lambda})} \quad (3)$$

Similarly, the conditional expected non-bankruptcy rate for customer with bankruptcy in the past year is:

$$C_{q+} = \frac{4(4-5e^{-\Lambda}+e^{-5\Lambda})}{5(4\Lambda-1+e^{-4\Lambda})} \quad (4)$$

A.3. Expected Size of Balance Transfers

Lemma 3: (conditional expected balance of balance transfer customers) The conditional expected balances of customers who are eligible for balance transfer offers and those who are not eligible are:

$$B_{k+} = \int_k^B \frac{1}{B} x dx = \frac{B^2-k^2}{2B}$$
$$B_{k-} = \int_0^k \frac{1}{B} x dx = \frac{k^2}{2B} \quad (5)$$

A.4. Expected Profits for Each Bank

Given the above assumptions and lemma, we can calculate the market share and profitability of each individual bank in Quarter j.

Case 1: Status Quo

$$P^1{}_{CB,j} = P^1{}_{OB,j} = \frac{B}{2}\left(r_s - C_q\right)$$

$$P^1{}_{AB,j} = 0$$

Case 2: CB Initiates Preemptive Pricing Strategy

$$P^2{}_{CB,j} = \left(1\text{-}C_y\right)\frac{B}{2} r_p + C_y \begin{bmatrix} B_{k+}\left(r_n - C_{q-}\right) + \\ B_{k-}\left(r_s - C_{q-}\right) \end{bmatrix}$$

$$P^2{}_{OB,j} = \frac{B}{2}\left(r_s - C_q\right)$$

$$P^2{}_{AB,j} = 0$$

Case 3: CB Initiates Aggressive Pricing Strategy

$$P^3{}_{CB,j} = \left(1\text{-}C_y\right)\frac{B}{2}\left(r_p - C_{q+}\right) + C_y \begin{bmatrix} B_{t+}\left(r_n - C_{q-}\right) + \\ B_{t-}\left(r_s - C_{q-}\right) \end{bmatrix}$$
$$+ \left[(1-I)^{\max(0,j-4)} - (1-I)^j\right]\frac{B-t}{B} B_{t+}\left(r_l - C_q\right) +$$
$$\left[1-(1-I)^{\max(0,j-4)}\right]\frac{B-t}{B} B_{t+}\left(r_n - C_q\right)$$

$$P^3{}_{OB,j} = (1-I)^j \frac{B}{2}\left(r_s - C_q\right) + \left[1-(1-I)^j\right]\frac{tB_{t-}}{B}\left(r_s - C_q\right)$$

$$P^3{}_{AB,j} = 0$$

Case 4: CB and OB Do Nothing in Response to Attack

$$P^4{}_{CB,j} = (1-I)^j \frac{B}{2}\left(r_s - C_q\right) + \left[1-(1-I)^j\right]\frac{kB_{k-}}{B}\left(r_s - C_q\right)$$

$$P^4{}_{OB,j} = (1-I)^j \frac{B}{2}\left(r_s - C_q\right) + \left[1-(1-I)^j\right]\frac{kB_{k-}}{B}\left(r_s - C_q\right)$$

$$P^4{}_{AB,j} = 2\left[(1-I)^{\max(0,j-4)} - (1-I)^j\right]\frac{B-k}{B} B_{k+}\left(r_l - C_q\right) +$$
$$2\left[1-(1-I)^{\max(0,j-4)}\right]\frac{B-k}{B} B_{k+}\left(r_n - C_q\right)$$

Case 5: CB Does Nothing Until Ready to Replicate Strategy

If j < L, then

$$P^5{}_{CB,j} = (1-I)^j \frac{B}{2}\left(r_s - C_q\right) + \left[1-(1-I)^j\right]\frac{kB_{k-}}{B}\left(r_s - C_q\right)$$

$$P^5{}_{OB,j} = (1-I)^j \frac{B}{2}\left(r_s - C_q\right) + \left[1-(1-I)^j\right]\frac{kB_{k-}}{B}\left(r_s - C_q\right)$$

$$P^5{}_{AB,j} = 2\left[(1-I)^{\max(0,j-4)} - (1-I)^j\right]\frac{B-k}{B} B_{k+}\left(r_l - C_q\right) +$$
$$2\left[1-(1-I)^{\max(0,j-4)}\right]\frac{B-k}{B} B_{k+}\left(r_n - C_q\right)$$

If j > L, then

$$P^{5}{}_{CB,j} = (1-I)^{L}\left[(1-C_y)\frac{B}{2}r_p + C_y\begin{bmatrix} B_{k+}(r_n - C_{q-})+ \\ B_{k-}(r_s - C_{q-}) \end{bmatrix}\right]+$$

$$\left[1-(1-I)^{L}\right]\frac{kB_{k-}}{B}(r_s - C_q)+\frac{\begin{bmatrix}(1-I)^{\max(l,j-4)} - \\ (1-I)^{j}\end{bmatrix}\frac{B-k}{B}B_{k+}(r_l - C_q)}{2}+$$

$$\frac{\left[(1-I)^{L}-(1-I)^{\max(L,j-4)}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)}{2}$$

$$P^{5}{}_{OB,j} = (1-I)^{j}\frac{B}{2}(r_s - C_q)+\left[1-(1-I)^{j}\right]\frac{kB_{k-}}{B}(r_s - C_q)$$

$$P^{5}{}_{AB,j} = 2\left[(1-I)^{\min(l,\max(0,j-4))}-(1-I)^{L}\right]\frac{B-k}{B}B_{k+}(r_l - C_q)+$$

$$2\left[1-(1-I)^{\min(L,\max(0,j-4))}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)+$$

$$\frac{\left[(1-I)^{\max(L,j-4)}-(1-I)^{j}\right]\frac{B-k}{B}B_{k+}(r_l - C_q)}{2}+$$

$$\frac{\left[(1-I)^{l}-(1-I)^{\max(L,j-4)}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)}{2}$$

Case 6: CB Drops Rates for All Existing Customers Until Ready to Replicate Strategy

If j < L, then

$$P^{6}{}_{CB,j} = \frac{B}{2}(r_n - C_q)$$

$$P^{6}{}_{OB,j} = (1-I)^{j}\frac{B}{2}(r_s - C_q)+\left[1-(1-I)^{j}\right]\frac{kB_{k-}}{B}(r_s - C_q)$$

$$P^{6}{}_{AB,j} = \left[(1-I)^{\max(0,j-4)}-(1-I)^{j}\right]\frac{B-k}{B}B_{k+}(r_l - C_q)+$$

$$\left[1-(1-I)^{\max(0,j-4)}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)$$

If j > L, then

$$P^{6}{}_{CB,j} = \left[(1-C_y)\frac{B}{2}r_p + C_y\left[B_{k+}(r_n - C_{q-})+B_{k-}(r_s - C_{q-})\right]\right]$$

$$+\frac{\left[(1-I)^{\max(L,j-4)}-(1-I)^{j}\right]\frac{B-k}{B}B_{k+}(r_l - C_q)}{2}+$$

$$\frac{\left[(1-I)^{L}-(1-I)^{\max(L,j-4)}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)}{2}$$

$$P^{6}{}_{OB,j} = (1-I)^{j}\frac{B}{2}(r_s - C_q)+\left[1-(1-I)^{j}\right]\frac{kB_{k-}}{B}(r_s - C_q)$$

$$P^{6}{}_{AB,j} = \left[(1-I)^{\min(L,\max(0,j-4))}-(1-I)^{L}\right]\frac{B-k}{B}B_{k+}(r_l - C_q)+$$

$$\left[1-(1-I)^{\min(L,\max(0,j-4))}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)$$

$$+\frac{\left[(1-I)^{\max(L,j-4)}-(1-I)^{j}\right]\frac{B-k}{B}B_{k+}(r_l - C_q)}{2}+$$

$$\frac{\left[(1-I)^{L}-(1-I)^{\max(L,j-4)}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)}{2}$$

Case 7: CB Matches Offers for Customers Attempting to Defect Until Ready to Replicate Strategy

If j < L, then

$$P^{7}{}_{CB,j} = (1-I)^{j}\frac{B}{2}(r_s - C_q)+\left[1-(1-I)^{j}\right]\frac{kB_{k-}}{B}(r_s - C_q)$$

$$+R\begin{Bmatrix}\left[(1-I)^{\max(0,j-4)}-(1-I)^{j}\right](r_l - C_q)+ \\ \left[1-(1-I)^{\max(0,j-4)}\right](r_n - C_q)\end{Bmatrix}\frac{B-k}{B}B_{k+}$$

$$P^{7}{}_{OB,j} = (1-I)^{j}\frac{B}{2}(r_s - C_q)+\left[1-(1-I)^{j}\right]\frac{kB_{k-}}{B}(r_s - C_q)$$

$$P^{7}{}_{AB,j} = 2\left[(1-I)^{\max(0,j-4)}-(1-I)^{j}\right]\frac{B-k}{B}B_{k+}(r_l - C_q)+$$

$$2\left[1-(1-I)^{\max(0,j-4)}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)$$

$$-R\begin{Bmatrix}\left[(1-I)^{\max(0,j-4)}-(1-I)^{j}\right](r_l - C_q)+ \\ \left[1-(1-I)^{\max(0,j-4)}\right](r_n - C_q)\end{Bmatrix}\frac{B-k}{B}B_{k+}$$

If j > L, then

$$P^{7}{}_{CB,j} = (1-I)^{L}\begin{bmatrix}(1-C_y)\frac{B}{2}r_p + \\ C_y\left[B_{k+}(r_n - C_{q-})+B_{k-}(r_s - C_{q-})\right]\end{bmatrix}+$$

$$\left[1-(1-I)^{L}\right]\frac{kB_{k-}}{B}(r_s - C_q)+$$

$$\frac{\left[(1-I)^{\max(L,j-4)}-(1-I)^{j}\right]\frac{B-k}{B}B_{k+}(r_l - C_q)}{2}+$$

$$\frac{\left[(1-I)^{L}-(1-I)^{\max(L,j-4)}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)}{2}+$$

$$R\left(1-(1-I)^{L}\right)(r_n - C_q)\frac{B-k}{B}B_{k+}$$

$$P^{7}{}_{OB,j} = (1-I)^{j}\frac{B}{2}(r_s - C_q)+\left[1-(1-I)^{j}\right]\frac{kB_{k-}}{B}(r_s - C_q)$$

$$P^{7}{}_{AB,j} = (2-R)\begin{Bmatrix}\begin{bmatrix}(1-I)^{\min(L,\max(0,j-4))} - \\ (1-I)^{L}\end{bmatrix}\frac{B-k}{B}B_{k+}(r_l - C_q)+ \\ \left[1-(1-I)^{\min(L,\max(0,j-4))}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)\end{Bmatrix}+$$

$$\frac{\left[(1-I)^{\max(L,j-4)}-(1-I)^{j}\right]\frac{B-k}{B}B_{k+}(r_l - C_q)}{2}+$$

$$\frac{\left[(1-I)^{L}-(1-I)^{\max(L,j-4)}\right]\frac{B-k}{B}B_{k+}(r_n - C_q)}{2}$$

A.5. NPV Calculations

Given the equations for profit calculations presented in B above, the NPV of each bank (CB, OB, or AB) for each of the strategies Y described above can be easily calculated as following:

$$NPV^{Y}{}_{X}(l) = \sum_{j=1}^{\infty}\frac{P^{Y}{}_{X,j}(l)}{(1+r_f)^{j}}$$, where X ∈ {CB, OB, AB}

and Y ∈ {1, 2, 3, 4, 5, 6, 7}

As noted in A.4 above, the profits each bank earns from a strategy is a function of L, the delay required to complete and install systems before its implementation.

The option value for enabling immediate implementation of a strategy, instead of waiting for l periods before deploying it can thus be valued as:

$$V_X(l) = \max_{Y} NPV^{Y}{}_{X}(0) - \max_{Y} NPV^{Y}{}_{X}(l)$$

Appendix 2 presents the results of performing these calculations for specific values of interest rates, bankruptcy rates, balances, in-play ratios and retention effectiveness ratios.

Appendix 2
NPV Analysis

NPV Analysis	25% In Play 75% Retention	50% In Play 25% Retention	50% In Play 75% Retention
Case 1: Status Quo			
Creative Bank	$16,943,262	$16,943,262	$16,943,262
Other Bank	$6,943,262	$16,943,262	$16,943,262
Attacking Bank	$ -	$ -	$ -
TOTAL	$33,886,525	$33,886,525	$33,886,525
Case 2: CB initiates preemptive pricing strategy			
Creative Bank	$5,244,307	$15,244,307	$15,244,307
Other Bank	$16,943,262	$16,943,262	$16,943,262
Attacking Bank	$ -	$ -	$ -
TOTAL	$32,187,569	$32,187,569	$32,187,569
Case 3: CB initates aggressive pricing strategy			
Creative Bank	$8,597,366	$19,153,777	$19,153,777
Other Bank	$11,772,576	$10,943,265	$10,943,265
Attacking Bank	$ -	$ -	$ -
TOTAL	$30,369,942	$30,097,042	$30,097,042
Case 4: CB and OB do nothing in response to attack			
Creative Bank	$11,772,576	$10,943,265	$10,943,265
Other Bank	$11,772,576	$10,943,265	$10,943,265
Attacking Bank	$6,706,118	$7,818,941	$7,818,941
TOTAL	$30,251,271	$29,705,471	$29,705,471
Case 5: CB does nothing until ready to replicate strategy			
Creative Bank	$14,428,075	$12,942,986	$12,942,986
Other Bank	$11,772,576	$10,943,265	$10,943,265
Attacking Bank	$4,223,827	$6,130,713	$6,130,713
TOTAL	$ 30,424,478	$30,016,965	$30,016,965
Case 6: CB drops rates for all exisitng customers until ready to replicate strategy			
Creative Bank	$13,999,291	$13,734,603	$13,734,603
Other Bank	$11,772,576	$10,943,265	$10,943,265
Attacking Bank	$2,525,629	$3,346,728	$3,346,728
TOTAL	$28,297,496	$28,024,596	$28,024,596
Case 7: CB matchs offers for customers attempting to defect until ready to replicate strategy			
Creative Bank	$15,701,723	$13,638,983	$15,030,975
Other Bank	$11,772,576	$10,943,265	$10,943,265
Attacking Bank	$2,950,178	$5,434,717	$4,042,724
TOTAL	$30,424,478	$30,016,965	$30,016,965

Appendix 3 uses the results of appendix 2 to perform the calculations over probability distributions for in-play ratios, retention effectiveness ratios, and timing of AB's attack.

Appendix 3
Option Value Calculation

Option Valuation ($ million) In-Play/ Retention	Lag 8	6	4	2	No Entry
25/25	$2.07	$1.67	$1.21	$0.65	$0.00
25/50	$1.64	$1.33	$0.96	$0.52	$0.00
25/75	$1.22	$0.99	$0.71	$0.38	$0.00
50/25	$3.46	$2.76	$1.97	$1.06	$0.00
50/50	$2.86	$2.43	$1.85	$1.06	$0.00
50/75	$2.17	$1.84	$1.40	$0.81	$0.00
75/25	$3.80	$3.11	$2.30	$1.29	$0.00
75/50	$3.63	$3.11	$2.30	$1.29	$0.00
75/75	$2.77	$2.45	$1.96	$1.20	$0.00

Probability In-Play/ Retention	8	6	4	2	No Entry	Marginal Probability
25/25	1.25%	0.94%	0.63%	0.31%	0.63%	**6.25%**
25/50	2.50%	1.88%	1.25%	0.63%	1.25%	**12.50%**
25/75	1.25%	0.94%	0.63%	0.31%	0.63%	**6.25%**
50/25	2.50%	1.88%	1.25%	0.63%	1.25%	**12.50%**
50/50	5.00%	3.75%	2.50%	1.25%	2.50%	**25.00%**
50/75	2.50%	1.88%	1.25%	0.63%	1.25%	**12.50%**
75/25	1.25%	0.94%	0.63%	0.31%	0.63%	**6.25%**
75/50	2.50%	1.88%	1.25%	0.63%	1.25%	**12.50%**
75/75	1.25%	0.94%	0.63%	0.31%	0.63%	**6.25%**
Marginal Probability	**20.0%**	**15.0%**	**10.0%**	**5.00%**	**10.00%**	**100.00%**

Option Value	**$1.89**
Option Variance	**$1.03**