ASP-based Software Delivery: a Real Options Analysis

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Abstract: Application Service Provider (ASP) is a recently emerged software delivery model under which an ASP hosts, manages and delivers software as a service to customers via the Internet or a private network. The ASP model offers benefits from cost savings, specialized expertise, a faster time to market, and a reduced risk due to a lower capital investment. Buying services also provides more financial and technological flexibility than owning the technology in-house. However, customers who are unsure about the value of ASP services and their demands, in terms of the number of users and a usage level, may be reluctant to commit to ASP contracts. Many customers are also concerned with security and loss of control and performance, especially when the software becomes more critical as the company grows. Thus, for the ASP industry to move forward, ASPs must help customers cope with these uncertainties and risks. In this paper we propose three real options based approaches. First, in order to deal with the uncertainties of software value and usage level, we propose a usage-based pricing structure with an option to switch to a flat subscription fee. This arrangement allows ASPs to penetrate the low-usage market and to link their revenue to the value customers receive from their software, while still providing an upper bound on customers' cost. Second, we evaluate an option to bring the software in-house after an initial period of ASP-based access. In addition to allowing customers to manage the risk created by uncertainty in their usage level, the number of users and the value per usage that the software will provide, this option allows customers to hedge against assuming an unacceptable level of security and performance risk. Implicitly, the option to bring software in-house is a growth option for a company to invest fully in the software should it become desirable to do so. Lastly, we analyze an option to end an ASP contract prior to its expiration, including when customers are under a minimum usage requirement and a minimum time commitment. This exit option allows customers to manage their software investments when they are unsure of the value of the software. It also alleviates the risks of relying on certain technologies and service providers, which may be especially valuable in a fast-changing technology environment, and when dealing with early-stage ASPs. As a result, this option illustrates the value of technological flexibility that ASP-based software delivery offers relative to an in-house implementation. In order to study these real options, we identify the three key underlying uncertainties to be software value per usage, usage level and the number of users. We then employ a mean reverting process with a time-varying mean and a time varying variance to model these uncertainties and their correlations. This method allows us to pattern after a software cycle, a learning effect, a company growth and the correlations between software benefit and usage. Finally, we utilize a Monte-Carlo simulation approach to approximate the option values and the exercise thresholds of these real options.

1. Introduction

According to the ASP Industry Consortium, "An ASP deploys, hosts and manages access to a packaged application to multiple parties from a centrally managed facility." In other words, instead of selling an application as shrink-wrapped copies, a software owner puts an application on a hosting system and delivers a service to customers via the Internet or a private network. Rather than licensing the software individually, customers simply pay rental fees for using the services.

The emergence of the ASP model has been driven by mid-market demand for an affordable alternative to enterprise solutions, the difficulty of staffing internal IT departments, the need for rapid deployment, and the increased focus on companies' core competencies. However, because the ASP services are delivered over the network, prospective customers may also be concerned about security, reliability and performance, especially for critical applications, or as the company grows. In addition, customers who are unsure about the value of ASP services or their likely usage level of the software may have difficulties in deciding between alternative ASP service and pricing models and an in-house implementation.

In this article, we propose three real options approaches to address the uncertainties and risks associated with the ASP model, and of software investments in general. We start by building models of software value and cost from the perspectives of both software owners and customers (section 2). These models provide a foundation for identifying key uncertainties and the basis for a logical segmentation of the software market between segments in which ASP-based software delivery may be preferable to non-ASP based delivery (section 3). In section 4, we propose three real options approaches used to structure contracts that address these key uncertainties. We model the uncertainties in details using a mean reverting process with a time-varying mean and a time-varying variance and analyze their characteristics in section 5. In section 6, we use these uncertainties to construct value functions of the real options. We describe a Monte Carlo simulation along with parameter values and sensitivity analysis in section 7. Finally, we present the results and analysis for all options in section 8, followed by concluding remarks in section 9.

2. ASP Value/Cost Model

The ASP model offers numerous benefits, such as lower upfront and maintenance costs, a faster time to market, a superior practice from specialized expertise, a reduced risk due to a lower capital investment, accessibility using thin clients, scalability, flexibility of add-ons and changes, and ability to focus on core businesses. Buying services also provides more financial and technological flexibility than owning the technology in-house. However, there are several concerns associated with the ASP model. These include security, reliability and performance risks from transmitting data over the network as well as a privacy risk and loss of control from yielding information to the third-party provider. Moreover, the ASP model does not accommodate extensive customization and integration with existing legacy systems.

In order to understand the values and costs that drive the ASP delivery, we build an ASP value/cost model both from a software owner' and a customer' perspectives and compare it with a value/cost model of shrink-wrapped software.

2.1. Value and Cost Models

Figure 2.1 shows the primary components of value and cost to an owner of software considering whether to offer the software under a traditional license model or as an ASP service. The software owner's objective is to maximize its profit. Under the traditional license alternative (hereafter "Non-ASP"), the software owner receives an up-front software price (license fee) and recurring revenues from upgrades while incurring only a support cost. Under ASP delivery, the software owner receives an up-front payment, which is typically substantially smaller than the up-front software license fee. It also charges customers on-going service fees, and derives additional value from the sale of indirect sources, such as add-on (non-software) services. On the cost side, the seller must incur the (fixed) cost of making an application ASP-enabled and establishing and maintaining necessary hosting services. In addition, it must incur the variable costs associated with software support, hardware maintenance, and customer specific set-up and customization.

Figure 2.1: Value/Cost Model from Software Owner's Perspective

	Non-ASP	ASP
Price (P)	$P_{SW} + P_{UG}$	$P_{UF} + P_{service} + V_{indirect}$
Demand (Q)	Q_1	$Q_{2,3,4}$
Fixed Cost (FC)	-	$C_{ASPing} + C_{hosting\text{-}pvd}$
Variable Cost (VC)	$C_{supp\text{-}NASP}$	$C_{supp\text{-}ASP} + C_{server\text{-}pvd} + C_{data\text{-}pvd} + C_{HW\text{-}mtn\text{-}pvd} + C_{install\text{-}ASP}$
Profit	(P-VC)*Q – FC	

P_{SW} = software price
P_{UG} = an equivalent upfront price for all future upgrades
Q_1 = demand for NASP (shrink-wrapped) software
$C_{supp\text{-}NASP}$ = cost of providing software support in an NASP environment
P_{UF} = upfront charge for ASP service
$P_{service}$ = ASP service fees, which could be subscription-based (2), usage-based (3) or no charge (4)
$V_{indirect}$ = value from indirect sources, such as sales of add-on services, advertisement, value of customer information
$Q_{2,3,4}$ = demand for ASP service when service fees are subscription-based (2), usage-based (3) or no charge (4)
C_{ASPing} = fixed cost to a software owner for transforming an application to ASP-based
$C_{hosting\text{-}pvd}$ = cost of establishing and maintaining necessary hosting services, including providing network connectivity to servers and data centers
$C_{supp\text{-}ASP}$ = cost of providing software support in an ASP environment
$C_{server\text{-}pvd}$ = cost of providing servers to a customer
$C_{data\text{-}pvd}$ = cost of providing data storage to a customer
$C_{HW\text{-}mtn\text{-}pvd}$ = cost of providing hardware support and maintenance
$C_{install\text{-}ASP}$ = cost of an initial ASP setup for a customer (proportional to customization level)

Figure 2.2 shows the primary components of value and cost to a software buyer considering whether to acquire the software under a traditional license model or as an ASP service. The customer's objective is to maximize the value, net of cost, of the software. Under the traditional license model, the customer starts deriving value from the software after the in-house implementation is completed. The customer pays the software price and upgrade fees along with internal hardware costs, which include the customer's own servers, data storage, client computers and the extra intranet within the company. The customer also incurs the initial software setup cost and internal IT costs to support both the software and required hardware. Under the ASP alternative, the customer starts deriving value from the software after its ASP delivery is set up, which is normally much faster than an in-house implementation. The customer also gains other ASP-related benefits, such as ease of future upgrades or add-ons, accessibility and connectivity with remote employees and partners, and ease of scalability. On the cost side, the customer pays the up-front ASP fee and on-going service fees as well as certain (reduced) hardware costs, which include client computers and the network to connect to the service provider. The customer also implicitly incurs ASP-related costs in the form of security, privacy and reliability/performance risks.

Figure 2.2: Value/Cost Model from Customer's Perspective

	Non-ASP	ASP
Value	V_{SW} (delayed by d_{NASP})	V_{SW} (delayed by d_{ASP}) + V_{add} + V_{acc} + V_{scale}
Cost	$P_{SW} + P_{UG} + (C_{server\text{-}c} + C_{data\text{-}c} + C_{client} + C_{network\text{-}intra}) + C_{install\text{-}NASP} + C_{IT\text{-}SW} + C_{IT\text{-}HW}$	$P_{UF} + P_{service} + (C_{client} + C_{network\text{-}ASP}) + C_{sr} + C_{pr} + C_{rr}$
Net Value	Value – Cost	

V_{SW} = value from software
d_{NASP} = implementation time for NASP ($d_{NASP} > d_{ASP}$)
$C_{server\text{-}c}$ = cost of customer's servers
$C_{data\text{-}c}$ = cost of customer's data storage
C_{client} = cost of hardware to run a client application such as a browser
$C_{network\text{-}intra}$ = cost of extra intranet needed beyond status quo (0, if existing internal network is sufficient)
$C_{install\text{-}NASP}$ = cost of software initial setup and customization for an in-house implementation
$C_{IT\text{-}SW}$ = cost of internal IT to support software
$C_{IT\text{-}HW}$ = cost of internal IT to support hardware
d_{ASP} = initial software setup time for ASP service
V_{add} = value from ease of future upgrades, add-ons and changes
V_{acc} = value from high accessibility and connectivity with remote employees and partners
V_{scale} = value from ease of scalability
$C_{network\text{-}ASP}$ = cost of extra network needed to connect to the ASP (i.e. Internet or a private network, depending on performance needed)
C_{sr} = cost from network security risk
C_{pr} = cost from privacy risk
C_{rr} = cost from reduction in reliability or performance due to network problems

Analyzing the cost structures from both the software owner's and the customer's perspectives, we observe that the ASP value arises from bundling together two distinct value propositions, namely the software value and the value of outsourcing hosting services. The ASP provides cost savings due to economies of scale from hardware sharing and efficiency from utilizing specialized expertise in the installation, customization, and maintenance of the software. Other unique benefits of ASP-based software delivery include ease of upgrades and add-ons, and accessibility and scalability. These ASP-related benefits must be traded against ASP-related costs from security, privacy, reliability and performance risks.

2.2. Upper and Lower Bounds on ASP Prices

Using the value/cost model in section 2.1, we obtain upper and lower bounds on ASP prices. Specifically, the customer's perspective yields the following upper bound on ASP prices:

$$P_{UF} + P_{service} <= (P_{SW} + P_{UG}) + (V_{SW}(d_{ASP}) - V_{SW}(d_{NASP})) + (C_{server\text{-}c} + C_{data\text{-}c} + C_{install\text{-}NASP} + C_{IT\text{-}SW} + C_{IT\text{-}HW}) + (3V\text{'s} - 3C\text{'s}) - (C_{network\text{-}ASP} - C_{network\text{-}intra})$$

In other words, the customer prefers ASP over Non-ASP software delivery when ASP prices are less than the summation of the up-front license fee, the value associated with faster time to market, the hardware and support costs that the customer would otherwise have to spend internally on the in-house implementation, less the extra network connectivity cost required to support ASP-based use of the software.

The software owner's perspective yields the following lower bound on ASP prices:

$$P_{UF} + P_{service} >= (P_{SW} + P_{UG}) * Q_1/Q_{2,3,4} + (C_{supp\text{-}ASP} - (C_{supp\text{-}NASP} * Q_1/Q_{2,3,4})) + (C_{server\text{-}pvd} + C_{data\text{-}pvd} + C_{HW\text{-}mtn\text{-}pvd} + C_{install\text{-}ASP}) + C_{ASPing}/Q_{2,3,4} + C_{hosting\text{-}pvd}/Q_{2,3,4} - V_{indirect}$$

In other words, the software owner prefers ASP-based delivery of the software when it can charge ASP fees greater than or equal to the traditional up-front license fee plus the change in support and hosting costs, all adjusted for the change in demand which results from ASP delivery, less the extra value it receives from indirect sources.

3. Key Uncertainties and Segmentation

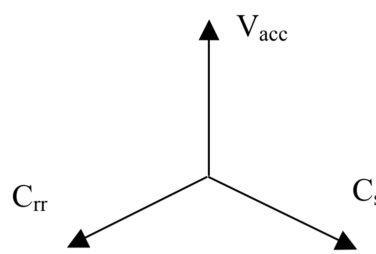
3.1. Key Uncertainties

From the value and cost models of section 2, we identify the key uncertainties faced by the software owner and customer. From the software owner's perspective, the important uncertainties are the ASP service fees ($P_{service}$), the value from indirect sources ($V_{indirect}$), the variable hosting and support costs ($C_{supp\text{-}ASP}$, $C_{server-pvd}$, $C_{data\text{-}pvd}$, $C_{HW\text{-}mtn\text{-}pvd}$) and the demand for ASP services ($Q_{2,3,4}$). From the customer's perspective, the key uncertainties are the software value (V_{SW}) and the ASP service fees ($P_{service}$).

All the above uncertain value and cost components are driven by common underlying uncertainties related to the customer's usage. Thus, we formulate a model of the customer's usage as a function of the uncertainty about the number of users per company (n) and the level of usage (u) per user. In addition to these usage-related variables, the value of software is also a function of an uncertain intrinsic software benefit (b, for value per usage). We model uncertain usage and software value based on these random variables (n, u, b) and their correlations in section 5.

3.2. Segmentation

Figure 3.1: Segmentation and Suitability of ASP Delivery



$\underline{V_{acc} = low}$

Cost of Reliability/ Performance	Cost of Security: Hi	Cost of Security: Lo
Hi	NASP	NASP?
Lo	NASP?	ASP/ NASP

$\underline{V_{acc} = high}$

Cost of Reliability/ Performance	Cost of Security: Hi	Cost of Security: Lo
Hi	ASP/ NASP	ASP?
Lo	ASP?	ASP

Value of Accessibility	Cost of Security, Reliability and Performance: Hi	Cost of Security, Reliability and Performance: Lo
Hi	ASP? - mission critical - highly accessed i.e. e-commerce, SCM	ASP - highly accessed - tolerates delay i.e. messaging, collaboration/ groupware
Lo	Non-ASP - proprietary, mission critical, internal software i.e. ERP	ASP? - non-mission critical, non-data sensitive - low access i.e. Utility SW

In addition to the key uncertainties identified above, the relative value of ASP and Non-ASP software delivery also depends on the other determinants of cost and value identified in section 2 above. Among the ASP-related benefits (specifically ease of upgrades and add-ons (V_{add}), accessibility (V_{acc}) and scalability (V_{scale})), accessibility and connectivity will in many cases be the most significant. Among the ASP-related costs (which include security risk (C_{sr}), privacy risk (C_{pr}), and reduction in reliability and performance (C_{rr})), security and reliability/performance likewise will in many cases be the most significant. As a result, these three variables (specifically V_{acc} (value of accessibility/connectivity), C_{sr} (cost of security risk), C_{rr} (cost of reliability and performance reduction), form a natural basis by which to segment the space of all software applications into regions in which either ASP or Non-ASP delivery may offer greater relative benefits. Figure 3.1 illustrates this segmentation and estimates the relative suitability of ASP delivery by segment.

4. Real Option Approaches

In this section, we explore the use of real options to address the key uncertainties faced by software owners and their customers under ASP and Non-ASP delivery of the software. Specifically, we consider ways to address the impact of uncertainty about both software value and the usage expressed as a function of the number of users per company (n), level of usage (u) and value per usage (b).

Uncertainty about the value a customer will realize from a specific piece of software can be addressed most directly by pricing the software on a per usage basis, something ASP-based software delivery is uniquely capable of enabling. However, usage-based pricing makes cost unpredictable to the buyer, and in particular leaves buyers with substantial upward cost exposure. Thus, we propose a usage-based pricing structure with an option to switch to a fixed subscription fee.

In order to address uncertainty about the customer's level of usage and the number of users, we categorize customers into two groups. The first group of customers are uncertain that their usage may exceed a threshold at which in-house implementation becomes more economical than ASP-based access of the software. For these users we propose an option to bring the software in-house following an initial period of ASP-based access, should their usage levels grow to justify doing so. The second group of customers are uncertain about the time period over which they will find the software valuable. For these users we propose contract-based ASP-based access to the software with an option to end the ASP contract prior to its expiration.

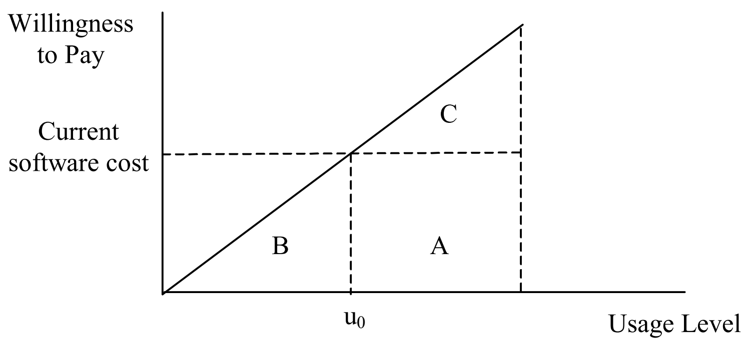
These three real options address the key uncertainties underlying the ASP model from both the software buyer and seller perspectives. In the sections below we describe each option in greater detail, and consider how each affects the software owner's and the customers' uncertainties. We also discuss their applicability in practice.

Option 1: Usage-based pricing with an option to switch to a subscription fee

Since the value of software lies in its ability to enable the execution of certain tasks, software is essentially a service good. This suggests that usage-based software pricing structures enabled by ASP-based software delivery may in many cases be more appropriate than traditional per-copy based pricing structures. From the seller's perspective, usage-based pricing enables the capture of a share of the value customers derive using the software. When combined with the lower set-up costs of the ASP model, it enables ASPs to penetrate a new market segment of infrequent users, as well as the potential to extract additional customer surplus not previously captured by a subscription fee or a fixed software price. Figure 4.1 shows the economics of usage-based pricing.

Besides capturing a share of customer value, usage-based pricing also gives the ASP flexibility to price proportional to its variable costs, such as its hosting and support costs. Finally, from the value/cost model, the ASP service fee ($P_{service}$) should depend on the value it gets from indirect sources ($V_{indirect}$), which in turns also depends on customer usage. Thus, usage-based pricing allows the ASP to price more efficiently for each customer, after taking into account this additional source of value. For example, high usage could lead to a high level of indirect value captured as well, allowing the ASP to price at a lower per-usage rate, making the ASP model more attractive. From the customer's perspective, usage-based pricing allows the customer to pay based on value actually received, rather than estimated value. It also makes software more affordable for infrequent users, and enables customers to test software without committing to a high fixed fee.

Figure 4.1: The Economics of Usage-based Pricing

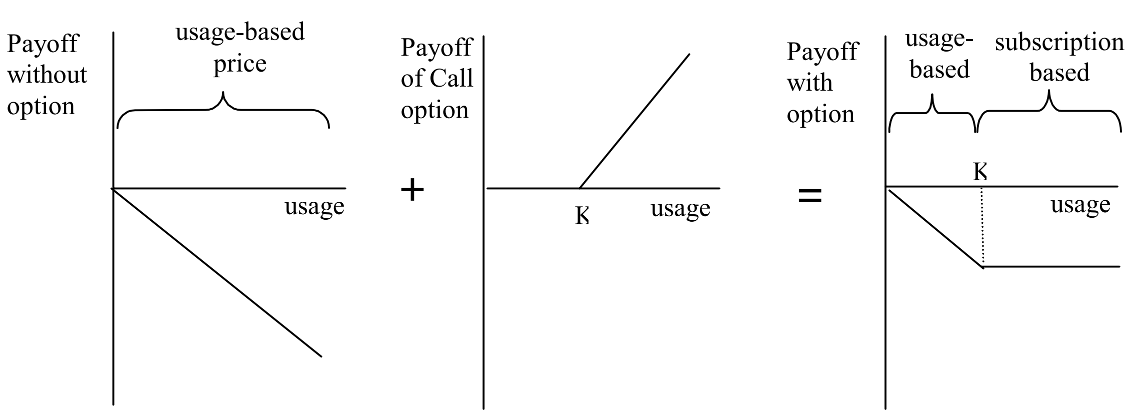


Only those who use more than u_0 buy fixed-price software (and pay a subscription fee or shrink-wrapped price)
A = Revenue from fixed-price software
B = Extra usage-based revenue from infrequent users (previously not customers)
C = Extra usage-based revenue from heavy users (previously a surplus to customers)
A+ B + C = Usage-based revenue

However, from the customer's perspective, a major drawback of usage-based pricing is the unpredictable (and uncapped) costs that result. Therefore, we propose a usage-based pricing structure with an option to switch to a subscription fee. This arrangement enables the ASP to penetrate the low-usage market while allowing the customers to put a cap on their service cost. From the software owner's perspective, providing this option means forfeiting the potential gain in area C (Figure 4.1) but being compensated by an extra market in area B (Figure 4.1) and an option price.

Note that structurally, this option is similar to a customer buying a call on their usage cost (or usage level) with a subscription fee (or threshold usage corresponding to the fee) as a strike price, as illustrated in Figure 4.2.

Figure 4.2: A Call Analogy of An Option to Switch from Usage-based Pricing to A Subscription Fee



From the customer's perspective, this option addresses the usage level uncertainty (u) by allowing the customer to hedge against the usage risk. Moreover, it deals with uncertainty in software benefit (b), as it permits the customers to test out software, with usage-based pricing, when the value is not clear. From the software owner's perspective, usage-based pricing with an option to switch to a fixed price model allows the ASP to capture both infrequent users and users that are uncertain about their usage level, or about the value the software will provide them.

Option 2: Option to bring the software in-house

From the value/cost model, as a company grows, the benefits from economies of scale of the ASP model decrease; the time-to-market value disappears after the initial implementation; the value of upgrade and add-on flexibility and scalability become smaller as the company's own infrastructure grows, while security, reliability and performance may become more critical. It is conceivable that once the company reaches a certain size, with sufficiently heavy usage (n and u combined is large), it becomes optimal for the company to bring the software in-house instead of continuing paying service fees to the ASP. Thus, this option to bring the software in-house is valuable to the customer. In a sense, the ASP allows the customer to try out the software and wait until the software becomes valuable enough for the company to fully invest in it – characteristic of a growth option. In addition, the fast time to market associated with ASP delivery may make it desirable for a company to access the software initially through an ASP, even if the company plans to move the software in-house later.

By giving a customer this option, the ASP assumes the investment risk associated with its now uncertain future service fees. However, the seller may be compensated for these risks through an up-front option price, and will benefit from the demand increase associated with offering this, as well as the exercise price charged to the customers for buying out the application. In order to mitigate the risk of uncertain service fees, the provider may set an exercise price that depends on the remaining time to expiration and the customer's usage level.

Note that structurally, this option is similar to a customer buying a call on their total cost of the ASP services, with a strike price equals to the sum of the actual exercise price charged and the total cost of an in-house implementation with the same underlying uncertain usage and software value (n, u, b).

From the customer's perspective, this option addresses all of the customer's uncertain usage variables (n and u) and software value (b). This option also allows the customer to hedge against an unacceptable level of security and performance risk that may arise from using the ASP services, as the customer has an option to bring the software in-house and thus limits these risks. From a software owner's perspective, this option leads to an increase in demand from those who are unsure about their usage or software value; these customers may have otherwise bought shrink-wrapped software instead of buying ASP services, or may have simply postponed their investment.

Option 3: Option to end ASP contract prior to expiration

A customer may value an option to end the ASP contract with specified duration prior to expiration for a range of reasons. First, the customer may discover that the value of the software to it is less than the price it is being asked to pay. This situation may arise when the customer's business conditions change, such as a switch in business model leading to less use of certain applications, a business expansion leading to the discovery of the software limitations, etc. Second, the customer may be uncertain of its term of usage, over which the software will be valuable to them, and would like a flexibility to stop the services. This flexibility is especially valuable in a fast changing technology environment, where the customer may want to switch to a better technology/application as it becomes available. Moreover, this option helps alleviate the risk of relying on a certain service provider, which is especially valuable given the current early-stage, high-risk nature of the ASP industry.

To an extent, this option is analogous to the value of flexibility that ASP model offers over an in-house implementation. Without a large up-front capital investment from buying software, ASP customers have more flexibility to switch to new technologies. Thus, from the customer's perspective, this option addresses uncertainties in the software value and the term of usage. It also addresses the security, reliability and performance concerns, as it allows the customer to end the ASP contract once those risks become unacceptable. From a software owner's perspective, offering this option potentially attracts new demand from those who otherwise hesitate to commit to a specific provider or application.

With pure usage-based pricing, a provider effectively gives a customer a free option to end the ASP service anytime by simply stopping usage and paying nothing. However, in reality, the customer may not have that flexibility to stop using the software due to necessity, lack of alternatives, compatibility with partners, etc. Moreover, in practice, the provider is likely to impose a minimum usage requirement and/or a minimum time commitment in order to recoup its fixed-cost investment. Therefore, we will explore an option to end ASP contract under these constraints.

5. Modeling Underlying Uncertainty

In section 3, we identify the three key underlying uncertainties of the ASP model to be software benefit per usage (b), level of usage per user (u) and the number of users per company (n). In order to capture realistic evolutions of these uncertainties, we employ a mean reverting process whose mean is time varying according to a plausible model and whose variance may also vary with time. In addition, we model correlations among these uncertainties through the means that they revert to. This method allows us to pattern after a software cycle, a learning effect, a company growth and the correlations between software benefit and usage.

5.1. Uncertainty Model

5.1.1. b = benefit per usage (i.e., $/hours)

$db = \kappa_b (\bar{b}_t - b) dt + \sigma_{bt} b dz$

κ_b = speed of reversion

$\bar{b}_t$ = a time-varying mean benefit, taking into account of the learning curve and the decay in software value at the end of its life cycle

$\bar{b}_t = b_{max} * (1 - e^{-gt})$ for $t <= L$

$= \bar{b}_L + 1 - e^{h(t-L)}$ for $L <= t <= L + (1/h)*\ln(1 + \bar{b}_L)$

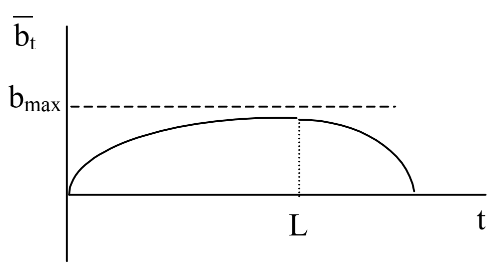
$= 0$ for $t >= L + (1/h)*\ln(1 + \bar{b}_L)$

b_{max} = intrinsic maximum benefit/value of software

g = benefit growth rate, which represents the learning curve

h = benefit decay rate, which represents the decline in software value after the end of the software cycle

L = software life cycle



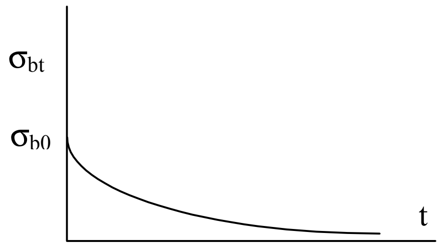
σ_{bt} = decreasing variance term of b

$\sigma_{bt} = \sigma_{b0} * e^{-ct}$

σ_{b0} = initial (t=0) standard deviation of b

c = decreasing rate of the standard deviation

dz = an increment of a Wiener process



The benefit per usage follows a mean reverting process, whose mean benefit evolves over a software cycle. Specifically, the mean benefit initially increases during the learning phase and subsequently decreases after the end of the software cycle to bottom at zero thereafter. The variance term of benefit reduces over time, reflecting better knowledge of the software value as time progresses. An overall variance of benefit process depends on the current benefit level.

<u>5.1.2. u = level of usage per user (i.e., hours/time period, hours/week)</u>

$du = \kappa_u (\bar{u}(b) - u) dt + \sigma_u u \, dz$

κ_u = speed of reversion
σ_u = variance term of u
$\bar{u}(b)$ = long-run equilibrium usage level, which is a function of software benefit (random) and price per usage (deterministic)
$\bar{u}(b) = f(b_t, p_{use}) = u_{breakeven} * b_t/p_{use}$
$u_{breakeven}$ = breakeven usage level
b_t = benefit per usage at time t ($/hour)
p_{use} = price per usage ($/hour)

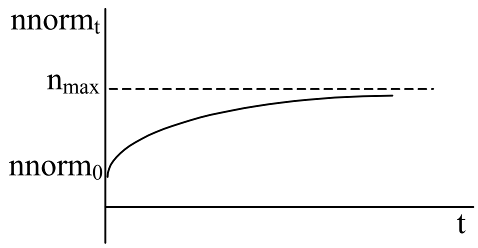
The usage level per user follows a mean reverting process, whose mean usage level depends on the software benefit and the price per usage that a customer is charged. When benefit equals to price (b_t/p_{use} = 1, or the user pays exactly equal to the benefit it derives), the usage is at a breakeven usage level, an amount specific to each customer indicating how heavy a user it is. When benefit falls below (rises above) the price, the mean usage drops below (exceeds) the breakeven level. Note that the mean usage does not go to zero even though the benefit is less than the price; in reality, there may be a necessity to use the software even though it is too expensive. The mean usage drops to zero only when benefit also falls to zero. The variance of the usage process is proportional to the usage level.

<u>5.1.3. n = the number of users per company</u>

$dn = \kappa_n (\bar{n}_t(b) - n) dt + \sigma_n n \, dz$

κ_n = speed of reversion
σ_n = variance term of n
$\bar{n}_t(b)$ = the time-varying mean number of users, which is a function of software benefit and its price
$\bar{n}_t(b) = nnorm_t * b_t/p_{use}$
$nnorm_t$ = the time-varying normal number of users, taking into account of changes in company size

$nnorm_t$ follows a deterministic growth model:
$nnorm_t = (n_{max} - nnorm_0) * (1 - e^{-at}) + nnorm_0$
n_{max} = the long-term maximum number of users in a mature company
$nnorm_0$ = the initial normal number of users when a company starts using ASP
a = growth rate of a company



Similar to the level of usage, the number of users per company also follows a meaning reverting process, whose mean depends on the software benefit, its price, and the "normal" number of users, which grows as the company size changes. The variance of the number of users is proportional to its size.

5.2. Uncertainty Plot

Figure 5.1-5.6 show sample evolutions of b, u and n, using the same parameter values as in the simulation section. For each case, we construct 10,000 sample paths to obtain means and standard deviations. Figure 5.1-5.3 illustrate the mean values that b, u and n revert to, their sample means and sample paths for base-case variances ($\sigma_{b0} = 0.6$, $\sigma_u = 0.2$, $\sigma_n = 0.2$). Figure 5.4-5.6 show similar results for high variances ($\sigma_{b0} = 1.0$, $\sigma_u = 0.4$, $\sigma_n = 0.4$).

As shown in the first chart of Figure 5.1, b sample mean follows the movement of $\bar{b}_t$, although they are not exactly equal. When $\bar{b}_t$ is larger than the mean and increasing, the mean increases towards $\bar{b}_t$. Once $\bar{b}_t$ turns downward, the sample mean follows with some lag but a smoother transition. We will also observe this same behavior from sample means of u and n. In general, we can expect this common characteristic from a mean-reverting process whose mean is time-variant and mean-reverting coefficient is less than 1 ($\kappa_b = \kappa_u = \kappa_n = 0.5$, in our case) so that the process always adjusts towards its reverting mean but not fully.

The second chart of Figure 5.1 shows b sample path along with its sample mean and the 68% confidence interval (+/- one standard deviation from mean). Note that the standard deviation increases along with the mean, starts decreasing before the mean reaches its maximum, and drops to zero rapidly towards the end. From the benefit model, the standard deviation is proportional to $\sigma_{bt}*b_t$, namely the time-varying sigma and the current level of benefit. We model this time varying sigma to decrease exponentially, reflecting the decline in benefit uncertainty due to learning. Therefore, we observe the total effect of the two factors when the standard deviation increases at the beginning with a high growth in b that is larger than a declining rate of σ_{bt}. As the growth in b slows down, the declining σ_{bt} dominates and reduces the total volatility to zero towards the end.

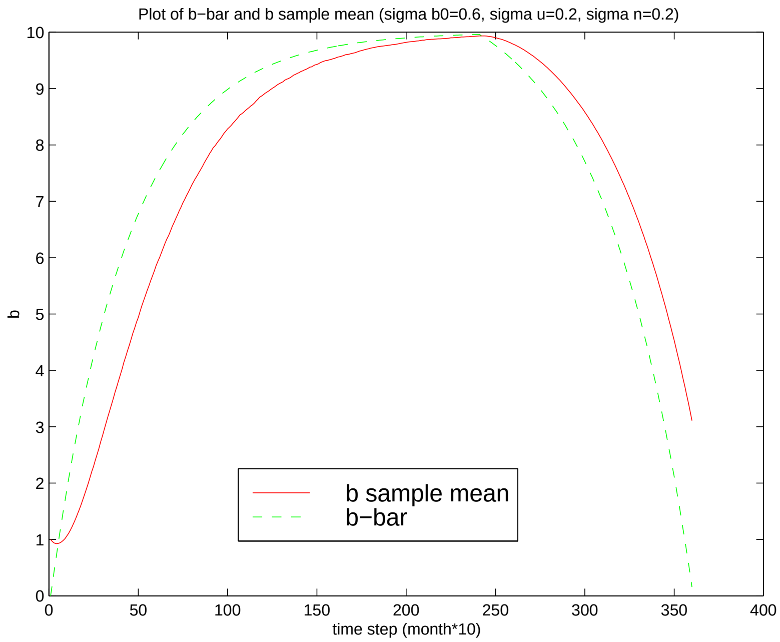
Figure 5.2 shows an evolution of u and its means. We note that $\bar{u}$ depends on the current benefit; thus, it is a random variable itself and takes on a different sample path depending on the corresponding b sample path.[1] We also plot $\bar{u}$ when the current benefit equals to $\bar{b}$ for reference. As mentioned, we observe that the u sample mean follows $\bar{u}$. The standard deviation of u grows with u initially and shrinks with u towards the end, as its standard deviation depends on the current magnitude of u.

Figure 5.3 shows an evolution of n and its means. The graphs of n exhibit many similar characteristics to u; namely, the sample mean follows $\bar{n}$ with some lag but a smoother transition, and the standard deviation grows and shrinks with the magnitude of n. The only difference arises because, besides depending on b, $\bar{n}$ has its own growth path to reflect changes in a company size. Therefore, instead of ramping up quickly like u when benefit increases, n gradually grows, which is realistic as the number of users should not change as abruptly as the usage level. Note that, in all figures, uncertainty of u and n remains non-zero till

[1] In the first chart of Figure 5.2 (or 5.5), the sample path of $\bar{u}$ shown corresponds to the sample path of b in the second chart of Figure 5.1 (or 5.4). In the first chart of Figure 5.3 (or 5.6), the sample path of $\bar{n}$ shown corresponds to the sample path of b in the second chart of Figure 5.1 (or 5.4).

the end. The means of b, u and n are also positive till the end of the contract time even though the means that they revert to ($\bar{b}$, $\bar{u}$, $\bar{n}$) may drop to 0.

Figure 5.1: Mean value that b reverts to, its sample mean, and a sample path for base-case variances



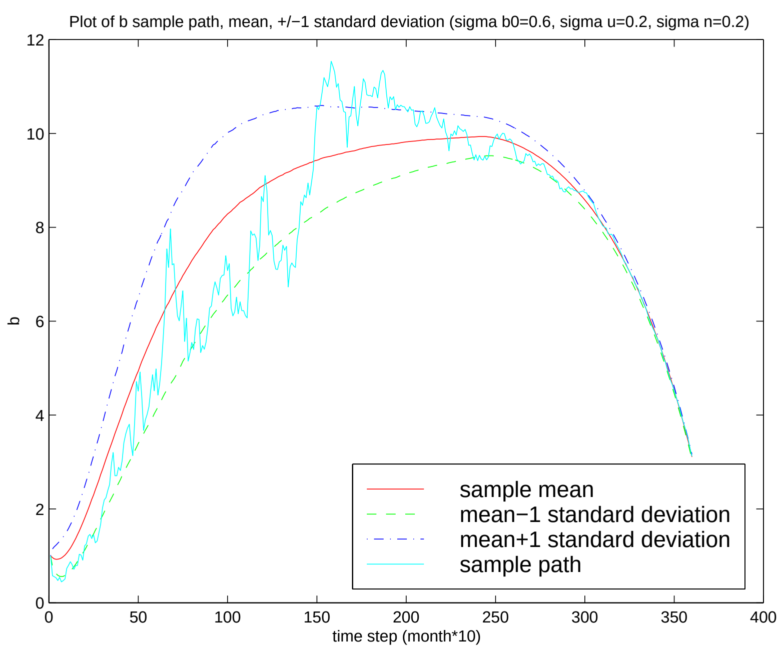
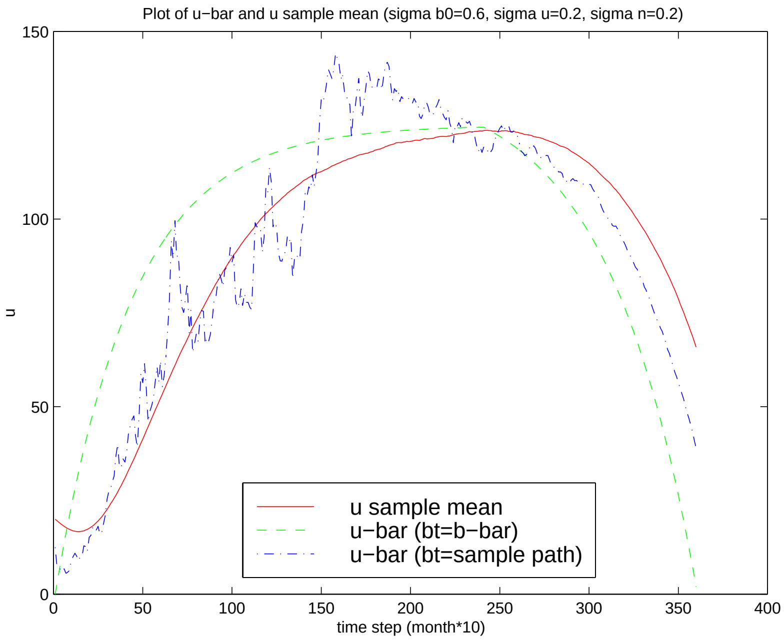


Figure 5.2: Mean value that u reverts to, its sample mean, and a sample path for base-case variances



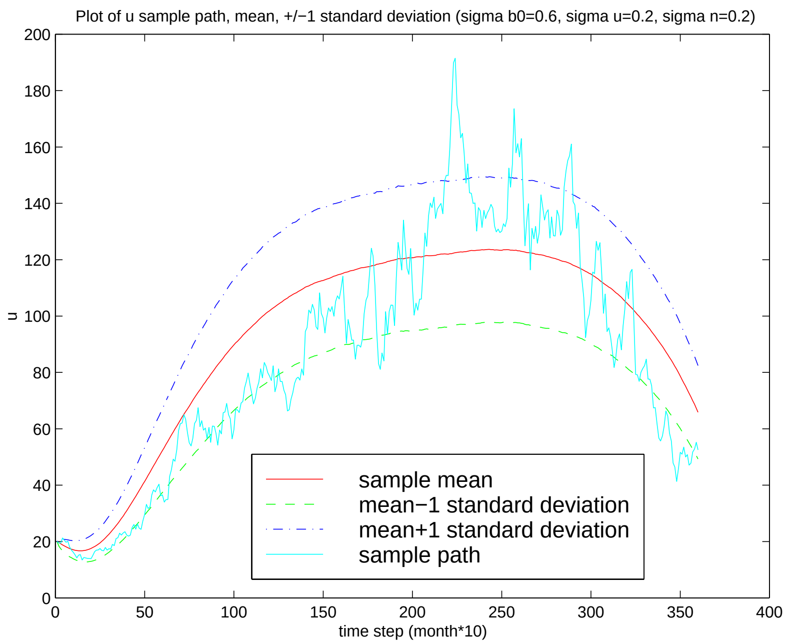


Figure 5.3: Mean value that n reverts to, its sample mean, and a sample path for base-case variances

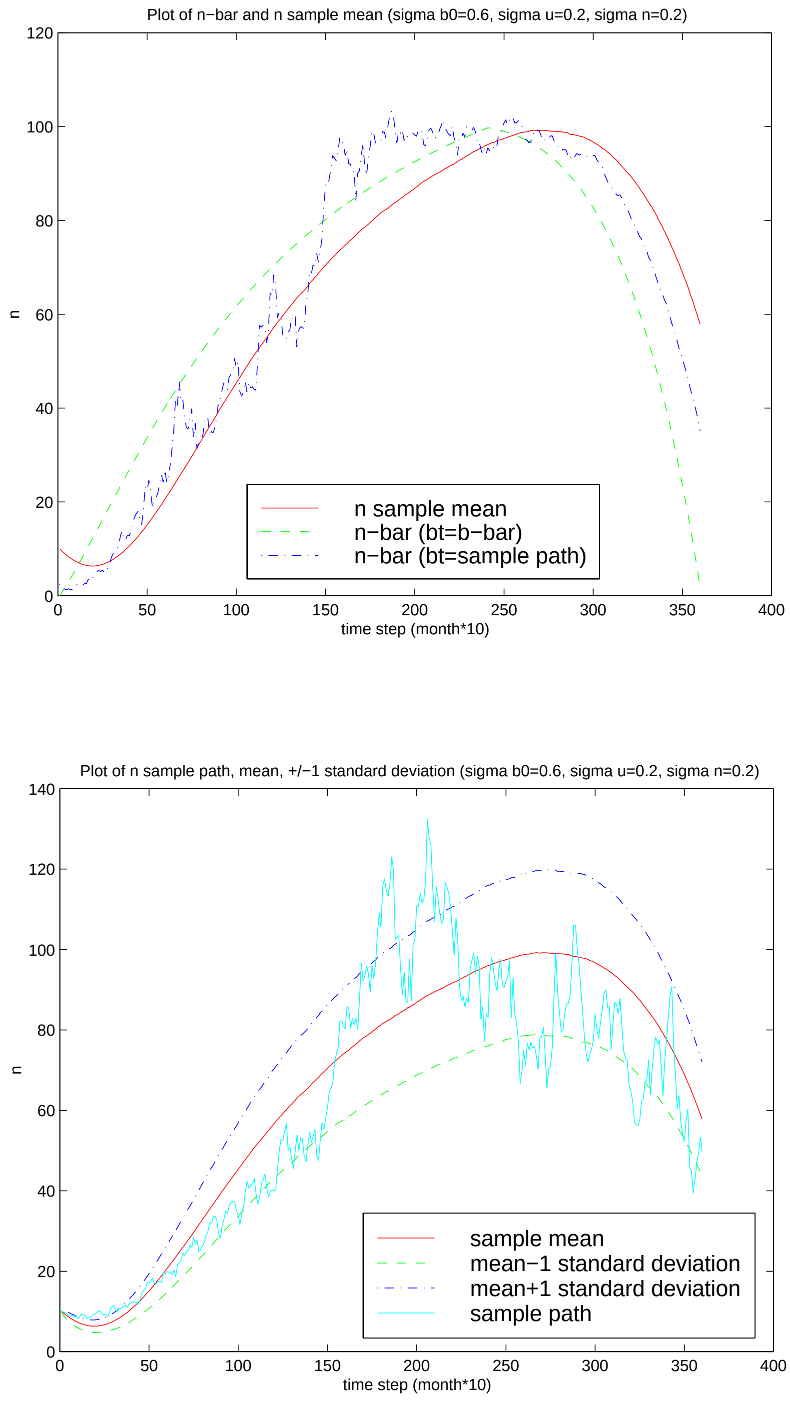
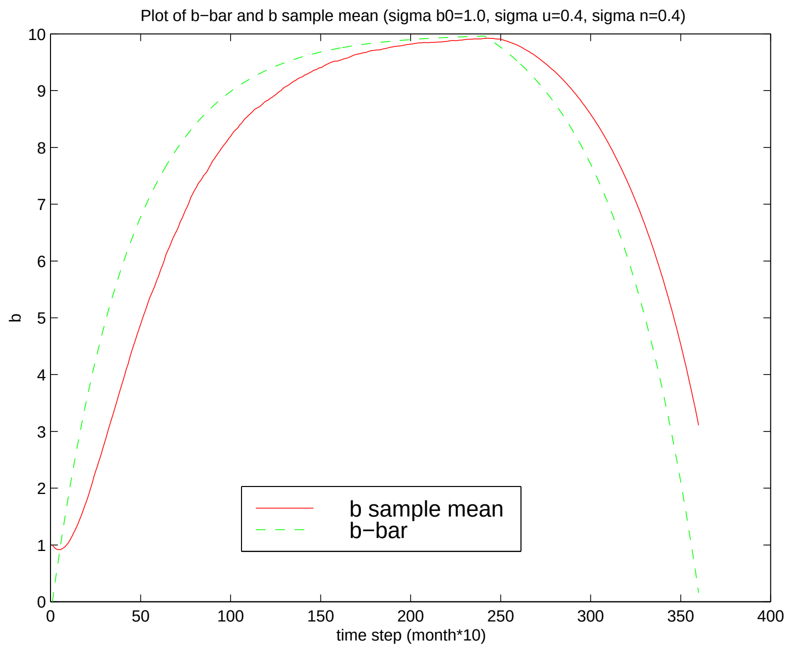


Figure 5.4-5.6 show the same set of values when variances are high. The sample means obviously do not change with variances, and nor does $\bar{b}$. However, $\bar{u}$ and $\bar{n}$ depend on the current benefit; thus, they fluctuate more wildly as the variance of b increases. In all three figures, the sample paths and the standard deviations illustrate higher volatility, as the sample paths swing over a bigger range of values than in Figure 5.1-5.3. Note that the volatility of u and n result from two factors: an increase in their own sigma and a rising volatility of their $\bar{u}$ and $\bar{n}$ due to an increase in b volatility. Besides higher variances, the shapes and other characteristics are similar to those with base-case variances in Figure 5.1-5.3.

Figure 5.4: Mean value that b reverts to, its sample mean, and a sample path for high variances



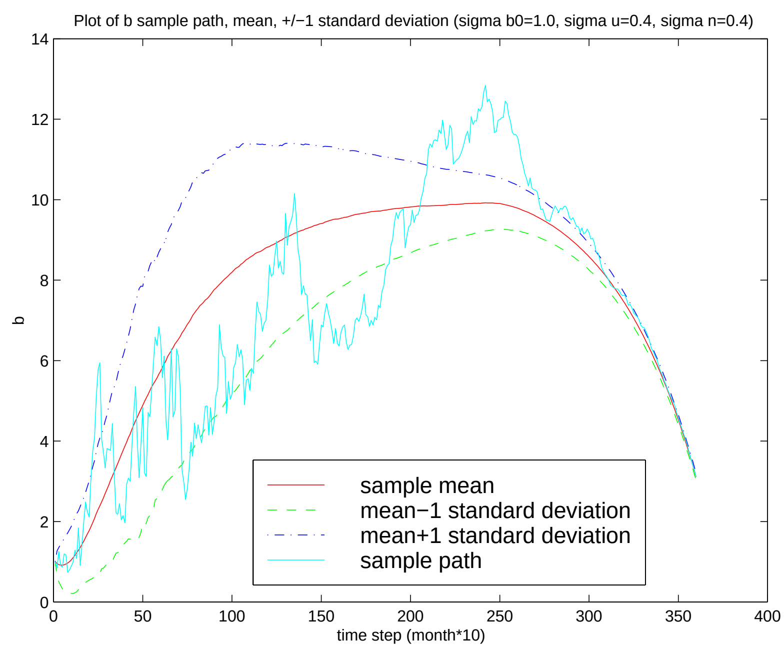
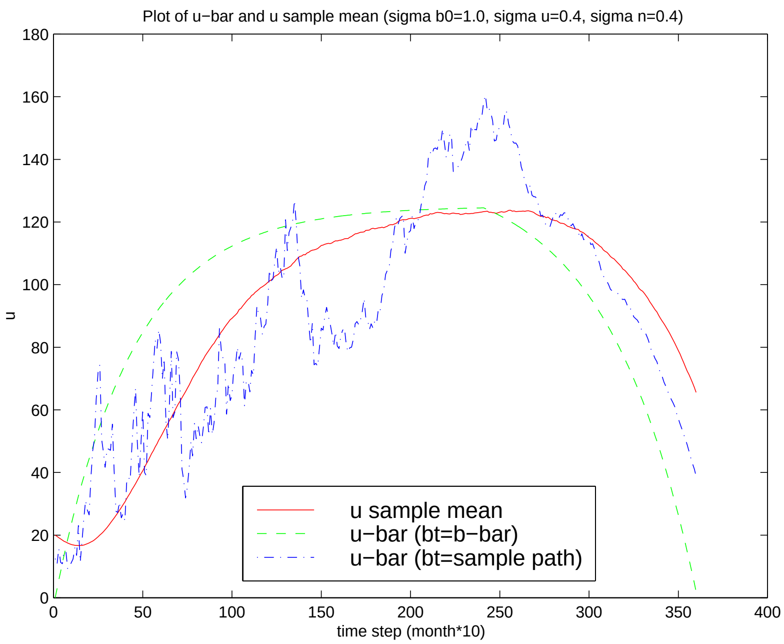


Figure 5.5: Mean value that u reverts to, its sample mean, and a sample path for high variances



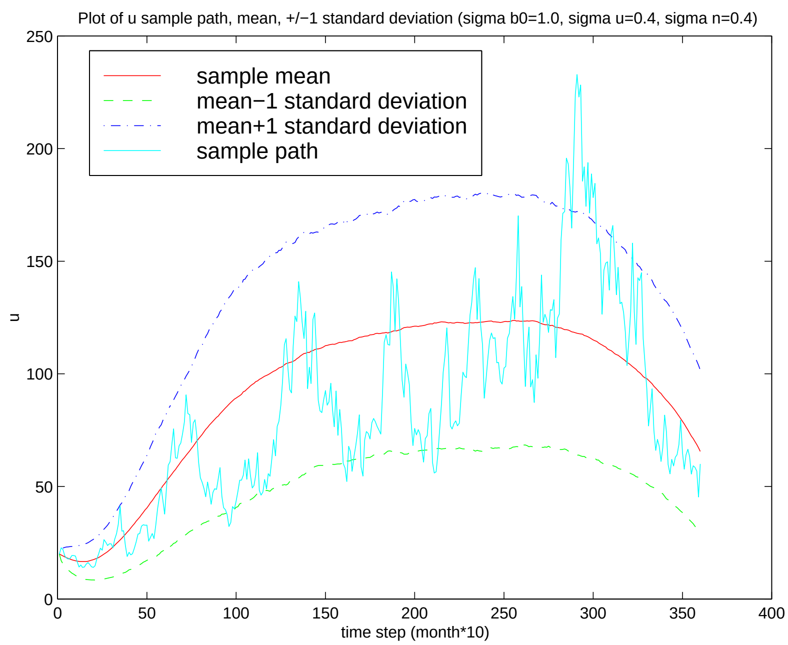
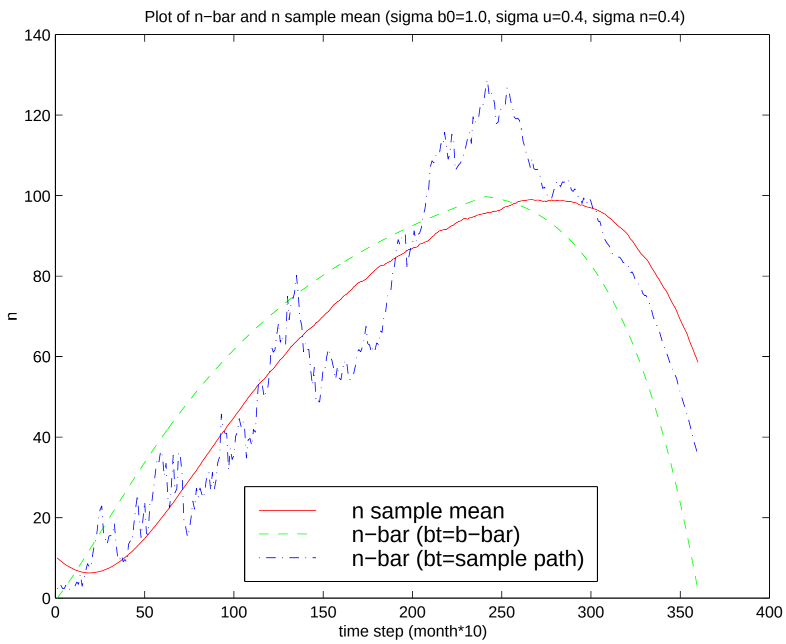
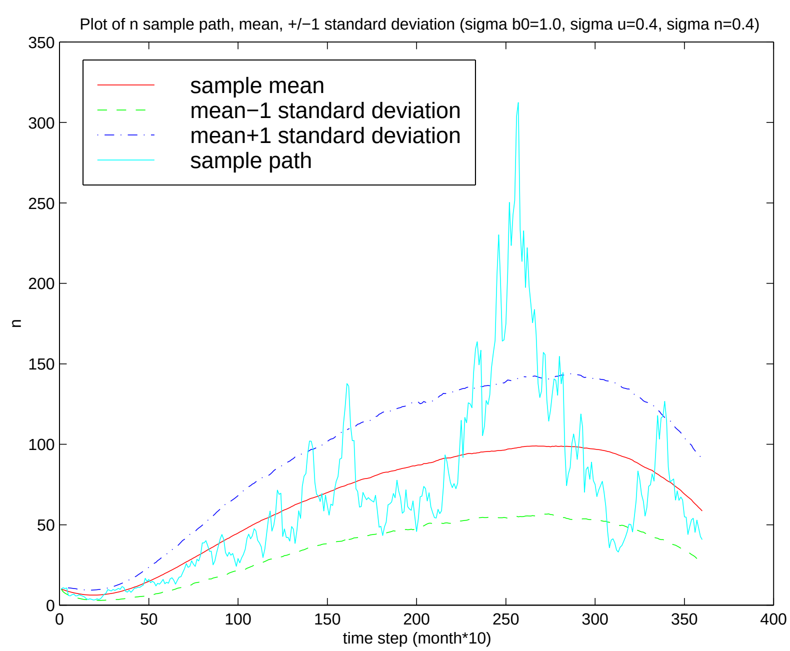


Figure 5.6: Mean value that n reverts to, its sample mean, and a sample path for high variances





In order to represent realistic dependence that usage level (u) and the number of users (n) have on benefit that the customer derive from software (b), we model the correlations via the means that u and n revert to. Namely, $\bar{u}$ and $\bar{n}$ are proportional to the current benefit. We find the following correlations from 10,000 sample paths of each process. Benefit and usage level have a high correlation coefficient of 0.795 because $\bar{u}$ exactly mimics the evolution of b, and u follows $\bar{u}$ with some lag. Benefit and the number of users have a correlation coefficient of 0.694, which is smaller than the coefficient of b and u because the number of users also independently grows over time. Finally, usage level and the number of users have a correlation coefficient of 0.7353. The usage level and the number of users follow an almost identical process with the means that they revert to depending on the same underlying current b. They only differ because n also has its own growth process.

6. Value Functions of Options

Our goal is to find option values and exercise thresholds for the proposed real options: an option to switch to a subscription fee, an option to bring software in-house and an option to exit ASP contract (with or without minimum usage and time commitment). We find the option premiums by taking the difference of cost or value to a customer under ASP contract with and without an option. Without any option, a customer is committed to buying ASP services over a contract time T (36 months) and derives cost or value purely from ASP services. If an option is available, we assume that a customer can exercise it at the beginning of every period Δt (month), after which corresponding cash flows occur immediately. Thus, the decision points are at the beginning of $t = 1,\ldots, T$, and the value at time $t = 1$ illustrates the cost/value of ASP services with an option. We assume ρ to be an appropriate risk-adjusted discount rate, and V_t represents values of underlying uncertainties (or state variables, i.e., b, u, n) at time t.

All options are irreversible. Once an option is exercised, a customer cannot switch back to a prior state until the end of the contract time. Specifically, a customer who exercises an option 1 pays a subscription fee until T, and a customer who exercises an option 2 or 3 pays applicable costs and cannot resume ASP services afterwards.

Option 1: Usage-based pricing with an option to switch to a subscription fee

According to industry practice, a subscription fee is generally quoted on a per-user per-period basis, e.g. $x per user monthly. Therefore, we model an option to switch from usage-based pricing to a subscription fee with an agreed upon per-user subscription rate. The relevant uncertainties are usage level per user (u) and benefit (b) that u depends on.[2] Under an ASP contract, a customer is committed to paying for ASP services until T. However, it can choose to switch from a usage-based price to a subscription rate at the beginning of every month, after which it is obligated to pay that subscription rate until T.

<u>Parameters:</u>
$p_{sub}(\Delta t)$ = subscription fee per user per Δt (agreed upon in case the option is exercised)
$p_u(u, \Delta t)$ = usage-based price for usage level u during Δt (i.e., for linear pricing $p_u(u, \Delta t) = p_{use} * u * \Delta t$ = price per usage * usage * Δt)

<u>Value Function:</u>
min E[NPV(ASP costs)]
$F(V_t) = \min \{$ subscription fees from t to T, usage fee for this period $+ e^{-\rho\Delta t} * E[F(V_{t+1}) \mid V_t] \}$
$F(V_t) = \min \{ \Sigma_{i=0 \text{ to } T-t}\, p_{sub}(\Delta t) * e^{-i\rho\Delta t},\ p_u(u_t, \Delta t) + e^{-\rho\Delta t} * E[F(V_{t+1}) \mid V_t] \}$

$F(V_t) = \min \{ p_{sub}(\Delta t) * (1 - e^{-\rho\Delta t(T-t+1)})/(1 - e^{-\rho\Delta t}),\ p_u(u_t, \Delta t) + e^{-\rho\Delta t} * E[F(V_{t+1}) \mid V_t] \}$
where
$F(V_T) = \min \{ p_{sub}(\Delta t),\ p_u(u_T, \Delta t) \}$

<u>*Note*</u>: $F(V_1)$ = a minimum ASP cost with an option to switch to a subscription fee

Option 2: Option to bring the software in-house

Overall, a customer wants to minimize the total software/hosting cost over the life of the software. Under an ASP contract, a customer agrees to buy ASP services and pay usage-based cost until time T, which

[2] This option does not depend on the number of users directly. However, in practice, ASP may be willing to offer different subscription rates to companies of different sizes.

covers both hosting and software prices. However, with an option to bring software in-house, a customer may choose to exit the contract monthly by paying an exercise price and starting to incur internal hosting costs. We assume that once the exercise price is paid, the customer can continue using the software seamlessly without delay. The exercise price charged by ASP effectively licenses software to the customer until the contract expiration at time T. Therefore, the provider may set this exercise price corresponding to an expected missing profit until contract expiration.

To quantify the internal hosting costs, we observe that an ASP price bundles together two components: the hosting price and the software price. Thus, a fraction of the ASP price arises from variable hosting costs (HW and HW/SW support) that the provider incurs, and we can relate this portion of the ASP price to the internal hosting costs. In addition, we adjust the internal hosting costs by a customer-specific inefficiency factor, which represents economies of scale and expertise that the provider has over the customer. Therefore, this option is essentially an option to pay a lump sum amount (total cost to switch to in-house) in order to stop paying a portion of the recurring ASP fee; the customer stops paying for the software cost but still pays for in-house hosting costs.

Option 2 and option 1 are quite similar in a sense that they both allow an exchange of an uncertain usage-based cost with a fixed cost. However, option 2 deals with risk on the total cost, which includes all key uncertainties: the number of users (n), usage level (u) and benefit (b), as n and u depend on b. Moreover, from the provider's point of view, once option 2 is exercised, the provider gets a fixed payment and is no longer exposed to further usage risks because it stops providing the service. With an exercise of option 1, the provider needs to offer the service at a fixed price and is thus liable to loss if the customers' usage is high. From the customer's point of view, exercising option 2 does not completely eliminate uncertain cash flows. The customer still incurs usage-dependent in-house hosting costs, but the magnitude should is less than the total ASP cost.[3]

<u>Parameters:</u>
f = fraction of ASP price that arises from variable hosting costs (HW and HW/SW support); $0 < f < 1$
k = inefficiency factor[4]; $k >= 1$
K_t = exercise price charged by ASP at time t
K = monthly annuity equivalent of the net present value of the provider's expected revenue until T[5]

$$K_t = \Sigma_{i=0 \text{ to } T-t} (1-f)*K = (1-f)*K*(1 - e^{-\rho\Delta t(T-t+1)})/(1 - e^{-\rho\Delta t})$$

FC_t = additional fixed cost to start in-house hosting/support infrastructure at time t. Assume $FC_t = FC$
Ω_t = value of owning the additional infrastructure at the end of the contract (at time T+1) when infrastructure is purchased at time t

$$\Omega_t = FC*e^{-d\Delta t(T-t+1)}$$ where d is depreciation rate

$p_u (n, u, \Delta t)$ = usage-based price for n users at usage level u during Δt (i.e., for linear pricing $p_u (n, u, \Delta t) = p_{use} * n * u * \Delta t$)

<u>Value Function:</u>
min E[NPV(software and hosting/support costs)]
$F(V_t) = \min \{$ cost to switch to in-house, ASP cost this period $+ e^{-\rho\Delta t}*E[F(V_{t+1}) \mid V_t] \}$
$F(V_t) = \min \{ K_t + FC_t - e^{-\rho\Delta t(T-t+1)}*\Omega_t + k*f*NPV(\text{ASP price from t to T}), p_u (n_t, u_t, \Delta t) + e^{-\rho\Delta t}*E[F(V_{t+1}) \mid V_t] \}$

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[3] The ASP price includes software price, hosting/support costs and margin. If the customer is so inefficient that its in-house hosting cost is higher than the ASP cost, it should never switch to in-house from a pure pricing perspective.
[4] Specifically, customer's variable hosting cost = k * provider's variable hosting cost. Usually, k>= 1 because the provider's has economies of scale and expertise.
[5] K is effectively a monthly payment till expiration that ASP is willing to accept in lieu of the missing revenue. From a customer's point of view, we can also interpret K to include other costs and benefits from bringing the software in-house, such as cost of less accessibility, benefits from reduced security and performance risks, etc. Logistically, customers may pay the total sum K_t as a fixed one-time payment when the option is exercised.

$F(V_t) = \min \{ K_t + FC_t - e^{-\rho\Delta t\,(T-t+1)}*\Omega_t,\ (1-k*f) * p_u (n_t, u_t, \Delta t) + e^{-\rho\Delta t}*E[\ F(V_{t+1}) \mid V_t\ ] \}$[6]

$F(V_t) = \min \{ (1-f)*K*(1 - e^{-\rho\Delta t(T-t+1)})/(1 - e^{-\rho\Delta t}) + FC - e^{-\rho\Delta t*(T-t+1)}(FC*e^{-d\Delta t(T-t+1)}),\ (1-k*f) * p_u (n_t, u_t, \Delta t) + e^{-\rho\Delta t}*E[\ F(V_{t+1}) \mid V_t\ ] \}$

$F(V_t) = \min \{ (1-f)*K*(1 - e^{-\rho\Delta t(T-t+1)})/(1 - e^{-\rho\Delta t}) + FC*(1 - e^{-(\rho+d)\Delta t*(T-t+1)}),\ (1-k*f) * p_u (n_t, u_t, \Delta t) + e^{-\rho\Delta t}*E[\ F(V_{t+1}) \mid V_t\ ] \}$[7]

where

$F(V_T) = \min \{ (1-f)*K + FC*(1 - e^{-(\rho+d)\Delta t}),\ (1-k*f) * p_u (n_T, u_T, \Delta t) \}$

__Note__: $F(V_1)$+k*f*(ASP price from 1 to T) = minimum total software/hosting/support cost with an option to bring the software in-house

Option 3: Option to end ASP contract prior to expiration

Option 3.1: Value of flexibility to end usage prior to expiration

With pure usage-based pricing, a provider implicitly gives a customer a free option to end ASP service anytime by simply stopping usage and paying nothing. This creates tremendous value for a customer when it is flexible to do so. However, in reality a customer may not be able to freely stop using the software due to necessity, lack of alternatives, compatibility with partners, etc. We model option 1 and 2 under this limitation, as we focus on cost and assume that a customer does not actively stop using the service even when benefit falls below price. Previously, the usage drops to zero only when the software no longer provides benefit.

In this section, we evaluate the value of flexibility to stop using ASP service before contract expiration at time T. Without an option, a customer derives a net value that depends all underlying uncertainties (u, n, b) during the entire contract time. With an option to stop using the service, a customer actively decides monthly whether to end the service by paying an exit fee and avoid subsequent cash flows. Once an option is exercised, a customer can no longer resume ASP services. The difference between the net values with and without an option signifies the value of flexibility to stop usage.

__Parameters:__

K_{exit} = an exit fee to end ASP contract (i.e. an actual penalty charged by the ASP when actively stopping the service is allowed, damage cost from not having ASP service, or a part of switching cost to other ASP). When $K_{exit} = 0$, the option premium represents a pure value of having the flexibility to stop service.

$p_u (n, u, \Delta t)$ = usage-based price for n users at usage level u during Δt (i.e., for linear pricing $p_u (n, u, \Delta t) = p_{use} * n * u * \Delta t$)

__Value Function:__

max E[NPV (ASP value)]

$F(V_t) = \max \{$ end contract, net value in current period $+ e^{-\rho\Delta t}*E[\ F(V_{t+1}) \mid V_t\ ] \}$

$F(V_t) = \max \{ - K_{exit},\ (n_t * u_t * b_t* \Delta t) - p_u (n_t, u_t, \Delta t) + e^{-\rho\Delta t}*E[\ F(V_{t+1}) \mid V_t\ ] \}$

$F(V_t) = \max \{ - K_{exit},\ (n_t * u_t * \Delta t) * (b_t - p_{use}) + e^{-\rho\Delta t}*E[\ F(V_{t+1}) \mid V_t\ ] \}$

where

$F(V_T) = \max \{ - K_{exit},\ (n_T * u_T * \Delta t) * (b_T - p_{use}) \}$

__Note__: $F(V_1)$ = maximum net ASP value when having flexibility to stop ASP service

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[6] Effectively, a customer has always paid ($k*f * p_u (n_t, u_t, \Delta t)$) every period, whether to ASP or to its internal IT. Thus, the only cash flows difference is $(1-k*f) * p_u (n_t, u_t, \Delta t)$, which is paid to the provider when using ASP.

[7] $FC*(1 - e^{-(\rho+d)\Delta t*(T-t+1)})$ is essentially the cost of technology depreciation in real terms (taking into account the time value of money) during the period from t to T+1.

Option 3.2: Value of option to end ASP contract prior to expiration under minimum per-period usage requirement

In practice, a provider is likely to impose a minimum per-period usage requirement in order to ensure recovery of its fixed-cost investment. Therefore, in this section we impose such constraint and evaluate the value of an option to actively end ASP contract prior to expiration. We assume that a customer does not derive benefit from additional usage that is imposed because of the requirement. As in option 3.1, a customer can only exercise the option once and cannot resume ASP services after the option is exercised.

Parameters:
U_{min} = a minimum per-period usage requirement (total users*hours)
U_t (n_t, u_t, U_{min}) = max { n_t * u_t, U_{min} }
$K_{exit-umin}$ = an exit fee to end ASP contract under a minimum usage requirement (same interpretation as in option 3.1)
p_u (u, Δt) = usage-based price for usage level u during Δt (i.e., for linear pricing p_u (u, Δt) = p_{use} * u * Δt)

Value Function:
max E[NPV (ASP value)]
$F(V_t) = \max \{ \text{end contract}, \text{ net value in current period} + e^{-\rho\Delta t} * E[F(V_{t+1}) \mid V_t] \}$
$F(V_t) = \max \{ - K_{exit-umin}, (n_t * u_t * b_t * \Delta t) - p_u (U_t (n_t, u_t, U_{min}), \Delta t) + e^{-\rho\Delta t} * E[F(V_{t+1}) \mid V_t] \}$
where
$F(V_T) = \max \{ - K_{exit-umin}, (n_T * u_T * b_T * \Delta t) - p_u (U_T (n_T, u_T, U_{min}), \Delta t) \}$

<u>Note</u>: $F(V_1)$ = maximum net ASP value with an option to end ASP contract under a minimum per-period usage requirement

Option 3.3: Value of option to end ASP contract prior to expiration under minimum per-period usage and minimum time commitment

In addition to a minimum per-period usage requirement, ASP may also impose a minimum time commitment before a customer can end the ASP contract in order to ensure recovery of initial fixed costs invested in acquiring and setting up for a customer. This option is similar to option 3.2 with an additional restriction on an exercise date to be after the minimum period.

Parameters:
t_{min} = a minimum time commitment before a customer can end the contract, $0 < t_{min} < T$ (the option is first exercisable at period t_{min} +1)

Value Function:
max E[NPV (ASP value)]

For $t > t_{min}$,
$F(V_t) = \max \{ \text{end contract}, \text{ net value in current period} + e^{-\rho\Delta t} * E[F(V_{t+1}) \mid V_t] \}$
$F(V_t) = \max \{ - K_{exit-umin}, (n_t * u_t * b_t * \Delta t) - p_u (U_t (n_t, u_t, U_{min}), \Delta t) + e^{-\rho\Delta t} * E[F(V_{t+1}) \mid V_t] \}$
where
$F(V_T) = \max \{ - K_{exit-umin}, (n_T * u_T * b_T * \Delta t) - p_u (U_T (n_T, u_T, U_{min}), \Delta t) \}$

For $t <= t_{min}$,

$$F(V_t) = \text{net value in current period} + e^{-\rho\Delta t} * E[F(V_{t+1}) \mid V_t]$$
$$= (n_t * u_t * b_t * \Delta t) - p_u (U_t (n_t, u_t, U_{min}), \Delta t) + e^{-\rho\Delta t} * E[F(V_{t+1}) \mid V_t]$$

<u>Note</u>: $F(V_1)$ = maximum net ASP value with an option to end ASP contract under a minimum per-period usage requirement and a minimum time commitment

7. Simulation Methodology

7.1. Simulation Algorithm

In order to evaluate the proposed real options, we follow simulation-based algorithm suggested by Barraquand and Martineau (1995), specifically Monte Carlo simulation with stratified state aggregation along the payoff. The procedures consist of stratifying the payoff space into bins by running preliminary Monte Carlo simulations, constructing an approximation of a binomial lattice from those bins using Monte Carlo simulations and finally solving for an option value through the dynamic programming backward recursion.

Raymar and Zwecher (1997) suggest an improvement on Barraquand and Martineau by using a two-dimensional algorithm with sub bins that produce more accurate results than Barraquand and Martineau's one-dimensional approach. However, as stated in the uncertainty section, we find high correlations among the uncertainties, ranging from 0.69 to 0.8. We also discover high correlations between the payoffs and our potential second factor (benefit), ranging from 0.69 to 0.89. Therefore, we believe that we will obtain more accurate results by using all sample paths to discretize our payoffs into finer grids than employing the second factor. In addition, Raymar and Zwecher's two-dimensional approach is less accurate for out-of–the-money options than Barraquand and Martineau's with the same number of sample paths.

In summary, we use Barraquand and Martineau's one-dimensional approach with the following payoffs:
Option 1: usage cost per user = u_t*p_{use}
Option 2: total cost for all users = $n_t*u_t*p_{use}$
Option 3.1: net value = total benefit – total cost = $n_t*u_t*b_t$ - $n_t*u_t*p_{use}$
Option 3.2: net value = total benefit – total cost with minimum usage = $n_t*u_t*b_t$ - $n_t*\max(U_{min},u_t)*p_{use}$
Option 3.3: same as option 3.2

Nonetheless, we find that Raymar and Zwecher provide informative guidelines on the number of simulations and bins, and we try to follow closely. Specifically, we break down the payoffs into 100 bins for each decision period; thus, each bin contains roughly 1% of sample paths. To find cutoff values for bins, we use 25 times the number of bins or 2,500 sample paths, and cutoffs are taken so that each bin has the same number of sample paths. For the real simulation runs to find optimal stopping region and to price option, we use 200 times the number of bins or 20,000 sample paths. Finally, we simulate 10 repetitions for each set of parameters to obtain a mean option price and a standard deviation.[8]

Since ASP contracts are commonly 2-3 years, we use a time horizon of three years or 36 months. The decision to exercise is allowed monthly at the beginning of each month from t = 1, …,36. All uncertainties evolve at a finer time step of 1/10 per month (or 360 times during our horizon). For all options, we solve for two values: an option premium and an exercise region.

7.2. Base Case Parameter Values

Parameters for uncertainty/payoff generation:
Price: p_{use} (price per usage) = \$8/hour, U_{min} (for option 3.1 and 3.2) = 3,000 hours/month
Benefit (b) uncertainty: κ_b = 0.5, b_{max} = \$10/hour, g = 0.231 (half-life[9] = 3 months), h = 0.2 (benefit decreases from 10 to 0 in 12 months), L = 24 months, σ_{b0} = 0.6, c = 0.1155 (half-life = 6 months)
Usage level (u) uncertainty: κ_u = 0.5, σ_u = 0.2, $u_{breakeven}$ = 100, initial usage level (t=1) = 20
The number of users (n) uncertainty: κ_n = 0.5, σ_n = 0.2, n_{max} = 100, $nnorm_0$ = 20, a = 0.058 (half-life = 12 months), the initial number of users (t=1) = 10

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[8] Raymar and Zwecher use 500 times the number of bins for sample paths in the real simulation and 100 repetitions. Because our uncertainties evolve at additional ten time steps per exercise period, we find the above numbers of simulations to be prohibitively expensive in our case.
[9] Half-life is a period during which a value grows/decreases to half of its maximum.

Parameters for option valuation:
Option 1: $\rho = 0.07/12$ per month, p_{sub} (Δt = month) = \$1,000
Option 2: d = 0.0385 (half-life = 18 months), f = 0.2, k = 1, FC = 50,000, K = 100,000
Option 3: $K_{exit} = 0$, $K_{exit\text{-}umin} = 0$, $t_{min} = 12$

7.3. Sensitivity Analysis

We perform sensitivity analysis along two major categories: variables that affect uncertainties and variables that affect option valuation. For variables that affect uncertainties, we investigate changes in degree of uncertainty (σ_{b0}, σ_u, σ_n), changes in mean variables that uncertainties revert to (b_{max}, $u_{breakeven}$, n_{max}) and changes in software cycle (L). The following table shows low, base, high values. We change one variable at a time from the base case values, yielding 15 test cases (7 low, 7high, 1 base).

	Variables	Low	Base	High
Degree of Uncertainty	σ_{b0}	0.2	0.6	1.0
	σ_u	0.1	0.2	0.4
	σ_n	0.1	0.2	0.4
Mean Variables	b_{max}	5	10	15
	$u_{breakeven}$	50	100	150
	n_{max}	50	100	150
Software Cycle	L	12	24	36

For the variables that affect option valuation, we explore the following values with each of the above fifteen uncertainty variable sets. Base case values are highlighted in bold.

Option 1:	p_{sub}	= 200, 400, 600, 800, **1000**, 1200, 1400, 1600, 1800, 2000
Option 2:	FC	= 0, **50000**, 100000
	K	= 50000, 75000, **100000**, 125000, 150000
Option 3.1:	K_{exit}	= **0**, 10000, 20000, 30000, 40000
Option 3.2:	$K_{exit\text{-}umin}$	= **0**
	t_{min}	= 0
Option 3.3:	t_{min}	= 1,2,3, …, 35

7.4. Technical Note

In order to find exercise thresholds, we average a minimum or maximum payoff that triggers an exercise at every period. We also report an upper bound (lower bound) on payoffs by averaging the highest (lowest) payoffs over all simulation repetitions. Therefore, we will sometimes observe an exercise threshold that is higher than the highest payoff. In general, the reported exercise thresholds are biased high. At time t, we average the exercise thresholds over all payoffs that trigger an exercise. Thus, we average over the points that are already inside the exercise region. The resulting mean will be higher than the true exercise threshold. Bias is unavoidable when we discretize the continuous payoff space into bins. However, with an adequately fine grid, errors should be within an acceptable range.

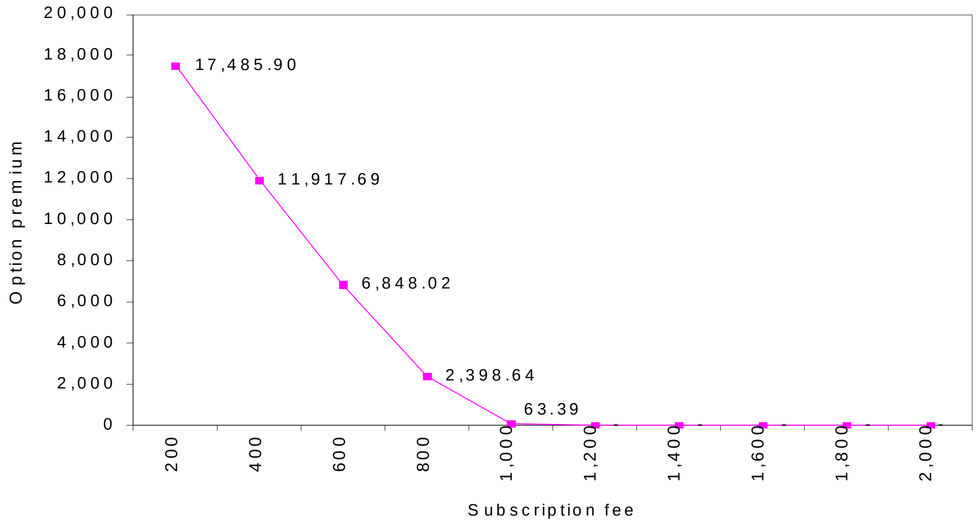
8. Simulation Results and Analysis

Option 1: Usage-based pricing with an option to switch to a subscription fee

1) Base Case

Option Premium

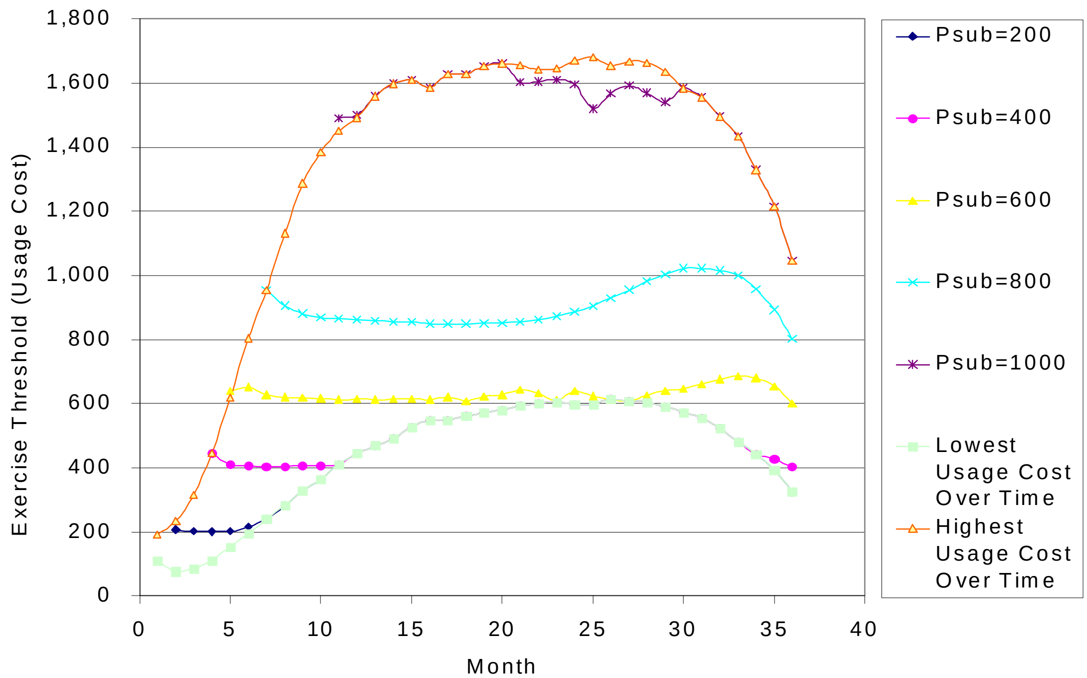
Figure 8.1.1: Base Case Option Premium vs. Subscription Fee



An option premium is calculated from the difference between the ASP usage costs per user with and without an option to switch to a subscription fee. A subscription fee is analogous to an exercise price of a call option on the usage cost. Figure 8.1.1 shows the option premium as a function of a subscription fee. As expected, an option premium drops dramatically as a subscription fee increases because an option with a low subscription fee is more likely to be exercised and, once exercised, leads to larger savings on the ASP cost. With our base case parameters, the option is never exercised when the subscription fee is more than $1000; thus, the options in those cases have zero value.

Exercise Threshold

Figure 8.1.2: Base Case Exercise Threshold (Usage Cost) Over Time



An exercise threshold for option 1 is the lowest usage cost that triggers an exercise over time. Thus, a customer should switch to a subscription fee once its usage cost rises above this threshold. Figure 8.1.2 shows the exercise thresholds for various subscription fees along with the evolution of the lowest and the highest usage costs, which are average usage costs in the first and the last bin of our lattice. Note that we can only identify the exercise threshold within in this region between the highest and the lowest usage costs, where we have representative sample paths.

As shown in Figure 8.1.2, a lower subscription fee enables a larger exercise region and a lower exercise threshold. In all cases, the exercise thresholds are always higher than their corresponding subscription fees, illustrating the value of keeping an option alive until expiration. This value of being alive increases substantially as we move to a higher subscription fee. When the subscription fee increases, the usage cost fluctuates closer to the exercise price; therefore, the value of keeping an option alive rises due to high uncertainty. As a result, an exercise threshold for a high subscription fee is quite a margin above its subscription fee. On the other hand, with a low subscription fee, the usage cost is comfortably above it; therefore, there is a low chance that the usage cost will fall below the subscription fee. Consequently, the value of keeping an option alive is minimal.

We note that the exercise thresholds decrease a little at the beginning to stabilize around the middle and have a hump towards the end. At the beginning, the usage ramps up with its benefit, leading to an increasing usage cost. Therefore, the value of option being alive decreases and stabilizes around the middle when the usage is high. At the end of the software cycle (24 months for our base case), the benefit and thus the usage start dropping. Therefore, the exercise threshold increases to account for a rising chance that the usage cost will fall below the subscription fee. Being alive loses its value towards the end as it comes closer to expiration, and the exercise threshold falls down and finally equals to the subscription fee at the last period.

Note that the exercise threshold for a subscription fee of $1000 and the evolution of the highest usage cost especially at the top are not as smooth as others. Since the volatility of usage is proportional to its value, a high usage cost has a high variance, leading to a large standard deviation in the estimation. Moreover, we will find that, throughout this paper, an estimation of the premium and the exercise threshold for out-of-the money option has a relatively high standard deviation.

2) Changes in Degree of Uncertainty

Option Premium

Table 8.1.1 shows option premiums for various degrees of uncertainty in benefit and usage. For all subscription fees, higher sigma's lead to higher option premiums. We notice that the effects of sigma's are more pronounced when the usage cost is around the subscription fee. Specifically, the largest proportional swing of option premiums over changes in sigma's occurs when a subscription fee is $1000, which is roughly the mean usage cost when benefit matures ($\bar{u}(b)*p_{use} = u_{breakeven}*(b_t/p_{use})*p_{use} = 100*10$). When the subscription fee is low, the option is exercised almost surely; thus, a large sigma does not increase the option value significantly. When the subscription fee is high, the option is likely to be out of the money, so a large sigma does not increase the option value substantially either.

Furthermore, we observe that changes in σ_u affects the option premiums more than changes in σ_{b0}, especially when the results shown are for a larger swing of $\sigma_{b0} = (0.2,0.6,1)$ than $\sigma_u = (0.1,0.2,0.4)$. One major reason is that σ_u directly affects u, the main driver of the usage cost, while σ_{b0} influences u via $\bar{u}$ that u reverts to. Intuitively, uncertainty in benefit affects the trend that usage is moving towards, while direct disturbance on usage immediately translates into fluctuation in usage costs. In addition, as σ_{b0} dies out over time, an initial uncertainty in benefit leaves no lasting effect on uncertainty of the usage cost.

Table 8.1.1: Option Premium for Various Sigma's
(Standard deviation in Italic below the mean value)

Case	Base (σ_{b0}=0.6, σ_u=0.2)	σ_{b0}		σ_u	
		0.2	1	0.1	0.4
Cost W/O Option	23,821.21 *12.74*	23,826.22 *12.80*	23,821.27 *25.01*	23,823.44 *11.68*	23,811.75 *25.41*
200	17,485.90 *12.65*	17,478.80 *12.76*	17,508.90 *25.03*	17,482.66 *11.54*	17,497.98 *25.28*
400	11,917.69 *12.09*	11,886.31 *12.35*	11,987.40 *24.70*	11,905.15 *10.99*	11,961.79 *24.33*
600	6,848.02 *11.56*	6,780.93 *12.01*	6,981.96 *23.56*	6,808.28 *10.38*	6,977.20 *23.02*
800	2,398.64 *11.18*	2,295.92 *11.44*	2,602.72 *19.31*	2,290.24 *8.99*	2,774.93 *22.56*
1,000	63.39 *3.46*	47.08 *3.53*	164.48 *6.70*	0.52 *0.62*	630.08 *17.73*
1,200	- -	- -	- -	- -	151.80 *11.70*
1,400	- -	- -	- -	- -	40.75 *4.91*
1,600	- -	- -	- -	- -	12.20 *1.54*
1,800	- -	- -	- -	- -	1.99 *0.90*
2,000	- -	- -	- -	- -	- -

Exercise Threshold

Figure 8.1.3: Exercise Threshold (Usage Cost) for Various Sigma's when P_{sub} = 800

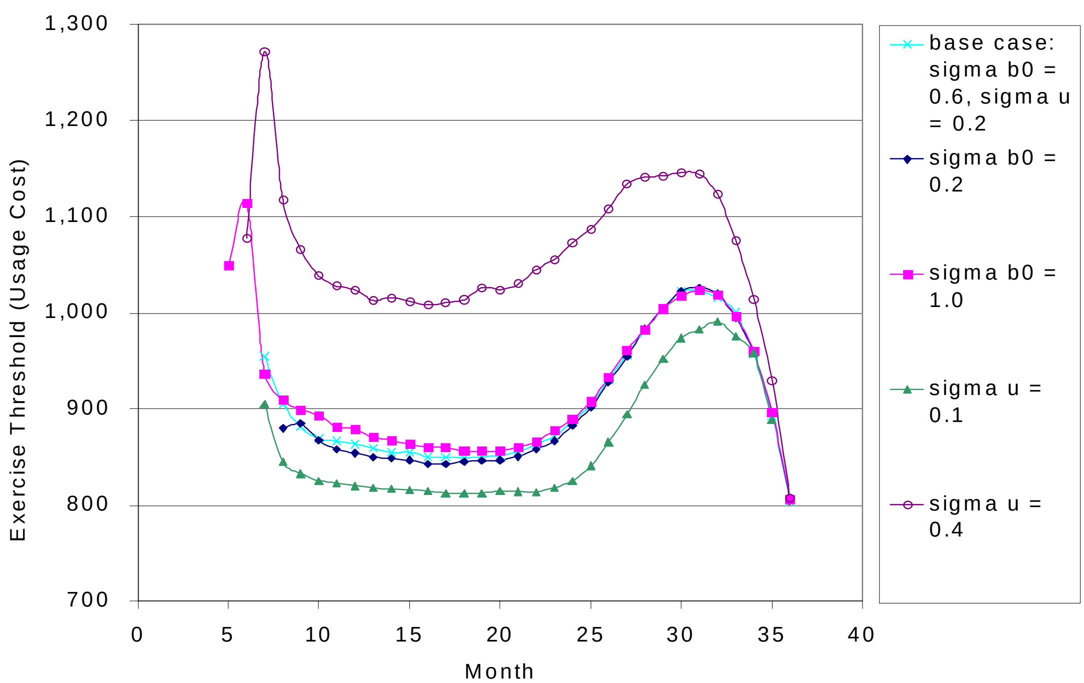


Figure 8.1.3 shows the exercise thresholds for various sigma's when the subscription fee is $800. As the sigma increases, the live value of the option also increases with the uncertainty and pushes up the exercise threshold. We also see clearly again that σ_u has more effect on the option premium and the exercise threshold than σ_{b0}. Note that the shape of the exercise thresholds is similar to that in the base case, except for an initial hike in the high sigma cases. With a large sigma and low benefit/usage during the beginning periods, an option has a high live value due to high uncertainty. Therefore, the exercise threshold ramps up as the volatility of usage cost grows with increasing benefit and usage. Once the benefit and usage, thus the usage cost, moves adequately far from a subscription fee, the live value of an option decreases and consequently brings down the exercise threshold.

3) Changes in Mean Variables

Option Premium

Table 8.1.2: Option Premium for Various Mean Variables
(Standard deviation in Italic below the mean value)

Case	Base (b_{max} =10, $u_{breakeven}$=100)	b_{max}		$u_{breakeven}$	
		5	15	50	150
Cost W/O Option	23,821.21 *12.74*	11,581.93 *7.69*	36,131.15 *25.58*	12,070.18 *7.37*	35,573.06 *18.43*
200	17,485.90 *12.65*	5,415.34 *7.52*	29,742.98 *25.79*	5,969.77 *7.30*	29,156.98 *18.48*
400	11,917.69 *12.09*	638.24 *6.32*	23,953.92 *25.88*	1,200.36 *6.47*	23,338.91 *18.15*
600	6,848.02 *11.56*	- -	18,497.19 *25.48*	- -	17,867.58 *17.30*
800	2,398.64 *11.18*	- -	13,354.48 *24.94*	- -	12,715.00 *16.50*
1,000	63.39 *3.46*	- -	8,565.91 *24.36*	- -	7,919.82 *16.51*
1,200	- -	- -	4,242.70 *21.19*	- -	3,594.52 *15.54*
1,400	- -	- -	924.46 *14.07*	- -	519.25 *11.40*
1,600	- -	- -	46.62 *3.62*	- -	2.33 *1.29*
1,800	- -	- -	1.47 *0.45*	- -	- -
2,000	- -	- -	- -	- -	- -

Table 8.1.2 shows option premiums for various mean-affecting variables, namely b_{max} and $u_{breakeven}$. As the mean usage cost is determined by $\overline{u}(b)*p_{use} = u_{breakeven}*(b_t/p_{use})*p_{use} = u_{breakeven}*b_t$, the option premiums increase as we increase either b_{max} (affecting b_t) or $u_{breakeven}$, which results in a larger usage cost, and therefore, larger savings from exercising the option.

From the section below, we will see that when the usage cost is around the exercise price, the value of an option being alive is more sensitive to the breakeven usage than the maximum benefit. Therefore, in Table 8.1.2, with the same proportional decrease (50%) in the maximum benefit and the breakeven usage, the option with a low breakeven usage has more value. However, as the maximum benefit and the breakeven usage increase, the options are well in the money, and the values of options being alive in both cases are similarly small. Thus, cost savings will dominate the live value of an option for an in–the-money option.

This is shown when b_{max} = 15 and when $u_{breakeven}$ = 150, the former has a higher usage cost without an option, therefore, enjoys larger cost savings and a slightly higher option premium.

Exercise Threshold

Figure 8.1.4: Exercise Threshold (Usage Cost) for Various Mean Variables when P_{sub} = 1000

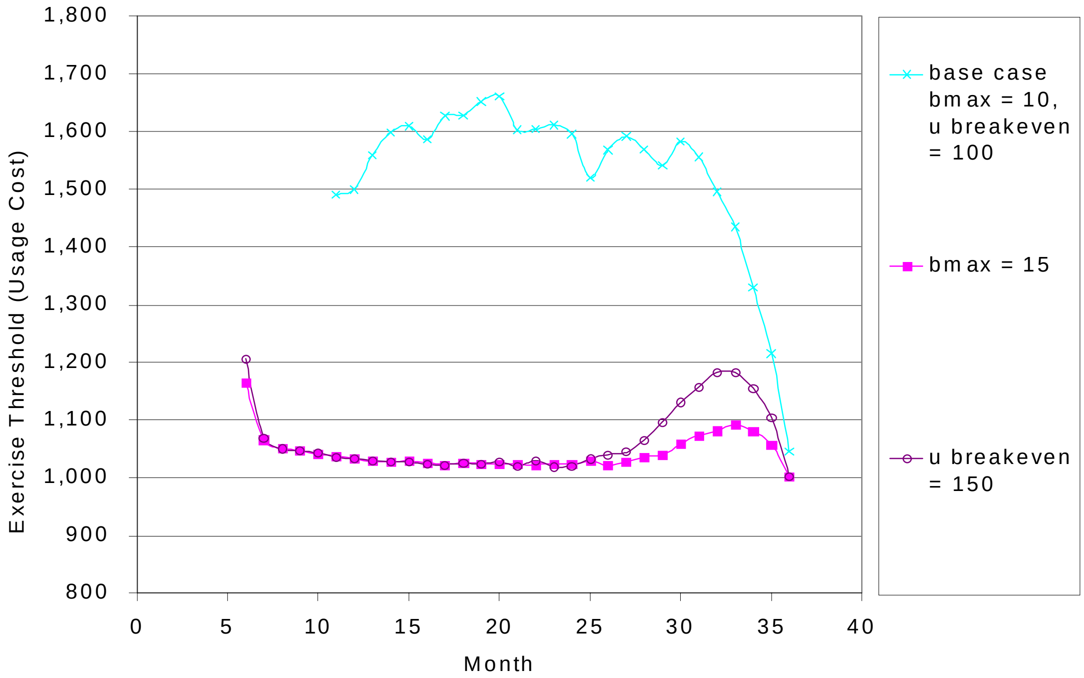


Figure 8.1.4 shows the exercise thresholds for various mean-affecting variables when the subscription fee is \$1000. An increase in either the maximum benefit or the breakeven usage pushes the exercise thresholds down towards the subscription fee. As the usage cost fluctuates around the mean that is substantially higher than the subscription fee, there is very little chance that the usage cost will fall below the exercise price. Therefore, there is not much value in keeping the option alive. A customer should exercise an option even though the current usage cost is only slightly higher than the subscription fee because the cost will soon get pulled up to the mean. Note that the live value of an option with the high maximum benefit or the high breakeven usage is only \$20-30 around the middle, and they are almost equal because both variables are 150% higher than their base case values.

From Figure 8.1.4, we also observe that the live value of an option is larger for the high breakeven usage than for the high maximum benefit at the beginning and towards the end. Because of the initial ramp-up and the final decline in the benefit and usage, the usage cost is small around those periods. Therefore, the live value of an option is large then. This live value is more sensitive to the high breakeven usage than the maximum benefit because the mean usage is directly proportional to the breakeven usage, while the maximum benefit only influences the trend of the current benefit and subsequently the trend of the current mean usage cost.

<u>4) Changes in Software Cycle</u>

Option Premium

Table 8.1.3 shows option premiums for various software cycles. The longer the software cycles, the higher the option premiums. Longer software cycles lead to prolonged high benefit and usage, resulting in large savings from exercising an option. With 12-month software cycle, an option is never exercised when a subscription fee is \$800 or above. Even though the mean usage cost exceeds \$800 since month 7, the usage dies down after the end of software cycle. Thus, it is not worthwhile to commit to the subscription fee till the end of the contract time.

Table 8.1.3: Option Premium for Various Software Cycles
(Standard deviation in Italic below the mean value)

Case	Base (L=24)	L 12	L 36
Cost W/O Option	23,821.21 *12.74*	14,594.21 *7.05*	25,131.52 *15.61*
200	17,485.90 *12.65*	8,259.02 *7.10*	18,796.27 *15.51*
400	11,917.69 *12.09*	2,691.16 *7.19*	13,227.82 *14.32*
600	6,848.02 *11.56*	2.67 *0.96*	8,156.76 *12.69*
800	2,398.64 *11.18*	- -	3,704.86 *11.02*
1,000	63.39 *3.46*	- -	644.47 *9.26*
1,200	- -	- -	55.66 *2.18*
1,400	- -	- -	7.07 *0.51*
1,600	- -	- -	0.65 *0.09*
1,800	- -	- -	- -
2,000	- -	- -	- -

Exercise Threshold

Figure 8.1.5: Exercise Threshold (Usage Cost) for Various Software Cycles

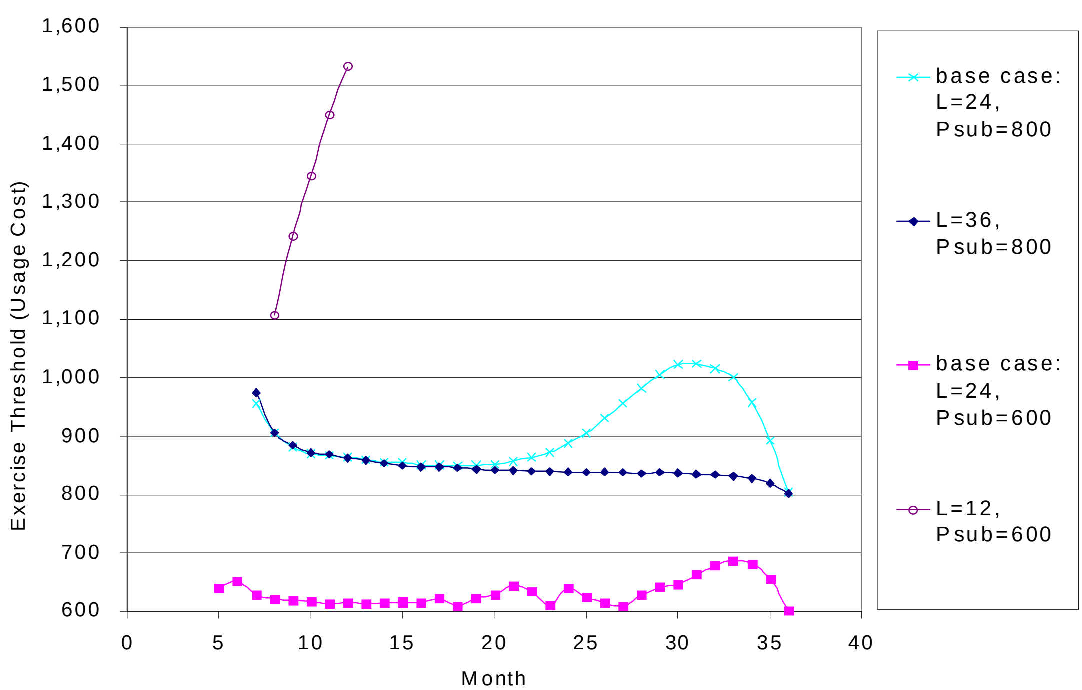


Figure 8.1.5 shows the exercise thresholds for various software cycles.[10] As seen from L=36 compared with L=24, a longer software cycle leads to a lower exercise threshold because the usage stays high for the entire contract time. The difference becomes clear after 24 months when the benefit of L=24 software starts decreasing while that for L=36 remains high. Therefore, the live value of an option is small and decreasing towards the end of the contract as the option approaches expiration. When the software cycle is short, 12 months for example, the exercise threshold increases towards the end because there is only a short period left that the software will be useful, while the customer has to continue paying the subscription fee till the end of the contract.

Option 2: Option to bring the software in-house

1) Base Case

Option Premium

Table 8.2.1: Option Premium for Base Case
(Standard deviation in Italic below the mean value)

Cost W/O Option		1,788,565.92 *1,661.62*
FC (K = 100,000)	0	2,762.78 *155.02*
	50,000	1,395.73 *134.50*
	100,000	497.66 *185.89*
K (FC = 50,000)	50,000	445,493.70 *1,303.80*
	75,000	103,939.92 *1,076.19*
	100,000	1,395.73 *134.50*
	125,000	- -
	150,000	- -

An option premium is the difference between the total software/hosting/support cost for all users with and without an option to bring the software in-house. Table 8.2.1 shows the option premiums for various one-time fixed infrastructure costs (FC) and various exercise price constants (K), which is an annuity equivalent of the net present value of the provider's expected revenue or, in other words, a monthly payment till expiration that ASP is willing to accept in lieu of the missing revenue. For example, with a variable cost of 20% of the ASP price, the exercise price paid to ASP is equivalent to 80%*K monthly till expiration.[11]

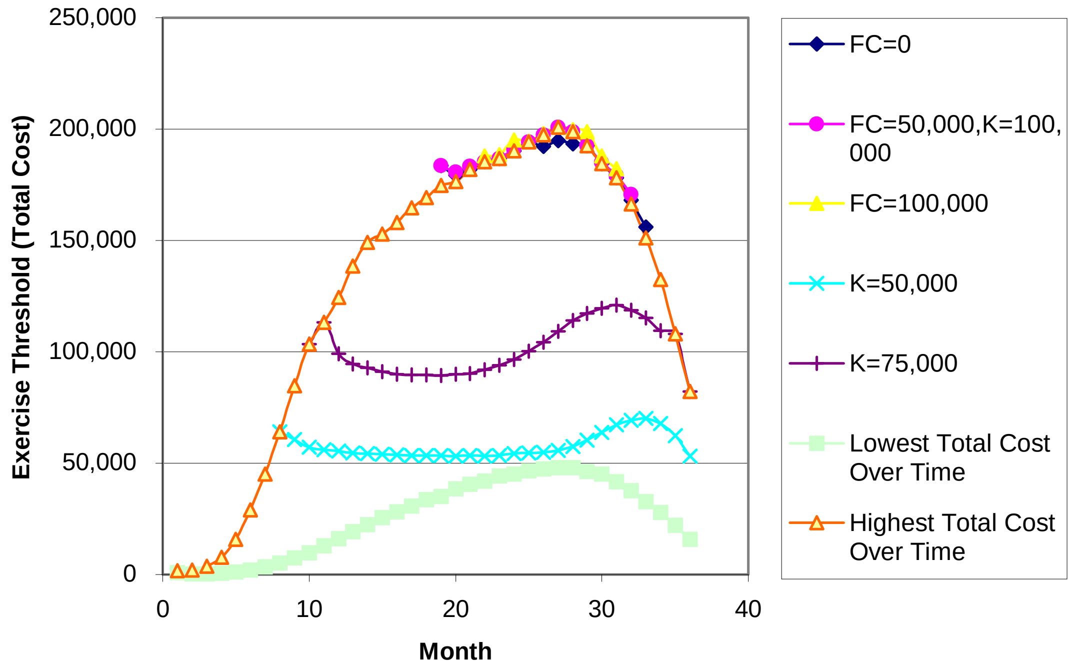
[10] We compare L=12 at a subscription fee of $600 because the option is out of the money at $800 or above. With L=36, the exercise threshold falls below the minimum usage cost region at $600 subscription fee or below, so we show the result at $800.

[11] To get some sense of the magnitude of K, the monthly expected missing revenue is roughly $\bar{u}_t * \bar{n}_t * p_{use}$. Thus, an upper bound on $K = (u_{breakeven}*b_{max}/p_{use})*(n_{max}*b_{max}/p_{use})* p_{use} = u_{breakeven}*n_{max}*(b_{max})^2/p_{use} = 100*100*10^2/8 = 125000$, which takes into account of only the missing revenue but not other costs and benefits.

Obviously, the higher the exercise costs, either an infrastructure investment or a direct exercise price paid to ASP, the lower is the option value. K has a stronger effect on the option premium than FC, as K represents a monthly annuity that sums to a much larger total than a one-time payment for infrastructure.

Exercise Threshold

Figure 8.2.1: Base Case Exercise Threshold (Total Cost) Over Time



An exercise threshold for option 2 is the lowest total cost for all users that triggers an exercise over time. As shown in Figure 8.2.1, a lower exercise cost enables a larger exercise region and a lower exercise threshold. For a base-case K=100,000, FC barely has any effects on the exercise threshold because K=100,000 leads to almost out-of-the-money option; thus, additional FC could only pushes to extremely high exercise thresholds. Moreover, FC is a one-time payment that is relatively small compared to the aggregate amount of K and the total cost without an option of 1.79M.

Note that the base-case exercise thresholds for option 2, with respect to various K, are similar to the base-case exercise thresholds for option 1, with respect to various subscription fees. A higher K leads to a much higher exercise threshold. When the exercise price is close to the total cost, there is high uncertainty that the total cost will fall below the exercise price; thus, the option has a high live value. The shape of the exercise thresholds also mimics that of option 1. With K as a monthly payment and the number of users (n) evolves mainly the same way as the usage level (u), we can interpret the option to bring software in-house with "a monthly fee" the same way as we interpret the option to switch to a subscription fee. However, the resulting risk characteristics to customers and providers once the option is exercised are very different, as described in the value function section.

2) Changes in Degree of Uncertainty

Option Premium

Table 8.2.2 shows option premiums for various degrees of uncertainty in benefit, usage level and the number of users. As expected, higher uncertainty of any factor leads to higher option premiums, regardless of the exercise price. We note that the percentage swing of option premiums between high and low σ_u (or σ_{b0}) is much larger than that of option 1. The option to bring software in-house provides a call on the total cost, which includes the number of users and its volatility. Therefore, this option hedges against more volatile cash flows and is consequently more valuable (even proportionally).

We observe that changes in σ_u have slightly more effect than changes in σ_n, but both affect option premiums much more than σ_{b0}. As we learn from the uncertainty plot, σ_u is scaled up by the usage level that ramps up quickly with the benefit, while σ_n is multiplied by the number of users that gradually increases with the company size. Therefore, volatility of the usage level grows faster than that of the number of users and consequently produces slightly more impact on the option premiums. Nonetheless, both u and n directly determine the total cost; therefore, their volatility has a higher impact on the option values than the benefit uncertainty, which only influences the means that u and n revert to. As in option 1, uncertainty becomes more significant as the options are around at-the-money.

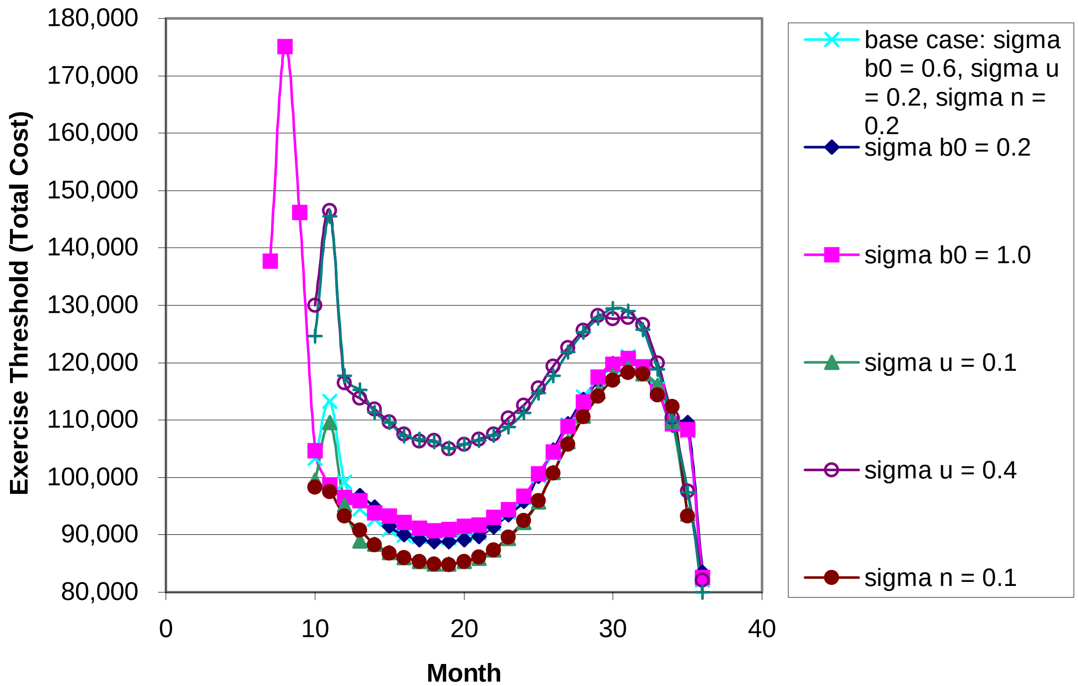
Table 8.2.2: Option Premium for Various Sigma's
(Standard deviation in Italic below the mean value)

Case	Base (σ_{b0}=0.6, σ_u=0.2, σ_n=0.2)	σ_{b0}		σ_u		σ_n	
		0.2	1	0.1	0.4	0.1	0.4
Cost W/O Option	1,788,565.92 *1,661.62*	1,778,605.01 *1,581.59*	1,812,751.14 *2,360.75*	1,788,390.64 *1,508.73*	1,787,716.78 *2,197.36*	1,788,426.42 *1,397.46*	1,788,831.95 *1,390.01*
FC when K = 100,000							
0	2,762.78 *155.02*	1,841.62 *138.82*	12,005.86 *718.19*	81.49 *53.87*	26,821.26 *864.89*	297.49 *176.24*	25,564.80 *514.28*
50,000	1,395.73 *134.50*	852.83 *175.90*	9,435.55 *730.06*	- -	23,070.16 *798.63*	5.44 *16.16*	21,970.55 *485.73*
100,000	497.66 *185.89*	257.30 *201.45*	7,207.74 *819.64*	- -	19,812.12 *739.56*	- -	18,801.82 *444.03*
K when FC = 50,000							
50,000	445,493.70 *1,303.80*	432,808.47 *1,280.11*	474,135.10 *1,521.59*	442,488.02 *1,038.42*	454,555.47 *1,779.81*	442,810.98 *999.62*	454,416.43 *1,028.02*
75,000	103,939.92 *1,076.19*	92,232.80 *1,026.23*	133,796.13 *883.10*	94,388.63 *688.91*	135,500.14 *1,636.29*	95,179.65 *797.10*	133,885.50 *737.67*
100,000	1,395.73 *134.50*	852.83 *175.90*	9,435.55 *730.06*	- -	23,070.16 *798.63*	5.44 *16.16*	21,970.55 *485.73*
125,000	- -	- -	- -	- -	3,604.24 *488.39*	- -	3,372.88 *482.04*
150,000	- -	- -	- -	- -	23.73 *38.68*	- -	0.53 *1.68*

Exercise Threshold

Figure 8.2.2 shows the exercise thresholds for various sigma's when FC = 50,000 and K = 75,000. As expected, higher uncertainties push the exercise thresholds up and away from the exercise price because there is a higher chance that the total cost may fall below the exercise price; thus, higher uncertainties lead to higher live values. We also see clearly again that volatility in the usage level and the number of users has more impact than the uncertainty in benefit. The shapes of the exercise thresholds in option 2 are quite similar to those in option 1. However, we notice that the high benefit uncertainty brings the exercise threshold way up during the initial period. As benefit influences both the usage level and the number of users, its volatility is important especially at the initial stage when the usage level and the numbers of users are small and the options are borderline out-of-the-money.

Figure 8.2.2: Exercise Threshold (Total Cost) for Various Sigma's when FC = 50,000, K = 75,000



3) Changes in Mean Variables

Option Premium

Table 8.2.3 shows option premiums for various mean-affecting variables, namely b_{max}, $u_{breakeven}$ and n_{max}. As expected, with a fixed exercise price K, an increase in any mean variable leads to a higher option premium. With a fixed exercise price, customers who derive a larger benefit, has a higher usage level or has a greater potential growth find an option to bring software in-house more valuable. In practice, we may expect the providers to adjust this exercise price to individual customer's mean variables as they directly impact the providers' potential missing revenue.

We also note that the maximum benefit has a stronger effect on the option premiums than the breakeven usage or the maximum number of users. Benefit influences both the usage level and the number of users simultaneously; thus, its effect is amplified in the total cost. The breakeven usage has a slightly larger impact on the option premiums than the maximum number of users. While an increase in the breakeven usage induces the same percentage increase in the usage level, an increase in the maximum number of users only has less than proportional effect on the actual number of users.

Table 8.2.3: Option Premium for Various Mean Variables
(Standard deviation in Italic below the mean value)

Case	Base (b_{max}=10, $u_{breakeven}$=100, n_{max}=100)	b_{max}		$u_{breakeven}$		n_{max}	
		5	15	50	150	50	150
Cost W/O Option	1,788,565.92 *1,661.62*	411,059.03 *350.91*	4,179,605.24 *4,719.06*	895,954.22 *860.10*	2,681,472.94 *2,261.84*	986,660.53 *881.36*	2,590,793.02 *3,517.20*
K when FC = 50,000							
50,000	445,493.70 *1,303.80*	- -	2,260,666.75 *3,717.41*	240.39 *84.01*	1,102,445.30 *1,766.97*	2,279.62 *78.67*	1,042,431.90 *2,667.21*
75,000	103,939.92 *1,076.19*	- -	1,799,600.15 *3,618.52*	- -	682,789.52 *1,696.19*	- -	631,253.64 *2,386.74*
100,000	1,395.73 *134.50*	- -	1,371,033.53 *3,448.71*	- -	317,570.64 *1,586.18*	- -	277,130.39 *2,018.36*
125,000	- -	- -	976,197.22 *3,177.08*	- -	62,439.71 *1,147.28*	- -	46,295.75 *1,075.49*
150,000	- -	- -	619,211.28 *2,805.01*	- -	2,951.49 *281.92*	- -	1,339.67 *328.43*

Exercise Threshold

Figure 8.2.3: Exercise Threshold (Total Cost) for Various Mean Variables when FC = 50,000, K = 100,000

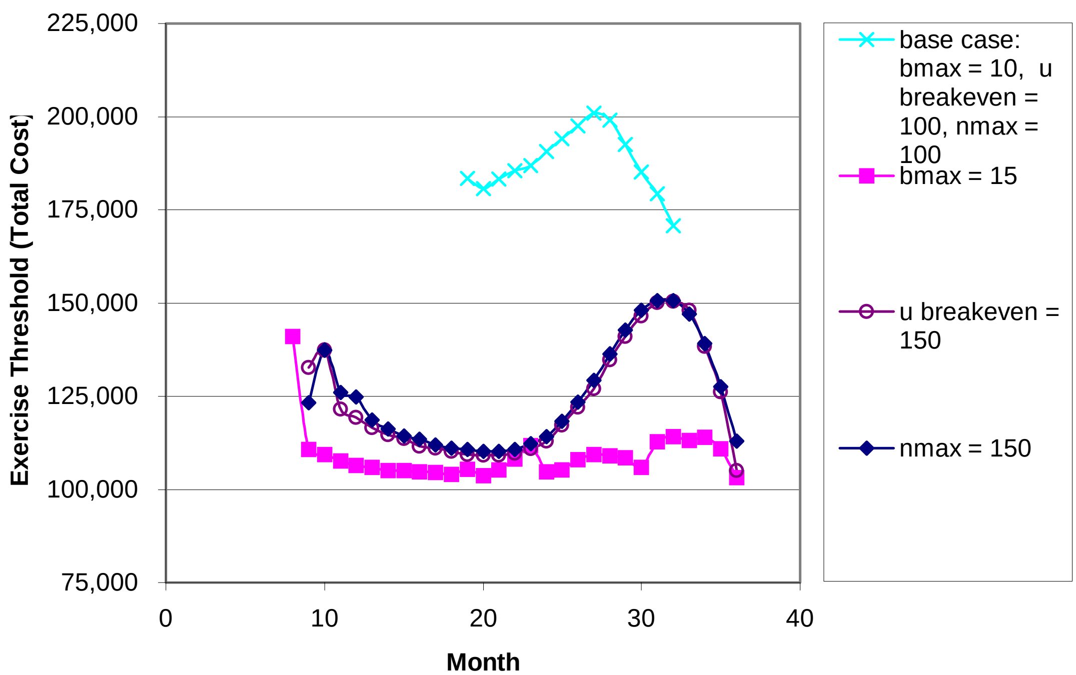


Figure 8.2.3 shows the exercise thresholds for various mean-affecting variables when FC = 50,000 and K = 100,000. An increase in the mean variables leads to a higher total cost. Therefore, the option is well in-the-money and the value of being alive is small; the exercise thresholds consequently shift down towards the exercise price. Once again, we notice that an increase in the maximum benefit has a larger effect than other mean variables.

4) Changes in Software Cycle

Option Premium

Table 8.2.4: Option Premium for Various Software Cycles
(Standard deviation in Italic below the mean value)

Case	Base (L=24)	L: 12	L: 36
Cost W/O Option	1,788,565.92 *1,661.62*	763,432.52 *712.95*	2,034,014.21 *1,789.20*
FC when K = 100,000			
0	2,762.78 *155.02*	- -	91,125.06 *817.27*
50,000	1,395.73 *134.50*	- -	79,162.83 *794.61*
100,000	497.66 *185.89*	- -	68,405.25 *716.85*
K when FC = 50,000			
50,000	445,493.70 *1,303.80*	- -	641,796.23 *1,245.61*
75,000	103,939.92 *1,076.19*	- -	294,494.02 *1,077.90*
100,000	1,395.73 *134.50*	- -	79,162.83 *794.61*
125,000	- -	- -	15,432.78 *292.81*
150,000	- -	- -	3,350.34 *99.85*

Table 8.2.4 shows option premiums for various software cycles. We note that with a twelve-month software cycle, it is never optimal to bring the software in-house at any of the above exercise prices, not surprisingly. Since the software benefit starts to decrease after the end of software cycle, usage level and the number of users decrease correspondingly, leading to a declining total cost if the customer remains with the ASP. Therefore, it is not optimal to lock in a fixed exercise price. As the software cycle increases, the option becomes more valuable due to prolonged benefit. Once again, the effects on the option premiums are percentage-wise larger as the option is at or out of the money.

Exercise Threshold

Figure 8.2.4: Exercise Threshold (Total Cost) for Various Software Cycles

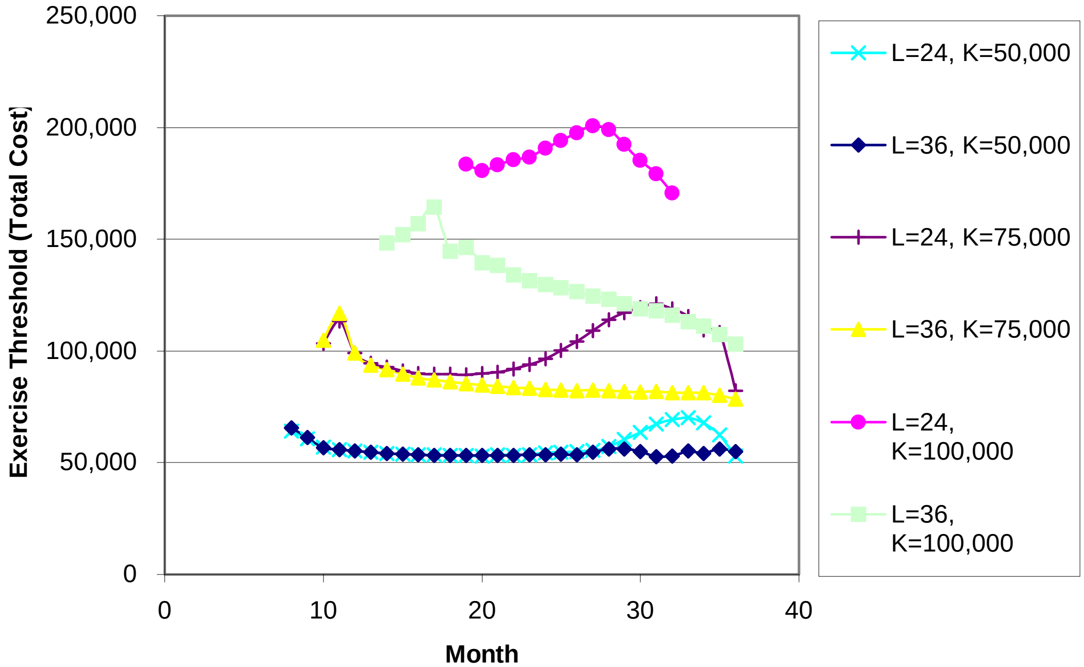


Figure 8.2.4 shows the exercise thresholds for various software cycles. At each exercise price, we see that the longer software cycle consistently leads to the lower exercise thresholds. After twenty-four months, the benefit of 24-month software starts to decrease, bringing down the total usage (and cost) and leading to a high live value and a hump in the exercise thresholds. On the other hand, the benefit of 36-month software remains high till the end of the contract time; therefore, the exercise thresholds decrease monotonically after the initial ramp-up. We also note that the effect of software cycle is more significant when an option approaches out-of-the-money -- a similar result we have seen throughout.

Option 3: Option to end ASP contract prior to expiration

Option 3.1: Value of flexibility to end usage

<u>1) Base Case</u>

Option Premium

An option premium is the difference between the net ASP value (total benefit less total cost) when the customers have and do not have the flexibility to stop using ASP services during the contract time. Table 8.3.1 shows option premiums for various exit fees. As expected, the option premium drops as the exit fee increases. However, we note that the declines in option premiums (8,345.43; 8,345.43; 8,344.90 and 8,339.04) are less than an increase in the exit fee of 10,000. From the exercise thresholds below, we will see that customers only exercise an option on or after the 31^{st} month. Therefore, decreases in option premiums reflect this discount factor and the probability that an option is exercised.[12]

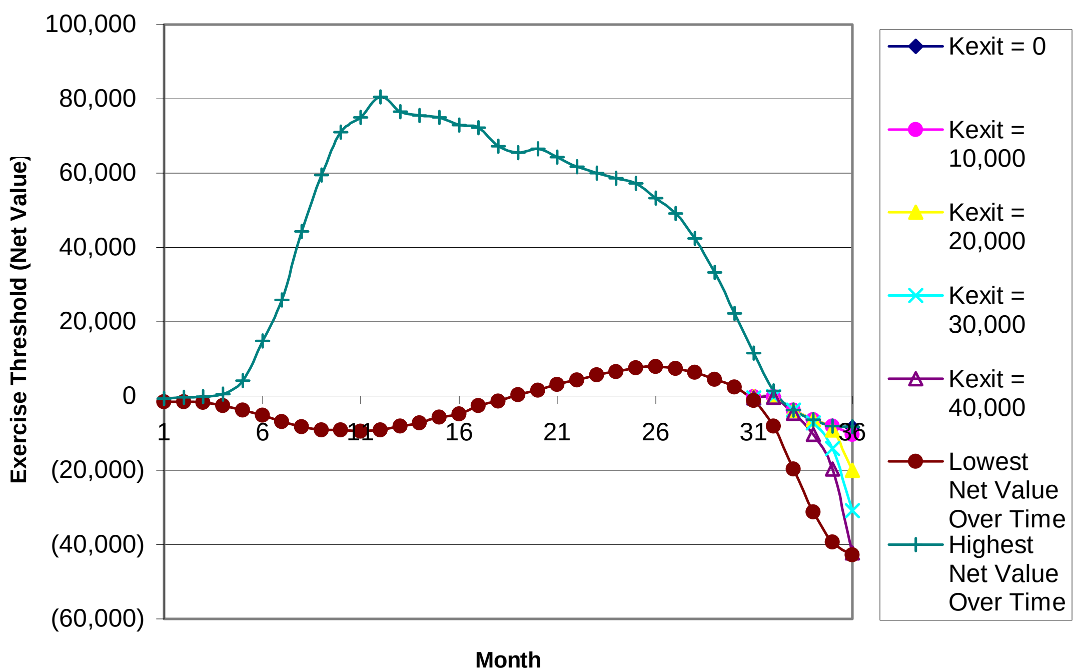
[12] With our parameters, the discount factor for the 31^{st} month is $e^{-(30*0.07/12)} = 0.8395$

Table 8.3.1: Option Premium for Base Case
(Standard deviation in Italic below the mean value)

Net Value W/O Option	227,074.07 *615.25*
$K_{exit} = 0$	50,757.70 *102.31*
$K_{exit} = 10{,}000$	42,412.27 *102.29*
$K_{exit} = 20{,}000$	34,066.84 *102.27*
$K_{exit} = 30{,}000$	25,721.94 *102.28*
$K_{exit} = 40{,}000$	17,382.90 *102.00*

Exercise Threshold

Figure 8.3.1: Base Case Exercise Threshold (Net Value) Over Time



An exercise threshold for option 3.1 is the maximum net value that triggers an exercise to terminate an ASP contract. Figure 8.3.1 shows the exercise thresholds for various exit fees over time as well as the evolution of maximum and minimum net values (for reference). Note that customers do not exercise an option till the 31st month, even though the net value possibly falls negative during the earlier periods. Our option allows for a one-time exercise after which customers can no longer use ASP services. Therefore, an option has a live or time value for potential future gain should the net value rise above zero. Consequently, it is optimal to accept some losses during earlier periods in order to keep an option alive.

As expected, a higher exit fee leads to a lower exercise threshold. Although it may not be clear from the picture, the exercise thresholds start at losses of a few hundred dollars in the 31st month and ramp down towards their corresponding exit fees at the end. Once again, the consistently negative exercise thresholds, even when the exit fee is zero, illustrate the live value of an option.

Figure 8.3.2: Low Benefit Exercise Threshold (Net Value) Over Time

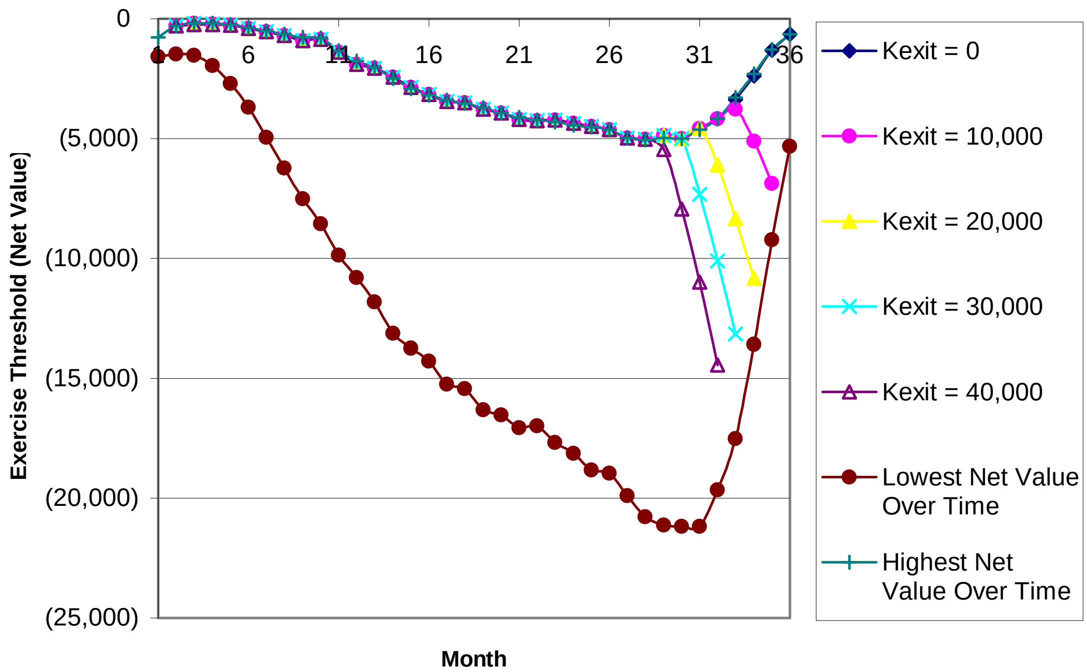


Figure 8.3.2 shows the exercise thresholds for various exit fees when the mean benefit per use is always lower than the price per use. In this case, it is optimal for customers to exercise the option early and eliminate future losses, especially when the exit fee is zero. For all positive exit fees, the exercise thresholds decrease towards the end, as the exit fee is traded off with cumulative losses during the remaining periods till the contract expiration.

2) Changes in Degree of Uncertainty

Option Premium

Table 8.3.2 shows option premiums for various degrees of uncertainty in benefit, usage level and the number of users. As uncertainty in benefit increases, the option has a slightly higher value. Uncertainties in the usage level and the number of users do not affect the option premiums significantly. This is expected since the option hedges against a drop in benefit.

Table 8.3.2: Option Premium for Various Sigma's
(Standard deviation in Italic below the mean value)

K_{exit}/Case	Base (σ_{b0}=0.6, σ_u=0.2, σ_n=0.2)	σ_{b0}		σ_u		σ_n	
		0.2	1	0.1	0.4	0.1	0.4
Net Value W/O Option	227,074.07 *615.25*	206,525.48 *475.16*	285,950.68 *3,064.42*	226,949.69 *837.01*	227,116.60 *860.30*	227,142.69 *619.87*	227,434.67 *819.05*
0	50,757.70 *102.31*	50,726.04 *81.97*	50,867.68 *121.25*	50,741.98 *81.38*	50,675.91 *141.91*	50,740.39 *77.15*	50,711.31 *137.66*
10,000	42,412.27 *102.29*	42,380.30 *81.97*	42,521.33 *121.19*	42,396.36 *81.35*	42,330.47 *141.89*	42,394.96 *77.13*	42,365.86 *137.63*
20,000	34,066.84 *102.27*	34,034.55 *81.97*	34,175.54 *121.12*	34,050.93 *81.32*	33,985.36 *141.87*	34,049.70 *77.12*	34,020.66 *137.62*
30,000	25,721.94 *102.28*	25,688.81 *81.97*	25,830.32 *121.05*	25,705.89 *81.30*	25,641.28 *141.64*	25,704.64 *77.09*	25,676.21 *137.78*
40,000	17,382.90 *102.00*	17,343.07 *81.97*	17,497.96 *121.86*	17,361.22 *81.29*	17,431.02 *138.00*	17,359.91 *77.06*	17,460.07 *135.62*

Exercise Threshold

Figure 8.3.3: Exercise Threshold (Net Value) for Various Sigma's when K_{exit} = 30,000

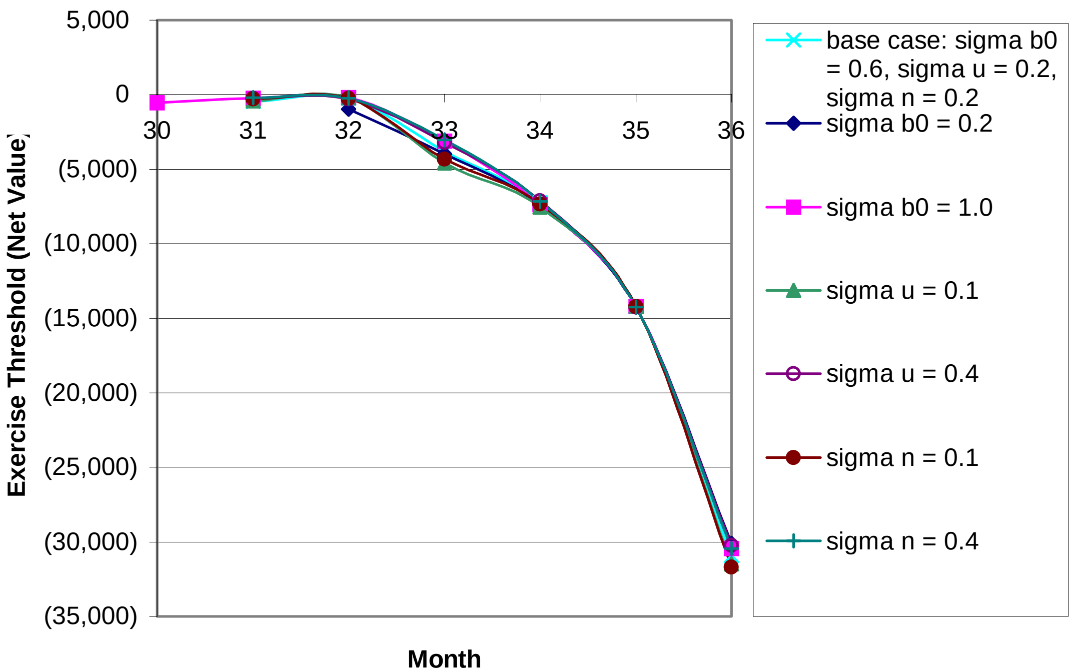


Figure 8.3.3 shows the exercise thresholds for various sigma's when the exit fee is 30,000. A higher uncertainty in benefit induces a possible earlier exercise. Specifically, a customer may exercise from the 30th, 31st and 32nd month when σ_{b0} is 1.0, 0.6 and 0.2 respectively. However, uncertainty in benefit does not vary the magnitude of the exercise threshold substantially. In fact, a low benefit uncertainty coupled with a low benefit itself offers the highest chance of exercise.[13]

The exercise thresholds do not vary greatly across different uncertainties in the usage level and the number of users. All the exercise thresholds start around the 31st month when the benefit has fallen low enough after the end of the software cycle. Once again, the exercise thresholds ramp down towards the 30,000 exit fee at the end of the contract time.

3) Changes in Mean Variables

Option Premium

Table 8.3.3: Option Premium for Various Mean Variables
(Standard deviation in Italic below the mean value)

K_{exit}/Case	Base (b_{max}=10, $u_{breakeven}$=100, n_{max}=100)	b_{max}		$u_{breakeven}$		n_{max}	
		5	15	50	150	50	150
Net Value W/O Option	227,074.07 *615.25*	(184,387.03) *138.47*	3,016,814.86 *5,223.52*	112,643.91 *421.57*	341,582.30 *927.91*	124,253.08 *411.68*	329,936.96 *1,761.08*
0	50,757.70 *102.31*	184,387.03 *138.47*	- -	25,390.38 *39.95*	76,120.64 *157.70*	26,290.41 *39.83*	75,212.31 *142.20*
10,000	42,412.27 *102.29*	174,387.03 *138.47*	- -	17,045.14 *40.06*	67,774.99 *157.64*	17,945.04 *39.81*	66,866.86 *142.21*
20,000	34,066.84 *102.27*	164,387.03 *138.47*	- -	8,703.42 *40.05*	59,429.73 *157.64*	9,601.37 *39.83*	58,521.58 *142.27*
30,000	25,721.94 *102.28*	154,387.03 *138.47*	- -	1,900.29 *36.89*	51,084.56 *157.64*	2,409.47 *19.53*	50,176.30 *142.32*
40,000	17,382.90 *102.00*	144,387.03 *138.47*	- -	185.80 *12.20*	42,739.60 *157.60*	266.21 *14.49*	41,831.25 *142.31*

Table 8.3.3 shows option premiums for various mean-affecting variables, namely b_{max}, $u_{breakeven}$, and n_{max}. When the mean maximum benefit per use is $5, which is below the $8 price per use, the option is always exercised immediately. Thus, the option value equals all the savings from loss less the exit fee. When the mean maximum benefit is 15, high enough above the price (that the negative net value during initial ramp-up is worth tolerating), the option is never exercised and has no value.

Lowering the breakeven usage level or the maximum number of users reduces the option premium, and increase in either factor does the opposite. Lowering mean usage values leads to smaller cost savings from

[13] The results show that when σ_{b0} = 0.2, the option is always exercised across all the tested exit fees at the 32nd month -- when the benefit is adequately low. We can observe these results from the option premiums for σ_{b0} = 0.2 in Table 8.3.2. When the exit fee is increased by 10,000, the declines in the option premiums are always 8,345.74, which is the discounted value of 10,000 exit fee from the 32nd month ($e^{-(31*0.07/12)}$ = 0.834574). The option is always exercised then.

exercising an option to eliminate the negative net value. Increasing the mean usage values obviously enlarges the total cost savings, as we can notice from the original net value without an option. We note that changes in the usage level have more effects on the option premiums than changes in the maximum number of users. As explained earlier, shifts in breakeven usage move the total usage by the same proportion, while shifts in the maximum number of users only expands the limit on growth of total usage.

Exercise Threshold

Figure 8.3.4: Exercise Threshold (Net Value) for Various Mean Variables when Kexit = 30,000

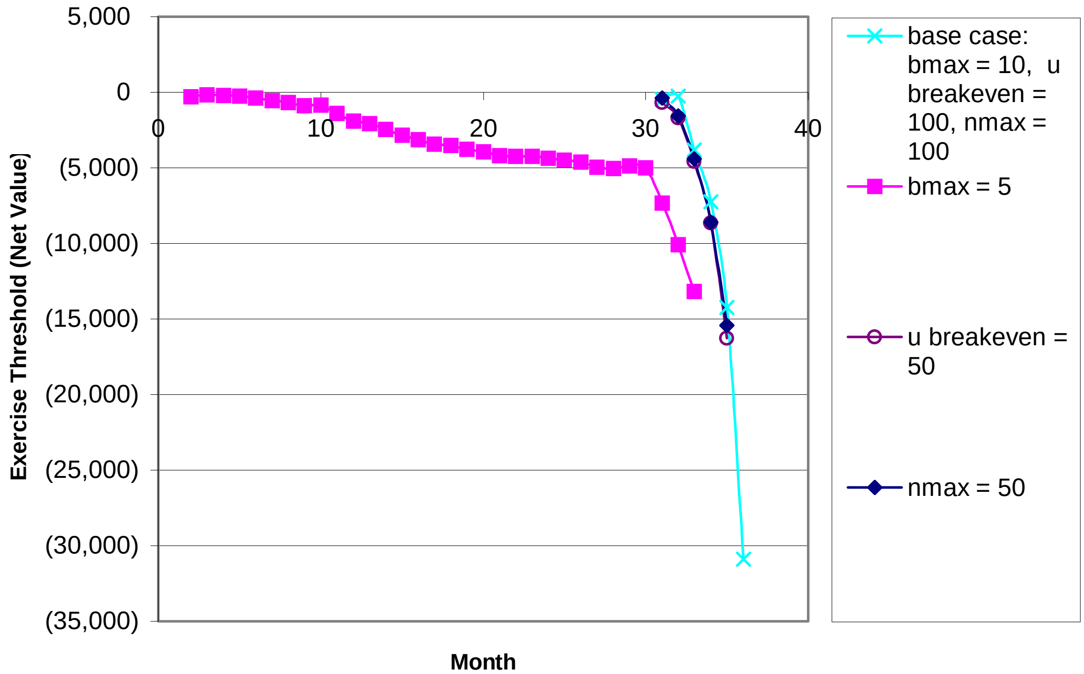


Figure 8.3.4 shows the exercise thresholds for various mean-affecting variables when the exit fee is 30,000. Lowering the maximum benefit causes potential earlier exercise. Note that the exercise threshold for low benefit is less than that of the base case because the net value is itself much less. In fact, the low-benefit exercise threshold is relatively close to its upper bound on the net value, yielding a very high chance of exercise. The option for the low benefit is not exercised after the 33rd month because the savings from the remaining periods are less than the 30,000 exit fee.

The exercise thresholds for the low breakeven usage and the low maximum number of users are quite close together and close to the base case. This supports our findings that the usage level and the number of users have less impact on this option than the benefit. Note also that the exercise thresholds for the low usage level and the low maximum number of users end one month earlier than expiration. With a smaller value at stake, it is not worth paying the exit fee of 30,000 when the total usage (thus the total negative net value) in the last period is relatively small.

<u>4) Changes in Software Cycle</u>

Option Premium

Table 8.3.4 shows option premiums for various software cycles. The lower is the software cycle, the higher is the option premium, as a customer can promptly terminate the ASP contract when the software benefit falls. When the software cycle is 36 months, the same as the contract length, the benefit remains high till the end and the customers never exercise the option. We also note that the exit fee has more impact on the option premium when the software cycle is short. A shorter software cycle leads to an earlier exercise and an earlier payment of the exit fee (thus a higher net present value of the exit fee).

Table 8.3.4: Option Premium for Various Software Cycles
(Standard deviation in Italic below the mean value)

K_{exit}/Case	Base (L=24)	L	
		12	36
Net Value W/O Option	227,074.07 *615.25*	(36,298.64) *445.76*	443,540.17 *23.98*
0	50,757.70 *102.31*	80,611.27 *127.31*	- -
10,000	42,412.27 *102.29*	71,559.70 *127.76*	- -
20,000	34,066.84 *102.27*	62,509.96 *127.77*	- -
30,000	25,721.94 *102.28*	53,462.52 *127.14*	- -
40,000	17,382.90 *102.00*	44,416.99 *126.75*	- -

Exercise Threshold

Figure 8.3.5: Exercise Threshold (Net Value) when Software Cycle = 12 Months

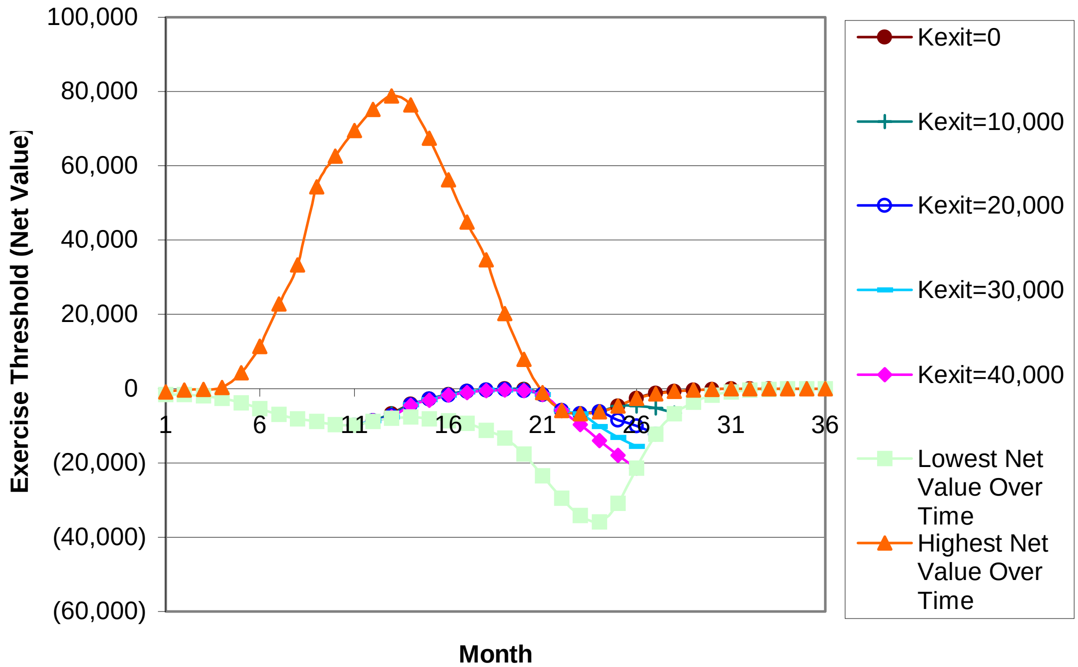


Figure 8.3.5 shows the exercise thresholds when the software cycle is 12 months. Compared to Figure 8.3.1 when the software cycle is 24 months, we see a shift in exercise thresholds to earlier periods. For a twelve-month software cycle, the exercise thresholds start to emerge around the end of the software cycle and peak close to zero net value. Then the exercise thresholds slope down at different rates depending on the exit fees towards the lower bound on the net value.

Because the usage variables are adjusted with the benefit, the usage will eventually dies out after the benefit dies out. Therefore, the total loss (or negative net value) is limited to only the periods when the adjustment has not completed. Thus, we see the exercise thresholds that reflect the tradeoffs between the exit fees and the expected loss before the adjustment completion. Previously when the software cycle is 24 months, and the tradeoffs are between the exit fees and the expected loss before the contract expiration, which happens before the adjustment completion.

The exercise thresholds ramp up from a negative value after initial periods of possible losses because of the decreasing live value of an option. If the exit fee is zero, the exercise threshold continues close to the upper bound of the net value and moves towards 0 at the end of the contract, when the live value dies out. Therefore, without an exit fee, after some initial periods, it is optimal to exercise even when the net value is minimally negative. For other exit fees, the exercise thresholds ramp down according to the exit fee that is traded off with the expected loss during the remaining periods.

Option 3.2, 3.3: Value of option to end ASP contract prior to expiration under minimum per-period usage requirement (and minimum time commitment)

For the results in this section, the minimum usage requirement is 3,000 users-hours per month, which is roughly 20% of the maximum mean usage.[14] The results are shown for various minimum time commitments ranging from 0 (no time commitment) to 35 months (option exercisable only at the last period).[15] There is no exit fee to exercise an option in this section.

<u>1) Base Case</u>

Option Premium

An option premium is the difference between the net ASP value (total benefit less total cost) with and without an option to end the ASP contract prior to expiration, under a minimum per-period usage requirement and various minimum time commitments. Table 8.4.1 shows the option premiums for various minimum time commitments. Note that, without an option, imposing a minimum usage requirement decreases the net value substantially (73,595 in this option, compared to 227,074 in option 3.1); in other words, customers are considerably worse off under a minimum usage requirement.

Providing an option to end the ASP contract improves the customers' situation, as we can observe from the positive option premiums. However, the option value under a minimum usage requirement (51,050) is not significantly higher than the option value under no constraints (50,758, in option 3.1). Even though customers suffer the initial loss (when benefit is less than price) that is compounded by the required minimum usage, the customers do not exercise an option until later stages because they gain large value in the middle when the benefit peaks. Therefore, imposing a minimum usage requirement essentially takes away some of the customers' value. And providing an option to end the contract, though seems useful, effectively does not improve the situation substantially as the customers will not exercise the option too early anyway.

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[14] Total mean usage per period = usage level*the number of users = ($\overline{u}_t$ * $\overline{n}_t$). Thus, the maximum mean usage per period = ($u_{breakeven}$*b_{max}/p_{use})*(n_{max}*b_{max}/p_{use}) = $u_{breakeven}$*n_{max}*(b_{max}/p_{use})^2 = 100*100*(10/8)^2 = 15,625, twenty percent of which is 3,125 hours per month. We use a round number of 3,000 hours per month.

[15] t_{min} = minimum time commitment; i.e., the first exercisable month is t_{min} + 1.

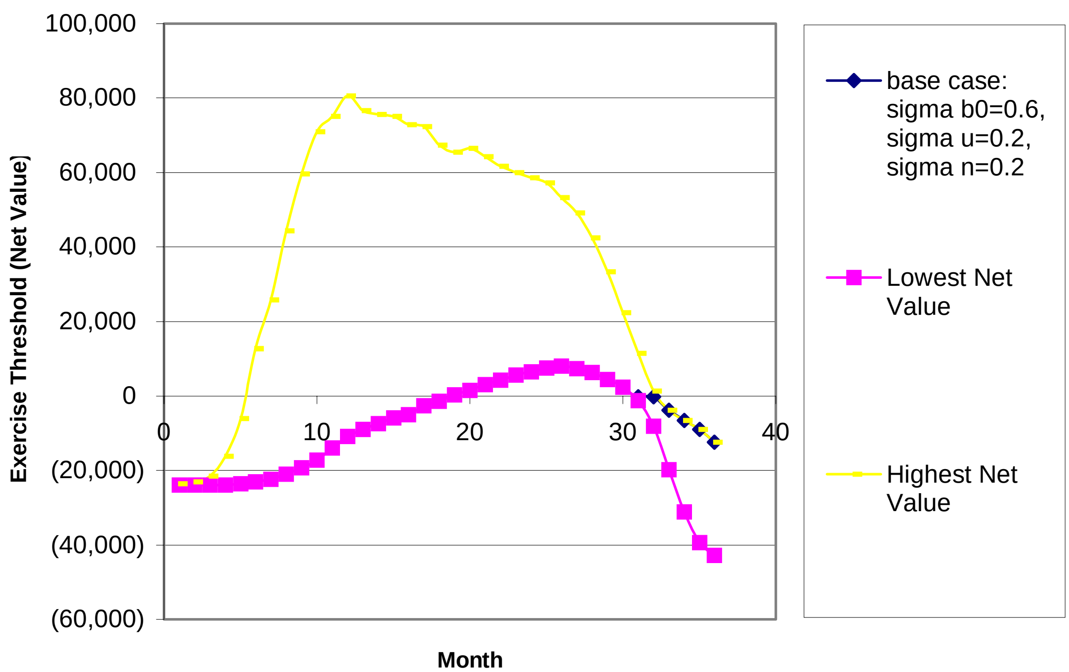
From Table 8.4.1, we also note that the option premiums are insensitive to the minimum time commitments that are shorter than 31 months. Since the option is not exercised early, the minimum time commitments during those periods have no effects on the option premiums. After 31 months, the time commitments reduce the option premiums, as the customer cannot exercise an option to eliminate loss promptly when needed. We note that the impact of the time commitment increases over time because the software benefit is falling more rapidly.

Table 8.4.1: Option Premium for Base Case
(Standard deviation in Italic below the mean value)

Net Value W/O Option	73,595.01 *545.87*
t_{min} = 0 to 30	51,050.18 *98.60*
t_{min} = 31	51,033.48 *98.79*
t_{min} = 32	48,830.06 *94.77*
t_{min} = 33	41,721.29 *77.06*
t_{min} = 34	30,278.37 *49.79*
t_{min} = 35	15,751.32 *26.44*

Exercise Threshold

Figure 8.4.1: Base Case Exercise Threshold (Net Value) Over Time



An exercise threshold for option 3.2 and 3.3 is the maximum net value that triggers an exercise to terminate the ASP contract under usage and time commitments. Figure 8.4.1 shows the exercise threshold over time for the base-case parameters. We note that the net value is deeper in the negative region initially than it is without any usage requirement (Figure 8.3.1). Even though the benefit is small at the beginning, the customers are obligated to pay for the minimum usage, resulting in a large loss.

However, the option is not exercised till the net value falls negative again in the 31st month. The exercise threshold starts with a loss of a couple hundreds dollars and moves quickly towards the highest net value (or zero at most), reflecting an increasing chance of exercise. Since the benefit is decreasing towards the end, an option has a declining live value; the sooner the option is exercised, the larger are the savings.

2) Changes in Degree of Uncertainty

Option Premium

Table 8.4.2: Option Premium for Various Sigma's
(Standard deviation in Italic below the mean value)

t_{min}/Case	Base (σ_{b0}=0.6, σ_u=0.2, σ_n=0.2)	σ_{b0}		σ_u		σ_n	
		0.2	1	0.1	0.4	0.1	0.4
Net Value W/O Option	73,595.01 *545.87*	56,163.34 *472.89*	126,683.00 *3,040.08*	74,651.57 *811.11*	68,880.79 *845.27*	74,702.65 *597.32*	69,599.96 *795.29*
0 to 29	51,050.18 *98.60*	51,019.87 *79.74*	51,172.44 *119.74*	50,832.94 *80.21*	52,148.87 *144.68*	50,834.59 *75.17*	52,152.05 *135.33*
30	51,050.18 *98.60*	51,019.87 *79.74*	51,169.06 *119.61*	50,832.94 *80.21*	52,148.87 *144.68*	50,834.59 *75.17*	52,152.05 *135.33*
31	51,033.48 *98.79*	51,019.87 *79.74*	51,020.72 *119.56*	50,816.08 *80.34*	52,131.40 *144.44*	50,817.99 *74.74*	52,134.74 *135.02*
32	48,830.06 *94.77*	48,809.72 *77.51*	48,736.97 *119.68*	48,613.38 *72.86*	49,929.30 *137.45*	48,619.16 *74.88*	49,932.82 *131.14*
33	41,721.29 *77.06*	41,690.22 *66.63*	41,671.24 *108.46*	41,507.67 *62.27*	42,822.15 *113.96*	41,517.39 *66.83*	42,823.51 *115.30*
34	30,278.37 *49.79*	30,249.94 *49.41*	30,259.39 *79.05*	30,066.47 *44.31*	31,346.94 *86.03*	30,079.34 *50.16*	31,350.12 *79.63*
35	15,751.32 *26.44*	15,734.80 *27.60*	15,750.89 *41.52*	15,555.94 *25.43*	16,612.68 *44.77*	15,571.59 *26.60*	16,604.59 *32.54*

Table 8.4.2 shows the option premiums for various degrees of uncertainty in benefit, usage level and the number of users. We note that the uncertainty in benefit has no significant effect on the option premiums. The option to end ASP contract is valuable when the benefit is low. However, low benefit induces low total usage, which in this case is replaced by a fixed required minimum usage. Therefore, the benefit fluctuation is not echoed in the total usage, and its effect reduces. From Table 8.4.2, we also note that uncertainties in usage level and the number of users increase the option premium by roughly the same amount. Fluctuations in usage level and the number of users directly impact the magnitude of the net value and thus the cost savings and the option premiums.

Uncertainties also affect the net value without an option. We note that as the uncertainty in benefit increases, the net value without an option increases substantially due to a high chance of benefit being high when its reverting mean is low. Since benefit cannot go negative, increasing its variance magnifies its upside potential. On the contrary, increasing uncertainties in usage level and the number of users decrease the net value without an option. With a minimum usage requirement, high uncertainty makes the required minimum usage more relevant, as this minimum comes to effect every time the usage drops. Therefore, high uncertainty in usage induces more downside potential.

Exercise Threshold

Figure 8.4.2: Exercise Threshold (Net Value) for Various Sigma's

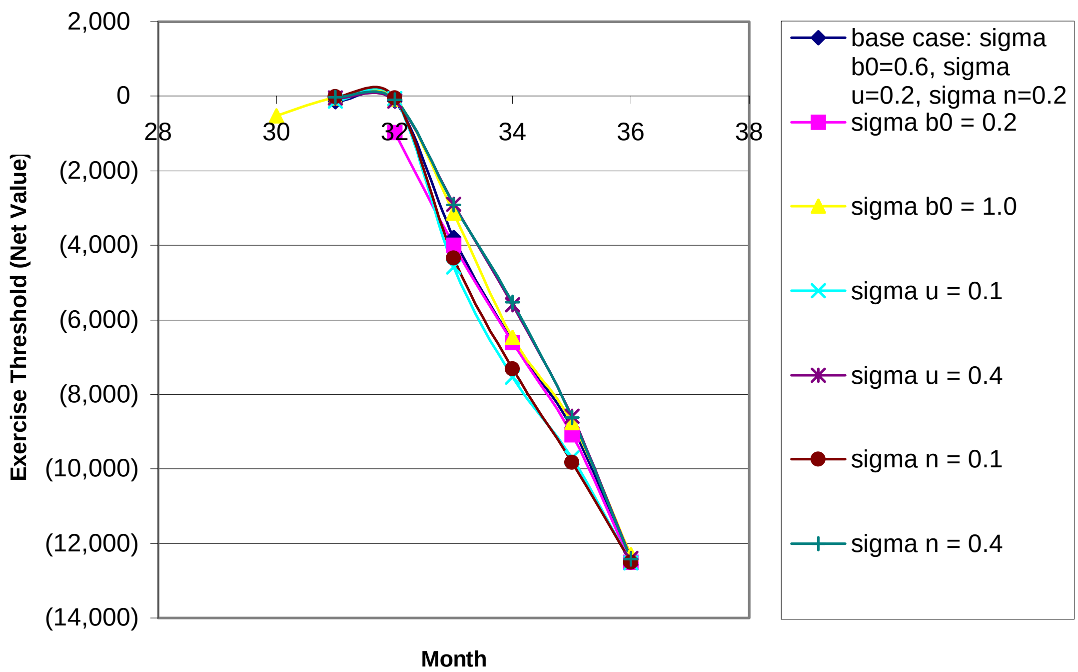


Figure 8.4.2 shows the exercise thresholds for various sigma's. Higher uncertainties in usage level and the number of users lead to higher exercise thresholds by roughly the same distance. For various usage uncertainties, all the exercise thresholds start from the 31st month. Similar to earlier results, uncertainty in benefit induces a possible earlier exercise. However, it does not shift the exercise threshold by as much as the usage uncertainties.[16]

3) Changes in Mean Variables

Option Premium

Figure 8.4.3 shows the option premiums for various mean-affecting variables. When the maximum benefit is high at 15, the option is never exercised and thus has no value. When the maximum benefit is low at 5, the option is exercised almost all the time (from the section below). Thus, the option premium consistently decreases as the minimum time commitment increases to reflect accumulation of losses from not being able to exercise early to avoid negative value in every period. Therefore, the minimum time commitment is especially important when the maximum benefit is low.

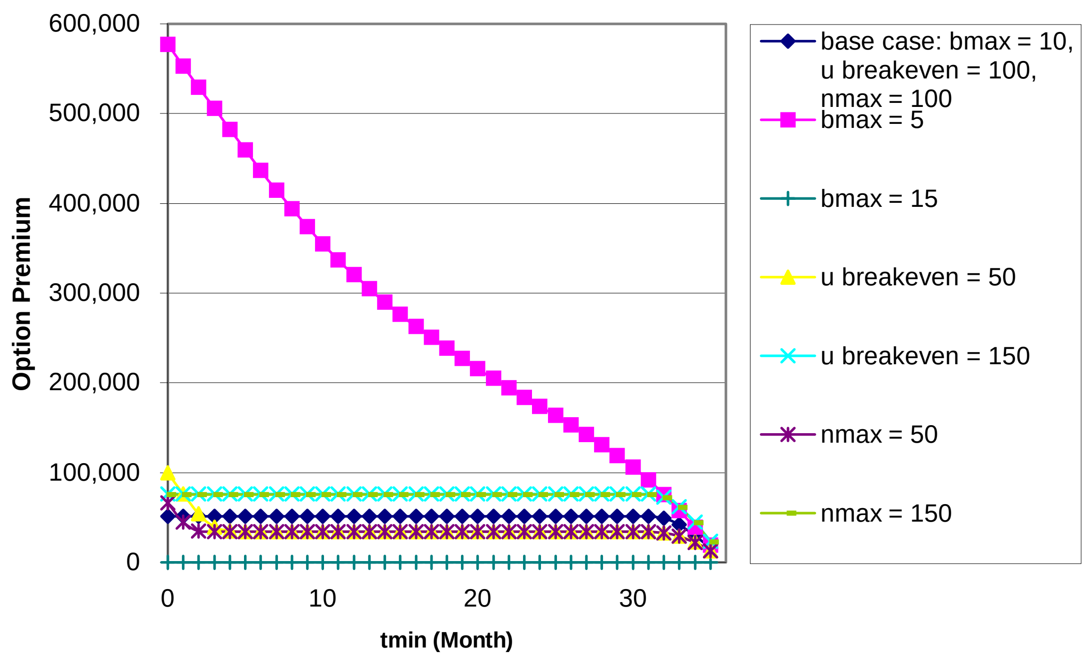
We also note that the higher the breakeven usage or the maximum number of users, the higher is an option premium in general. The higher total usage implies a larger net value at stake and thus bigger savings from having an option. However, the option with low usage may also have a high option premium when the

[16] As a note, even though the exercise threshold for $\sigma_{b0} = 0.2$ at the 32nd month is lower than others, it is actually on its highest net value boundary already.

time commitment is short. A low usage induces an early exercise possibility that eliminates substantial loss relative to not having an option. Finally, except for the low benefit, we see once again that the time commitments in the medium range do not affect the option premium because the option is never exercised then.

While an increase in the breakeven usage or the maximum number of users enlarges the option premiums by roughly the same amount, decreases in these variables cause different option premiums at the beginning. Specifically, a reduction in the breakeven usage has more impact on the initial option premium because it directly scales down the usage that is already small and under the minimum usage requirement. A reduction in the maximum number of users does not have as much impact because it only limits the growth of the number of users; therefore, it does not fully affect an initial usage.

Figure 8.4.3: Option Premium for Various Mean Variables



Exercise Threshold

Figure 8.4.4 shows the exercise thresholds for various usage variables. Note that the low breakeven usage and the low maximum number of users result in potential early exercise during the beginning stage. These exercise possibilities do not exist previously when customers are not under a minimum usage requirement. As expected, enforcing the minimum usage has extra impact when the usage is low. The exercise thresholds disappear in the middle when the benefit peaks, and customers never exercise. Exercising an option becomes optimal again towards the end after the software benefit has fallen. Although not shown, all the exercise thresholds are very close or on their corresponding net value upper bound near the end of the contract time, illustrating a high chance of exercise as the benefit is deeply low.

Figure 8.4.4: Exercise Threshold (Net Value) for Various Mean Variables

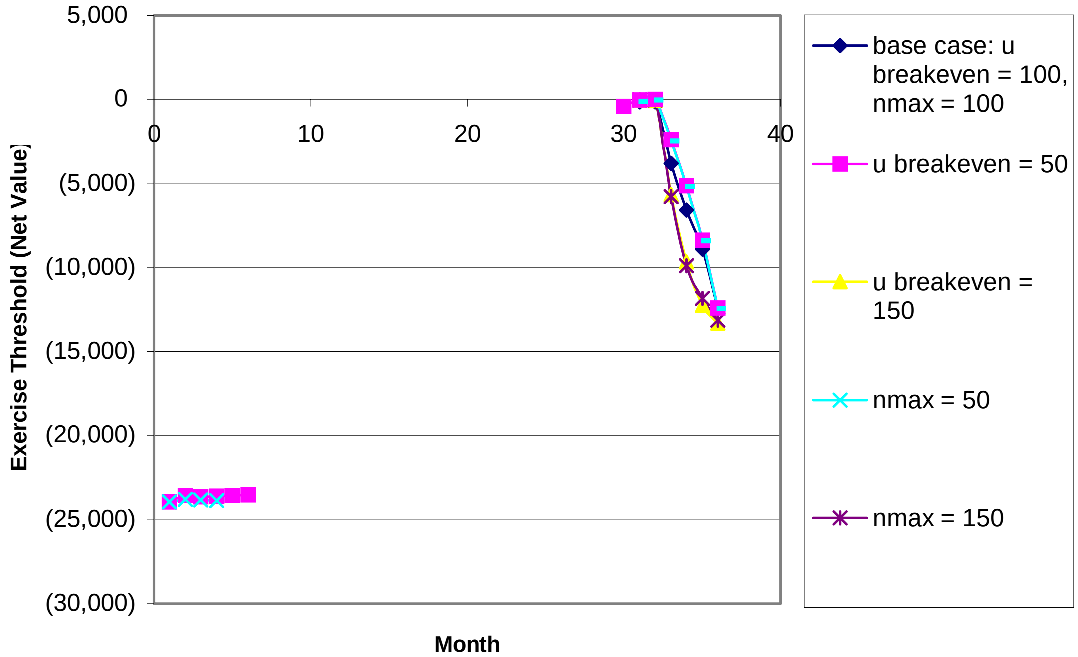


Figure 8.4.5: Exercise Threshold (Net Value) for Low Benefit

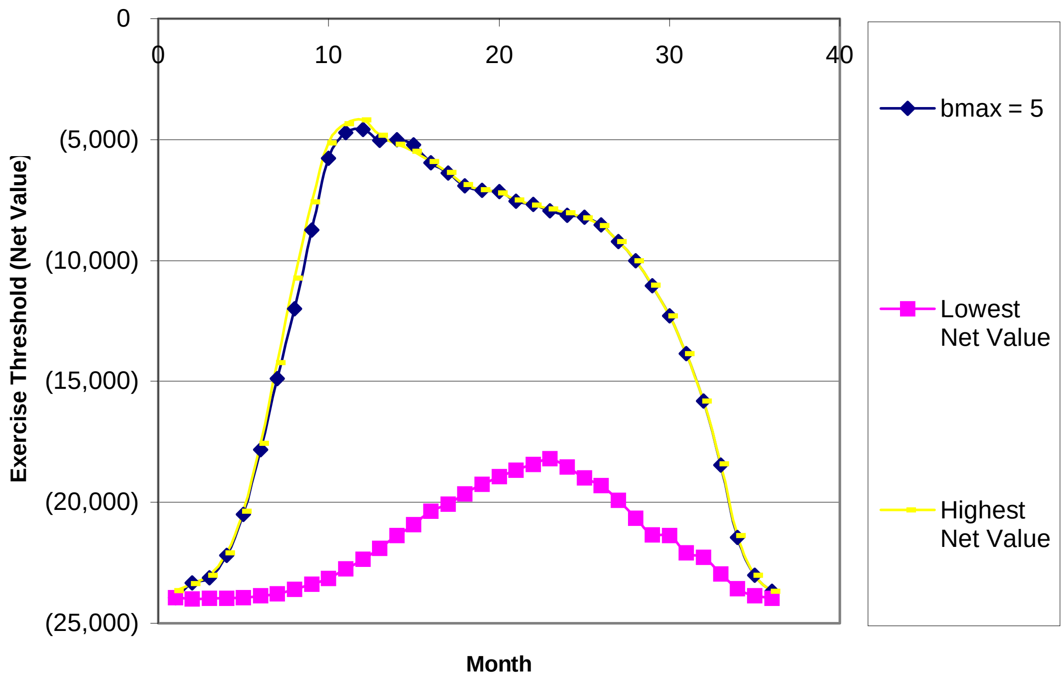


Figure 8.4.5 shows the exercise threshold for a low benefit case. Note that the exercise threshold follows the highest net value closely; thus, it is optimal to exercise almost all the time. Because the maximum benefit of $5 is less than the price per use of $8, using services results in a loss. We also observe that the exercise threshold is narrowly below the upper bound and gradually increases towards it, illustrating the live value of an option at the beginning that is decreasing over time.

4) Changes in Software Cycle

Option Premium

Figure 8.4.6: Option Premium for Various Software Cycles

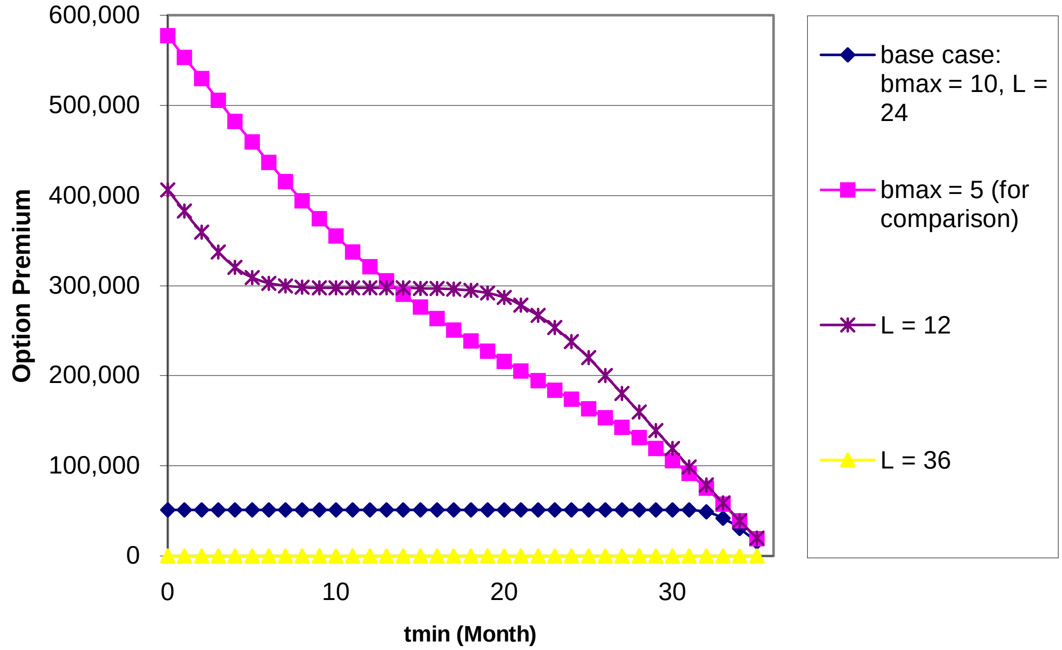


Figure 8.4.6 shows the option premiums for various software cycles. The option premium for the low maximum benefit is also shown for a magnitude comparison. When the software cycle is 36 months, the benefit remains high throughout the contract time, and the option is never exercised and has no value. When the software cycle is 12 months, the option premium decreases rapidly with the minimum time commitment during the beginning, slowly reduces around the middle and quickly drops again towards the end. We will see that these changes in the option premium closely relate to the varying chance of exercise, as explained in the exercise threshold section below.

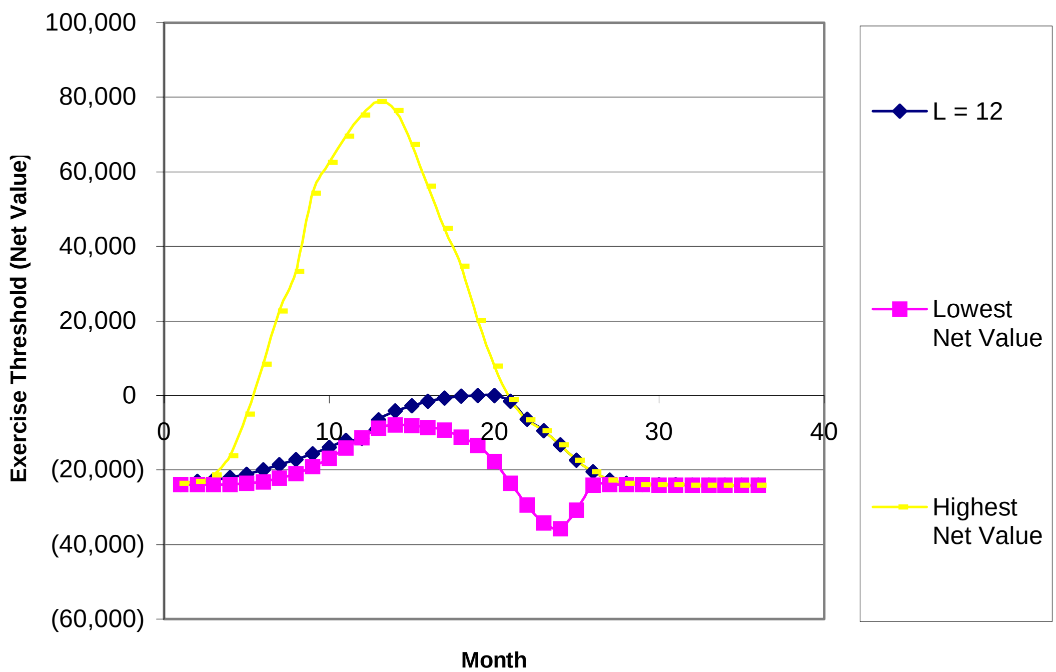
Overall, we note that low benefit affects the option premium the most, followed by a short software cycle, and low usage variables (usage level and the number of users). Volatilities in benefit and the usage variables do not affect the option premiums substantially. Not surprisingly, the minimum time commitment becomes critical in the low benefit situation. In a situation of a short software cycle or low usage variables, not having a minimum time commitment during the initial periods; i.e. the first 6 months, will improve the option premiums significantly.

Exercise Threshold

Figure 8.4.7 shows the exercise threshold when the software cycle is 12 months. We note that the probability of exercise is high at the beginning and quickly decreases as the highest net value (as well as the net value in general) shoots up with the benefit and usage. Thus, the probability of exercise remains small in the middle. After the 21th month, the net value has fallen down towards negative region and the exercise threshold stays close to the highest net value. Therefore, the option is exercised almost surely in this last stage of the contract.

The impact of the minimum time commitment on the option premiums is closely related to the chance of option being exercised. During the beginning when the benefit/usage is small, leading to a relatively high chance of exercise, increasing the minimum time commitment reduces the option premiums significantly. Around the middle when the exercise threshold is close to the lower bound, the minimum time commitment has only small effect on the option premiums because the option is rarely exercised anyway. After the 21st month when the option is exercised almost surely, having the minimum time commitments during this phase will lower the option premiums substantially.

Figure 8.4.7: Exercise Threshold (Net Value) when Software Cycle = 12 Months



9. Concluding Remarks

Using the value and cost model from the software owner's and the customer's perspectives, we identify the key uncertainties driving the ASP model to be the software value (b) and the usage, which is a function of the number of users per company (n) and a level of usage (u). We propose three real options approaches to address these uncertainties, namely the option to switch from usage-based pricing to a subscription fee, the option to bring the software in-house, and the option to end the ASP contract prior to expiration. In order to analyze these real options in details, we model the underlying uncertainties using a mean reverting process with a time-varying mean and a time-varying variance, which allows us to capture correlations among the uncertainties and to pattern after important characteristics, such as a software cycle, a learning effect, a company growth, etc. Finally, we utilize a Monte-Carlo simulation approach to approximate the option values and the exercise thresholds, the results of which give us insights into the implications of offering these real options with an ASP contract. The proposed real options together with the ASP model itself lead to a better management of software investments, as they help the customer and the software owner to manage the underlying uncertainties.

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